Chapter 2

2. Natural Conditions

2.1 General Condition of Zimbabwe

Zimbabwe is situated in the southern part of the continent of Africa between latitude 15^{O} 30' and 22^{O} 30' south of the Equator and between longitude 25^{O} and 33^{O} 10' East of the Greenwich Meridian.

It is bordered by Mozambique to the East, South-Africa to the South, Botswana to the west and Zambia to the North and North-west. Zimbabwe is completely landlocked. Its total land area is approximately 39,075,900 ha.

The distribution of land area by province is shown in Table 2 – 1. The Matabeleland North where the Survey Area is located occupies 19 % of the total land area of Zimbabwe.

Table 2 – 1 Land Area by Province

Land Area by Province	Land Area (ha)
Manicaland	3,487,000
Mashonaland Central	2,728,400
Mashonaland East	2,493,400
Mashonaland West	6,046,700
Matabeleland North	7,353,700
Matabeleland South	6,639,000
Midlands	5,896,700
Masvingo	4,431,000
Total	39,075,900

Source: Statistical Yearbook 1989

2.1.1 Topography and Geology

The most principal physical feature is the high plateau, the "*high veld*" that runs from southwest to northeast across the whole country from Plumtree through Gweru and Marondera to Nyanga.

This plateau is 650 km long, 80 km wide and lies mostly at an average elevation of about 1,525 meters. On each side of this central spine sloping down northward to the Zambezi River and southward to the Limpopo River, lies a wider plateau, the "*middle veld*" with an altitude between 600 and 1,200 m with average elevations of about 1,065 m. Beyond this, mostly in the south, where the Sabi, Lundi and Nuanetsi rivers drain, lies the "*low veld*". The low veld consists of the Zambezi Valley and the Limpopo and Sabi basins and the

altitude is below 600 m.

These three areas have undulating plateau with surfaces broken locally by rock formations, some quite large: the Great Dyke is more than 480 km long and approximately 10 km wide. The Mozambican border constitutes a fourth region known as the Eastern Highlands. This area marks the uplifted edge of the table land of south-central Africa and is extremely mountainous with many peaks exceeding 1,800 m and the Inyangani reaching a maximum elevation of 2,594 m.

The Survey Area is located in the *middle veld* and the basin of Gwaai River that is a tributary of the Zambezi River flowing into the Indian Ocean.

In the northwestern Zimbabwe, there is a marginal extent of Kalahari Desert amounting to more than 700,000 km^2. As a feature of the western part, sands appear in stead of red soils. The sands are brought by winds on the basalt parent rocks. The Survey Area is located in such area of aeolian sands.

2.1.2 Climate

Although Zimbabwe lies wholly within the Tropics, the normal tropical continental climate is considerably modified by altitude, especially on the central plateau where temperatures are lower than at sea level in the same latitude.

The year falls roughly into three seasons:

(1) a dry winter, covering the months from April to August, with cool temperatures especially at night when frost is sometimes experienced,

(2) a hot season with maximum temperatures in October or early November and

(3) a wet season in which the main rains usually come around mid-November and continue until March.

2.1.3 Vegetation

The nation-wide vegetation is classified into the following woody cover classes based on visual interpretation of Landsat-TM imagery acquired in 1992. The Survey Area is covered with “Woodland” mainly, and “Bushland” or “Cultivation” partially.

Table 2 – 2 Woody Cover in Zimbabwe

Class	Tree Height (m)	Canopy Cover (%)	Area Rate (%)
Natural Moist Forest	> 15	> 80	0.03
Forest Plantation			0.40
Woodland	5 – 15	20 – 80	53.20
Bushland	1 – 5	20 – 80	12.72
Wooded Grassland	1 – 15	2 – 20	3.08
Grassland			1.76
Cultivation			27.47
Rock Outcrop & Mine Dump			0.20
Waterbody			0.77
Settlement			0.36

Source: Woody Cover Map (1997)

2.2 Conditions of Survey Area

2.2.1 Topography and Geology

(1) Topography and Drainage

The rivers dissecting the Survey Area are Gwaai, Insuza and Bembesi Rivers. These flow in the direction of north or northwesterly. The Insuza and Bembesi Rivers are tributary of Gwaai River that flows into Zambezi River. Reflecting to the water permeability and consistency of sands, the terrain is almost flat and characterized with broad ridges and gentle depressions giving a maximum relief of about 20 m. The incision by the main rivers into the sand surface is about 100 – 150 m, with the transition typically being marked by a steep or gentle escarpment.

Table 2 – 3 Elevation Extremes in Survey Area

	Height	Location
Lowest point	960 m	The most north part of the Survey Area along Bubi River
Highest point	1,179 m	Triangular point located at the most east side of the Survey Area located in Bembesi Forest Land

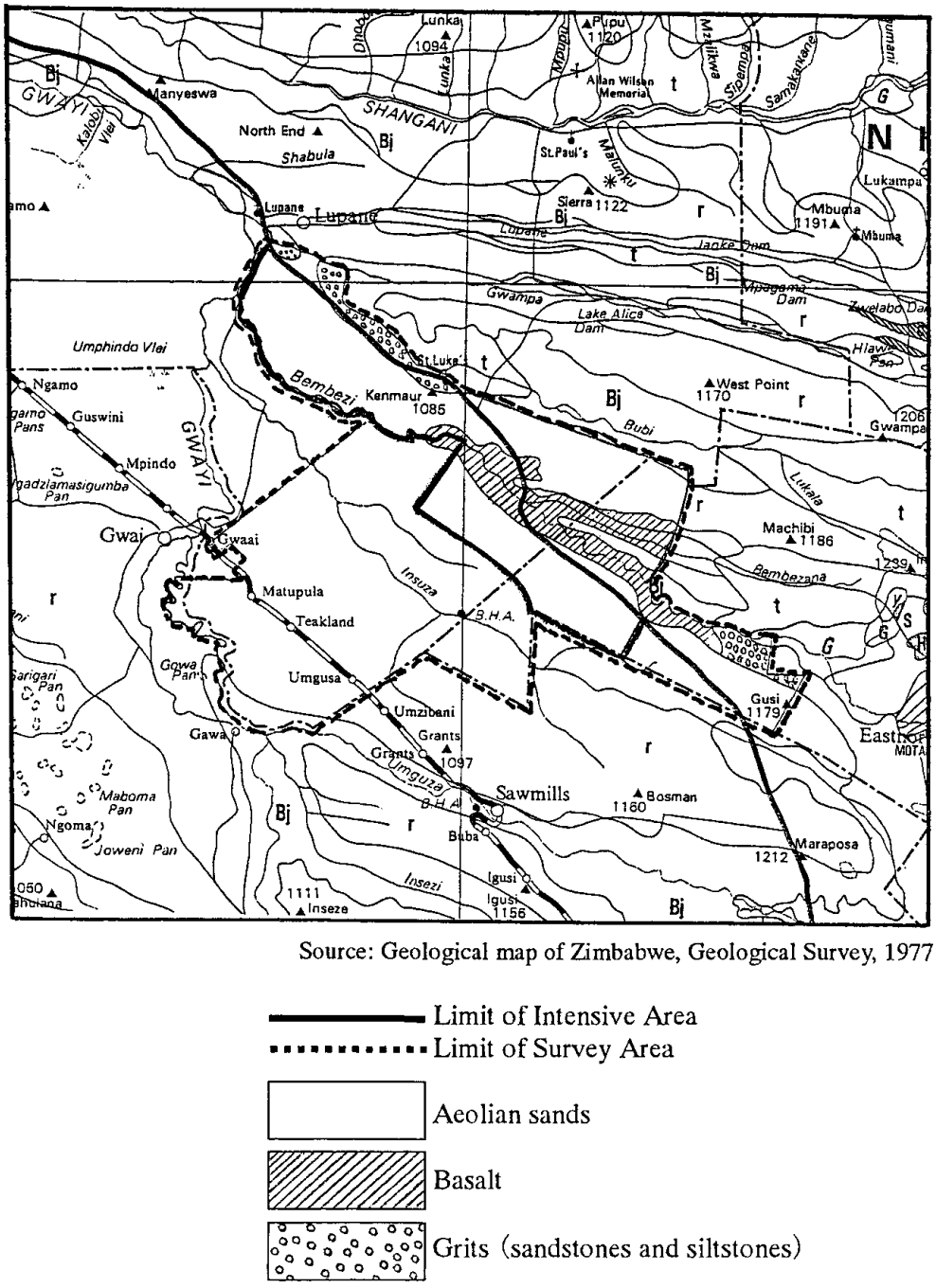
There is no perennial river but seasonal. But along the major rivers the open wells are facilitated for watering livestock. Even in the dry season, sufficient water is available by digging of such shallow wells.

(2) Geology

The most of the Survey Area is covered with aeolian sands, namely Kalahari sands. Except for the sand, there are two different geological types. One is the group of “Grits, sandstones and siltstones” which is distributed in the eastern side of the Falls Road north from Kemaur and located in the Bubi River basin. Another is the group of “basalt” which appears along Bembesi River. Beneath the sand there is a layer of Cretaceous

sedimentary rocks which overlie Karoo basalt and sedimentary deposits. Such rocks are exposed along the major rivers. Along the Bembesi River, the valley has many small gullies on the escarpment.

The geology of Survey Area described in the Geological map of Zimbabwe is shown in the Fig. 2 – 1 below.



Source: Geological map of Zimbabwe, Geological Survey, 1977

Limit of Intensive Area

Limit of Survey Area

Aeolian sands

Basalt

Grits (sandstones and siltstones)

Fig. 2 – 1 Geological Condition of Survey Area

2.2.2 Climate

The region around the Survey Area enjoys a rainfall of between 400 mm and 800 mm a year. But the rainfall pattern is short and erratic. It is said that the realistic figure of mean annual rainfall would be around 590 mm. According to the data of the nearest meteorological stations, 619 mm at Lupane (30 years observation, altitude 1,010 m) and 564 mm at Tsholotsho (45 years observation, altitude 1,100 m). Both stations have high variability of rainfall from year to year that is more than 30 % of coefficient of variation.

Zimbabwe has been classified into five agro-ecological regions based on annual rainfall, rainy pentads per season, altitude, etc. The Survey Area is found in region IV, Semi-Extensive Farming Region. The rainfall is too low and uncertain to cash cropping. The criteria suggest the livestock production to the extent of available fodder.

The mean monthly temperatures for Lupane range from 15 ^{O}C in June and July to 25 ^{O}C for October to December.

Ground frosts are experienced in most years between May and September. Severe frosts are associated with the influx of cold dry air from Botswana. Low ground temperatures are remarkable by the dry sandy soils having higher thermal conductivity than other silty or clayey soils. Reportedly the frost is known to kill a great deal of the thicket undergrowth and cause the fuel accumulation and extreme dryness of the vegetation, which is very hazardous for fire.

The cold air flows into the lower part of the area consisting of depressions and valleys. The more intense frosts can affect the living environment of plants and animals.

In the Forest Hill Office a rain gauge is installed but does not have a long and continuous data. There was a thermometer but broken at the moment.

The mean monthly rainfall from 1995 to 1998 at Forest Hill Office is shown in Table 2 – 4.

Table 2 – 4 Mean Monthly Rainfall at Forest Hill Office

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Rainfall (mm)	254	172	53	16	16	0	0	0	12	7	69	140	739

Source : Forest Hill Office

Also, the temperature and rainfall in Hwange National Park located northwest of Survey Area and Bulawayo located southeast of Survey Area are shown in the table below.

Table 2 – 5 Climate of Hwange National Park

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Mean Maximum Temperature (℃)	29	29	29	29	27	24	25	27	31	32	32	30	29
Mean Minimum Temperature (℃)	18	18	17	14	9	5	5	7	12	16	17	18	13
Mean Temperature (℃)	24	23	23	20	17	14	15	17	22	24	25	24	21
Rainfall (mm)	162	147	72	32	4	1	0	1	4	24	67	155	669

Source : Meteorological Office (Data recorded between 1988 and 1999)

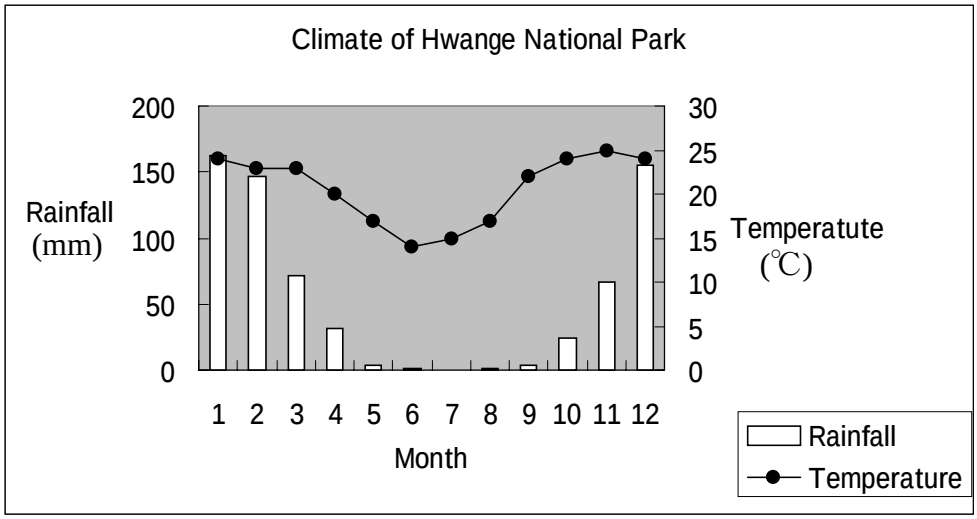


Fig. 2 – 2 Climate of Hwange National Park

Table 2 – 6 Climate of Bulawayo

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Mean Maximum Temperature (℃)	28	27	27	26	24	21	22	24	28	29	29	28	26
Mean Minimum Temperature (℃)	16	16	15	13	10	7	7	9	12	15	16	16	13
Mean Temperature (℃)	24	23	23	20	17	14	15	17	22	24	25	24	21
Rainfall (mm)	129	111	55	35	8	2	1	1	7	36	94	126	605

Source : Meteorological Office (Data recorded between 1988 and 1999)

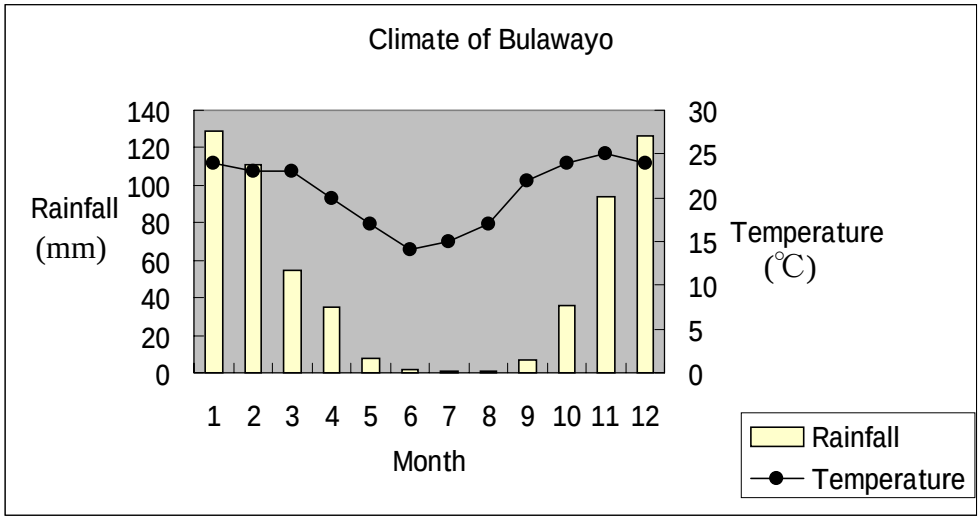


Fig. 2 – 3 Climate at Bulawayo

2.2.3 Soil

Except for alluvial or sedimentary soils along the major rivers, most of the land is covered with the sands. Reportedly soils of the Kalahari sands are strongly uniform, both physically and chemically, having high permeability and low consistency. The extremely low occurrence of silt and clay particles (< 10 %) is due to the absence of weatherable or volcanogenous minerals. The sands comprise mainly quartz that makes the soil fertility very low. There is no A_0 layer mixed or covered with organic matters and the soils are structureless. The soil depth varies from area to area but can be as deep as 75 cm to 100 m. Such a soil condition severely constrains not only the farming but also the growth of grass and trees. On the other hand it supports the dominance of woody species such as *Baikiaea plurijuga*.

Along the major rivers such as Bembesi and Gwaai River, different, varied and more fertile soils are distributed. There is a common soil type, locally called as "*isibomvu*", is highly favoured for farming.

2.2.4 Vegetation

The vegetation in the Survey Area is generally categorized into the one in the valley and the others out of the valley where the Kalahari sands occur. Both of them are strongly impacted by logging, fire and grazing. The present form of the vegetation in the Survey Area is attributed not only to natural impacts but also to such human impacts.

Deep penetration of affordable moisture, and the dryness and large diurnal range on ground due to the sands are the favourable factors for deeper rooted woody species over shallower rooted herbaceous plants. The principal vegetation type on the sands comprises deciduous teak woodlands, dominated by *Baikiaea plurijuga, Guibourtia coleosperma*, *Burkea Africana*, *Erythrophleum africanum, Pterocarpus angolensis, Combretum collinum*, *Terminalia sericea* and *Ricinodendron rautanenii*. Those trees presently appears in 8 – 14 m in height, although they would have had larger heights before the logging after the early 1900's. There is no record on primeval forests or monumental trees having the largest diameter in Zimbabwe.

In the open forests, the overstorey mainly comprises *Baikiaea plurijuga, Guibourtia coleosperma*, *Burkea Africana*, *Erythrophleum africanum* and *Diplorhynchus condylocarpon*. One particular form of the open forest is a dense layer of *Baikiaea plurijuga* coppice of multi-stemmed sprout growth, which are commonly known as "Dwarf Teak". The height is up to 1.5 m, over which there is a sparse occurrence of *Pterocarpus angolensis*, *Burkea Africana, Erythrophleum africanum* and *Ricinodendron rautanenii*.

Along the major rivers, some vegetation types reflect several kinds of soils. The basalt soils support a mopane-dominated forest. *Acacia* spp., *Combretum* spp. and *Terminalia* spp. are also prominent.

Reportedly the following six vegetation types are commonly observed in the Survey Area and the neighboring forest lands.

(a) Teak Woodland

The vegetation is dominated by zambesi teak, *Baikiaea plurijuga*. The deep Kalahari sand allows the full development of the teak woodland. Climate does not seem to be a major factor influencing the distribution of *Baikiaea plurijuga*. *Baikiaea plurijuga* develops a long tap root that is capable of exploiting water at considerable depths, i.e. 70 to 100 cm in the case of three-year seedlings. All of the teak forests are strongly intervened with human-originated impacts such as fire and logging.

(b) Brachystegia woodland

The vegetation is dominated by *Brachystegia spiciformis*. The field observation indicates that this vegetation type would tend to grow at the soil condition less affected by the

dryness of Kalahari sands, compared to the teak woodland. In other words, it would be shallower or contain more silt. In some areas *Brachystegia spiciformis* is in association with *Brachystegia boehmii* and *Julbernardia globiflora*. Other common tree species in this vegetation type are *Grewia* species, *Ximenia caffra*, *Bauhinia tementosa*, *Bauhinia petersiana*, *Ochna* species, *Terminalia sericea*, *Peltophorum africana*, and *Burkea africana*. The herbaceous layer is dominated by grasses such as Finger grass *Digitaria eriantha*, Kalahari Sand Quick *Schmidta pappophoroides*, *Stipagrostis uniphumis*, *Eragrostis pallens* and *Perotis patens*.

Commonly it is named as MIOMBO forest. In the Survey Area, the subject forest would be a transitional one from MIOMBO forest to Teak Woodland. This type mainly appears along the upper Bembesi River within the Survey Area.

The MIOMBO forests are known to have defoliation at the end of dry season and start to bud just before the rainy season.

(c) Colophospermum mopane woodland

The vegetation is characterized by either a stunted and multi-stemmed shrubby growth of mopane. It is known that the mopane is capable of forming climax woodland on alluvial poorly drained and generally highly erodable soils. It is associated with individuals or clumps of Leadwood *Combretum imberbe*, Russet Bush willow *Combretum hereroense*, Knob Thorn *Acacia nigresence* and *Dalbergia melanoxylon*. Grasses include species of *Setaria incrassata*, *Panicum coloratum*, *Themeda triandra* and *Digitaria eriantha*

In the Survey Area, this type is only seen along the riverside where the people are settled and cut the mopane (*Colophospermum mopane*) for multiple use.

(d) Vleis

"vlei" is a vernacular word for Depression Grassland or Dambos that is similar to "valley" but not as deep as it. Vleis are dominated by a single layer of grasses. The amount of grass cover depends mainly on the degree of grazing primarily by game. Trees maybe absent, isolated, in clumps or are generally found along vlei fringes. Two types of grasses can be found in vleis. There are the sweet grasses that have a lower fibre content. These maintain their nutrients in the leaves in winter and are therefore palatable. The sour grasses have high fibre content. They withdraw their nutrients in winter and hence are unpalatable. The vlei grasses are tolerant to fire, mowing and grazing. Most species resprout from rootstocks. However, overgrazing and untimely use of management fires tends to increase the amount of pioneer and annual species.

Common grass species in most vleis include, White Buffalo grass *Panicum coloratum*, Weeping Love grass *Eragrostis curvula, Themeda triandra, Aristida bipartita* and *Cynodon dactylon*. *A. bipartita* becomes prominent in severely degraded areas. Woody species include *Ziziphus mucronata, Rhus zeyheri, Acacia karoo, Maytenus heterophylla, Ilala palm, Combretum imberbe* and *Burkea Africana*. *Terminalia sericea* and *Acacia species* usually encroach drying vleis.

In the Survey Area, this type is mainly distributed along the Insuza River where the settlers moved out in the 1970's.

(e) Pterocarpus angolensis Belts

These belts form a component of the teak woodland. They are usually in localised formations inside the teak woodland. The belts are dominated by *Pterocarpus angolensis* which in some areas can found in association with *Burkea Africana*. Other associated species are *Combretum* species, *Terminalia sericea* and *Ochna* species.

These belts are believed to have evolved through fire. For the species to germinate the seed requires slight scorching from fire. Stand level die back due to pathological infections of the species was reported as early as 1930. No remedy or countermeasures have been found for the problem.

Pterocarpus angolensis is recognized as one of the most popular species for the poachers for its high value of timber. Therefore the die back and logging of those trees are changing the distribution from year to year. On site, there are some teak stands with scattered *Pterocarpus angolensis*. But the stands dominated with this tree were rarely observed.

(f) Guibourtia coleosperma / Baikiaea plurijuga woodland

This type is characterised by dominance of Mchibi, *Guibourtia coleosperma* and scattered teak, *Baikiaea plurijuga*. Other associated species are *Ricinodendron rautenanni, Pterocarpus angolensis, Bauhinia petersiana, Bauhinia tementosa, Diplorhynchus condylocarpon* and *Combretum collinum*.

The natural condition for this woodland is quite similar to the one of the above Teak Woodland. *Guibourtia coleosperma* is a third popular timber species in the Survey Area to *Pterocarpus angolensis* and *Baikiaea plurijuga*.

Chapter 3

3. Socioeconomic Conditions

3.1 General Condition of Zimbabwe

3.1.1 Social Conditions

(1) Population

Zimbabwe's population, which was 7,600,000 in 1982, increased, according to a census taken in 1992, to 10,400,000: an increase of some 37% in a 10-year period. During this period, an annual population growth rate of 3.14% had been recorded. An increase at this rate will mean doubling of population in about 23 years. However, according to the UN estimates, the population growth rate has fallen to around 2% in 1998 as a result of birth control, etc. The 1998 census shows the country's population to be 11,040,000. According to the government estimates the population will reach 16,500,000 in the year 2007.

The proportion of urban and rural population in total population was 31% and 69% respectively. The average size of households was found to be 4.8 and population density was 27 persons per km^2. Matabeleland North, where the survey area is located, had the lowest population density: 8.55 persons per Km^2. Zimbabwe's age distribution shows a great number of children and youth in overall population as seen in the Table 3 – 1.

Table 3 – 1 Percentage of Age Group

Age Group	Percentage of Population
0 – 4	17
5 – 14	31
15 – 64	49
65+	3
All Ages	100

Source: "CSO, 1992a" in "Children and Women in Zimbabwe, UNICEF, 1994"

The languages spoken as the mother tongue are Shona (74%), Ndebele (18%), English (4%) and others (4%).

(2) Land Tenure System

It is generally considered that there are the following four land tenure systems in Zimbabwe. (Data on land area, population and population density for each land tenure type is quoted from "Contesting Inequality in Access to Forests, Zimbabwe, 1998 by Nhira et al")

(a) Commercial Land

Comprised of both the large and small-scale commercial farms. In these areas, land is a

marketable commodity which can be bought, sold and used at discretion of the owner. The area of commercial land is some 12,450,000 ha, which corresponds to 31% of the total land area of the country. Population and population density per km^2 in the area were some 1,347,000 and 10 persons per km^2 respectively.

(b) Communal Land

In communal areas, a system of communal landholding is practiced, based on usufructuary rights. Here, land is not a marketable commodity. Rather, households with a traditional claim to residence in that area may remain there as long as they continue to cultivate. Also, there are areas set aside for collective uses such as grazing. Communal land covers some 16,360,000 ha or 42% of the total land area of the country. With a population of some 5,352,000 and population density of 32 persons per km^2, communal land is the most populated of all land tenure types.

(c) Resettlement Area

This land category was introduced after independence in response to increasing population pressure in the communal lands, and to deal with landlessness among households that were displaced during the war. Resettlement areas are mainly purchased commercial farms. To be allocated land in a resettlement scheme, farmers must give up any claim they have to living in a communal area, and must promise to become full-time farmers on the resettlement scheme. They then have rights to stay and farm that land and pass it on to their descendants under the same terms and conditions.

Resettlement area occupy some 3,790,000 ha or 8% of the total land area of the country. Population of resettlement area was about 433,000 and its population density per km^2 was 11 persons.

(d) State Land

State land includes mainly national parks, gazetted forest lands, such as Survey Area, and State farm enterprises. State land is some 6,970,000 ha in area, which is equal to 18% of the country's total land area. Population of state land was 39,000 and population density per km^2 was 2 persons. This makes this land tenure type one of the least populated in the country.

Some 80% of the total agricultural production of the country come from commercial farms, while communal farms and resettlement areas contribute 18% and 2% respectively.

(3) Land Use

Forest area of Zimbabwe is some 25 million hectares, which corresponds to 66% of the 39.1 million hectares total land area of the country. However, Woodland and bushland, rather than commercial forest, make most of the forest area. Land use, including forest land, of Zimbabwe is shown in Table 3 – 2.

Table 3 – 2 Forest and Land Use in Zimbabwe

Land Use	Crown Density (%)	Tree Height (m)	Land Area (1000 ha)	Percent of National Land Area
Natural Forest (moist, deciduous)	>80	>15	12	0.03
Forest Plantation	>80	>15	156	0.40
Woodland	bet. 20 & 80	bet. 5 & 15	20,788	53.21
Bushland	bet. 20 & 80	bet. 1 & 5	4,970	12.72
Wooded Grassland	bet. 2 & 20	< 15	1,204	3.08
Grassland	< 2	< 15	688	1.76
Cultivation			10,734	27.47
Rock Outcrop & Mine Dump			78	0.20
Waterbody			301	0.77
Settlement			141	0.36
Total of National Land			39,072	100

Source for legend: Newsletter of the Research & Development Division of the FC, Vol. 10 No.1, 1998

(4) Administrative System

The administration of the country is divided into provinces, districts, wards and villages as shown in the diagram below. The Survey Area is located in Matabeleland North Province.

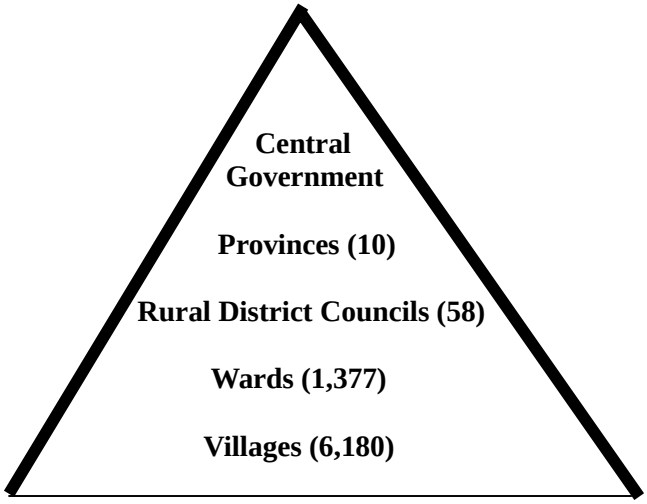


Fig. 3 – 1 Administrative System in Zimbabwe
Source: "Ministry of Local Government, Rural and Urban Development" in "A Situational Analysis in Zimbabwe, UNICEF, 1994"

The government appoints provincial governors as well as provincial and district administrators. Provincial and district development budgets come from central government through the line ministries. In each province there is the Provincial Development Committee which produces a development plan for that province encompassing plans from each district and urban council. The Provincial Development Plan is forwarded to central authorities for consideration and eventual incorporation into the National Development Plan.

Next in administration hierarchy are districts which are run by the Rural District Councils (RDC), the main functions of which are promotion of development, preparation of annual development plans and policies. Through the RDC Act, RDCs have the right to formulate new district-specific by-laws, including the protection and management of common property resources. RDC members are composed of those who are elected from each ward of the district and those who are appointed by the government.

Below the district is the ward level of administration and below the ward is the lowest level, the village. Each ward is run by a Ward Development Committee (WADCO) and each village is run by a Village Development Committee (VIDCO). A VIDCO consists of six members, four of whom are elected and two are members of youth and women organizations. Head of the VIDCO, who is elected by people, represents the village at the ward level and the head of the WADCO represents that ward at Rural District Development Committee (RDDC). A ward consists of Six VIDCOs. The VIDCOs and WADCOs are viewed as an indication of decentralization and reduction of government's control at local level.

(5) Infrastructure

Various locations in Zimbabwe are connected through an extensive network of roads and railway, which are in relatively good condition.

(a) Roads

In 1990, there were 12,896 km of paved roads in Zimbabwe and an overall road density of 1,389 km of road per million inhabitants, a much higher figure than for any other low income country (UNICEF, 1994). However, road density is high in urban and large scale commercial farming areas than the communal areas.

(b) Railway Network

The National Railways of Zimbabwe operate passenger and freight services throughout the country and are connected to the South African, Zambian and Mozambique Railways.

3.1.2 Economic Conditions

(1) Main Industries

Manufacturing, agriculture and mining sectors make the three pillars of Zimbabwe's economy. By forming some 40% of the GDP, the manufacturing industry is the country's very important industry. The industry produces not only most of the goods for the domestic consumption within the country, but also produces goods which are exported to the neighboring countries.

Though contribution from agriculture and forestry sectors to the GDP does not exceed 16%, nonetheless this sector supplies raw material for the manufacturing sector, some 40% to 45% of export items are agriculture related and about 70% of the population make their livings from agriculture. Horticultural products are expanding fast and, among agricultural export items, is the second foreign currency earner after tobacco.

(2) Exports and Imports

Zimbabwe exports primary (unprocessed) goods and relatively less processed manufactured goods while imports highly processed manufactured goods and oil. The main export items of the country are tobacco, food and gold, and these items constitute some 50% of the country's total export value. Other important export items are nickel and asbestos. Chemicals, machinery, fuel and electricity, electric appliances and transport equipment are the main import items.

3.1.3 Development Plans

Public investment in social sector was the main pillar of national social and economic development plans implemented between 1982 and 1990. By the end of the 1980s, as the necessity of transition from a regulated economy to a market economy was recognized, the main objectives of the subsequent plans were shifted to a high economic growth to achieve a substantial increase in the real income of the population and decrease of unemployment. The main objectives of the plans already implemented and those of the current plan are shown in tables below.

(1) Transitional National Development Plan (TNDP) 1982 – 1985

Table 3 – 3 Specifications of Transitional National Development Plan (TNDP)

Main objectives	Achievements
Annual economic growth of 8% in real terms	1.9% annual economic growth
90% increase in export	Export increased some 3% in 1982 & 1983 but decreased in 1984
Creation of employment (average annual increase of 3.2%) which will correspond with 3% increase in population growth	Below the target of 0.5% average annual increase
Control of inflation to below 15%	The target was almost achieved (the average annual inflation was 15.6%)

Source: Association for the Promotion of International Cooperation, Africa, Vol. No. 17, Zimbabwe, Economic Cooperation Series 3rd Edition (in Japanese), 1998.

(2) First Five Year National Development Plan (FNDP) 1986 – 1990

Table 3 – 4 Specifications of First Five Year National Development Plan (FNDP)

Main objectives	Achievements
Economic reform and economic expansion	As GDP growth rate and increase of export, which are direct indicators of the economic expansion, showed, the target was not achieved.
Land reform and efficient use of the land	Some 51,000 households were resettled by the first quarter of 1989, which was close to the target figure of resettling 55,000 households.
Improvement of the living standard of people, specially farmers	-
Development of human resources and expansion of employment	Significant achievements were made in the increase of employment and control of inflation
Maintenance of balance between development and the environment	-
Main macro-economic targets: 5.1% annual growth of GDP, 7.0% annual increase in export, 2.7% annual increase in employment	GDP grew at an average annual rate of 3.1%. Between 1986 and 1990 a positive growth of 1.5% was recorded in export only in 1987.Other years had a minus growth. Employment increased 2.4%.

Source: Association for the Promotion of International Cooperation, Africa, Vol. No. 17, Zimbabwe, Economic Cooperation Series 3rd Edition (in Japanese), 1998.

(3) Economic Structural Adjustment Program (ESAP) 1991 – 1995

Table 3 – 5 Specifications of Economic Structural Adjustment Program (ESAP)

Main objectives	Achievements
Reduction of the central government deficit from 10% to 5%	Throughout ESAP period, budget deficits exceeded the target
Reform of public enterprises to eliminate the large budgetary burden caused by subsidies	The overall performance of the PEs deteriorated significantly during the plan period. Losses incurred amounted to some Z$2.0 billion. However, significant progress was made with regard to privatization.
Civil service reform	The objectives were largely met
Monetary policy & financial sector reform	A significant progress was made in the reform of monetary policy
Trade and exchange market liberalization	The exchange control regime was deregulated and liberalized
Domestic deregulation & investment promotion	All price & distribution controls had been removed by the end of the plan. The objectives have largely been met.
Implementation of a social dimensions of adjustment program	Social Development Fund was established to provide a social safety net for those below a threshold income of Z$400 per month.

Source: Association for the Promotion of International Cooperation, Africa, Vol. No. 17, Zimbabwe, Economic Cooperation Series 3rd Edition (in Japanese), 1998.

(4) Zimbabwe Program for Economic and Social Transformation (ZIMPREST) 1996 – 2000

Environmental protection and proper conservation are recognized as a pre-requisite for continued growth, and greater emphasis is placed on the sustainability of development during ZIMPREST period. Establishing national requirements for Environmental Impact Assessment of projects and environmental strategies for particular sectors are cited as examples of specific actions. Other Objectives and strategies of ZIMPREST are: 1) Economic growth, employment creation, entrepreneurial development and, through these, sustainable poverty alleviation. 2) Fiscal rationalization and reorientation of government complemented by specific policies and programs so that government can facilitate economic empowerment and private sector development.

3.1.4 Donor Organizations and Aid Trend

Zimbabwe's dependency on foreign aid, which comprises less than 10% of the country's GDP, is remarkably low in comparison to other countries in southern Africa. The government's attitude towards foreign aid is based on the principles of maintenance of a relationship of partnership with the donor countries and organizations and the importance of self-endeavor.

The United Kingdom, USA, Germany, Japan, The Netherlands, Denmark and Sweden are the main donor countries. Also, various organizations of the United Nations, and since 1992, such international organizations as the World Bank, IMF and EU have provided assistance to Zimbabwe. The activities of some donor organizations involved in forestry sector are stated below:

- Canadian International Development Agency (CIDA) conducts a pilot program which supports the Forestry Extension Service (FES) of the Forestry Commission in the design and implementation of co-management options in Mafungautsi Forest Reserve in the Midlands Province.
- The Department for International Development (DFID) of the United Kingdom under its 'Shared Forest Management Preparation Project, Zimbabwe' will develop a shared forest management (SFM) approach for the State Forest Reserves, including Gwaai and Bembesi forest reserves. The project will work primarily with the FC's Indigenous Resources Division but will also involve Forestry Extension Services Division and Ngamo Safaris.
- Danish International Development Agency (DANIDA) has previously supported rural afforestation programs in both communal and resettlement areas and will implement a program to support forestry extension in these areas.
- GTZ of Germany is implementing a social forestry program in the communal areas which aims to formulate a project proposal in the field of social forestry. Forestry Extension Division of the FC is the counterpart to this project.

3.2 Conditions of Survey Area

3.2.1 Social Conditions

(1) Background of the Issue of Forest Residents

Much of the Gwaai forests were demarcated (gazetted) as state land in 1936 under the Land Apportionment Act of 1930. The reminder of Gwaai forests and all of Bembesi forests were demarcated in 1941. Before demarcation, people were living in the forests and were engaged in subsistence farming and livestock raising. As these people were providing a source of seasonal labor for forestry operations and were helping fight forest fires, Forestry Commission allowed them to reside in the forests.

Over the years the population of forest residents expanded, due to migration and also naturally. The Forestry Commission, in order to control the forest residents, issued them permits, for a fee of 10 shillings per year, to reside and farm in the forest. The permits

contained such information as the names of family members and the locality and extent of each site. Moreover, rules were established under which the permit holders were not allowed to own goats, visitors could not stay for more than seven days, the children of permit holders were required to leave the forest when they married or reached adulthood, and the residents were obliged to help put out forest fires.

However, despite these measures the population of forest residents continued expanding which forced the commission to adopt new measures such as the introduction of a registration system and raising of the permit (rent) fee to Z$ 10 per year in 1970. Those residents who could not afford to pay the new fee left the forest and this resulted in a sharp fall in the number of people living in forest - from over 1,350 to 350 by 1972. As the commission's intention was to reduce the number of residents still further, to 180, its Agricultural Unit prepared a detailed agricultural plan in 1975 to provide selected residents with sufficient land (50 ha) and infrastructure. These measures, however, were not implemented due to the war of independence in the 1970s and disturbances in the area in the early 1980s. It is mainly during this period of the commission's absences from the forests that families without permits moved to live and farm in the forests. In the mid 1980s the commission was able to restart its activities in the forests. In 1987 it issued permits to the people who were already living in the forest to formalize their residency and to stop any further migrations by unregistered persons, but these actions failed to stem the influx of new settlers.

In the early 1990s, in an effort to solve the problem, the commission refused to renew permits to all people living in the forest, including the former tenants, and regarded everyone as an illegal settler or squatter. The commission adopted the policy of evicting the most recent settlers and settling the remaining residents in neighboring communal lands. In 1990 it evicted over 150 households from Bembesi forest. In the mean time, local administration failed to provide land for additional households to be settled. To tackle the problem, the commission established a relocation area in 1994 in state forest land north-east of the main highway to settle the remaining households. Although many households from the Bembesi forest moved to the relocation area, others living along the lower reaches of the Bembesi river valley in Gwaai forest (Mafa and Lilho communities) refused settlement in relocation area.

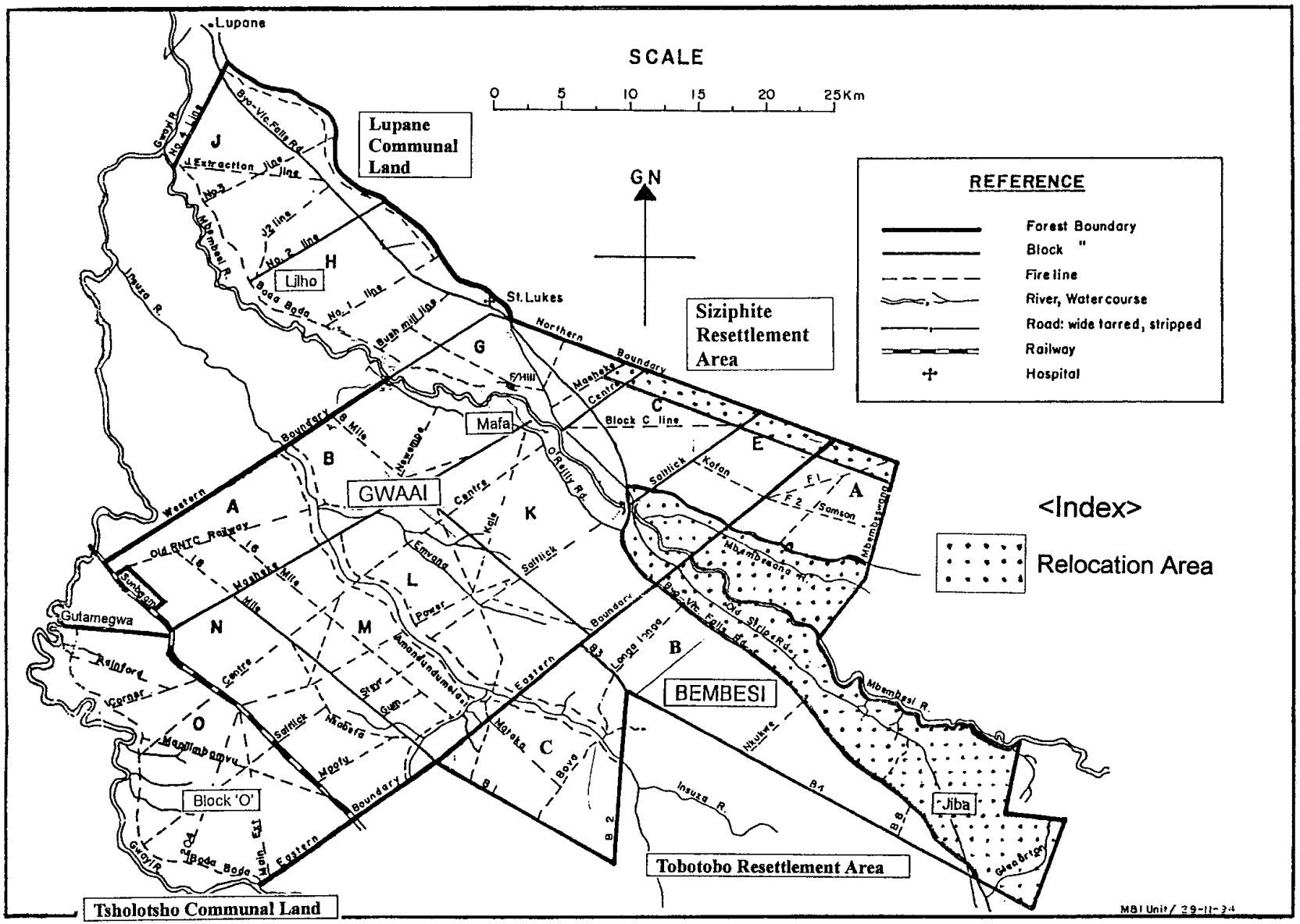


Fig. 3 – 2 Location of Communities and Relocation Area

(2) Population

(a) Forest Residents

Forest residents are living in the forests all over the Survey Area but the bulk of these residents are concentrated mainly along the Bembesi river valley in the eastern sector of the area and along Gwaai river valley in the western sector of the area. This is said to be mainly due to the existence of fertile soils and availability of water in the valleys.

Social Development Studies conducted by DFID in 1999, found that while households in resettlement and communal areas around Gwaai and Bembesi forests tend to be single household oriented, in forest residents villages and in relocation areas more than one household live in one compound or homestead. This could be due to the desire of the majority of the forest resident's grown up children to live in the same compound with their parents in order to maintain the kinship ties, which are important in these communities. It could also be due to the forest policy that does not allow the allocation of separate plots of land to the newly married children.

The results of the same surveys show the average members per household in forest resident communities, in relocation area, in surrounding resettlement and communal areas to be 10, 8, 7 and 7 persons respectively. Also, the average size of household members in the forest residents communities is above the average household size for the district, which is 6 persons. The large size of households in forest communities could be attributed to the existence of several households in one homestead, as mentioned above.

Human and livestock population in Gwaai and Bembesi forest reserves from 1969 to 1995 is shown in Table 3 – 6.

Table 3 – 6 Human and Livestock Population in Gwaai and Bembesi Forest Reserve

	Permit Holders		Non-permit Holders		
Year	Household	Population	Household	Population	Livestock
1969	264	2,112	132	1,056	-
1974	264	2,112	105	840	-
1980	265	2,120	80	640	4,790
1982	365	2,920	258	2,064	5,100
1985	356	2,848	92	736	5,990
1987	373	2,984	179	1,432	6,124
1988	463	3,784	240	1,920	6,695
1989	473	3,784	300	2,400	9,124
1990	360	2,880	289	3,212	9,400
1993	354	2,832	528	4,224	9,600
1995	365	2,920	882	7,056	10,100

Source: "Forestry Commission" in DFID report: "Social Issues in the Shared Forest Management Preparation Project: Gwayi-Mbembesi Forest Reserve, 1999"

Note: Population data are estimated in the report by assuming an average family size of 8 persons.

The decrease in the number of non-permit holders in 1980 and 1985 is attributed to the Forestry Commission's efforts to remove such residents from the forests. The increase in their numbers in 1982 is said to be due to the political disturbances in the area which disrupted the activities of the FC in the forest reserve. From 1990 onward the number of non-permit holders shows a drastic increase, and reaches to some 2.4 times of the permit holders population in 1995. The number of livestock owned per household, however, shows a decrease from 13.8 head per household in 1980 to some 8 head per household in 1995. This could be due to the droughts of the 1980s and also due to the fact that the non-permit holders have fewer livestock than the permit holders.

However, the growth pattern of forest resident's population in the period between 1964 and 1996 is not uniform in all forest communities. For example, between 1964 and 1983 the average growth rates in the number of households was 1.1% for Lilho and 4.9% for Mafa. Over the subsequent 13 years interval (1983-1996), however, the number of households in Mafa declined by 2.5%, due possibly to younger people leaving the forests. On the other hand, relocation area has experienced a tremendous increase of 8.7% per annum in the number of households for the same period (1983-96). This rapid growth could be due to natural growth, migration from areas outside forest, etc.

The current number of household and population in the forest area (except Jiba relocation area for which data were unavailable), as provided by the Forestry Commission and related Kraal-heads are shown in Table 3 – 7.

Table 3 – 7 Current Household Number and Population in the Forest Area (except Jiba) as Provided by the FC and the Related Kraal-heads

Area	Forestry Commission Data		Kraal-Head Data	
	Household	Population	Household	Population
Mafa (forest)	294	2,352	315	2,550
Lilho (forest)	120	960	138	1,104
Block O (forest)	80	640	88	704
Jiba (relocation area inside forest)	Data unavailable	-	Data unavailable	-
Total	494	3,952	541	4,358

Source: "Forestry Commission" in DFID report: "Social Issues in the Shared Forest Management Preparation Project: Gwayi-Mbembesi Forest Reserve, 1999"
Note: Population data are estimated in the report by assuming an average family size of 8 persons.

The differences between the figures provided by the FC and those of the Kraal-heads could be due to under-reporting by the residents to the FC. Considering the under-reporting and the 10 person average size of households in forest resident's villages, as

reported by DFID's Social Development Studies, 1999, the population in the forests may be actually somewhat higher than the figures given in the tables.

(b) Neighboring Communities

The recent available data on population in the communities neighboring Gwaai and Bembesi forest reserves are shown in Table 3 – 8.

Table 3 – 8 Population of the Communities Bordering Gwaai and Bembesi Forest (1992)

District	Ward	Population
Lupane	Lupanda	2,423
	Gwamba	4,192
	Daluka	5,084
	Resettlement area	2,875
Dubi	Ward 3	6,941
	Ward 4	8,257
	Ward 5	2,937
Umguza	Ward 10	1,999
	Ward 11	4,775
	Ward 12	2,117
Tsholotsho	Ward 4	3,906
	Ward 5	5,381
	Ward 6	6,447
Total		57,334

Source: Central Statistical Office, 1992

Assuming an increase of 20% in population between 1992 and 1999, current population of the communities surrounding Gwaai and Bembesi forest could be some 68,800 persons. Population of the neighboring communities affects the forest in many ways. Some of them could be the former residents with relatives still living in the forest. These communities benefit directly from the forests through grazing and utilization of various forest products such as firewood, fruits, medicinal plants, thatch grass, construction poles etc.

Education status of household members in four communities is shown in Table 3 – 9.

Table 3 – 9 Education Status of Four Communities in Survey Area

Education Status	Jiba	Mafa	Lilho	Block O
No formal education	10	14	18	13
Primary school graduate	26	22	14	28
Currently in primary school	19	33	22	38
Total HH members	78 (missing cases 2)	115 (missing case 1)	113	115(missing cases 2)

Data source: DFID report: Social Development Studies for the Gwaai-Bembesi Settlement Options Study, Household Survey, 1999.
Note: 1) Figures in the table represent actual household members under a category. 2) The original data also contain information on school drop outs & those with an education higher than primary school level.

As can be seen from the table, the majority of household members either completed primary school education or is currently enrolled in primary school.

(3) Land Tenure

The main type of land tenure in Survey Area is state forest land which was demarcated as forest reserve in the 1930s and 1940s. According to Forest Act, the ownership and management of state forest land and its resources lies with the state. Individuals and groups may be able to make use of the forest land resources only through the permission and agreement of the state.

Land tenure type in areas around Survey Area consists of Lupane communal land and Siziphite resettlement area in the north and Tobotobo resettlement area and Tsholotsho communal land in the south. Communal lands belong ultimately to the state, and are based on a usufruct tenure system. Resettlement areas, which were introduced after independence in 1980 to reduce the increasing population pressure in the communal lands, are based on a leasehold tenure system. Relocation area in the north-east along the main highway, which is actually inside the state forest land, was designated as relocation area by the Forestry Commission in 1994 to settle forest residents.

(4) Land Use

Existing land use categories in Survey Area comprise forest, agricultural land - which consists mainly of farmlands under cultivation but also of some abandon or fallow parcels of farmland - and settlements. Forests are found in Kalahari sand areas and are the main source of timber, thatching grass, firewood, poles for fencing of farmlands and houses and grazing area for livestock. Settlements and agricultural lands are found along Gwaai and Bembesi river valleys due to the availability of water supplies, occurrence of

fertile soils and better grazing areas. Wildlife area is located along the Insuza vlei (broad grassy depression), where there is no human settlement and cultivation area.

(5) History of Cutting

The timber cutting of the Survey Area of Gwaai and Bembesi forests began in the early 1900s, and the history is divided into 2 terms. The first cutting cycle is from 1911 to 1973, and the second cutting cycle is from 1974 to now (1999). History of each cutting cycle is shown in Table 3 – 10.

Table 3 – 10 Summary of Exploitation of Timber within Gwaai and Bembesi Forests (1900－1999)

DATE	AREA/BLOCK	COMPANY	COMMENT
FIRST CUTTING CYCLE: C.1911－1973			
C. 1903－04	Along the railway line	Pauling and Co.	Reported by Sim 1910
1911－31	Gwaai, up to 8Km either side of the railway line	1911－17 Meister 1917－30 RNTC	Numerous alterations, extensions and additions to the original contract
1932－ ?	Bembesi	RNTC	New agreement, no details provided
1944－47	Gwaai B	RNTC	Single contract, also covering Gwampa and Lake Alice. 25,000m^3 per annum teak and/or mchibi (>33cm dbh ob*); 6,800m^3 per annum mukwa (29cm dbh ob)
1947－52	Gwaai C	RNTC	
1952－61	Gwaai E,G,H,J	RNTC	
1961－65	Gwaai K and L	RNTC	
1965－73	Gwaai M and N	RNTC and Perry & Co.	
SECOND CUTTING CYCLE: 1970－2010			
1970－74	Gwaai O	Perry & Co.	Start of 2nd cycle
1986	Bembesi C, west of Insuza River	Forestry Commission	Timber to mill at Sawmill Siding
1988	Gwaai A, west of 16 mile rd.	Forestry Commission	Timber to Gwaai Siding
1988	Gwaai M and N, west of 16 mile rd.	Forestry Commission	Timber to Gwaai Siding
1992－93	Gwaai J and H	Forestry Commission	SANO Operation. Timber to St. Lukes
1994－95	Gwaai B	Forestry Products	Also along Inkosikazi Road
1996－97	Bembesi A	Supreme Searchers	Relocation area to East of Main Road
1996－99	Gwaai C and G	Zimbabwe Building Services	Portion to east of main road, ongoing

* dbh ob= diameter at breast height over bark.

Source: Environmental assessment of current land use and four settlement options for Gwaai and Bembesi state forests

(6) Timber Concession

In recent years the Forestry Commission granted two concessions for logging in Gwaai and Bembesi forests, centering on relocation area north-east of the Bulawayo-Victoria Falls Road. Contracts were awarded in 1996 to Zimbabwe Building Services to log in the Gwaai, while Supreme Searchers, which subsequently terminated operation in 1997, had been contracted to cut in Bembesi (The extraction was terminated in 1998). These concessions were granted in the relocation area set aside for forest residents in order to recover exploitable commercial timber that might otherwise have been lost when new fields were cleared. Concessions are awarded for one year and are subject to approval by the Forestry Commission every year. Timber extracted by the two concessionaires between 1996 and 1998 is shown in Table 3 – 11.

Table 3 – 11 Timber Extracted By Concessionaires in Survey Area (Timber Vol. Unit: m^3)

Concessionaire	Year	Type of Timber					
		Teak	Mchibi	Wet Mukwa	Dry Mukwa	Others	Total
Supreme Searches	1997	1,738	47	2, 049	191	-	4,025
	1998	781	25	508	5	-	1,319
	Sub-Total	2,519	72	2,557	196	-	5,344
Zimbabwe Building Services	1996	1,570	39	588	-	93	2,290
	1997	2,180	-	295	-	4	2,479
	1998	5,399	151	920	156	22	6,648
	Sub-Total	9,149	190	1,803	156	119	11,417
	Total	11,668	262	4,360	352	119	16,761

Data source: DFID report: Environmental Assessment of Current Land Use and Four Settlement Options for Gwaai and Bembesi State Forests, 1999

(7) Leasehold Grazing

The system of leasehold was initiated in the 1970s. Currently the FC has signed agreements with a number of farmers and livestock owners from surrounding areas to graze their cattle in six areas within the Gwaai and Bembesi forests. The leased areas cover some 25,000 ha, and the leasing period is five years. The grazing lease agreement is renewable for Z$ 8 per hectare per year. The grazing schemes raise earnings for the FC through lease fees on the agreement. They also reduce the herbaceous matter and, hence, serve as a fire prevention measure.

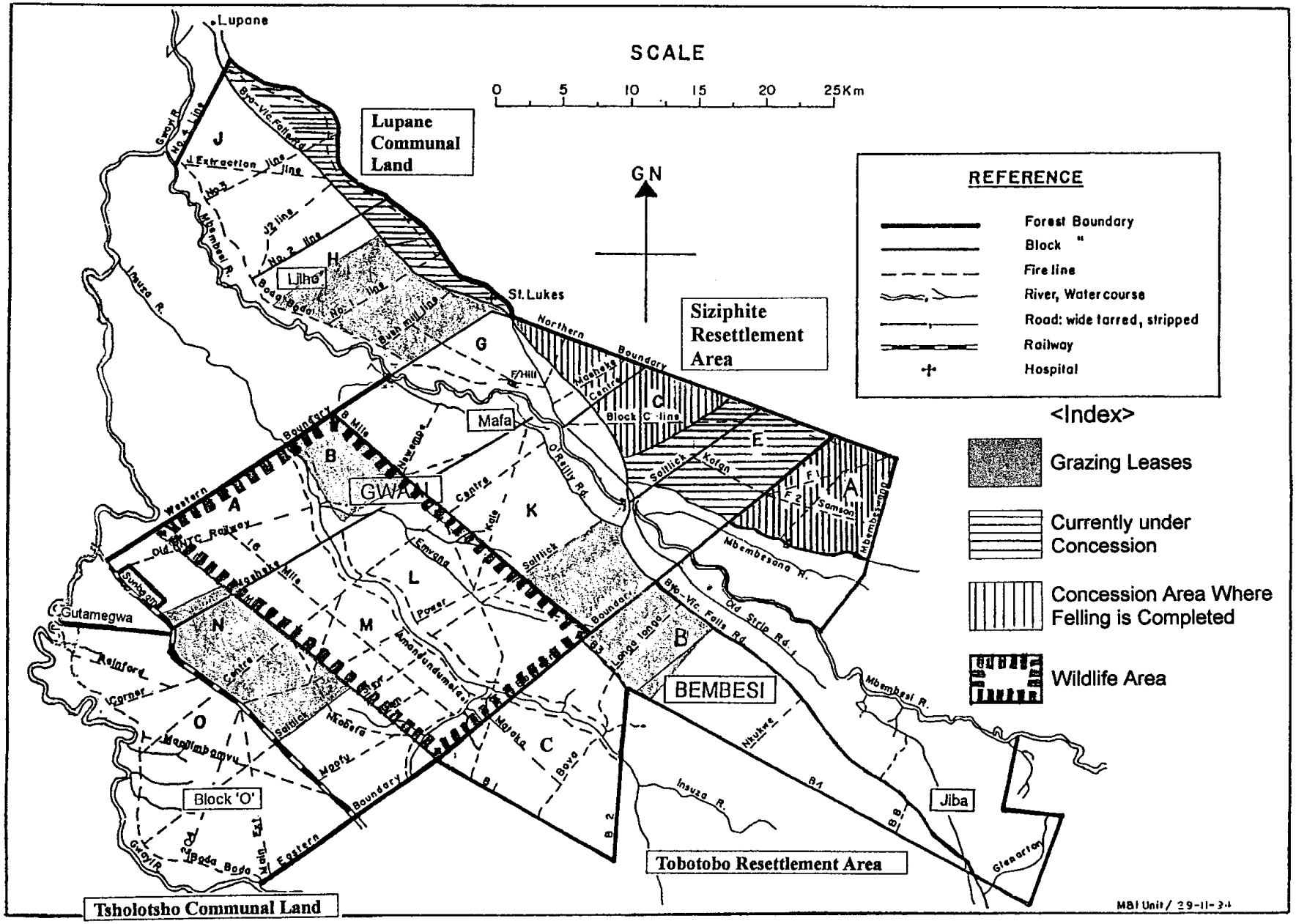


Fig. 3 – 3 Grazing Lease, Wildlife and Concession Areas

Initially when leasehold system began around 1970, cattle were making use of the relatively good quality summer grazing resources, and then removed back onto their ranches for the winter period. Currently, however, cattle are maintained on the lease area on a permanent basis.

(8) Administrative System

Gwaai Forest Land is located in Lupanda Ward of Lupane District. There are five villages within the ward. Bembesi Forest Land is located in Wards 17 and 18 of Bubi District. The first councilors for the Gwaai and Bembesi forest residents were elected in 1998. This was the first time that the residents had representation in the RDC. As a result the forest residents now pay levies to the RDC.

(9) Social Infrastructure

(a) Existing Infrastructure

As was observed in the field, social infrastructure is either lacking or is in a poor condition in the areas of forest residents. The residents, therefore, depend to a great extent on the neighboring communal lands, resettlement area and relocation area for such infrastructure as schools, shops, grinding mills, dips and cattle sale pens. Near the confluence of Gwaai and Umguza rivers in Block O, for example, wells, some two meters deep, are dug by the local people in the riverbeds during the dry season, and water from these wells are used for drinking and for livestock. In the rainy season the river sediment fills the wells, so every dry season the wells have to be rebuilt. Well digging is done by men and carrying water from wells to home is the work of women and children. Also, there was no school in the locality, and the children of the residents had to cross the river and travel long hours to attend school in the neighboring Tsholotsho Communal land. The condition of existing infrastructure in and around Survey Area is shown in Table 3 – 12.

Table 3 – 12 Existing Social Infrastructure in Four Locations in and around Survey Area

Area	Infrastructure Type	Furthest Distance Traveled (km)	Existing Condition	Location in Relation to Forest Area
Mafa (in forest)	School (three schools)	9 ~ 12	insufficient classrooms, shortage of toilet facilities, insufficient or no furniture, lack of houses for teachers	within
	Bore-hole	-	some have broken down	within
	Bridge	25	-	boundary with neighboring communal area
	Clinic	19	good	outside
	Shops	19	Good	outside
	Grinding mill	19	good	outside
	dip-tank	15	shortage of water	within
	asphalt road	19	very good	outside
Lilho (in forest)	School (three primary schools)	5 ~ 20	similar condition as Mafa, except the existence of toilet facilities & lack of books	one primary school within, others outside
	St. lukes hospital	25	very good	outside
	Business center	40	very good	outside
Block O (in forest)	School (two primary & one secondary)	14 ~ 16	shortages of teachers (Secondary school only) , water, furniture & classrooms	outside
	Dip-tank	14	enough medicine to pump	outside
	Clinic	16	Fair	outside
	Roads	14	fair but no bridge	outside
	Grinding mill	14	frequent breakdowns, inaccessible during flooding	outside
	Cattle sale pens	14	very far (lose of cattle weight due to long distance walk)	outside
	Business center	14	inaccessible during flooding	outside
Jiba (relocation area)	School (one primary & one secondary)	16	Insufficient teachers (primary), furniture, classrooms, inaccessible during flooding (secondary)	Primary school within, secondary school outside
	Business center	3	functioning well	within
	Bore-holes	3	frequent breakdowns	within
	Clinic	-	Good	within
	Dip tank	-	Good	within

Data source: DFID report: Social Issues in the Shared Forest Management Preparation Project, Gwayi-Mbembesi Forest Reserve, 1999

Providers of the infrastructure are the community, governmental departments, donors, private individuals and religious organizations. From among the four sites, Block O is lacking its own infrastructure. People in the block depend for infrastructure use on the neighboring Tsholotsho communal land.

It is reported that, opinions among the forest residents are divided regarding neighboring communities use of forest resources. Some of the residents believe in sharing forest resources with neighboring communities as reciprocation for the benefits forest residents derive from existing infrastructure in those outside communities. There are others who think that outside communities should not benefit from forest resources because while the residents pay for the services they get from the communities those communities generally do not pay for the resources they get from the forest. Moreover, the residents attribute most of the illegal activities in the forest area to members of neighboring communities. Residents suggest that neighboring communities should benefit from forest resources under two conditions. They have to pay and that their activities have to be strictly regulated and monitored

(b) Infrastructure Desired by the Residents

The infrastructure desired the most by the forest residents in the three sites inside the forest is water supply related infrastructure. Other infrastructure desired by the residents are clinics, schools, and roads. In Jiba relocation area there was little desire for water supply facilities because this area has a number of wells which supply water for human needs and livestock.

3.2.2 Economic Conditions

The economy in Survey Area is based mainly on livestock raising and subsistence agriculture. Mutual assistance and exchange of goods among the residence is common, and the area's degree of dependency on and access to the market is very low. Some surplus crops, mainly corn, is produced by those residents who's farms are located along the valleys. The surplus is either exchanged for goods or sold to the residents and people from the surrounding communities who's lands are located on gusu, which is infertile. Other significant commercial activities inside forest lands are concessions and lease arrangements. A number of the residents is said to earn some cash income from working in timber concession operations.

3.2.3 Local Living Conditions

(1) People's Livelihood

The top three sources of income for households in Survey Area are livestock, crop and beer sales. Other income generating sources for local inhabitants are sale of craft from reeds and palms by women, sale of wooden craft by men and sales of thatching grass, milk, vegetables, etc. by both women and men (Matose et al, 1996). Also, both men and women earn some income by hiring out their labor for agriculture activities during peak agricultural periods and for building, thatching huts and pole/firewood cutting. Small

livestock such as goats and chicken are mainly sold locally, while cattle is sold to private buyers and to organizations involved in beef industry. Crops are mainly produced for self-consumption but sometimes may be sold locally or to private buyers in order to cover immediate household needs. Also, a few people sell forest products such as firewood and indigenous fruits in urban markets to obtain cash income.

The issue of livelihood strategies of households by wealth category was investigated by DFID in four communities (Mafa, Jiba, Lilho and Block O) in Survey Area. Wealth indicators used were mainly livestock ownership, size of land cultivated, type of housing, ownership of movable property, money, formal employment, etc. Based on the wealth indicators and using scouring method, the participants in PRA in the communities ranked households into the four categories as shown in Table 3 – 13. In Mafa, Jiba, Lilho and Block O the percentages of households that were categorized as poor and very poor were 75, 64, 84 and 35 respectively. In Block O the majority of households, 60%, were categorized as average.

Table 3 – 13 Livelihood Strategies by Wealth Category in Four Communities in Survey Area

Livelihood Strategy	Rich	Average	Poor	Very poor
Livestock	29	21	12	3
Crops	31	16	10	3
Forest products	2	8	21	28
Formal employment	8	14	7	1
Piecework	0	1	11	16
Remittance	3	8	3	0
Brick moulding	0	2	7	9

Data sources: DFID reports: ① Final Report, An Appraisal of Alternative Settlement Options for Residents in the Gwaai and Bembesi State Forest Reserves, 1999. ② Social Issues in the Shared Forest Management Preparation Project, Gwayi-Mbembesi Forest Reserve, 1999. Note: Figures in the table are out of a max. of 40. Piecework excludes Jiba & Lilho. Remittance excludes Mafa. Brick molding in Block O only.

As is shown in the table, livestock and farming are the most important livelihood strategies for the wealthier households. Also, this category has a better chance of earning cash income through employment and remittances. The very poor and poor groups, however, who may not possess land or livestock, are to a great extent, dependent on products from forest for their livelihoods. There is little employment opportunity for the poorer households and their main sources of income are piecework and brick molding.

(2) Customary Practices Related to Resource Use

Surveys by the FC (J. Clarke, 1994) show that there exist throughout rural communities in Zimbabwe a deep concern and respect for trees as well as a detailed knowledge of tree

species and their uses. Also, due to the people's dependence on woodland resources, a conservation ethic has been built into their culture, traditions and religion. Customary woodland management practices consist of rules, beliefs and taboos regarding the use of particular tree species, individual trees and woodland areas. However, these customary practices are under strain as a result of the effects of modernization and changing conditions.

Some traditionally protected woodland sites and trees in the country are: i) Sacred hills and forests, formerly ancient burial grounds where a variety of indigenous species grow; ii) Traditional court sites and ceremonial sites (rain-making, etc.) with trees such as muhacha (*Parinari curatellifolia*), muonde (*Ficus sur*), etc.; iii) Graveyards (family or communal) where certain trees are planted e.g. muchecheni (*Ziziphus mucronata*) and others are not cut e.g. mushuma (*Diospyros mespiliformis*); iv) Taboo trees (traditionally associated with bad luck, death or witchcraft if utilized) such as ichithamuzi (*Lonchocarpus capassa*), muzeze (*Peltophorum sp*.) and chizhuzhu (*Maytenus spp*.).

Customary practices and regulations concerning the use of natural resource, which had been common in Survey Area, had many elements of resource conservation and resource sharing. In Gwaai and Bembesi Areas, prior to the gazetting of forest reserves, resource (trees, grasses and wild animals) was used according to local regulations which varied by type of resource. Disputes about the resource use were settled by headman or kraal heads (Matose et al ,1996). Some examples of the regulations are mentioned below.

- Trees were only cut for immediate use or when fields were cleared;
- Thatching grass was collected during the dry season when its seeds had matured to ensure its regeneration and thus its availability the following year;
- Whole trees were not felled for medicine and instead medicine was obtained from tree barks and roots;
- People did not use some trees for firewood because they believed that using these trees would bring bad luck to the family. The trees that did not make good fire were also not used.

Members of the community shared the meat from wild animals hunted by groups of hunters from the community. Hunting was regulated and not all animals were hunted. For example, eland and pangolin were not hunted due to certain cultural beliefs. Use of some shrubs and trees from Survey Area forests is shown in Table 3 – 14.

Table 3 – 14 Use of Trees and Shrubs from Gwaai and Bembesi Forest Reserves

		Utilization								
Trees and Shrubs	**Scientific Name**	Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits
Ichithamuzi	*Loncocarpus capassa*			X						
Umvagazi	*Pterocarpus angolensis*	O		X	O				O	
Umphafa	*Ziziphus mucronata*		O	X						
Umgoma	*Shynziophyton rautenaii*			X						
Umtshibi	*Guibourtia coleosperma*			X						
Umkamba	*Afzelia quanzensis*			X						
Umqhobampunzi	*Pseudolachnostylis maprouneifolia*			X						
Ibhanda	*Loncocarpus capassa*			X						
Umnyelenyele	*Ochna pulchra*			X						
Umnondo	*Julbernardia globiflora*	O								
Umganu	*Sclerocarrya birrea*	O								
Umangwe	*Terminalia sericea*		O			O				
Umkhaya	*Acacia nigrescens*		O							
Isinga	*Acacia karoo*		O							
Iphane	*Colophospermum mopane*	O	O	O		O				
Ithetshane	*Combretum hereroense*		O	O				O		
Igagu	*Dichrostachys cinerea*		O							
Igonde	*Brachystegia spiciformis*			O	O		O			
Itshabela	*Brachystegia boehmii*						O			
Ikhalimela	*Dicoma anomala*								O	
Intolwane	*Elephantorriza goetzei*								O	
Umkusu	*Baikiaea plurijuga*		O	O	O			O		
Umsosoviyana	*Grewia occidentalis*									O
Umviyo	*Vangueria infausta*									O
Umqokolo	*Dovyalis caffra*									O
Umxakuxaku	*Azanza garckeana*									O
Umtshwankela	*Vitex payos*									O
Umthunduluka	*Ximenia caffra*									O
Umkhemeswana	*Strychnos cocculoides*									O
Umswantsha	*Ximenia americana*									O
Umgalanyeza	*Albizia spp.*	O								
Iwohlo	*Acacia erioloba*		O							
Isihaqa	Unknown								O	
Unyawutshana	Unknown								O	
Ihlwili	*Combretum imberbe*								O	
Umgwadi	Unknown									O

Source: Matose et al., 1996

Note: Household items include mortars, plates, milk containers, pestles, stools, etc. Bark is used for fiber.
O; utilized X; not utilized due to either traditional brief or fire making

(3) Informal Organizations

Permit Holder's Association or Resident's Associations were formed under the Land Use Regulation, which ushered in the tenancy system. The resident's associations were

established to act as a communication link between the FC and the residents. They were also a mechanism for developing groups of residents who would manage infrastructure such as dips and schools and the formation of cooperatives for the provision of agricultural inputs and services. Resident's elected members and all permit holders were eligible for election. The operations of the Resident's Association were disrupted during the war and subsequent disturbances. Currently a number of these associations are active in the area.

(4) The Issue of Relocation

In the early 1990s the Forestry Commission hoped to resettle forest residents outside the state forest or relocate them to one or more designated areas within the state forests. In 1990 it evicted over 150 households from Bembesi forest. In 1994 the commission established a relocation area of some 30,000 ha in state forest land north-east of the main highway, to settle the remaining households. Those households who moved into the relocation area were given 0.25 ha of land for house building and 6 ha of land for farming. Although health care facilities still have to be built in the relocation area, a number of wells and schools had been built to make the area attractive for relocation. Even though many households from the Bembesi forest moved to the relocation area (currently the population of the relocation area is estimated at 700 households), others living along the lower reaches of the Bembesi river valley in Gwaai forest (Mafa and Lilho communities) refused settlement in the relocation area. The main reason given by the residents for their refusal to be relocated is said to be the poor quality of land in the designated relocation area, in comparison to the forest areas where they live.

The refusal of the forest residents to be relocated have created tension between the residents and the Forestry Commission, and become a source of conflict between the two sides. Realizing the fact that without the cooperation and participation of people living in the forest and in its surrounding areas an effective protection and management of the indigenous forest resources could not be materialized, the commission is attempting a new policy of indigenous forest management through participation of all stake holders, including the forest residents.

3.2.4 Agriculture and Livestock Raising

(1) Farming

The major crops grown in farms managed by the forest residents and in neighboring areas are corn, sorghum, pearl millet, ground nuts, pumpkin, beans and cow-peas. Corn and millet are grown from November to January, depending on the start of the rainy season, and harvested in March-April. Manure and hybrid corn seeds are used extensively. The

latter is the only external input in agriculture system in the area.

The average yield of corn in the area is estimated at 0.8 ton/ha, which is low in comparison to the neighboring area's commercial farmlands where, according to local farmers, tones per hectare yield of corn in rainfed and irrigated farms ranges from 2.5 ~ 3.0 and 6.0 ~ 8.0 respectively . The low crop yield in the area can be attributed mainly to the poor nutrient contents of the soils, insufficient application of fertilizer, unfamiliarity of farmers to modern farming techniques, the annual rainfall which does not exceed 600mm and the occurrence of frequent droughts. This makes the production of a significant and stable amount of agricultural crops, for consumption as well as for sale, in the area very difficult.

In Mafa, Jiba, Lilho and Block O, the average landholdings of the poor and very poor households, who constituted some 65% of the total households, are 0.5 ha to 3.25 ha, while the wealthier household's average landholdings, which constituted the remaining 35% of the households, are 4.75 ha to 7.25 ha.

Although exact figures are unavailable, it is commonly believed that in Survey Area some households produce a surplus crop, which is sold or exchanged with other goods. This might be the case with soils cultivated in the valleys at the four communities, which are characterized as being good to very good, allowing households with larger holdings to practice semi-commercial cropping. The rest of the households are engaged in subsistence farming.

(2) Livestock Raising

Livestock raising is the most important livelihood component of the residents in Survey Area, and the sale of livestock is their main source of income, as stated in (1) of 3.2.3. One of the significant changes in Livestock population, as compared to the 1970s, has been the introduction of goats. Data from the Forestry Commission for 1993 shows the livestock numbers in Gwaai and Bembesi forest area as 10,046 cattle, 2,302 goats and 1,884 donkeys. The total numbers for the three animals in 1996 was 16,075. Cattle are raised for milk, meat and manure, and are also used for draft power. Other livestock owned by the residents include sheep and chicken.

In Mafa, Jiba, Lilho and Block O, the average number of cattle and donkeys owned by the very poor and poor households, which constitute some 65% of the total households, is 3. The average number of the same animals owned by the wealthier households, which form the remaining households, is 173. However, there is variation among the communities. In

Block O, for example, the combined number of cattle and donkeys owned by the average and rich households is 440 cattle and donkeys, while the number for the same group of households in Lilho is 70.

Grazing in gusu sand areas during the rainy months, and mostly in the valleys during the dry season, constitute the grazing pattern in the area. One of the most important benefits of summer grazing in gusu sands is the reduction of fuel load and thus reduced risk of forest fire.

3.2.5 Environmental Concern

The major issues of environmental degradation in Zimbabwe are associated with deforestation, soil erosion, overgrazing and siltation. Increasing demand for wood (firewood and timber for construction), expansion of land for cultivation and forest fire could be cited as the three main causes of deforestation in the country. Most of the demarcated indigenous forests, including the forests in Survey Area, are located on deep Kalahari sands in the Natural Regions which receive around 600mm of rainfall per year. Major environmental problems facing these areas are fire, improper logging and cultivation, which may result in degradation of the fragile soils as well as deterioration of forest condition.

DFID commissioned environmental survey has evaluated expected impacts arising from current land use in Gwaai and Bembesi forests. Factors evaluated are logging, fire, settlement and cropping, livestock production and wildlife production. The likely significance of the impacts of each factor is classified as minor, moderate, and major.

The survey finding show that "the principal environmental impacts of logging relate to the impairment of future production through (possibly) unsustainable levels of offtake, and also increased burning. The latter results from the opening of the forest canopy and disturbance to the forest floor. Both these factors contribute to significantly increased herbaceous production, and thus increased risk of fire." The detrimental effects of fire include both the loss of and damage to standing timber, and also diminished levels of natural regeneration. Concerning the effects of livestock on the forests, the survey does not foresee serious environmental impacts at the current rates of stocking. It states that "cattle do not have any marked negative impact to timber species. On the other hand, if managed effectively, livestock can have the strongly beneficial effect of reducing the fuel load within specific priority areas, thus lowering the risk of fire".

(1) Legal System

According to the Natural Resources Department of the Ministry of Mines, Environment and Tourism, currently the implementation of Environmental Impact Assessment (EIA) of the development projects is voluntary, because the Environmental Management Act has not yet been approved by the parliament. And Implementation of EIA at the planning stage of a project is encouraged but is not obligatory.

Environmental Impact Assessment Policy states that the EIA policy is administered by the Ministry of Mines, Environment and Tourism and the Director of Natural Resource of the Ministry has been delegated the responsibility to overseeing the process of EIA submission. The process consists of the following three stages.

(a) Proposal development.
(b) EIA preparation and review.
(c) Implementation.

In forestry sector it is the developer of a project who will conduct EIA survey which will be reviewed by the Natural Resources Department. The role of the Forestry Commission is as a referral, specially in technical matters. Sub-sectors covered by the EIA guidelines for forestry sector, which was prepared by the Ministry, are 1) Plantation development/reafforestation; 2) Sawmilling, pulp and paper industry; 3) Indigenous forest management/extraction. The guideline assists with the preparation of an EIA by providing five checklists which identify the typical :

- Major project activities (checklist A)
- Major environmental issues (checklist B)
- Typical impacts (checklist C)
- Type of analysis and tools which may be applied (checklist D)
- Management steps to mitigate the impacts (checklist E)

(2) Especially Protected and Restricted Species of Fauna and Flora

The Department of National Parks and Wildlife Management defines the following two distinct categories of protection for plant and animal species of Zimbabwe.

- Specially protected species

These are species which are rare or threatened for which the State would not normally issue permits for their exploitation, notwithstanding the provision of section 37 of The Parks and Wildlife Act.

- Restricted species

These species do not satisfy the strict criteria for Special Protection but their exploitation will be controlled and monitored by the State through a system of permits.

(a) Fauna

Especially protected and restricted species of animals (mammals) of Zimbabwe and their existence in Survey Area are shown in Table 3 – 15.

Table 3 – 15 Especially Protected and Restricted Species of Animals (Mammals) of Zimbabwe and Their Occurrence in Survey Area

Especially Protected Animals			Restricted Animals		
Common Name	Scientific Name	Existence in Survey Area	Common Name	Scientific Name	Existence in Survey Area
Pangolin	Manis termmincki	exist	Aardwolf	Proteles cristatus	do not exist
Wild Dog	Lycaon pictus	exist	Cheetah	Acinonyx jubatus	do no exist
White Rhino	Ceratotherium simum	exist	Lichtenstein' s Hatrebeest	Alcelaphus lichtensteini	do not exist
Black Rhino	Diceros bicornis	do not exist	Roan	Hippotragus equinus	exist
Brown Hyaena	Hyaena brunnea	exist	Gemsbok	Oryx gazella	do not exist

Source: The Department of National Parks and Wildlife management: Protected Species of Animals and Plants in Zimbabwe, 1991.

(b) Flora

Protected Species of Animals and Plants in Zimbabwe, 1991, mentions twenty four species and four genera of plants as "specially protected indigenous plants", and two species, four genera and one family as "restricted indigenous plants". Those plant related to Survey Area are listed in Table 3 – 16.

Table 3 – 16 Specially Protected Indigenous Plants and Restricted Indigenous Plants of Zimbabwe and Their Occurrence in Survey Area

Specially Protected Indigenous Plants	Existence in Survey Area	Restricted Indigenous Plants	Existence in Survey Area
Twenty four species, four genera	some do not exist, some could not be confirmed	Two species, four genera, , one family	Some species of the genera Aloes
			Gloriesa superba (flame lily)

Source: The Department of National Parks and Wildlife management: Protected Species of Animals and Plants in Zimbabwe, 1991.

3.2.6 Safaris

Ngamo Safaris, the wildlife utilization branch of the FC, manages Amandundumella Hunting Camp in Gwaai Forest, Intundla Hunting Camp in Ngamo, Sijarira-photo/hunting; Jafuta photo; Kazum Hunting. Data provided by Ngamo Safaris, showed that it recorded a total turnover of Z$10.75 million from both hunting and photographic safaris in fiscal year 1994/95.The turnover for the fiscal year 1995/96 was Z$15. 53

millions which represents a 44% increase. Net profit, however, decreased some 43% in fiscal 1995/96 in comparison to previous fiscal year due mainly to poor performance of photographic safaris as the result of delays in opening and renovation of some lodges. In fiscal 1996/97, Ngamo Safaris posted a loss of Z$ 2.4 millions but in fiscal 1997/98, due to improvement in operations, it had a turnover of Z$ 49.7 millions and an operating profit of Z$ 4.2 millions.

Amandundumella hunting camp, which is located in the wildlife area of Gwaai Forest Land in Insuza vlei, had a total revenue of Z$ 1.4 millions and a net operating profit of Z$ 296 thousands in fiscal 1996/97 from hunting, trophy fees, sales of meat and hide, and souvenirs. In fiscal 1997/98, due to improvements in operations, the total revenue posted was Z$ 2.8 millions and net operating profit was Z$ 651 thousands, an increase of some 2.2 times in comparison to previous year.

In the wildlife area of Gwaai Forest Land, enumeration of wild animals is conducted by the staff of Indigenous Resources Division once a year in August-September . Based on the results of the enumeration, quota for hunting is established for the area after approval of the Department of National Parks and Wildlife Management. The hunting season is from April to November. Annual census data for the Insuza vlei from 1993 to 1997, and 1999 safari quota for Gwaai-Bembesi are given in Table 3 – 17 and 3 – 18.

Table 3 – 17 Annual Census Data of Wild Animals for Insuza Vlei

Category	Species	1993	1994	1995	1996	1997
Mainly Grazers	White Rhino	0	6	4	4	5
	Buffalo	81	70	21	0	14
	Zebra	124	52	96	102	396
	Roan	31	10	0	33	15
	Sable	503	392	533	639	954
	Wildebeest	159	196	354	430	593
	Waterbuck	55	66	70	85	127
	Tsessebe	43	18	69	73	82
	Warthog	195	67	76	180	178
	Reedbuck	6	4	4	4	1
Mixed Feeders	Elephant	0	0	0	0	63
	Eland	496	95	479	408	1,320
	Impala	290	192	258	235	75
Mainly Browsers	Giraffe	3	1	7	31	38
	Kudu	158	78	75	83	197
	Bushbuck	1	1	0	0	26
	Duiker	15	9	27	0	18
Predators	Leopard	0	2	1	0	3
	Hyena	0	2	0	1	13
	Painted dogs	3	0	0	0	24
	Jackal	9	6	3	1	19
Others	Hare	0	0	0	0	2
	Ostrich	10	16	3	0	16

Source: DFID report: Environmental Assessment of Current Land Use and Four Settlement Options for Gwaai and Bembesi State Forests, 1999.

Table 3 – 18 1999 Safari Quota for Gwaai-Bembesi

Common name	Scientific name	1999 Quota	Trophy Fees (US $ per unit)
1. Buffalo (NT)	Synceros caffer	unlimited	975
2. Duicker	Sylvicapra grimmia	4	60
3. Eland (T)	Taurotragus oryx	10	525
4. Eland (NT)	Taurotragus oryx	3	525
5. Elephant	Afrodonta africana	1	7,500
6. Hyena	Hyaena brunnea	3	60
7. Impala (T)	Aepyceros melampus	10	90
8. Impala (NT)	Aepyceros melampus	4	90
9. Jackal	Canis mesomelas / Canis adustus	2	30
10. Kudu	Tragelaphus strepsiceros	5	490
11. Leopard	Panthera pardus	2	1,875
12. Sable	Hippotragus nigre	10	1,350
13. Steenbok	Raphicerus campestris	2	-
14. Warthog	Phacochoerus aethiopicus	6	60
15. Waterbuck	Kobus ellipsiprymnus	1	175
16. Wildebeest	Connochaetes taurinus	7	360
17. Zebra	Equus burchelli	2	490

Data source: Indigenous Resources Division, The Forestry Commission, 1999.
Note: T; Trophy, NT; Non-trophy

3.2.7 Progress of DFID's Shared Forest Management (SFM) Preparation Project

(1) Specifications of SFM Preparation Project

Shared Forest Management Project by DFID intends to explore a durable and acceptable

solution to the issue of the forest residents as well as a fresh approach to the management of the forest reserves in general. The project will work with Indigenous Resources Division, Forest Extension Services and Ngamo Safaris of the FC. Specifications of the project, as stated in Draft Project Memorandum, are summarized below.

(a) Project Aim

The project aims to developing a shared forest management (SFM) approach, agreed among key stakeholders, for the State Forest Reserves of Zimbabwe. The project intends to increase awareness of SFM, create a consensus around negotiated solutions to the controversial issue of forest residents, and prepare a project which will begin the process of implementation.

(b) Project Duration

The project will last for twelve months.

(c) Project Output and Activities

The main output of the project will be a detailed project proposal for developing and implementing a SFM project. The main activities proposed are an introductory SFM workshop, an SFM study tour program within and outside Zimbabwe, participatory information gathering and local level planning workshops in three reserves with forest residents, an environmental impact study, and a final project planning workshop involving key stakeholders.

(d) Current Situation of Indigenous Forest Reserves

Some 20,000 people * are living within the reserved indigenous forests of Matabeleland. Approximately 4,000 of these reside in demarcated relocation areas within the reserves. Others are former tenants of the FC (those who were present in 1930 when the reserve was created). The remainder is a mix of recent and long term settlers. The FC regards all forest residents as squatters.

* The figure do not refer to the project area which is Gwaai/Bembesi, but to the greater forest reserve estate.

For the residents a principal issue is security of tenure for agricultural land and secure access to forest products. As the result of this insecurity of tenure neither communities nor the local authorities are investing in primary social infrastructure. Illegal felling, wildlife poaching, cattle grazing and the harvesting of thatch grass characterize residents forest use patterns.

For those communities neighboring the forest reserves, while some grazing permits are issued, access to other forest products are restricted. The lack of secure benefits from the forests to local communities has resulted in limited support for forest protection among these communities. This has created conflict between the FC, communities outside the reserves and forest residents.

(e) Brief Historical Background of the Issue of Forest Residents

1960's: A multiple land use policy allowing controlled settlement within the forest reserves was declared.

1970's and early 1980's: An agricultural tenancy system was introduced but was not implemented due to war. The war and dissident activities disrupted forestry works during this period and large numbers of inhabitants settled the forests.

Late 1980's: The FC adopted a policy of eviction of all forest settlers. This policy was only partially implemented.

1990's: The FC has sought to exert increased control over the forests, forest residents and their neighbors.

(f) The FC Policy on the Issue of Forest Residents

As mentioned earlier, the overall approach of the FC has been to regard all forest residents as squatters. Two strategies have been employed to implement this approach.

- Relocation of forest residents to those parts of the forest that are less affected by settlement and agriculture. In Gwaai and Bembesi Areas the strategy has been resisted by most of the early inhabitants, because they believe that the land in relocation areas is inferior to the valley land currently used. However, relocation has already been implemented in Gwampa Forest.

- Resettlement of forest residents in state lands by re-designating these lands as resettlement areas. This strategy was to do with residents getting resettled in the national resettlement program. But the residents were unwilling to register for resettlement.

(g) DFID's Position on Options Available to the FC for Resolving the Forest Residents

Issue

- Eviction
  This involves the forced removal of forest residents from forest reserves without provision for resettlement. As a matter of policy, DFID does not support eviction without resettlement.

- Resettlement
  The voluntary resettlement of forest residents to designated resettlement areas is not considered to be a feasible solution as there is no scheme for the resettlement of forest residents. The likelihood of sufficient and suitable land being made available in the short to medium term is low.

- Involuntary Relocation
  Involuntary relocation means the relocation of forest residents to defined areas on the periphery of forest reserves. Relocation is unacceptable to the majority of remaining forest residents in Gwaai and Bembesi Areas because the residents believe that the land offered by the FC is inferior to the land currently used. Other problems involved are the unwillingness of people to move and unavailability of basic infrastructure in relocation areas. This option as currently envisaged is inconsistent with DFID policy on poverty and resettlement.

- Voluntary Relocation
  Voluntary relocation involves the negotiated and agreed relocation of households within forest reserves. Under this option, communities and households would be offered a fair choice without coercion.

- Improved Status Quo
  This option will allow existing forest residents to remain in their present location, with provisions made for secure tenure, improved infrastructure, and shared forest management agreements. A combination of voluntary relocation and improved status quo would, according to DFID, provide the best prospects for a positive resolution of the forest residents issue but needs to be examined on a case by case basis as part of the preparation project.

(2) Progress of SFM Preparation Project

(a) Assessment of Alternative Settlement Options

DFID commissioned a series of studies in February 1999 to assess alternative settlement options as an means of building consensus towards an agreed approach centered around negotiated solutions to the controversial issue of forest residents. The studies were conducted through collection and review of relevant data, household interviews in the forest communities and in neighboring communities, and Participatory Rural Appraisal (PRA) approaches which were conducted only in the forest communities. Overall objective, method used, major findings and recommendations of each study are described below.

- Social Development Studies for the Gwaai-Bembesi Settlement Options Study, Household Survey, 1999.

- The study was carried out through interviews involving 64 households to understand household dynamics and livelihood, and thereby enhance assessment of the social impacts of the different settlement options. The household interviews were conducted in four forest communities of Mafa, Lilho, Block O and Jiba (relocation area), in Sivalo communal area in Lupane district and in Tobotobo resettlement area in Umguza district.

- On the use of the forest resources by the communities the study found that the major use was firewood and grazing.

- The report on the study states that the residents responses to the question of what resources people would want to see shared if the FC decides on a shared forest management program "were not very elaborate". The study suggests, therefore, that if the FC decides to adopt a shared forest management program, there is a need to carefully investigate the nature and types of resources to be shared.

- During the interviews conducted under the study, it was found that there are more compounds than the numbers listed on the household lists, which suggests that population growth is currently not well contained. However, the study was not able to establish population trends in the forest resident's communities.

- The study's findings on the current institutions operating in the forest communities show that Kraal-heads have a key role to play in any new arrangements concerning forests because majority of the people respect them.

- Social Issues in the Shared Forest Management Preparation Project: Gwayi-

Mbembesi Forest Reserve, 1999.

- The study, through PRA approaches, collected and analyzed information on the population trends and social histories of forest residents, stakeholders, wealth condition, existing and desired social infrastructure, etc.

- The study quotes population figures from the FC which indicate that the number of forest residents and their livestock have been increasing since the forests were gazetted. It concludes that this is largely attributable to the breakdown of the tenancy system in the 1970s because of the liberation war and in the 1980s because of the political disturbances in Matabeleland. In these years the FC's activities in the forests were severely disrupted.

- On the issue of stakeholders involved, the study points out to a high number of stakeholders, to the existence of a complex relationship among these stakeholders, and to the fact that the stakeholders interests often create overlapping and conflicting demands on the forest. The stakeholders most likely to be directly affected by the shared forest management program are identified as the forest residents and neighboring communities. These communities are characterized as not being homogenous, and as having differences and conflicts within and between themselves.

- The study points out to the two most important indicators of wealth among the forest residents as livestock ownership and amount of land owned, and states that the poorer households depend on other sources of income such as forest products and contract labor.

- Social infrastructure in the forest resident's communities was found to be inferior in comparison to the infrastructure in the neighboring communities. The study suggests the provision of social infrastructure as a useful entry point for the shared forest management program, but cautions on the encouragement of more resettlements in the forest as the result of infrastructure development.

- On the subject of settlement options, the study suggests improved status quo as the best option for adoption for the shared forest management program. The reasons given are: i) the forest resident's strong preference for the improved status quo; ii) the option being least disruptive to the resident's way of life and having the least financial cost; iii) the likelihood of the option getting political support and leading to the enhancement of the resident's livelihood.

- Land Use, Settlement and Infrastructure Study, An Assessment of Forest Residents Options in the Gwayi-Mbembesi Forest Land, 1999.

- Only the "First Rough Draft" of the report on the study was available at the time of writing this report. The draft report mentions that the study was carried out through collection and analysis of existing data, photo interpretation, satellite imagery interpretation, interviews and PRA approaches. The study aim, though is not clearly stated in the draft report, could be, as judged from the report contents, an assessment of the current land use condition and the best options for settlement from the view point of land use in Gwaai and Bembesi area.

- Main current land use categories in the area are forest and cultivated land. Farmlands are located on Kalahari sands and along Gwaai river and Bembesi river valleys. Crops grown in the farmlands are maize, sorghum, millet and sunflower. Crop yield in the farmlands on Kalahari sands is very low, estimated at around 0.8 tons/ha in the case of maize.

- The study evaluates social infrastructure such as wells, schools, health clinics, extension services, roads, bridges, etc. in the area as either in a poor condition or non-existent. It states that for infrastructure use people in the forest communities depend on the neighboring resettlement areas and communal areas.

- The study uses four criteria such as suitability (mainly environmental and land resources), adequacy (mainly source of subsistence), acceptability (mainly tenure and offspring regulations) and feasibility (mainly land, financial, capital and human resources) to evaluate the four settlement options. All four criteria are ranked together and improved status quo gets the highest score, followed by no change, then resettlement. Relocation gets the lowest score.

- Legal and Policy Studies for Shared Forest Management, 1999.

- The overall objectives of this study is to provide guidance on the implications of national law and policy as well as on international law for resources use, settlement and management within demarcated forests in Zimbabwe. The analysis conducted in this study is based solely on secondary research. Seventeen pieces of legislation - ranging from the Forest Act to the Constitution – that are directly or indirectly relevant to the management and utilization of forest and forest resources within state

forests, are examined. A number of relevant international laws and treaties are also discussed.

- The study evaluates six settlement options for forest residents. These are: i) voluntary resettlement outside the reserves; ii) involuntary resettlement outside the reserves; iii) voluntary relocation, iv) involuntary relocation; v) improved states quo options; vi) no change.

- After reviewing all relevant national and international laws, the study concludes that the FC is not responsible for the resettlement program and thus has no legal authority to resettle persons (this rules out options i and ii). Eviction is not consistent with trends in national policy, international law, and international policy and trends that increasingly focuses on addressing problems of management through negotiation rather than exclusion.

- The FC is not entitled to forcibly move people, whether inside or outside of forest estate. It is, however, entitled to determine the conditions of settlement in forests. In extinguishing rights or restoring the status quo it must follow the processes determined by law. This effectively rules out option vi.

- In order to avoid the acquisition of rights by prescription it advises the FC not to opt for options vi and have no change.

- The study concludes that through a process of elimination the only option that the FC has other than to evict is to legalize the residents occupation and enter into agreement about the terms and conditions of settlement (either option iii or v).

- Economic Assessment of Alternative Settlement Options for Residents in the Gwaai and Bembesi State Forest Reserves, 1999.

- The approach and method used for economic assessment were review of the most relevant literature, collection of data provided by the FC and collection of field data using PRA methods. The three central components of the study were: an economic understanding of the livelihood strategies; the income generating potential of forest products; and a cost benefit analysis of the different options.

- Cropping and livestock raising were found to be the most important livelihood activities in the area. The study results showed that the poor were more dependent

upon forest products than wealthier households. For people to have an incentive to use forest resources more productively and to conserve them, the study suggests placing an opportunity cost on the land in the form of a levy. These lease fees should be plowed back into the communities in the most direct and transparent manner, so that it is evident that they are benefiting from them.

- The study assessed whether the FC could support a shared forest management program. It found out that while the 1998 operating profits for the Gwaai/Bembesi forests provides a solid foundation for a forest sharing arrangement, once the accounts were consolidated under Indigenous Resources Division, profits declined considerably.

- The study shows that royalties on indigenous hardwood timbers are inadequate and that local hardwoods sell at less than half the price of imported substitutes. To remedy the situation, the study suggests that the FC dispense with the concept of a royalty and charge prices which optimize revenue potential. The revenues obtained could be used by the FC for managing a program of shared forest management and other activities. Moreover, higher prices of local indigenous hardwoods will create an incentive to use this timber in the production of high value added products, such as furniture.

- The study finds commercial grazing schemes not generating large revenue and being underutilized. For the best use of the forest's grazing potential it suggests incorporating it into the people's livelihoods as part of a shared forest management.

- On the settlement options the study found the resettlement to be most costly option. Proposals for Phase II of the resettlement program estimates that the cost of settling each family on a Model AI scheme is about Z$800,000. Due to the shortages of funds, the study predicts that it is highly unlikely that the resettlement program will make any meaningful progress in the short term.

- Relocation was found to be the next most costly option. Relocation would be more expensive than the improved status quo because of higher translocation and planning costs.

- No change is considered as the least favorable option because it does not guarantee security of tenure and development of social infrastructure for the residents and is also not favored by the FC.

- The study suggests improved status quo as the most pragmatic strategy to adopt for settling the forest residents.

- Concerning wealth categories and the issue of settling the residents, the study suggests that residents with best and largest piece of land, and who own the most cattle, will certainly prefer the improved status quo option. Those households who fall into the average wealth category are also likely to remain in the forest because, although the resettlement option starts looking attractive, the cost of moving would tip the balance in favor of remaining in the forest. The poor and very poor forest residents, who make up the majority of households, would gain access to much larger plots if they opted for either relocation or resettlement.

- Environmental Assessment of Current Land Use and Four Settlement Options For Gwaai and Bembesi State Forests, 1999.

- This study was conducted through collection of relevant existing data, PRA exercises, aerial photo and satellite imagery analysis. The study comprise an environmental assessment of the current natural resource and land use for Gwaai and Bembesi forests, and of four potential settlement options for the residents of these forests.

- The study evaluates environmental impacts of logging, forest fire, livestock raising and wildlife in Gwaai and Bembesi forest area. The principal environmental impacts of logging relate to the impairment of future production, through (possibly) unsustainable levels of offtake, and also increased burning. Fire results through the opening of the forest canopy and disturbance to the forest floor. Both these factors contribute to significantly increased herbaceous production, and thus risk of fire. The detrimental effects of fire include loss of and damage to standing timber, and also diminished levels of regeneration.

- On livestock the study suggests that at current rates of stocking livestock are not seen as causing any serious environmental impact. And cattle do not have any marked negative impact to timber species. Similarly wildlife production is not seen as having resulted in any significant degradation of the Insuza vlei, where the intensity of use is highest. The increase in elephant is leading to growing problems of crop destruction, and may require intervention. Any increase in elephant densities over about 0.25 animals per km^2, is likely to be detrimental to timber species, specially mukwa, both through the destruction of standing trees and also limiting regeneration.

- On four settlement options for the forest residents the study recommends reorganization. This is a form of improved status quo where people may be required to move locally in order to rationalize the micro-scale pattern of resettlement, and to coordinate settlement with the provision of facilities. The study recommends this option on the ground that it offers the potential for significantly improved environmental management and, thus, for mitigation against the bulk of the likely detrimental impacts associated with no change option.

A general conclusion that all the studies draw is the need for a participatory approach, involving all stakeholders, to the management of indigenous forests of Gwaai and Bembesi. The results and findings of the studies are arranged by the experts involved in conducting the above mentioned six studies and the following final report is produced.

- Final Report, An Appraisal of Alternative Settlement Options for Residents in the Gwaai and Bembesi State Forest Reserves, 1999;

The Shared Forest Management Preparation Project team formulated the following project concept note.

- Project Concept Note, 1999;

The main findings and conclusions of the Final Report and Project Concept Note are summarized below.

Four options for settlement of forest residents:

- Resettlement outside the forest reserves.
- Relocation within the Gwaai/Bembesi or other forest reserves.
- Improved status quo: people remaining more or less where they are, but with possible improvement to the existing settlement pattern and resource management.
- No change: that is, allowing the situation to continue as at present.

Assessment of the options

Resettlement option

Problems concerning resettlement option are: i) A lack of mandate or authority in the part of the Forestry Commission concerning resettlement. ii) Inadequacy of government funds to implement phase II of the resettlement program. Only 3% of the resettlement budget

has been allocated for the three-tier resettlement models which are appropriate for the area. Thus only a limited number of households are to be resettled, and forest residents have not been accorded any priority for the resettlement.

Relocation option

Relocation option's drawbacks are: i) Land suitable for cultivation in the designated area has already being taken up, which are mostly in the valleys, and the remaining land is situated on Kalahari sand which is inappropriate for extensive cultivation. ii) The land reserved for forest residents has been allocated to new migrants. As a result, the area is too small for the 700 households already living there. This effectively rules out relocation to the area set aside by the Forestry Commission.

Evicting people living in the forest could be politically problematic, as was proved in other eviction cases. Moreover, some eviction may run counter to international law which increasingly support solutions that promote local level involvement and the historical and traditional resource rights of forest residents.

No change option

This option is ruled out because continuation of the present condition may create more conflict between the Forestry Commission and the residents. Also, both the commission and the residents rejected no change option.

Improved status quo (reorganization) option

In the study, the forest residents expressed a strong preference for the improved status quo as can be seen from Table 3 – 19.

Table 3 – 19 Ranking of Participant's Preference at Study Site Meetings and Implied Preferences of the Forestry Commission

Options	Mafa	Jiba	Lilho	Block O	Overall rank	Forestry Commission
Resettlement	2	3	4	3	3(12)	1
Relocation	3	2	3	2	2(10)	2
Improved status quo	1	1	1	1	1 (4)	3
No change	4	4	2	4	4(14)	4

Source: DFID report: Final Report, Options, 1999.
Ranking: first preference = 1

Moreover, a cost analysis showed that improved status quo cost least, and a technical assessment concluded that the improved status quo option scored highest in terms of suitability, adequacy, acceptability and feasibility. Based on these results the studies commissioned by DFID concludes that the improved status quo is the best alternative

settlement option and recommend it for adoption as part of the proposed shared forest management.

(b) Proposed Project Period

Project Concept Note mentions five main areas of activity that DFID will support:

- The development of capacity of key stakeholders to develop effective partnerships, plan, implement and monitor the development of forest areas.
- The establishment of mechanisms for funding project interventions that will be widely accessible to a range of service providers and responsive to plans generated through participatory processes in forest resident and forest margin communities.
- The establishment of rational, productive and sustainable land use systems within forest reserves, which ensure the core objectives of both the FC and communities are achieved. Secure access to and development of the agricultural and forest resources of the forest reserves represents one of the main benefits of this project.
- The planning and provision of a national standard of social infrastructure to forest resident communities.
- The establishment of community-based forest resource management and other income generating schemes in forest resident and forest margin communities.

The note envisages shared forest management as a process and as a pilot. It notes that " the divers array of local and institutional stakeholders makes it difficult to anticipate where effective coalition might form, and to designate of roles and responsibilities too concretely in advance. Instead, the project will create the opportunity to explore and develop partnerships in the course of implementation".

While the note mentions that "a planning horizon of 10 years – typical for community based resource management- is used for SFM", it proposes "an initial project period of three years, an intensive learning phase" for SFM project in Gwaai and Bembesi area. "Based on the experience of such a phase, it may then be possible and reasonable to prepare a more perspective program for a second phase of funding". A "bridging project" of four to six months is proposed for the time between project submission and implementation.

Chapter 4

4. Forests and Forestry

4.1 Legal Issues

Main points of current key acts that have a bearing on land use and forestry are described below.

4.1.1. Forest Act

The Forest Act was enacted in 1948 and amended after independence in 1982. The Forestry Commission was established under this act through the transfer of the undertaking of the Forestry Branch of the Department of Agriculture. The Act gives the FC the control and management over demarcated forests, expropriated land and other state land designated as forest, and in the case of demarcated forests lease arrangements are permitted within these forests where rents accrue to the FC.

The Act defines regulations to protect forested land (section 39) and set aside land for production forestry (Section 40). Section 44 prohibits timber extraction for mining from demarcated forests or protected private forests. Timber extraction for mining from other sources is allowed after permission is obtained from Mining Timber Permit Board, the chairman of which will be a forest officer appointed by the FC. The Act gives powers to regulate the extraction of indigenous timber on private land (Section 55), requiring land holders to apply for permission from the FC.

4.1.2. Communal Land Act

The Communal Land Act of 1982 (amended 1985) replaced the Tribal Trust Land Act. The Act refers to communal land as the land which, immediately before the 1st February, 1983 was Tribal Trust Land. Control over communal land is assigned to the President with administration by the RDCs. The act removed the power of the chiefs to control land, and allows land use plans made by the councils to override any customary land claims. However, Section 8 of the law states that a RDC, where appropriate, shall have regard to customary law relating to the allocation, occupation and use of land.

4.1.3 Natural Resources Act

The Natural Resources Act was enacted in 1942 and has since been amended several times. The Natural Resources Board, established under Section 3 of the Act, exercises general supervision over natural resources. Other functions of the Board include stimulation of public interest in the conservation and improvement of natural resources, and recommendation to the State legislation or measures deemed necessary for the proper conservation, use and improvement of natural resources. The board is accountable to the

President.

If land holders in an area wish to take measures for conservation or improvement of natural resources, they can request the relevant Minister to declare the area an Intensive Conservation Area (Section 36). The land holders in an Intensive Conservation Area can elect a Conservation Committee the main functions of which will be the preservation, protection and improvement of natural resources in the area and to make recommendations to the board. The costs of carrying out the measures (activities) and maintenance works are borne by the land user. The Minister, on the recommendation of the Board, may make loans, subsidies or grants-in-aid to a Conservation Committee (section 42).

If a Communal Land is found to be deteriorating by overgrazing or other misuse, the Board may, with the approval of the Minister protect the whole or part of such land against human occupation or cultivation, prohibit livestock grazing or cutting of trees and other vegetation.

4.1.4 Communal Lands Forest Produce Act

The act, which was first known as the Tribal Trust Lands Forest Produce Act, passed in 1928. The CLFP Act restricts the use of forest products by local people to "own use", that is, products cannot be sold, except where permits are allocated. Permits can be obtained for sale of forest products such as firewood, and levies are paid to the RDC. The act provides for RDCs to grant licenses to concessionaires to cut trees for commercial purposes, with revenue going to RDCs. Under the act the removal of tree products from within 100 meters of a riverbank is prohibited.

4.2 Forest Policy

Forestry sector policy of the Government of Zimbabwe is described in the Forest Act mentioned above. The act authorizes the FC as forest authority to protect and conserve forests and woodlands for the benefit of the nation. The act defines the criteria under which the FC, as forest enterprise, can set aside forest land for production and conservation purposes, and Section 15 of the act gives the FC the power to regulate the use of the demarcated forest reserves.

4.3 Administrative System

The Zimbabwe Forestry Commission, a parastatal organization, under the Ministry of Mines, Environment and Tourism is the principal agency for managing and developing

policy with regard to forests and woodlands. It was established in 1954 under the Forest Act. The commission is involved in both developmental (State Services) and commercial activities. However, preparations are made to separate these sections, and to establish a private company for the commercial activities. Developmental activities will continue to be undertaken by such departments of the FC as Research and Development Division, Forestry Extension Services (FES), Indigenous Resources Division (IRD), Colleges, and Ngamo Safaris. The commercial department concentrates mainly on the development of exotic plantations, and timber and timber product processing and marketing. Organization of the FC is shown below.

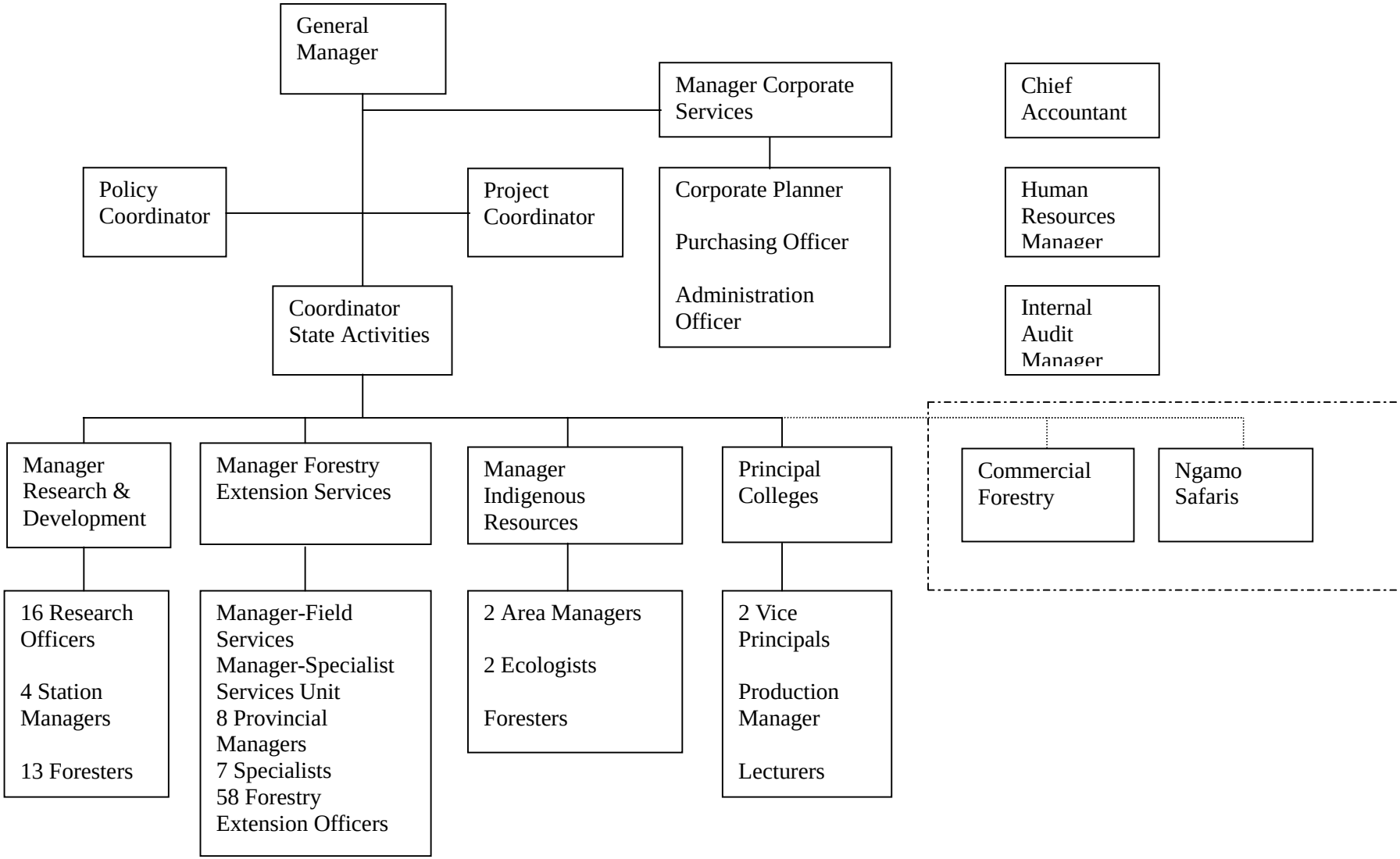


Fig. 4 – 1 Organization of the Forestry Commission

4.4 Forestry

It is suggested that in Zimbabwe forest resources directly contribute to about 3% of the GDP. Indirectly, however, the country's forests contribute to the national economy through preservation of the environment, sustained agriculture, generation of local income and improvement of food security.

Indigenous woodlands cover some 23 million hectares or about 60% of Zimbabwe's land area. The projected increase in rural population will continue to place pressure on woodland areas. A sustainable future for forest resources will, therefore, depend on making better use of these limited resources.

Commercial timbers utilized from indigenous woodland are mainly *Baikiaea plurijuga* (Zambezi teak or mukusi) and *Pterocapus angolensis* (mukwa) and, to lesser extent, *Guibourtia coleosperma.* Teak and mukwa are primarily found growing in association in dry deciduous forests on Kalahari Sands which are not fertile. Regeneration of teak takes place mainly through natural regeneration but newly germinating seedlings are prone to attack by rodents and large mammals. Teak is a slow growing species. Its exploitation is limited to trees with a DBH greater than 35cm (currently 31 cm) which amounts to a rotation of about 200 years. The species is mainly used for the production of railway sleepers, timber for mines, and for the production of parquet flooring.

Regeneration of mukwa is less clear than mukusi and the species is vulnerable to die-back. Its growth is faster than teak, and is said to reach a dbh of approximately 51cm in some 200 years. It is utilized mainly for furniture making and joinery.

The gross value of processed forest industrial products in Zimbabwe (sawn timber, panels and paperboard) exceeds US$40 million a year, and forest industries provide employment for about 16,000 people. Main categories of forest resources in Zimbabwe are shown below.

Table 4 – 1 Main Categories of Forest Resources

Forest category	Area (million ha)	Main products & uses	Remarks
Woodlands, forests & trees in communal areas	10	Construction timber, firewood, wild fruits and other foods for rural households	The quality of this woodland is various but mostly consist of scattered trees.
Woodlands & trees in large-scale commercial farming areas	7	Wildlife habitat, timber	Accounts for about 17% of the county's commercially productive indigenous forests.
Woodlands & forests on state lands & in protected areas	6	Parks & protected areas which are important for tourism industry	The Department of Parks &Wildlife operates some 568,000 ha.
Industrial forest plantations	0.11	Timber & timber based products for domestic and export markets	Main tree species planted are pines, eucalypts and wattle.

Source: World Bank Technical Paper Number 210, 1993

Some 72% of the country's plantation area is planted to pines which are predominantly in the eastern provinces. In approximately 15% of the area eucalypts and in the remaining 13% wattle is planted. While eucalypts is planted throughout the country, wattle is planted mainly in the eastern provinces. In 1992/93 plantations produced some 872,000 m^3 of timber and the whole industry employed a total of 8,253 persons.

4.4.1 Timber Products

The exploitation of timber in Gwaai forest started during the 1920s when the Rhodesia Native Timber Concession harvested large portions of teak forest. In 1970 the same company harvested in Block O of Gwaai forest. During these years there was a huge demand for teak as railway sleepers and mine support. After the 1970s mukwa found favorable market in the furniture industry due to bits fine and easily workable timber. Between 1992 and 1994 there were a salvage operation to remove dying mukwa.

Table 4 – 2 Planned Cutting Volume in Blocks A ~ O in Gwaai Forest (year 1994)
(Unit: Vol. overbark (m^3))

Species	Productive Area (ha)	Class 1	Class 2	Class 3	Total
Mukwa	92,787	63,626	23,568	1,862	89,056
Teak	92,787	198,657	94,986	24,012	317,655
Mchibi	92,787	77,491	31,680	8,229	117,400

Data source: Area South Forest Management Plan, the FC.
Note: Class 1; 34 cm dbh and above, Class 2; 26 cm to 33.9 cm dbh, Class 3; 20 cm to 25.9 cm dbh.

The Bembesi forest was exploited in the early 1950s and later in 1980-1984. The main commercial timber species in Bembesi forest are *Pterocarpus angolensis, Baikiaea*

plurijuga, Guibourtia coleosperma, Ricinodendron rautanenii and *Afzelia quanzensis.* The most recent timber survey results, as shown in the table below, show that blocks A ~ C are due for cutting.

Table 4 – 3 Planned Cutting Volume in Blocks A ~ C in Bembesi Forest (year 1994) (Unit: Vol. overbark (m^3))

Species	Productive Area (ha)	Class 1	Class 2	Class 3	Total
Mukwa	34,758	13,690	3,563	457	17,710
Teak	34,758	81,021	25,513	5,208	111,742
Mchibi	34,758	41,770	16,569	13,845	72,184

Data source: Area South Forest Management Plan, the FC.
Note: Class 1; 34 cm dbh and above, Class 2; 26 cm to 33.9 cm dbh, Class 3; 20 cm to 25.9 cm dbh

4.4.2 Non-Timber Forest Products

Information collected during the 1992 census on the type of energy mainly used for cooking revealed that 66% of the households in the country used wood. In rural areas 95% of the households used wood compared with only 12% in the urban areas as shown below.

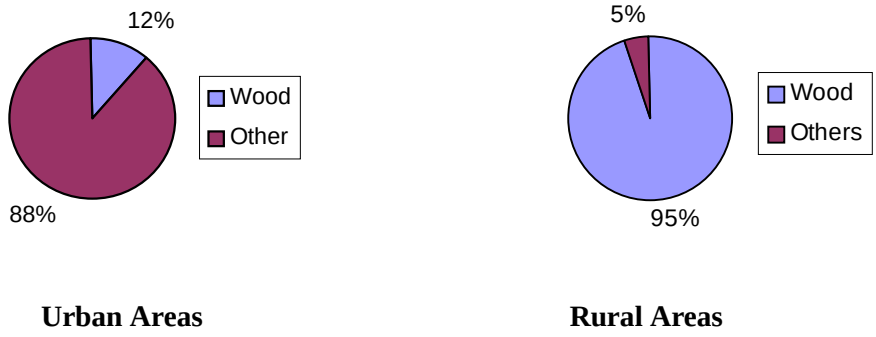


Fig. 4 – 2 Percentage of Households by Main Source of Energy (Zimbabwe Census 1992)

Beside timber harvesting and hunting, other sources of revenue from forest land are from the sale of firewood, thatch grass, posts, sand from river for construction and lease of grazing land. Specifications of non-timber forest products in Survey Area are shown in Table 4 – 4.

Table 4 – 4 Specifications of Non-timber Forest Products in Survey Area

Area	Non-timber Product	Price Per Unit (Z$)	Unit Sold	Revenue	Years Products utilized
	Firewood	15 – 30	680 cord	13,600	bet. 1990- 1994
Gwaai	Thatch Grass	1 – 3	2,114 bundle	4,228	bet. 1992- 94
	River Sand	5/m^3	150 m^3	750	bet. 1992-94
	Firewood	18 – 30	127 cord	3,856	bet. 1992-94
Bembesi	Thatch Grass	2 – 3	2,113 bundles	5,709	1994/93

Source: Area South Forest Management Plans, 1994
Note: One cord is equivalent to 128 cu. ft.

Table 4 – 5 Revenue from Grazing Leases in Gwaai Forest

Year	Area (ha)	Rate (Z$)	Revenue (Z$)
1991/92	4,500	3/herd	1,400
1992/93	9,500	6/ha	58,000
1993/94	9,500	6/ha	58,000

Source: Area South Forest Management Plans, 1994

The current price of good quality, kiln-dried local mukwa and teak, when delivered to the merchants or manufacturers, is about Z$ 11,000/m^3. This is less than half the price paid for the cheapest imported hardwood timber. For example, the landed cost price of imported hardwood timbers to merchants or manufacturers ranges from Z$ 23,000/m^3 for Maranti from Malaysia to about Z$ 32,000/m^3 for oak. All-brown, wet-off-saw, 1.8m lengths of Mozambican mukwa and mahogany lands at Z$ 24,000/m^3 and 27,000m^3 respectively. Moreover, the current royalties for commercial timbers from Gwaai and Bembesi forests, as shown in the table below, are also low.

Table 4 – 6 Royalties for Commercial Timbers from Gwaai and Bembesi Forests (Unit: Z$/$m^3$)

Timber Species	1997	1998	1999
Mukwa	400	400	700
Dry Mukwa	-	150	400
Teak	300	300	350
Mchibi	-	200	350

Source: DFID report: Economic Assessment of Alternative Settlement Options for Residents in the Gwaai and Bembesi State Forest reserves, 1999.

It is widely believed that there is good scope for substantial increases in royalties as a means of pushing indigenous hardwoods prices closer to those of imported hardwoods. As the price increases, its (indigenous timber) use may be reserved for high value added production, such as the manufacture of quality furniture directed at the important overseas markets.

4.4.3 Forest Management

The demarcated forests, which are located in Matabeleland North and Midlands Provinces, are managed by the FC for the protection of watersheds, conservation, and forest products (such as timber, wildlife, grazing and thatch grass).

The recent forest management plan covering Survey Area is Area South Forest Management Plans prepared in 1994 by the Forestry Commission. The plan period is set at 5 years. The plan sets forest utilization targets by major tree species such as mukwa, teak and mchibi (refer to (2) above). In connection to the issue of forest residents, the plan adopts a policy of moving "squatters" into selected areas of the forest (relocation area) for settlement.

For forest fire fighting activities the plan proposes a "rotational concentrated grazing" to reduce the fuel load and holding of conservation education seminars in the neighboring communities, etc.

The plan sets forest improvement targets(figures are given only for Bembesi) the main points of which are shown in the table below.

Table 4 – 7 Planned Forest Improvement Activities (Bembesi Forest)

Activity	Year 1	Year 2	Year 3	Year 4	Year 5
Seedling production in the nursery (number of seedling)	2,000	2,500	3,000	3,500	4,000
Planting (ha)	40	50	60	70	80
Thinning plots	Select site	Mark & thin 3x3 ha	record	record	analyze

The wildlife activities are playing an important role in generating income for the FC, as mentioned in 3.2.6. Currently a greater participation by local population in the management of the forest resources is encouraged through implementation of SFM preparation project.

Timber utilization in the area went through two felling cycles as mentioned below.

- First cutting cycle: Started from early 1900 to 1973, during which time all suitable trees larger than 40 cm in dbh were cut.
- second cutting cycle: 1970 up to the present. This cycle was planned on the basis of a 40 year rotation, during which it was anticipated that, for all the state forests, a mean annual timber yield of 28,000 m^3 could be supported. For various reasons this plan has not been adhered to.

Fire is considered a major problem in the management of the demarcated indigenous forests of Zimbabwe. One of the main effects of fire on these forests is the destruction of young saplings which are susceptible to the heat and it tends to cause discontinuous stand structure.

The present system of fire protection practiced by the FC is based on early detection, quick reaction and suppression. Under this system, each fire is recorded and such data as weather conditions, cause, area burnt, reaction time, etc. are registered.

Forest fires occur due to various activities. Fore example, 65% of forest fires was caused by poachers, 15% was attributed to cultivation practices, 10% to wild fires, and 10% to controlled burning and to public road users in 1994/95. It is believed that poachers frequently use fire as a diversionary tactic and to mislead patrolling forest guards during their operations, which is why the incidence of fire is high by poachers. Cases of incendiarism and deliberate fires may be linked to the existence of conflict between forest residents, neighboring communities and the FC.

In Survey Area, same as in other indigenous forests, due to the continual occurrence of forest fires fire fighting has become a major operation. Tow fire towers, manned by forest guards and equipped with communication equipment, exist for fire detection. Patrolling at regular intervals are conducted to prevent forest fire. Fire fighting equipment used consists of shovels, axes, hoes and water containers. The Table 4 – 8 shows the area of forest affected by forest fire in Survey Area between 1990 and 1993.

Table 4 – 8 Forest Burnt in Survey Area

Forest	Area burnt per year (ha)				Total	
	1990/91	1991/92	1992/93	1993/94	(ha)	%
Gwaai	6,736 (4.7%)	5,220 (3.6%)	759 (0.5%)	7,000 (4.9%)	19,715	13.7
Bembesi	2,542 (4.6%)	5,528 (10.0%)	2,100 (3.8%)	7,194 (13.0%)	17,364	31.5
Total	9,278	10,748	2,859	14,194	37,079	18.6

Source: Forestry Commission

Chapter 5

5. Topographic Mapping

Topographic mapping was conducted for the Intensive Area at the scale of 1/20,000 (refer to Fig. 5 – 1). Fig. 5 – 2 shows the flowchart for topographic mapping.

5.1 Aerial Photography

Aerial photography was conducted by sub-contracting with the South African agents of SWEDESURVEY.

5.1.1 Installation of Aerial Signals

The installation of aerial signals for aerial photogrammetry (refer to Fig. 5 – 4) was conducted. Each point was selected in the most suitable position to facilitate other operations.

Number of signals installed:	1 existing triangulation point, 30 new control points
Signal specification:	3 blades (blade size: 120 cm x 50 cm)
Signal colour, material:	White hemp
Centre pile specification:	Metal marker

5.1.2 Aerial Photography

Aerial photography covering the Survey Area (refer to Fig. 5 – 3 Aerial Photography Index Map) was carried out between July 31 and August 11, 1999.

Flight permission and clearance were obtained prior to aerial photography on July 22, 1999 from the Ministry of Defence and the Department of the Surveyor General.
The work volume of aerial photography and specifications were as follows:

(1) Work Volume

Photography area (scale of 1/20,000):	Approx. 200,000 ha
Number of strips:	17 strips
Number of aerial photos:	622 sheets (black & white)

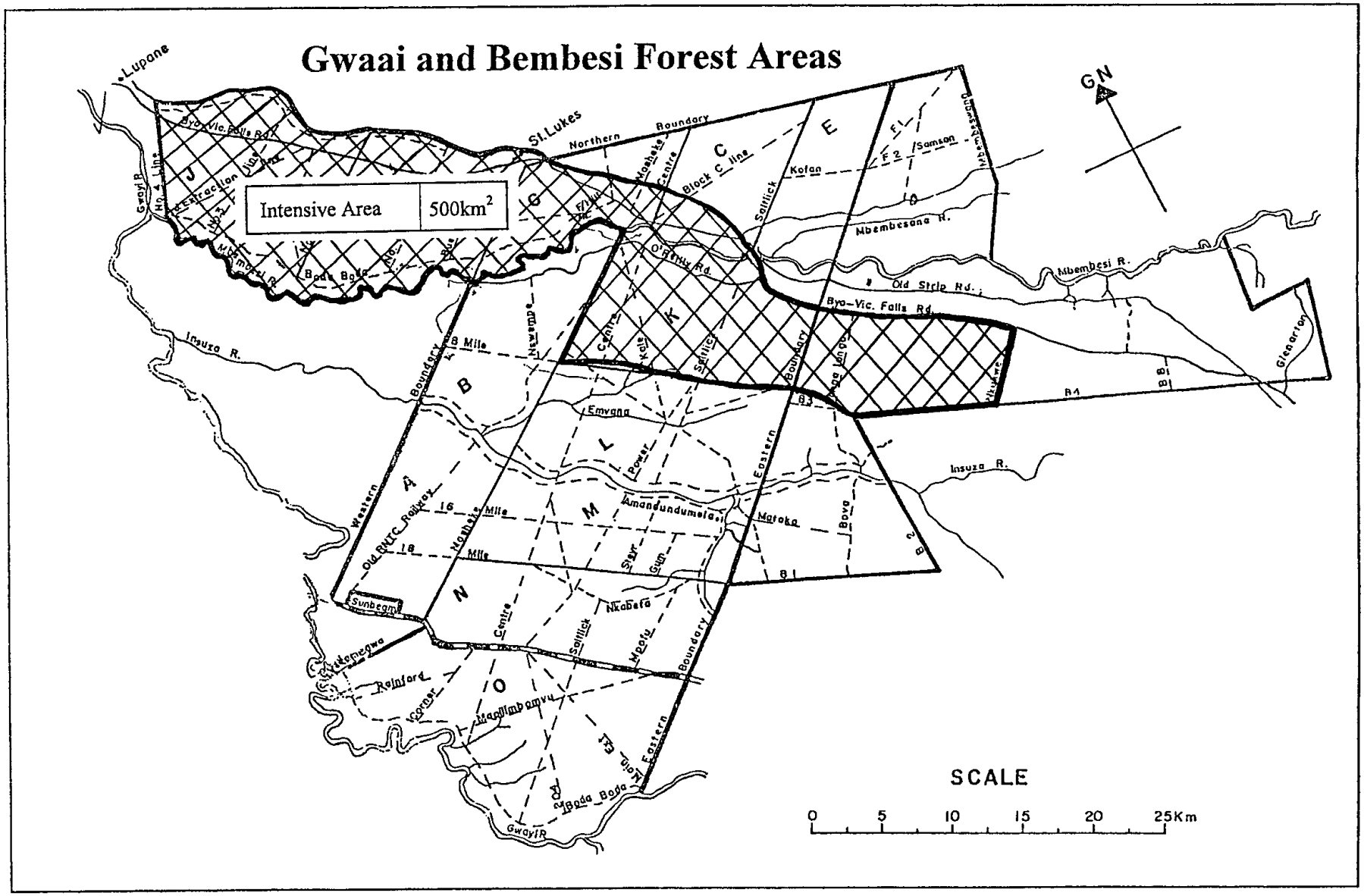


Fig. 5 – 1 Location of Intensive Area

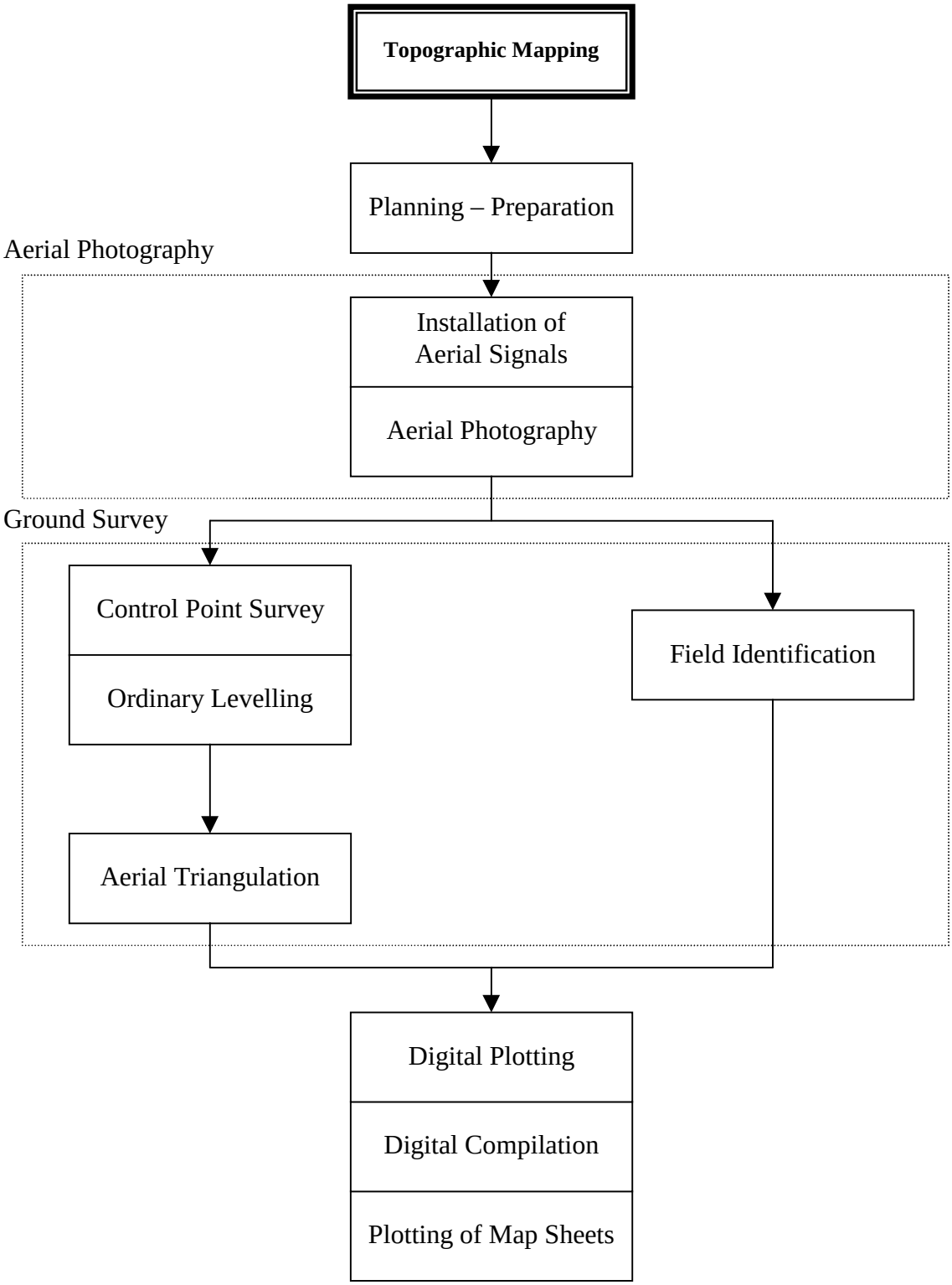


Fig. 5 – 2 Flowchart of Topographic Mapping

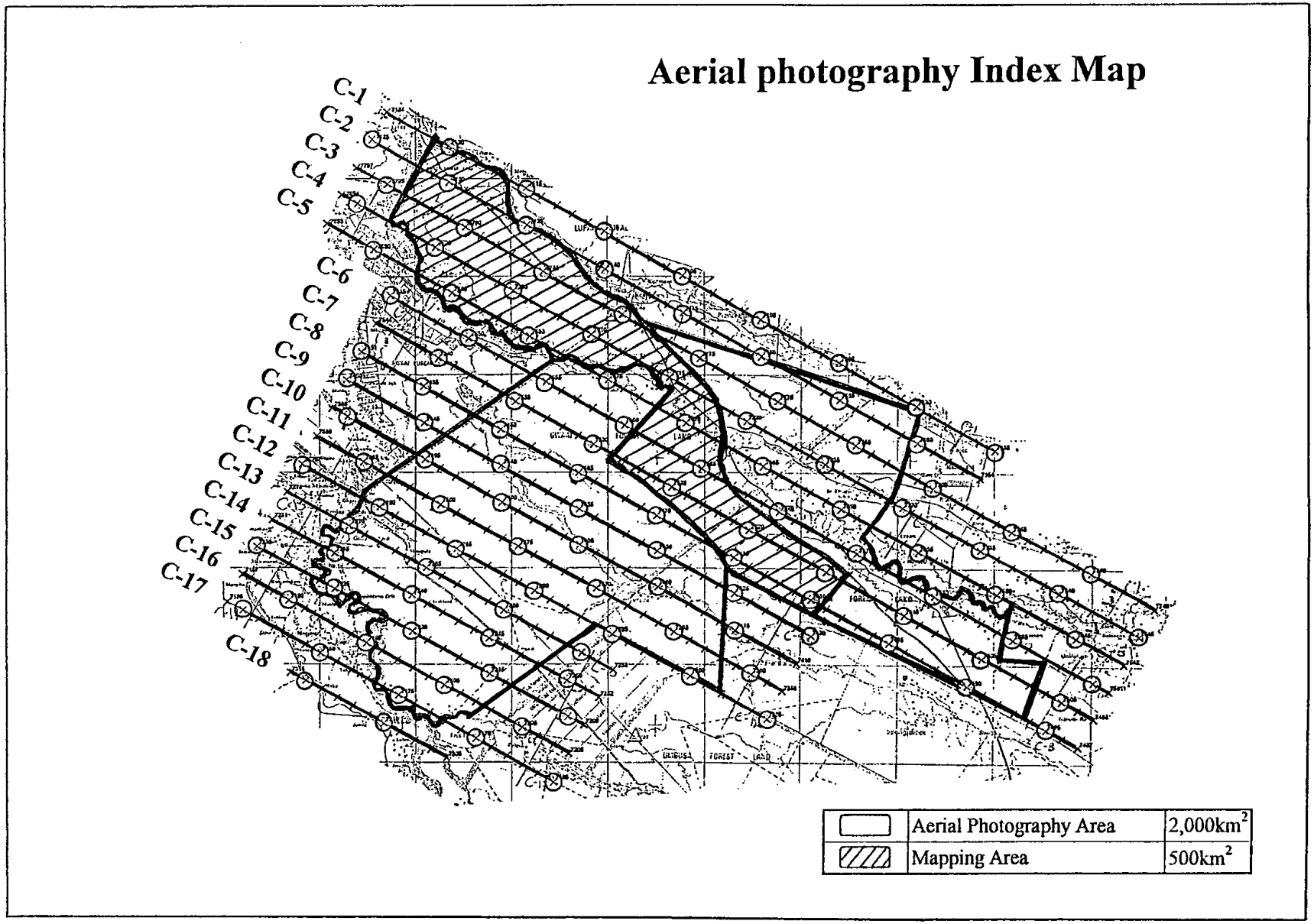


Fig. 5 – 3 Aerial Photography Index Map

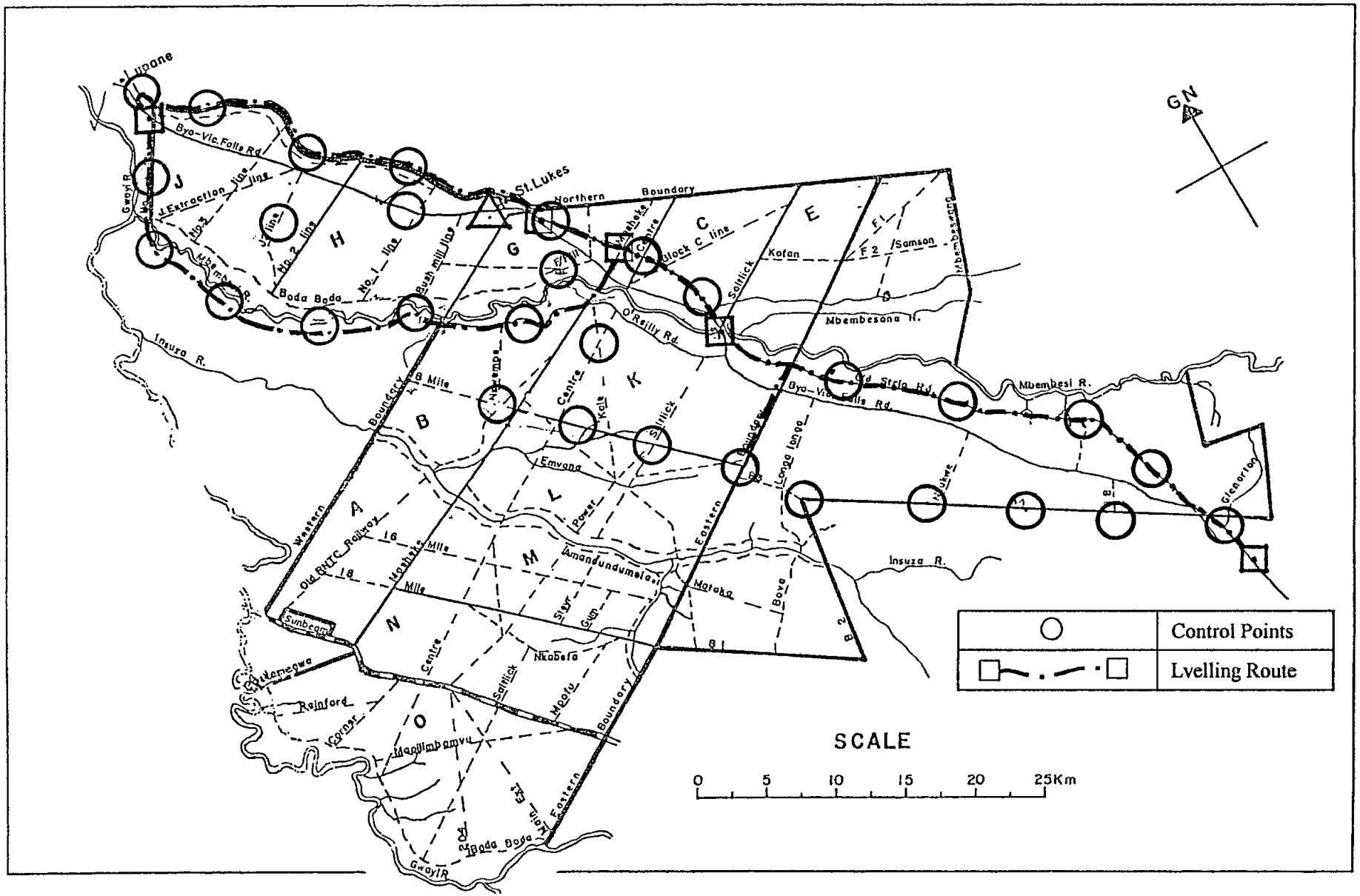


Fig. 5 – 4 Map for Control Points and Levelling Route

(2) Photography Specifications

Photographic scale:	1/20,000
Flight altitude:	4,160m
	(datum for photography: 1,100m)
Aerial camera:	LEICA RC30
Focal length of camera:	f = 152.63 mm
Photo size:	23 x 23 cm
Overlap:	60%
Side lap:	30%

Inspection of aerial photos was performed by the relevant member of the survey team.

5.2 Ground Survey

The ground survey consisted of control point survey, ordinary levelling and field identification. The control point survey and ordinary levelling were sub-contracted with the South African agents of SWEDESURVEY.

Data pertaining to the survey work, such as triangulation point coordinates (X, Y, Z) and benchmark elevations (H), were obtained beforehand from the Department of the Surveyor General.

5.2.1 Control Point Survey

New control points were installed using the GPS survey method at (or in the vicinity of) the 30 aerial signals installed around the Intensive Area (refer to Fig. 5 – 4).

The GPS survey for the new control points, including 1 national triangulation point used as known point, was conducted between July 20 and August 25, 1999.
The observation method was as follows:

GPS receivers:	Dual-frequency type
Functions of the GPS receivers:	±5mm+1ppm×D (D = distance in km)
Number of GPS receivers:	3 units
Observation time:	20 minutes or more
Interval of data acquisition:	15 seconds
Number of GPS satellites:	5 satellites or more

After GPS data were computed, based on the results of the analysis of each baseline and on the adjustment computation of traverse net, the geographic coordinates of the

new control points, XY coordinates on the UTM system and the ellipsoidal heights were determined and arranged as results.
The inspection showed that the accuracy obtained was within the required tolerance.

5.2.2 Ordinary Levelling

The ordinary levelling was performed along a distance of 170 km (refer to Fig. 5-4) between August 19 and September 2, 1999 using auto levels. Five reference points were used for the ordinary levelling.

Points were pricked every 500 m along the levelling routes and their elevations were determined. Also, 20 control points were connected to the levelling routes.

The observation method was as follows:

Observation method:	Closed and open routes (reciprocal observations in case of open routes)
Interval of measurement:	80m or less
Measurement unit:	mm
Tolerable error of observation:	40 mm $\sqrt{S}$ (S = route length, in km)

The accuracy control showed that the accuracy was within the specified limit.

5.2.3 Field Identification

The field identification was conducted using the contact prints (at the scale of 1/20,000). All the main features, such as structures, roads and vegetation, that could be verified were annotated on the contact prints.

Information such as place names, administrative boundaries and public facilities were adopted from the existing 1/50,000-scale topographic map obtained from the FC.

5.3 Photogrammetry

5.3.1 Aerial Triangulation

Aerial triangulation entailed computing the coordinates of points necessary for orientation in digital plotting, such as pass points and tie points, as well as orientation elements.

Positive films and contact prints were made using the aerial films and the control point coordinates obtained as a result of the control point survey and the ordinary levelling. The aerial triangulation method, program name and work volume were as follows:

Adjustment computation method:	Bundle method
Program name:	BLUHS
Number of models:	8 flight lines, 143 models

The control point residual errors of adjustment computations were as follows:

Standard deviation of horizontal residual error:	0.219m (permissible limit: 0.6m)
Maximum horizontal residual error:	0.452m (permissible limit: 1.2m)
Standard deviation of vertical residual error:	0.243m
Maximum vertical residual error:	0.644m

The above results were perfect for the subsequent implementation of digital plotting.

5.3.2 Digital Plotting

Map symbols and codes were examined and decided for digital plotting, which was then conducted using the results of aerial triangulation: positive films, contact prints, and results of adjustment computations.

(1) Map Symbols and Codes

As the plotting scale was 1/20,000, the map symbols were examined and decided based on the 1/50,000-scale topographic maps of Zimbabwe. Concerning the code system for map symbols, the codes of the national base map of the Department of the Surveyor General under the Ministry of Construction were adopted, and the codes of newly introduced map symbols were decided in consideration of geographic features.

(2) Digital Plotting

The topographic and planimetric features were plotted digitally in accordance with the

map symbols and code system decided above. The main specifications for digital plotting were as follows:

Plotting scale:	1/20,000
Plotting area:	520 km^2 (number of sheets: 8)
Contour lines:	Interval of main contours: 10m
	Interval of intermediate contours: 5m
Analytical plotters used:	Planicomp P33 (Zeiss)
	DSR 2000 (L/H Systems)

After digital plotting, the digital topographic and planimetric feature data were output from files divided into sheet units.

5.3.3 Digital Compilation

This work entailed the digital compilation of topographic and planimetric features in accordance with map symbol specifications (map symbols and code system), using the digital plotting data obtained in 5.3.2 and the results of the field identification obtained in 5.2.3. Also, all the data provided by the counterpart agency (annotations for place names, administrative boundaries, annotations for administrative names) were added digitally. Concerning contour lines, elevations were added as attribute data. The main specifications of digital compilation were the same as for digital plotting. Additionally, the following software was used for digital compilation.

Digital compilation software:	Microstation 95

The digital data obtained after digital compilation were converted into two types of files: files for the production of map sheets, and DXF files for use in GIS.

5.3.4 Plotting of Map Sheets

The files for the production of map sheets created in 5.3.3 were output as topographic draft maps (black and white) on polyester film using a laser plotter. The draft maps were duplicated by photo-processing. The topographic draft maps produced were as follows:

Original draft map (black & white)	1 copy of each
Duplicated draft map (black & white)	1 copy of each

Chapter 6

6. Geographic Information System (GIS)

6.1 GIS Outline

6.1.1 What is GIS?

Geographic Information System (GIS) is a type of computer system that is used to capture, create, edit, query, retrieve, display and store spatial data and its related attribute data. It allows effective management of these geo-referenced data, formulation of new plans, computation of attribute data statistics, and creation of new data by computing a number of data.

GIS data are composed of vector data and raster data with geo-referenced data, and text and image data which are attributes of the spatial data.

GIS functions and data can be operated by a standalone or network computer with different platforms ranging from PCs and Engineering Work Stations (EWS) to main frame computers. Nowadays, with the appearance of high speed and high capacity PCs, an increasing number of users have adopted network PCs for GIS.

6.1.2 GIS Configuration

Generally speaking, GIS is composed of four components: computer hardware, software, spatial and attribute data, and GIS staff.

(1) Computer Hardware

The computer hardware must be able to smoothly operate the GIS software and process large volume of spatial and attribute data. Whereas in the past GIS was mainly operated on main frame computers, the current downsizing trend brought about by the advance of computer systems allows the operation of GIS on EWS and network PCs.

(2) Software

Nowadays, there are many all-purpose GIS software in the market, such as ARC/INFO and ArcView. These GIS software can be customised to be used for specific purposes, but there are also GIS software which are specially designed for original objectives.

(3) Spatial and Attribute Data

Geo-referenced data correspond to spatial data and map data created for special

purposes, and are generally in the form of graphic data. Attribute data are attached to those geo-referenced data, and are generally in the form of text or image.

(4) GIS Staff

GIS staff must have full understanding of the purpose of GIS, and know the hardware and software thoroughly.

6.2 Organization of the FC in Relation to GIS

The FC, which is the counterpart agency to JICA, is made up of various departments. Among these, a number of departments are related to GIS.

6.2.1 Structure of the FC

The departments of the FC related to GIS are the Research & Development Division and the Mapping and Inventory Unit.

(1) Research & Development Division

The Research & Development Division's duty is to undertake and conduct cost-effective research and development for the entire forest sector in Zimbabwe, responsible to user needs, and to make known the results of that research.

(2) Mapping and Inventory Unit

The Mapping and Inventory Unit is responsible for monitoring the nation's forest resources, and for compiling this information into a form useful for management planning and decision making. The Unit's main activities include execution of timber surveys in both Gazetted Forests and Communal Lands, production of vegetation maps both at the national and local levels, analysis of fire data from the Gazetted Forests, and assessment of Permanent Increment Plots for growth estimation.

The Mapping and Inventory Unit has developed a GIS application called Vegetation Resources Information System (VegRIS) in association with the German Agency for Technical Cooperation (GTZ).

6.2.2 Human Resources of the FC

There are six GIS staff in the Mapping and Inventory Unit of the FC as shown in the following table. Four are working in Harare, and the other two in Chesa Forest Research Station in Bulawayo.

Table 6 – 1 Current Staffing Position

NAME	POSITION	QUALIFICATIONS
Mr. D.KWESHA	Mapping & Inventory Officer (Remote Sensing and GIS specialist), Project Manager – VegRIS	• Dip. in Forestry 1985 • Dip. in Forest Survey 1991 • Work Experience: 1986-95 M&I • M.Sc. GIS October 1994-Sept. 1996
Mr. F. MKOSANA	Forest Inventory Officer	• Dip. In Forestry 1987 • Work experience: 1988-1989 Indigenous Resources. 1989-1995 M&I • Post grad Dip. Forest Survey Aug. '95-June '96
Mr. K. C. GUMBO	Senior Forester M&I (Image Interpretation & Field Inventory)	• Cert. In Forestry 1984 • Dip. In Forestry 1990 • Post. Grad. Dip. GIS • Work experience: 1985 Forest Extension. 1986-88 & 1991-99 M&I
Ms. J. MAMBO	Forester M&I (GIS/RS)	• Dip. In Forestry 1991, Dip. in GIS • Work experience: 1992-1995 Forestry Extension. 1994 M&I
Mr. A. MUSHORE	GIS Assistant	• Dip. In Surveying • O Level, A Level
Mr. A. MUSHIPI	Principal Forest Assistant M&I Mapping, Image Interpretation & Cartography	• Cert. In Forestry 1983 • Dip. In Forestry 1999. • Work experience: 1984-88 Forestry Extension. 1988-95 M&I

Note: This table was provided by FC
Dip. = Diploma, M&I = Mapping & Inventory Unit, Cert. = Certificate

The staff within the Unit are trained to fully utilise modern technology and to cope with the new information demands and requirements placed on the Unit. Staff are trained in different levels in OS and PC GIS software such as PC ARC/INFO, PC ERDAS and others. The following training courses listed in Table 6 – 2 were provided by GTZ.

Table 6 – 2 Subject Training Courses for Staff Provided by GTZ

FC's Staff / Training Courses	GIS/RS Technical Officer (Data Encoders)	Computer Operator (Data Base)	Resource Assessment Officers	Application Specialists: Remote Sensing Inventory & GIS	Manager
Advanced DOS	○	○	○	○	○
Aerial Photograph Interpretation				○	○
Theory of Remote Sensing and ERDAS applications				○	○
Introduction to ARC/INFO	○		○		
Customizing ARC/INFO with SML	○		○		
Introduction to GPS			○	○	
Information Management for Natural Resources Development	○				
Forest Inventory Techniques			○	○	
Intercultural Project Management					
MSc Course Remote Sensing/GIS					○
Introduction to PM and ZOPP					○
Post Grad. Dip. Forest Survey				○	

Source: Forestry Commission

6.3 GIS at the FC

The Mapping & Inventory Unit uses VegRIS for its GIS applications, and has a number of equipment for this software.

6.3.1 GIS Hardware

In the Mapping and Inventory Unit of the Research & Development Division, there are 4 sets of PCs that are connected by "Pear to Pear Network (LAN)" and coaxial cables. One set of PC is set in Chesa Forest Research Station. All the PCs were from the VegRIS project aided by GTZ. The specifications of the hardware are as follows:

(1) PC Micron: This PC is set in Harare.
Micron Millennia XKU 300 has the following specifications:
Intel 300 MHz Pentium II processor (MMX)
128 SDRAM
8.4 GB Ultra ATA hard disk
82440LX chip set
512 KB internal L2 cache, 2MB BIOS
Integrated 100 MB Iomega Zip drive
3.5" floppy drive
24x EIDE variable speed CD-ROM drive
HP CD-writer plus 7200 series 650 MB
32 voice wavetable stereo sound with Advent 009 speakers with subwoofer
USR Sportster 56K x 2 data/fax modem
Diamond Viper V330 128-bit 3D video with 4 MB SGRAM
Microsoft IntelliMouse, USB connections
Microsoft Windows 95 and MS Plus!
Microsoft Office 97 Small Business Edition
21" Hitachi SuperScan CM801.26dp colour monitor
HP DesignJet750c colour plotter
UPS PowerSaver 1200VR

(2) PC 1: GEOSYSTEMS (Set in Harare)
Pentium 133 MHz processor (Upgraded from 486/66 MHz)
48 RAM memory
4.3 GB hard disk
3.5" floppy drive
5" floppy drive
CD-ROM drive
HP CD-writer plus 7200 series 650 MB
Mitsubishi Diamond Pro 91TXM 20" Monitor 1024x768
CalComp 9100 A0 size digitizer
HP DeskJet 690c colour printer
UPS PowerSaver 1200 VR

Microsoft Windows 95 and MS Plus!
Microsoft Office 97 Small Business Edition

(3) PC 2: GEOSYSTEMS (Set in Harare)
Pentium 133 MHz processor (Upgraded from 486/66 MHz)
48 RAM memory
4.3 GB hard disk
3.5” floppy drive
5” floppy drive
CD-ROM drive
HP CD-writer plus 7200 series 650 MB
Mitsubishi Diamond Pro 91TXM 20” Monitor 1024x768
CalComp 9100 A0 size digitizer
HP DeskJet 690c colour printer
CONTEX FSS 8300 DSP FULL SCALE SCANNER A0 size
UPS PowerSaver 1200 VR
Microsoft Windows 95 and MS Plus!
Microsoft Office 97 Small Business Edition

(4) PC 3: GEOSYSTEMS (Set in Harare)
486/66 MHz CPU
1.2 GB hard disk
3.5” floppy drive
5” floppy drive
CD-ROM drive
UPS PowerSaver 1200VR
Microsoft Windows 95 and MS Plus!
Microsoft Office 97 Small Business Edition
HP LaserJet 4M A4 size monochrome printer

(5) Gateway 2000 P5-133: This PC is set in Bulawayo.
Pentium 133 MHz processor
16 MB EDO RAM
1.6 GB hard disk
2 MB DRAM PCI video card
15” monitor
100 MB Zip drive
CalComp 33360 A1 size digitizer
HP DeskJet 690c colour printer
Microsoft Windows 95 and MS Plus!
Microsoft Office 97 Small Business Edition

PC (1) to (4) (PC Micron to PC 3) are connected through a LAN.

6.3.2 Specification of GIS Software

(1) The FC has the following software provided by GTZ:

- PC ARC/INFO Ver 3.5: 2 licenses
- ERDAS image Ver 8.2: 2 licenses
- ArcView Ver 3.0a: 1 license
- Professional TNTMips Ver 6.2: 3 licenses
- TNTMips Edit: 1 license
- MapInfo Ver 4.0: 1 license

The above software are installed in the hardware described in 6.3.1 above, and used on a daily basis.

The Mapping and Inventory Unit has also developed a GIS application called VegRIS in association with GTZ.

(2) Conditions of utilisation of GIS software

Among the GIS software, TNTMips was purchased for its capacity to process both vector and raster data. It also carries out a number of data processing tasks using SML (Simple Macro Language) of ARC/INFO. Moreover, it provides the user with the necessary digital data using these software.

VegRIS runs on PC ARC/INFO and PC ERDAS, and is used to make and update woody cover maps.

6.3.3 What is VegRIS?

(1) VegRIS development process

The FC is responsible for the smooth and efficient implementation of forestry policy. However, it did not have comprehensive information on vegetation resources, which are essential for forestry policy planning.

In these conditions, the FC intends to apply the latest GIS technology to nation-wide woody cover information.

In June 1993, the FC, in association with GTZ, launched the Vegetation Resources Information System (VegRIS) project based on purchased GIS software. Its upgrade, started in July 1999, is still in progress.

(2) Objectives of VegRIS

VegRIS stands for Vegetation Resources Information System. It has been designed to improve the protection and management of nation-wide forest resources, and to maintain and keep the information up-to-date.

The specific objectives of the VegRIS are as follows:

(a) To produce national woody cover maps at the scales of 1/250,000 and 1/1,000,000
(b) To establish an operational vegetation resources information system
(c) To develop methodology for monitoring vegetation changes
(d) To develop methodology for local level forestry inventory, for management purposes
(e) To provide training programmes
(f) To strengthen the institutional capacity of the Mapping and Inventory Unit
(g) To strengthen inter-institutional relationships for sustainable management of natural resources
(h) To disseminate the resulting information on the woody vegetation resources to users.

(3) Technology Used by the VegRIS

The operation of VegRIS entails the creation of all the data used by the system as well as the maintenance and update of these data.

Digitisation or scanning of 1/250,000-scale and 1/50,000-scale topographic maps, 1/25,000 aerial photos and orthophotos are applied to create, maintain and update map data.

Image processing technology (combination of various bands, highlighting, filtering, etc.) using Landsat TM image data or aerial photos is applied to create, maintain and update vegetation data. GPS is also used to verify the exact position during field surveys.

(4) Classification system in VegRIS

A new vegetation classification system has been developed in order to make it compatible with the existing classification systems and more useful to a variety of users. The physiognomic aspects such as tree height and canopy coverage are taken into consideration in the vegetation classification system of VegRIS. The classification

system for the woody cover map series is shown in Table 6 – 3.

Table 6 – 3 Classification System for the Woody Cover Map Series

Tree height / Canopy cover	15m	15~5m	5~1m	1m
100~80%	Natural forest - moist - deciduous			
100~80%	Forest plantation	Forest plantation	Forest plantation	Forest plantation
80~20%		Woodland - medium dense - open	Bushland - medium dense - open	
＜20%	Wooded grassland	Wooded grassland	Wooded grassland	
±2%	Grassland	Grassland	Grassland	Grassland
NA	Cultivation, rock outcrop (incl. mine dump) Water body, settlement (incl. wooded suburb)			

Source: Forestry Commission

(5) Data acquisition and storage in VegRIS

• Topographic map data

1/250,000- and 1/1,000,000-scale topographic maps as well as 1/25,000 aerial photos and orthophoto maps were obtained from the Department of the Surveyor General in Zimbabwe and were digitised. They are now stored in digital format.

• Vegetation interpretation data

Landsat TM image data were processed (combination of various bands, highlighting, filtering, re-projection, re-extraction) and interpreted together with 1/25,000-scale aerial photos. The vegetation data obtained by interpretation were digitised and stored in digital form.

• Attribute data

Attribute data related to vegetation are composed of text data. These data are converted into a database form so that they can be used with VegRIS.

The final digital data are stored as seamless countrywide data set in both PC ARC/INFO and TNTMips formats.

(6) Outputs of VegRIS

The main outputs of the VegRIS project are the compilation of the digital woody cover database and its maintenance and update. This database allows the production of 1/25,000- and 1/1,000,000-scale woody cover maps.

(7) Prospects of VegRIS

The VegRIS is currently in the process of developing methods for change detection and local level forest management inventories.

6.3.4 Current Situation of GIS Use

According to the survey of GIS hardware and software as well as the use of VegRIS at the FC, GIS is used as follows:

The GIS staff uses TNTMips as a main GIS tool for the daily use because it is menu-driven and almost all the operations can be done with the mouse. It could be another reason that a lot of GIS software format can be imported and exported to TNTMips such as ARC/INFO E00 file, ArcView shape file, MapInfo MIF, Microstation DGN and DXF file.

The following limiting factors on the use of GIS have been pointed out:

- Satellite image data and aerial photos are really expensive to be used to update vegetation resources information.
- There are not enough GIS staff at the FC.
- There is a lack of training to keep up with the new GIS technology developments.
- The upgrade of GIS software and hardware is difficult due to economic reasons.

6.4 GIS Data Format

The format of GIS data to be created in the course of this survey was decided after discussions with the FC.

6.4.1 GIS Data Format

According to the M/M on S/W signed on February 18, 1999, the FC was requested to submit the following digital data to be used by the JICA survey team:

- Land use and vegetation maps
- Forest type maps

- Soil maps

According to the results of the discussions held at the meeting for the explanation of the Inception Report on August 20, 1999 and at the August 25, 1999 meeting, the format of the GIS digital data to be provided to the FC was agreed as follows:

- The final GIS data format will be ARC/INFO export files (E00 file).
- The E00 files will also be saved in ArcView shape files as a backup.

  (Note: E00 file is in an ASCII file format which is common to EWS ARC/INFO, NT ARC/INFO and PC ARC/INFO.

6.4.2 Other Agreements Regarding Data Format

The FC has agreed to the following conditions regarding data format:

- The FC will provide the nation-wide forest and boundary data, the administration boundary data and the national projection files to the survey team in digital format.
- Those data will only be used for this JICA project and the copyright belong to the FC.

6.5 Digitizing of Thematic Maps

The three types of thematic maps (land use and vegetation maps, soil maps and forest type maps) were produced based on the results of the surveys carried out. The various types of information contained in these thematic maps were digitized in order to efficiently utilize them in GIS.

6.5.1 Methods for the Digitizing of Thematic Maps

Every thematic map shows the results of all surveys and analyses carried out in analog form. These maps were digitized as shown below.

① Scanning of Thematic Maps
The maps were scanned per sheet to obtain data in raster format.

② Screen Digitizing
The raster data obtained from the thematic maps were shown on screen per map sheet basis and the defined digitized items were converted into vector format.

③ Digital Compilation
Data converted into the vector format were compared with the data in the thematic maps while carrying out digital compilation. Simultaneously, adjacent map sheets were adjoined.

④ Structuring
In accordance with the definition of every digitized thematic maps, every data was converted into the designated data type (e.g. point data, line data, polygon data, etc.) and assigned codes.

⑤ Format Conversion
①～④ were carried out based on the format dependent on the software used as a tool. Afterwards, these data were converted into the following format agreed upon during the discussions with the FC on 25 August 1999, and the digital data for GIS were made.

(a) Data for Installation: Arc/Info Output File (E00 File)
(b) E00 File Back-up Data: Arc/View Shape File

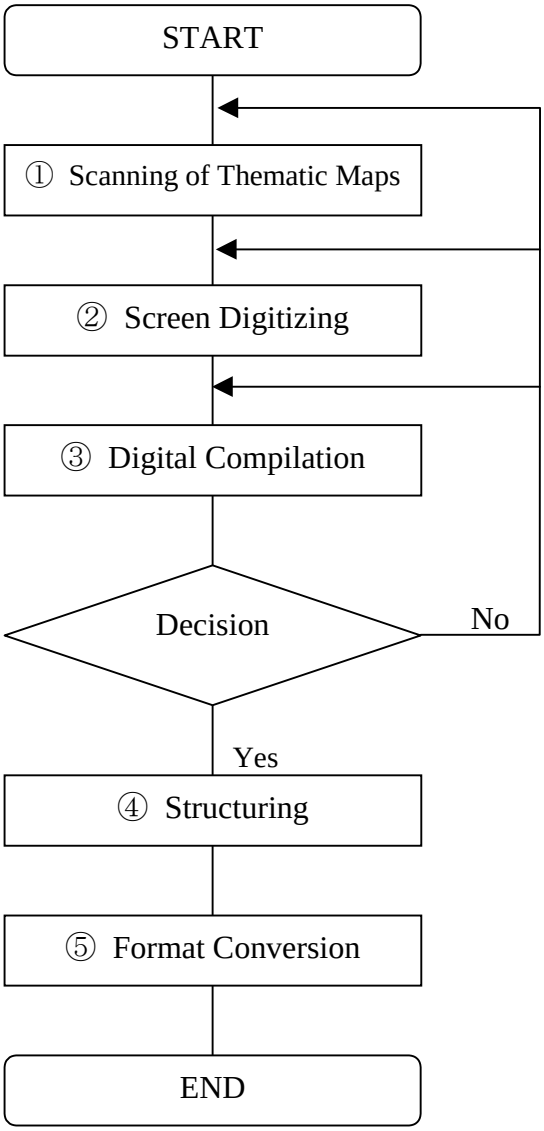


Fig. 6 – 1 Thematic Map Digitizing Flow Chart

6.5.2 Digitizing of Land Use and Vegetation Maps

(1) Items for Digitizing

The digitizing of the land use and vegetation maps covered the following items.

- Survey Area Boundary
- Forest Land Boundary
- Block Boundary
- Wide road (represented by a double line)
- Wide river (represented by a double line)
- Land use and vegetation boundaries
- Block code

- Category code

(2) Data Type

The digitized items were categorized into the following data type.

(a) Point Data
- Block code
- Category code

(b) Line Data
- Survey Area Boundary
- Forest Land Boundary
- Block Boundary
- Wide road
- Wide river

(c) Polygon Data
- Land use and vegetation boundaries

(3) Coding System

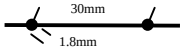
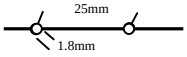
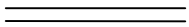
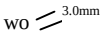
The coding system is summarized in Table 6 – 4.

(4) Others

When combined with the land use and vegetation boundaries, overlapping line data were obtained and the boundary data were converted into polygon type.

For data on "Forest Land Boundary" and "Block Boundary", the forest type maps (scale 1/20,000) were used. Boundaries that were not delineated in the forest type maps were digitized using land use and vegetation maps as reference.

Table 6 – 4 Coding System for Land Use and Vegetation Maps

Code	Items for Digitizing	Symbols	Data Type	Line	Colour	Remarks
1101	Survey Area Boundary		Line data	8	Black	
1102	Forest Land Boundary		Line data	6	black	
1103	Block Boundary		Line data	5	black	
2102	Wide Road		Line data	3	black	
5101	Wide River		Line data	3	blue	
1201	Land use and vegetation boundary		Polygon data	4	black	Represented by a hidden line
9101	Block code		Point data		black	
9102	Category code		Point data		black	

6.5.3 Digitizing of Soil Maps

(1) Items for Digitizing

The digitizing of the soil maps covered the following items.

- Intensive Area Boundary
- Soil Boundary Line
- Classification Code
- Profile Survey Point
- Profile Survey Point Number

(2) Data Type

The digitized items were classified into the following data types.

(a) Point Data

- Profile Survey Point
- Profile Survey Point Number

(b) Line Data

- Intensive Area Boundary

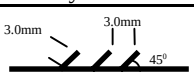
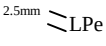
(c) Polygon Data

- Soil Boundary Line

(3) Coding System

The coding system is summarized in Table 6 – 5.

Table 6 – 5 Coding System for Soil Maps

Code	Items for Digitizing	Symbols	Data Type	Line	Colour	Remarks
1100	Intensive Area Boundary		Line Data	8	Black	Eventually will be converted into polygon data.
1203	Soil Boundary		Polygon Data	4	Black	
9103	Classification Code		Point Data		Black	
9104	Profile Survey Point		Point Data		Black	
9105	Profile Survey Point Number		Point Data		Black	

(4) Others

When combined with the soil boundary, overlapping line data were acquired and the soil boundary data were converted into the polygon format.

6.5.4 Digitizing of Forest Type Maps

(1) Items for Digitizing

The digitizing of the forest type maps covered the following items.

- Intensive Area Boundary
- Forest Land Boundary
- Block Boundary
- Forest Cover Boundary Line
- Block code
- Parcel Number, Classification Code, Height Class, Canopy Density Class
- Road and Line Names

(2) Data Type

The digitized items were classified into the following data types.

(a) Point Data

- Block code
- Parcel Number, Classification Code, Height Class, Canopy Density Class
- Road and Line Names

(b) Line Data

- Intensive Area Boundary

- Forest Land Boundary
- Block Boundary

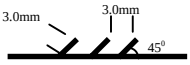
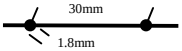
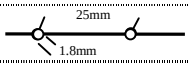
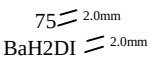
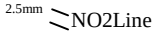
(c) Polygon Data

- Forest Type Boundary Line

(3) Coding System

The coding system is summarized in Table 6 – 6.

Table 6 – 6 Coding System for Forest Type Maps

Code	Items for Digitizing	Symbols	Data Type	Line	Colour	Remarks
1100	Intensive Area Boundary		Line Data	8	Black	Eventually will be converted into polygon data.
1102	Forest Land Boundary		Line Data	6	Black	
1103	Block Boundary		Line Data	5	Black	
1204	Forest type Boundary Line (Parcel Boundary)		Polygon Data	4	Black	
9101	Block code				Black	
9106	Parcel Number, Classification Code, Height Class, Canopy Density Class				Black	
9107	Road and Line Names				Black	The letters will be in Italics.

(4) Others

When combined with the forest cover boundary line, overlapping line data were obtained and the forest cover boundary line was converted into the polygon format.

6.5.5 Others

(1) Quality Control

For quality control of digitized data, the following methods were adopted.

- Logical Inspection of Digital Data
  Logical inspection was carried out for the conversion of the data into polygon format.
- Visual Inspection of Digital Data
  The digital data were printed out in the designated map symbols, colours, lines, and line types, and these were compared visually with the input map.

(2) Output Map Production

An output map was produced to visually inspect digitized data. However, to facilitate visual confirmation of the results – which in this case is the GIS digital data – the output map was produced with the same sheet index and marginal information as the input map. The colours of the classification code for every thematic map were decided in view of convenience.

6.6 Installation of the Thematic Maps into the System

The digital data obtained under section "6.5 Digitizing of Thematic Maps" will be installed into the system of the FC.

6.6.1 Installation of Topographic Data

The topographic data (scale 1/20,000) will be installed into the GIS software Arc/Info owned by the FC so that they can be accessed using Arc/View. In the installation, the symbols and colours will be appropriately represented and will be ere processed to produce an output. These data will be also processed for the future improvement of the system.

6.6.2 Installation of Thematic Map Data

The digital thematic maps, e.g. Land Use and Vegetation Maps, Soil Maps and Forest Type Maps, will be installed for use under the GIS software Arc/Info and Arc/View.

Chapter 7

7. Preparation of Land Use and Vegetation Map

7.1 Field Reconnaissance

Forests in the Survey Area consist of deciduous species that start to defoliate during June and October after rainy season. When the survey was conducted in the early September, the same tree species had leaves in some places and no leaves in others. It is needless to say in the case of grass. The aerial photos were taken in August. The trees on photo images appear under such a dynamic background that could sometimes embarrass the comparison between the on-site reality and the photo image. The findings through the field reconnaissance are described as follows.

(1) Misleading Factor of Photo Image

Misleading factors for photo interpretation are summarized as follows.

(a) It is probably sure that *Brachystegia* had leaves when the photography was conducted in the early August. All of the trees with leaves appear as black dots on photos. Also it is confirmed that *Combretum collinum* had leaves at that time. It is difficult to distinct those.

(b) From August, *Brachystegia* and *Julbernardia* that are dominant species of MIOMBO forests start to have juvenile shoots. Some of them with juvenile leaves are without leaves on photos.

(c) It is difficult to distinct the species of trees with green leaves, even in the case of *Baikiaea*'s leaves and *Acacia*'s smaller leaves.

(d) Fire-damaged area is distinctive with the color of ground. It shows black when the carbonated plants covers the ground. On the other hand it shows white when the humus layer is burnt out, namely "ground fire".

(e) Trees tend to keep the leaves around and within human facilities such as settlements, farmlands and roads.

These factors are considered to cause difficulties in identifying consistent tendency that could support the photo interpretation.

(2) Converting Factor of Forest Coverage

Recently no shifting cultivation is done in the Survey Area. The factors likely to change the forest coverage would be confined to fire, logging by FC and land allocation for settlers although it changes according to the natural stand development. For example, FC allows the private sectors to conduct selective felling of valuable species in those stands which are scheduled to be the relocation area.

Traces of forest fire are broadly found over the Survey Area. As far as visiting around,

there is no trace of crown fire or stem fire. The major fire type is probably ground fire that does not cause fatal damage to tall trees more than 5 – 10 m. But, it could be pointed out as the exceptional case that *Baikiaea* trees with the heights of some 15 m had epicormic buds on stems and branches. This case was observed along the railway side only and deemed to be caused by repeated and strong fire that can reach to the height over 10 m. The forests adjacent to the railway are presumably exposed to the harder impact of fire compared to the other sites.

7.2 Aerial Photo Interpretation Criteria

(1) Examination of Existing Category

For the reference material for preparing the interpretation criteria, the following maps were found appropriate to be examined.

(a) CODA Maps (Scale 1/25,000) prepared in 1989 based on the black and white photos (Scale 1/25,000) taken in 1983 by a Kenyan company, namely CODA

(b) Attached Maps (Scale 1/250,000) in "Forest Management Plan for Area South" prepared planning in 1994 mainly based on the experience of the officer in charge

The subject area for both of maps is the Gwaai and Bembesi Forest Land that are the Survey Area. In terms of categorization those are similar while the interpretation results slightly differ from each other in minor species.

The CODA Maps consists of categories such as canopy character, canopy density, floor cover and dominant species as follows. It was very regretted that no criteria for photo interpretation is available for CODA Maps. Partially the collected copies do not cover the whole Survey Area and Intensive Area.

Table 7 – 1 Categories of CODA Maps (Scale 1/25,000)

Canopy character	1	multi-storey	Dominant species	A	Acacia spp.
	2	single-storey		B	Baikiaea plurijuga (mukusu)
	3	two-storey		C	Combretum spp.
Canopy density	1	closed		Co	Colophospermum mopane (mopane)
	2	partially closed		G	Guibourtia coleosperma (mtchibi)
	3	open		Br1	Brachystegia spiciformis (musasa)
	4	scattered		Br2	Brachystegia boehmii (itshabela)
	5	very scattered		Bu	Burkea africana (umnodo)
Floor cover	1	regeneration (up to 6 m height)		K	Kirkia acuminata (umvumila)
	2	grassy		P	Pterocarpus angolensis (mukwa)
	3	thicket		T	Terminalia spp. (mangwe)

The category of the Attached Maps for the Bembesi Forest and Gwaai Forest are put together as follows.

Table 7 – 2 Categories of Attached Maps (Scale 1/250,000)

Description	Symbol
Scrub	S
Vlei scrub	VS
Two-storey, open, grassy MIOMBO	Br
Two-storey, open Burkea/Pterocarpus woodland	Bu/P
Multi-storey, open, grassy Baikiaea woodland	B
Two-storey, open, grassy MIOMBO/Pterocarpus	Br/P
Single-storey, open, Baikiaea/Guibortia woodland	BG
Multi-storey, partially closed Baikiaea thicket with Baikiaea regeneration	BB
Open, grassy Pterocarpus/Burkea woodland	Pt/B
Multi-storey, partially closed, mopane/Baikiaea woodland	MOP/B

Both maps categorizes forests in:

(a) tree species
(b) canopy density
(c) storey of canopy
(d) floor cover

The canopy density and storey of canopy could be interpreted through the photo images. For tree species and floor cover, however, the information obtained through the ground observation will be probably relied on rather than aerial photo images.

In order to clarify the possibility of interpretation of dominant species, the plot data was referred as follows. The dominance of Baikiaea is coherently read throughout the data. But it seems to be difficult for the co-dominant species.

Table 7 – 3 Plot Data and Interpretation Categories

	Observed on Ground					Existing Data	
Plot No.	Dominant Species	Species with Leaves	Canopy Density (%)	Ave. H (m)	Canopy Character* Floor Cover	CODA Map (Based on photos taken in '83.)	Forest Manage-ment Plan('94)
1-1	T C	-	10	6	- two-storey - regeneration/grass	B (multi-storey / scattered / grassy)	B
1-2	B	B	30	7	- multi-storey - regeneration/grass	B (multi-storey / scattered / grassy)	CL
1-3	B Br	B Br	30	7	- multi-storey - regeneration/grass	BP (multi-storey / open / grassy)	B
1-4	B C	Br	40	7	- multi-storey - regeneration/grass	BBr (multi-storey / open / grassy)	B
1-5	B C	B Br	45	7	- multi-storey - regeneration/grass	B/B (multi-storey / open / regeneration)	BB
1-6	B G	B	20	8	- multi-storey - regeneration/grass	B (multi-storey / open / grassy)	B
1-7	B G	B G	40	7	- multi-storey - regeneration/grass	B (multi-storey / open / grassy)	B
1-8	B C	B	10	7	- two-storey - regeneration/grass	B/B (multi-storey / scattered / regeneration)	Pt/Bu
1-9	Co B	B G	40	9	- multi-storey - regeneration/grass	B (multi-storey / scattered / grassy)	Pt/Bu
1-10	B G	B G	25	8	- two-storey - regeneration/grass	BG (multi-storey / open / regeneration)	B
1-11	B	B	30	7	- two-storey - regeneration/grass	GB (single-storey / partially closed / regeneration)	B

Note: Abbreviations for the species are referred to the of CODA Maps shown in Table 7 – 1.
*: The number of storey is counted by including the storey of forest floor.

FC inspected the CODA maps in February 1989. The related letters in FC complain about misleading in dominant species and out-dated condition, and mention that:

After all the Survey Team concluded that interpretation of dominant species for the Survey Area is not rational in terms of the scale at 1/50,000 and schedule constraint in order to prepare the Land Use and Vegetation Maps.

(2) Interpretation Category and Criteria

The following category and criteria were prepared and agreed on Land Use and Vegetation Maps (Scale 1/50,000) between FC side and the Survey Team.

Table 7 – 4 Category and Criteria for Photo Interpretation of Land Use and Vegetation Maps

	Category	Mapping Symbol	Criteria
Manmade Forest	Eucalyptus Plantation	E	The subject area is located to southwest to Kenmaur.
Natural Forest	Closed Woodland	WC	Tree height ≧ 5 m Canopy density ≧ 50 %
	Open Woodland	WO	Tree height ≧ 5 m Canopy density < 50 %
	Closed Bushland	BC	Tree height < 5 m Canopy density ≧ 50 %
	Open Bushland	BO	Tree height < 5 m Canopy density < 50 %
	Riverine Forest	R	Forests which specifically grow at riverside
Non-Forest	Bare Land	BL	Bare land
	Wet Land	WL	Wet land such as swamp and pond
	Vlei/Grassland	VG	Vlei or grasslands such as Insuza Vlei
	River	RI	Rivers such as Bembesi River
	Cultivated Land	CL	Cultivated land for crops such as maize
	Settlement	ST	Settlements clustered with small buildings that are found around St. Lukas and railway
	Others	OT	Roads, railways, power line, etc.

Note: Vlei means broad grassy depression.

On the Land Use and Vegetation Maps the block boundaries currently used by the FC were described appropriately.

(3) Interpretation for Forest Type Maps

Based on the Land Use and Vegetation Maps (Scale 1/50,000) and forest survey conducted in 2000, the Forest Type Maps (Scale 1/25,000) were prepared with the following considerations.

In terms of dominant species, the following types of forests will be identified as far as the comparison between photo images and field observations allows.

(a) Woodland dominated by *Baikiaea*
(b) Woodland dominated by *Brachystegia*
(c) Woodland dominated by *Guibourtia* and *Baikiaea*

7.3 Contents of Land Use and Vegetation Map

The land area of each category of Land Use and Vegetation Maps is as shown in Table 7 – 5 and Fig. 7 – 1. The Open Woodland and Closed Bushland account for 82 % of the whole Survey Area and are found to be the dominant category.

The forest lands of Gwaai and Bembesi differ in the amount of Cultivated Land. The relocation area concentrated in the Bembesi Forest Land and the rate for Cultivated Land of Bembesi is more than fourth the one of Gwaai.

Table 7 – 5 Areal Composition of Land Use and Vegetation Maps

Category	Symbol	Gwaai FL		Bembesi FL		Total	
		Area(ha)	%	Area(ha)	%	Area(ha)	%
Eucalyptus Plantation	E	122	0	0	0	122	0
Closed Woodland	WC	4,424	3	839	2	5,263	3
Open Woodland	WO	87,625	60	31,088	56	118,713	59
Closed Bushland	BC	36,617	25	9,304	17	45,921	23
Open Bushland	BO	6,490	4	2,271	4	8,761	4
Riverine Forest	R	2,751	2	677	1	3,428	2
Bare Land	BL	40	0	68	0	108	0
Wet Land	WL	38	0	11	0	49	0
Vlei/Grassland	VG	1,212	1	560	1	1,772	1
River	RI	141	0	36	0	177	0
Cultivated Land	CL	5,999	4	10,186	18	16,185	8
Settlement	ST	90	0	0	0	90	0
Others	OT	284	0	74	0	358	0
	Total	145,833	100	55,114	100	200,947	100

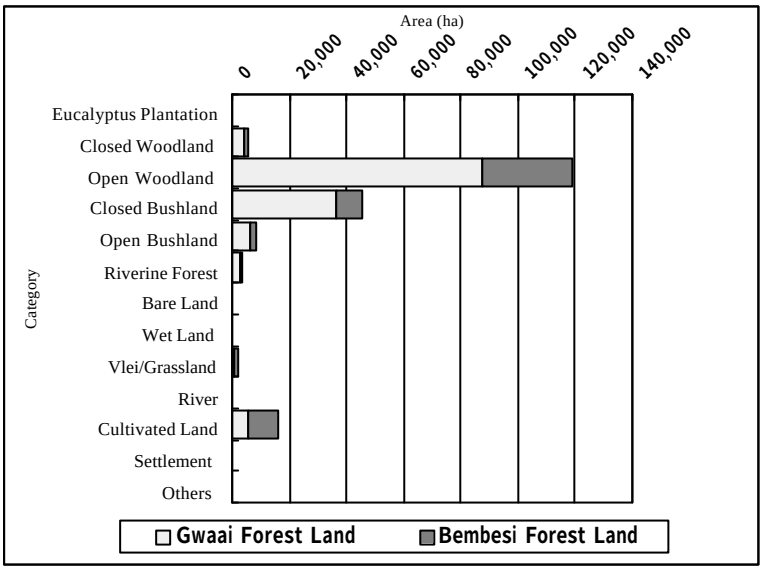


Fig. 7 – 1 Areal Composition of Land Use and Vegetation Maps

Bushland is distributed mainly along the southwestern side of Bembesi River while Cultivated Land is distributed mainly along the Falls Road and in and around the relocation area.

The maximum and minimum areas of the blocks are as follows.

Table 7 – 6 Maximum and Minimum Areas of Blocks

Subject Area	Maximum Area	Minimum Area
Gwaai Forest Land	21,942 (Block O)	7,237 (Block E)
Bembesi Forest Land	31,877 (Block B)	11,366 (Block C)
Survey Area (Both of the Forest Lands)	31,877	7,237

The areas corresponding to each Forest Land and Block are tabulated as Table 7 – 7.

Table 7 – 7 Areal Composition Corresponding to Each Forest Land and the Blocks （Unit：ha）

	Blocks of Gwaai Forest Land												
Category	A	B	C	E	G	H	J	K	L	M	N	O	Total
Eucalyptus Plantation					122								122
Closed Woodland	37	19	43	110	178	133	395	138	532	927	1,077	835	4,424
Open Woodland	5,674	6,220	5,288	4,009	5,108	9,102	10,612	5,323	10,874	7,256	5,024	13,135	87,625
Closed Bushland	3,377	2,366	1,283	1,740	971	1,640	2,465	5,539	1,909	3,272	6,055	6,000	36,617
Open Bushland	1,243	949		124	134	8	42	2,461	412	192	255	670	6,490
Riverine Forest		478	33		379	335	462	160	15	13		876	2,751
Bare Land							40						40
Wet Land					9	23						6	38
Vlei/Grassland	93	111					25		358	539	86		1,212
River		17	1	4	18	18	17	8				58	141
Cultivated Land	22	276	1,003	1,246	563	799	671	1,033	10		20	356	5,999
Settlement	39				38	13							90
Others	52		17	4	17	17	21	14			136	6	284
Total	10,537	10,436	7,668	7,237	7,537	12,088	14,750	14,676	14,110	12,199	12,653	21,942	145,833

	Blocks of Bembesi Forest Land			
Category	A	B	C	Total
Eucalyptus Plantation				
Closed Woodland	293	318	228	839
Open Woodland	2,440	22,772	5,876	31,088
Closed Bushland	2,033	3,028	4,243	9,304
Open Bushland	325	1,523	423	2,271
Riverine Forest	48	629		677
Bare Land		68		68
Wet Land		11		11
Vlei/Grassland			560	560
River	10	26		36
Cultivated Land	6,717	3,433	36	10,186
Settlement				
Others s	5	69		74
Total	11,871	31,877	11,366	55,114

Chapter 8

8. Forest Survey

8.1 Forest Survey

8.1.1 Design of Survey

(1) Basic Principle of the Survey

The sample survey method which objectively establishes the volume of forest resources was adopted for this survey.

(2) Access and Process

(a) Access

Along the longest direction of the Survey Area, there is a well-paved and 2-lane road known as “Bulawayo – Victoria Falls Road (or Falls Road)”, which secures the access from Bulawayo to the Survey Area. The base for the survey was established at Halfway between the Bulawayo City and Victoria Falls.

Within the Survey Area, unpaved sandy roads exist around the Forest Hill Office and Gwaai Forest Station (Amandundumera). The roads had been developed through logging activities in the past 100 years in the linear form reflecting the flat terrain. At present the roads are maintained by the Forest Hill Office for forest management and enable 4WD vehicles to run at speeds from 20 to 40 km per hour. But the roads along three main rivers such as Bembesi River, Insuza River and Gwaai River are mainly used by donkey-drawn carriages and do not secure the said speed due to the narrow width and winding route.

(b) Process

The full-scale survey was scheduled to start from May which is just after the rainy season. But it was initiated from the end of July due to the prevailing social conditions. Before the start of the survey, there was a concern that the trees might defoliate. The main tree species except for *Pterocarpus angolensis*, however, did not defoliate because the rainy season started two months later than the usual time. Accordingly there was no problem to identify the main tree species, though almost all of grass species on the floor were dead.

In the full-scale forest survey two teams were formed consisting of the following members.

Engineer	2 persons
Assistant Engineer	1 person
Workers	3 - 4 persons

(3) Size and Shape of the Survey Plot

Based on the survey results of the year 1999, the size of a survey plot was decided as 0.1ha and its shape as rectangular (20 m x 50 m) by considering the work efficiency.

(4) Number of Plots

The necessary number of plots was calculated by using "total volume" data obtained as the result of the preliminary survey. The following equation was used and the target precision was the confidence level of 95% and estimated error of 10%.

$$n \geqq (t \cdot Cv / E)^2$$

n : Number of plots

t : Coefficient of confidence (t=2 、confidence level 95%)

Cv : Coefficient of variance

E : Estimated error ratio

Table 8 – 1 Results of the Preliminary Survey

Plot No.	Plot Area (ha)	Tree Species Appeared	Ave. DBH (cm)	Ave. H (m)	Tree Density (/ha)	Total Volume (m^3/ha)
1-1	0.1	3	15	6	110	8.710
1-2	0.1	5	23	7	290	62.940
1-3	0.1	5	18	7	220	38.130
1-4	0.1	6	18	7	360	58.880
1-5	0.1	5	18	7	180	39.770

Note: Subject trees for the measurement were of the DBH larger than 10 cm.

Table 8 – 2 Minimum Number of Plots Required

Plot Size (ha)	0.1
Standard Deviation (m^3/ha)	21.512
Average Volume (m^3/ha)	41.686
Coefficient of Variation (Cv)	0.516
Confidence Coefficient (t)	2
Estimated Error Ratio (E)	10%
Number of Plots	107

Therefore, it was estimated that the above mentioned precision may be achieved if the number of plots is more than 107.

(5) Sampling

Initially, based on the aerial photo interpretation results, it was planned to apply the stratified random sampling method. But as on the land use and vegetation maps, the target woodlands for the volume estimation could be divided into only two categories from the view point of canopy density, random sampling method was adopted instead.

(a) Location of Plots

In the woodland area in the Intensive Area the plots were randomly distributed. Firstly grid lines 0.5 km by 0.5 km were drafted on the maps at the scale of 1/50,000. The origin of the coordinates was set at the most north and west marginal points. The intersections of the grid lines were the candidate points for the sampling points by selecting the coordinates derived from the random numbers.

(b) Adjustments

The procedure as described in (a) above was repeated to obtain the sample plots and the following adjustments were made.

i) Areas without woody vegetation or the bushland of which tree height was less than 5 m was excluded from the subject area for the volume estimation. Therefore, those plots which dropped in the bushland were eliminated.
ii) Too remotely located plots from the roads were substituted with plots nearer to the roads by the same forest types to avoid inefficiency. The substitution made accounted for some 20 % of the total number of plots.
iii) The number of sample plots is allocated to each forest type by weighing the each area in order to attain the more accurate figure by the data analysis.

Finally the total number of the sample plots amounted to 136 which exceed the preliminary figure of 107. Thus the location of the plots was transcribed to the aerial photos and to the draft interpretation maps by carefully examining approach routes and land survey lines on the draft interpretation maps.

(6) Establishment of Plots

Through conducting land surveys using a compass, the survey team approached to the point of plots shown on the aerial photos and established rectangular shaped survey plots each 20 m and 50 m long.

(7) Survey Items

The following items were surveyed. The DBH was measured using diameter tapes or calipers and the tree height was measured using a hypsometer (Blime-Leiss).

Table 8 – 3 Survey Items

Item	Unit	Remarks
Tree Species		
DBH	2 cm	Diameter at breast height (approx. 1.3 m above ground). Every tree of which DBH is larger than 10 cm was measured.
Total Height	1 m	
Tree Vigor		1: sound, straight 2: sound but stem deformations, suitable for sawing 3. multi-stemmed or forked below 5 m 4: visible rot or hollow 5: moribund or dead
Fire Damage		1: no obvious damage from fire 2: blackened bark from fire 3: visible fire scars, damage not likely to kill the tree 4: lethal fire scars
Topographical Features		Elevation, gradient, bearing and land form, etc.
Regeneration		Adopting the Braun-Blanquet method, trees of less than 5 m in height were recorded in each plot.

Table 8 – 4 Class Criteria of Braun-Blanquet Method

Class Symbol	Abundance and Coverage
+	Individuals of a species sparsely present in the stand; coverage very small
1	Individuals plentiful, but coverage small; Individuals rather few, but coverage large
2	Individuals very numerous if small; if large, covering 10-25% of area
3	Individuals few or many, collectively covering 26-50% of the area
4	Individuals few or many, collectively covering 51-75% of the area
5	Individuals few or many, collectively covering 76-100% of the area

(8) Number of Plots Surveyed

The total number of plots surveyed was 136 and the numbers of plots surveyed in each forest type was as shown in Table 8 – 5.

Table 8 – 5 Plot Number by Forest Type

Forest Type	Symbols for Forest Type	Number of Plots Surveyed
Planted *Eucalyptus* spp.	Eu	4
Stand dominated by *Baikiaea plurijuga*	Ba	93
Stand dominated by *Guibourtia coleosperma*	Gc	20
Stand dominated by *Brachystegia* spp.	Br	8
Stand dominated by *Acacia* spp.	Ac	2
Stand dominated by Combretaceae	Co/Ts	5
Stand dominated by *Colophospermum mopane*	Cm	2
Riverine forest	R	2
Total		136

Note: The number of plots by tree height and canopy density is shown in Annex.

(9) Volume Estimation of Plots

The volume equations prepared by the Forest Inventory of Indigenous Forest - Mzola Woodland - Matabeleland North Province, which was conducted at Mzola Forest Land with German cooperation, was found to be applicable for the volume estimation of forests in Gwaai and Bembesi Forest Lands. Based on the discussions between the FC and the Survey Team, it was agreed that the existing equations for total volume and timber volume estimation were applicable for the present survey.

(a) Total Volume

For estimating whole tree volume over bark including stem and branches, the following equations were applied. The estimated volume comprises stem and branches, excluding stump and roots.

i) Volume equation for trees of which DBH is 22 cm or more

The total volume was estimated with a function based on form factor.

$$\text{Volume } (m^3) = \text{Basal area } (m^2) \times \text{Tree Height (m)} \times \text{Form Factor}$$

The form factor was calculated:

$$\text{Form Factor} = (-0.00128 + 0.563577 \times (1 - 1 / \text{DBH } (cm)^2)$$

The form factor is derived from the volume tables of Banks and Burrows for total volume to a tip diameter of 7.5 cm.

ii) Volume equation for trees of which DBH is less than 22 cm

The following equation estimates the total volume to a tip diameter of 5 cm.

$$V(m^3) = 0.0031379 + 0.439125 \times DBH\ (m)^2 \times \text{tree height (m)}$$

(b) Timber Volume

For the estimation of timber volume over bark, the following equation and coefficients were applied. This estimates the millable stem volume to a tip diameter of 15 cm and is based on the Banks and Burrows functions. The original coefficients were converted to metric units.

Table 8 – 6 Timber Volume Equation

$V(m^3) = a + b \times$ Tree Basal Area (m^2)		
Tree Species Group	a	b
Pterocarpus (*Brachystegia, Julbernardia, Erytrophleum*)	-0.335	9.423
Baikiaea (*Kirkia, Combretum*)	-0.219	6.976
Guiburtia (*Burkea, Afzelia, Sclerocarya*, others)	-0.225	6.997

In the original description of the Banks and Burrows the application of this equation is limited to the minimum DBH of 13.6 inches (i.e. some 35 cm). Applicability of this equation was discussed with the FC and it was agreed to use this equation with a restriction of DBH of 26 cm or more to estimate the timber volume.

The calculated results were attached in Annex.

8.1.2 Survey Results

Here tree species appeared in the surveyed plots, number of trees, DBH, height and volume are reported for trees of DBH of 10 cm or more.

(1) Appeared Trees and their Numbers

The trees appeared were simply counted. The major tree species were listed in descending order of the counts as shown in Table 8 – 7.

Baikiaea plurijuga appeared throughout the area except in the riverine forest and *Guibourtia coleosperma* appeared some quarter of it. The sum of the two species exceeded some half of all appeared trees. The next most appeared trees were *Combretum collinum* and *Commiphora* spp. but these were not as dominant as the other two species. *Colophospermum mopane* appeared as pure stands in the riverine forest and as mixed stands with *Acacia* spp. *Eucalyptus camaldulensis* is planted at the vicinity of the Kenmaur.

Table 8 – 7 Major Tree Species Appeared in the Plot Survey（Total of all plots）

Rank	Species	Total No. of Trees Appeared	Frequency of Species Appeared (%)	Accumu-rated Ratio (%)
1	*Baikiaea plurijuga*	1368	42	42
2	*Guibourtia coleosperma*	401	12	55
3	*Combretum collinum*	274	8	63
4	*Commiphora mossambicensis*	109	3	66
5	*Brachystegia spiciformis*	89	3	69
6	*Colophospermum mopane*	84	3	72
7	*Terminalia sericea*	83	3	74
8	*Pterocarpus angolensis*	82	3	77
9	*Commiphora pyracanthoides*	69	2	79
10	*Eucalyptus camaldulensis*	66	2	81
11	*Burkea Africana*	64	2	83
12	*Commiphora mollis*	60	2	85
13	*Diplorhynchus condylocarpon*	56	2	87
14	*Ochna pulchra*	51	2	88
15	*Acacia nigrescens*	46	1	90

The whole appeared species including the major species are listed in Annex.

(2) DBH and Tree Height

The simply averaged DBH and tree height by each forest type are as follows. The largest DBH and tree height were recorded among the trees of *Acacia ataxacantha which* appeared in the riverine forest within the Intensive Area.

Table 8 – 8 Average and Maximum DBH by Forest Type

DBH \ Forest Type	**Eu**	**Ba**	**Gc**	**Br**	**Ac**	**Co/Ts**	**Cm**	**R**	**All**
Average (cm)	14	18	20	19	14	14	14	30	18
Max (cm)	24	79	61	58	43	51	28	120	120

Table 8 – 9 Average, Maximum and Minimum Tree Height by Forest Type

Tree Height \ Forest Type	**Eu**	**Ba**	**Gc**	**Br**	**Ac**	**Co/Ts**	**Cm**	**R**	**All**
Average (m)	9	7	7	8	6	6	7	14	7
Max (m)	17	18	15	14	9	11	10	31	31
Min (m)	5	2	3	3	4	3	4	3	2

Most of the woodland and bushland in the Intensive Area are indigenous uneven-aged forests.

In principle, for a sustainable management of uneven-aged forests it is desirable to maintain the stand having the DBH class distribution with negative exponential curve.

The forests in the Intensive Area have been continuously subject to human intervention and disturbance, such as exploitative cutting of large-diameter trees and forest fires, since the early 1900s. Accordingly the DBH class distribution of these forests is highly disturbed. Therefore, the continuity or intermittence of the distribution which appears in the survey would be caused not only by natural conditions but also human affection. It would be difficult to identify the natural features from the results of the present survey. But the identification of current conditions is thought to be referred to the future forest management.

In the indigenous forests, such as the forests in the Intensive Area, the DBH class may have one of the three distribution patterns such as: ① Negative Exponential, ② Flat and ③ Bell-Shaped as shown below.

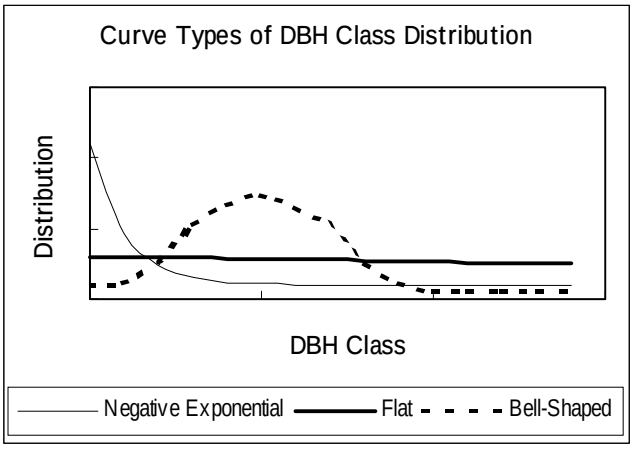


Fig. 8 – 1 Relationship between DBH Class and Distribution

According to each pattern of DBH distribution, forest conditions such as regeneration and mortality could be described in Table 8 – 10.

Table 8 – 10 Regeneration and Death of Trees by Pattern of DBH Class Distribution

Pattern of DBH Class Distribution	Regeneration Condition	Mortality Condition
① Negative Exponential	Active and continuous.	Mortality is distributed throughout the age-classes.
② Flat	Intermittent.	High at an early stage.
③ Bell-Shaped	Temporary under the favourable condition accompanied by exceptional disturbance.	High if there is no favourable condition.

Source: C.J. Geldenhuys, 1996, "The Use of Diameter Distributions in Sustained-Use Management of Forests: Examples from Southern Africa"

The sums of the plot data on the main tree species are shown in Fig. 8 – 2. As can be seen from the figure, while most species show negative exponential curves, exceptionally, *Pterocarpus angolensis* shows the flat curve of the distribution. Thus it can be said that the main species are actively regenerating and the mortality in these species is distributed throughout the age-classes.

In the case of *Pterocarpus angolensis*, regeneration will occur intermittently or in a dispersed manner if there is no human disturbance. The mortality would be high at young stage.

A common tendency among *Baikiaea plurijuga*, *Guibourtia coleosperma*, *Pterocarpus angolensis* and *Brachystegia* spp. is the less distribution of the DBH class from 15 to 19 cm. Though the reason for this tendency is not clear yet, the human disturbance must be deeply involved. Three reasons or forms of human disturbances could be cited for this situation. One is that the relevant mother trees were cut which seriously affected regeneration and therefore currently there are less trees of DBH class from 15 to 19 cm. Judging from the cutting records and the tree growth, the first cutting circle which was conducted from 50 to 100 years ago may had a significant effect. At that time the regeneration volume decreased due to cutting of mother trees and this reduced the number of trees which currently appear in the DBH class from 15 to 19 cm. Presumably after the first cutting cycle the remaining trees grew and the regeneration volume of the DBH class from 10 to 14 cm recovered.

Secondly, there may be many mother trees when the trees of the DBH class from 15 to 19 cm were regenerating, but that the mother trees were cut and many of regenerated trees were destroyed by forest fires.

Thirdly, it is presumed that the inhabitants tend to use the trees of the DBH class of 15 to

19 cm as firewood, etc. But such woods are thought to be secured from the vicinities of the settlements and thus cutting for firewood, etc. could not affect the trees of the DBH class from 15 to 19 cm throughout the survey area.

It would be reasonable to think that the nearly flat distribution of *Pterocarpus angolensis* is due to the decreased regeneration volume which may be caused by continuous legal or illegal selective cutting because the species produces good quality timber. If this type of distribution is caused by not only human influence but also by natural factors, then it can be said that the recruitment is intermittent and the mortality is high at a young age.

No matter what the possible reasons are, the future sustainable production of *Pterocarpus angolensis* will not be easy because of the said distribution pattern.

It should be noted that the trees of the DBH class from 15 to 19 cm should not be cut but protected from now on.

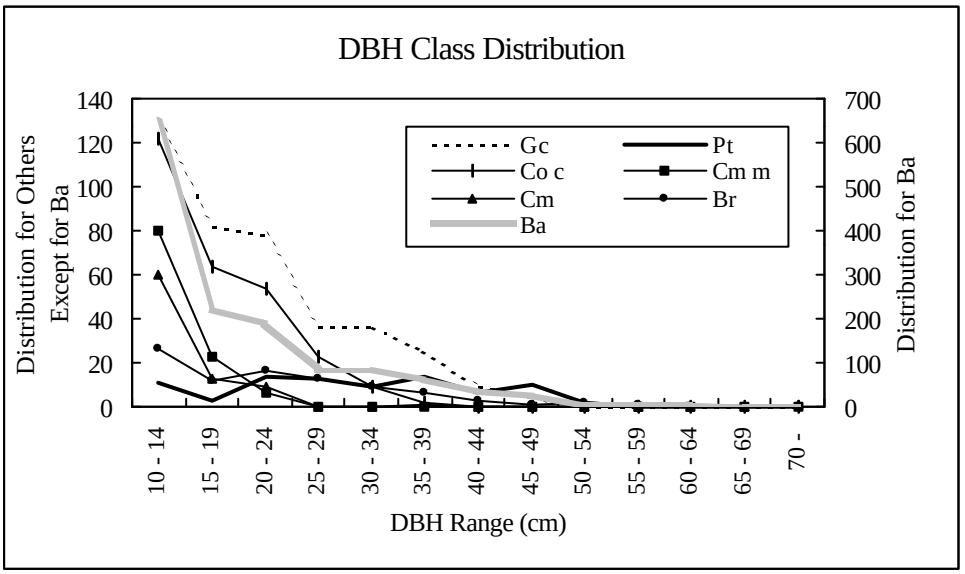


Fig. 8 – 2 Tendency of DBH Class Distribution of Main Tree Species
Note: Pt: *Pterocarpus angolensis* Co c: *Combretum collinum*
Cm m: *Commiphora mossambicensis* Br: *Brachystegia* spp.
Only *Baikiaea plurijuga* is plotted along the right Y axis while others are plotted along the left axis.

The said general tendency does not necessarily and similarly appear as a pattern within each plot data. At the size of 0.1 ha of each plot, three patterns of ① Negative

Exponential, ② Flat and ③ Bell-Shaped are mixed. In other words, in terms of tendency of DBH class distribution, the forest structure scoped through 0.1 ha is different from the general trend and shows more specific character as the sampled site.

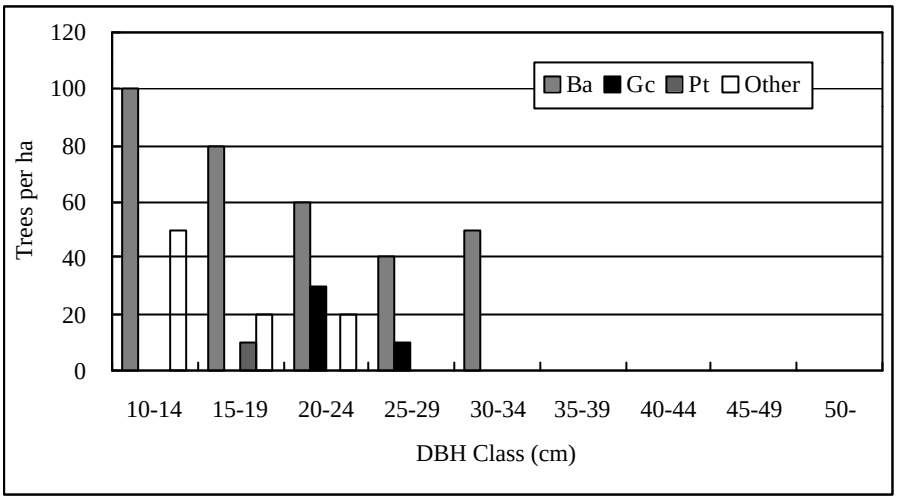
In terms of characteristics of each tree species, *Baikiaea plurijuga* often appeared in large numbers in the smaller DBH class from 10 to 19 cm. When the stand density was high, the distribution showed negative exponential pattern. By contrast it showed flat or bell-shaped pattern when the density was low.

In many cases *Guibourtia coleosperma* showed a bell-shaped pattern centering around the DBH class ranging from 20 to 34 cm. *Pterocarpus angolensis* did not show a continuous pattern but appeared as isolated trees in plots of 0.1 ha size in this survey.

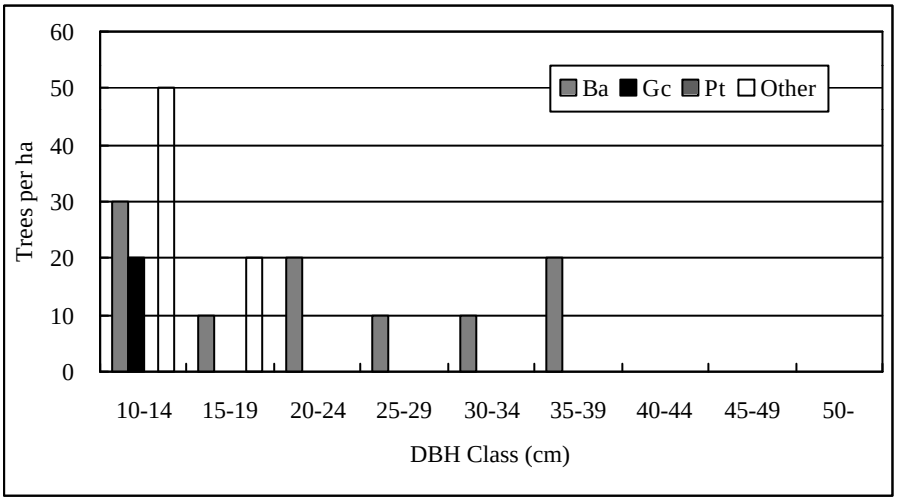
The negative exponential pattern of dominant species in all plots indicates a general tendency in the entire Intensive Area. If there is a certain human factor apparently causing the flat or bell-shaped pattern in dominant species at the level of area of plots, the pattern could change into the negative exponential pattern by removing the factor. However, the *Pterocarpus angolensis* is the exceptional species and trees of this species are decreasing.

Examples of patterns of DBH class distribution in stands dominated by *Baikiaea plurijuga* are shown in Fig. 8 – 3.

＜① Negative Exponential＞



＜② Flat＞



＜③ Bell-Shaped＞

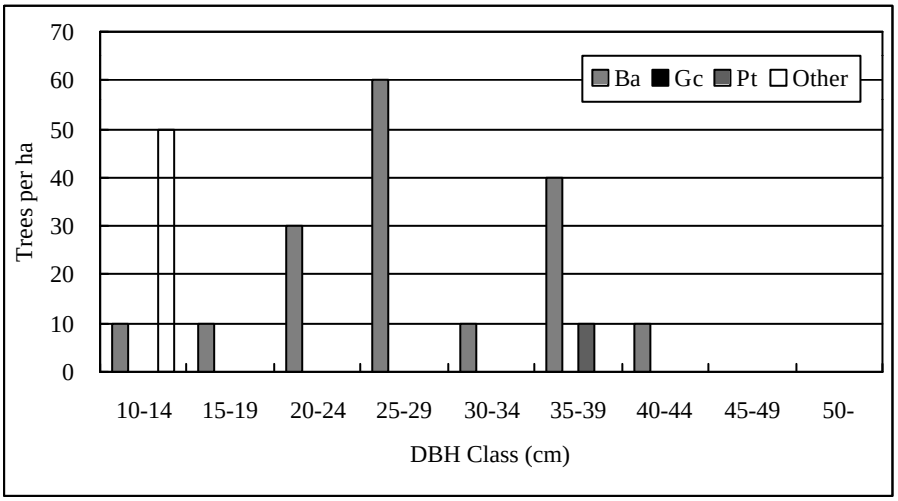
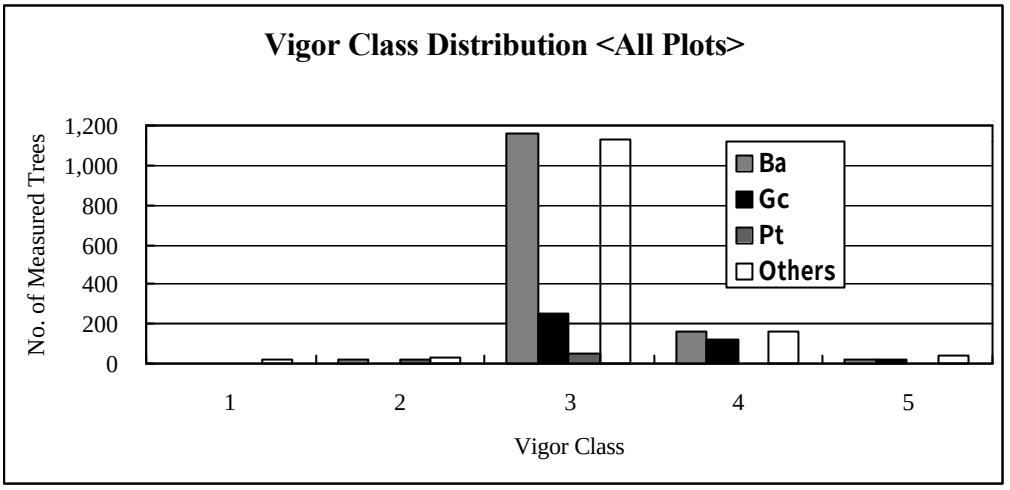


Fig. 8 – 3 Typical Pattern of DBH Class Distribution by Plot
Note: All figures were obtained from the plots of stands dominated by *Baikiaea plurijuga* (i.e. ① H45 ② S23 ③H9).

(3) Tree Vigor and Fire Damage

The tree vigor in all plots is shown in Fig. 8 – 4.

The Class 3 accounts for some 80%, which is the largest, while Class 1 and 2 appear rarely. This figure indicates that it is hard to find the trees of which main branches grow at the height of more than 5 m above the ground.



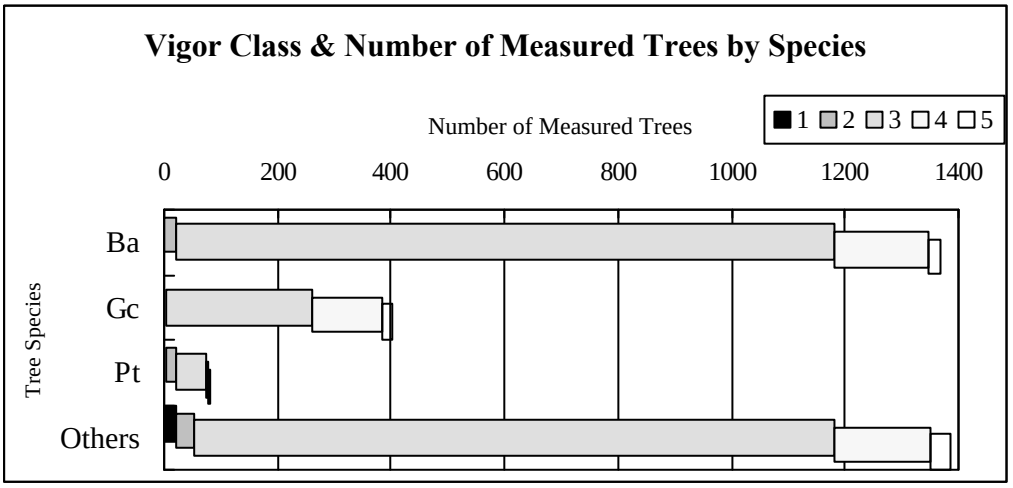


Fig. 8 – 4 Tree Vigor of Measured Trees

There could be two reasons behind this tendency. One is that it is natural to branch under the height of 5 m from the viewpoint that the subject trees belong to indigenous species and the maximum tree height is more or less 15 m. Another is that most of trees having straight stems were cut during the past logging activities.

As timber species, *Guibourtia coleosperma* has low tree vigor compared to *Baikiaea plurijuga*. It should be noted that some *Guibourtia coleosperma* trees were observed affected by a kind of disease which caused cracked stem barks with black sap exuding

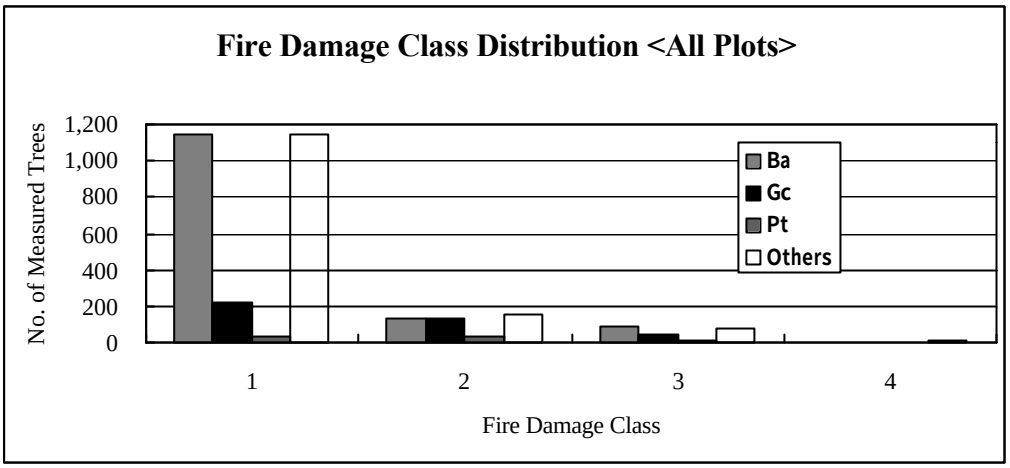
from them, and leaves with black spots of some 2 mm in size. On the other hand there were some standing trees of which bark cracked in a scaly manner and the cambium layer was likely to lignify. This symptom was observed at a very specific site frequently damaged by fires.

Other tree species such as *Acacia ataxacantha*, mainly appearing in riverine forests, showed Class 1 or 2 vigor.

The fire damage in all plots is shown in Fig. 8 – 5.

The Class 1 accounts for some 80% which is the largest while Class 4 appears rarely. Timber species such as *Guibourtia coleosperma* or *Pterocarpus angolensis* were rather seriously damaged compared to *Baikiaea plurijuga*.

With this background, *Baikiaea plurijuga* can be said to have high fire resistance and physiological functions which enable it to heal the scar of fires. More specifically it presumably means that the bark recovers after a fire or is fire resistant to the extent that it is not carbonized.



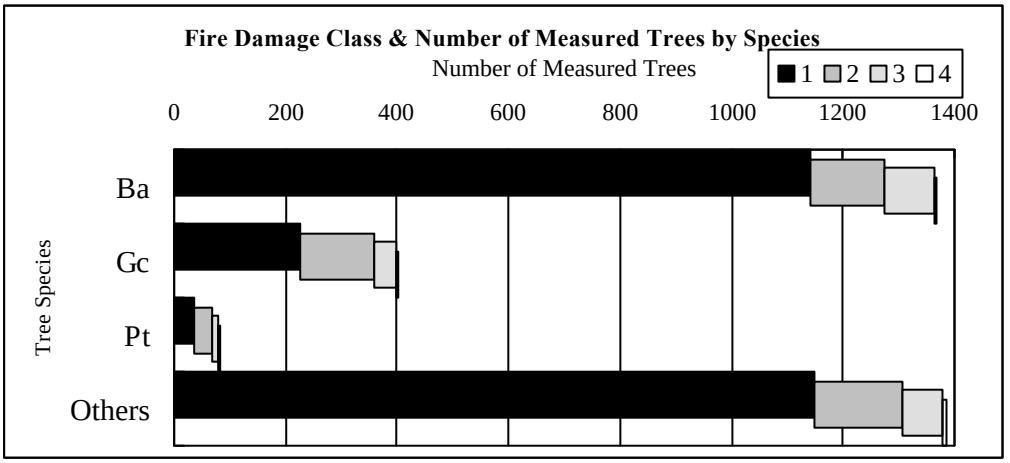


Fig. 8 – 5 Fire Damage of Measured Trees

Beside the said damages the damage by elephants to the trees is common in the Intensive Area which is located out of the wildlife area. The barks of the damaged trees are peeled, or the trees are uprooted, the latter being the main form of damage by elephants. However, a limited number of trees were damaged by elephants. The main damaged tree was *Diplorhynchus condylocarpon* and partially damaged trees was found to be *Pterocarpus angolensis*. Outside the Intensive Area *Baikiaea plurijuga* was found fallen on the forest floor or their stems broken.

8.1.3 Volume

(1) Results of Plot Survey

The survey results from a total of 136 plots are shown in the Annex.

(2) Estimation of Total Growing Stock

The total growing stock was estimated by the "total volume" and not by "timber volume".

The data from the following three plots were omitted from the data of 136 plots when estimating total growing stock volume, because the data from the three plots showed extremely large volumes, or the plots were in the bushland (tree height <5 m) which is not the subject area for volume estimation.

Table 8 – 11 Plots Omitted in Estimation of Total Growing Stock

Plot No.	Forest Type	H (m)	Canopy Density (cm)	Total Volume (m^3/ha)	Timber Volume (m^3/ha)	Reason
H55	R	23	80	490.610	191.770	Extremely large volume
S64	Ac	4	30	10.050	7.910	Interpreted height on aerial phots is less than 5 m.
S67	R	12	80	188.700	132.940	Extremely large volume

Excluding the above three plots, the random sampling method was applied by using the results of 133 plots (the results are shown in Annex). As can be seen from the table the estimated error ratio is 96% which largely exceeds the assumed ratio of 10% calculated during the preliminary survey in 1999. The reason could be that the variance of volumes from the sampling in the preliminary survey was not wide enough to represent the whole of the Intensive Area.

In order to reduce the estimated error, the volume of each plot were grouped and calculated by using the following stratum of similar forest physiognomy.

Table 8 – 12 Criteria for Stratification

Canopy Density (%)	Height (m)							
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5	**I**	**I**	**I**	**I**	**I**	**II**	**II**	**II**
10	**I**	**I**	**I**	**I**	**II**	**II**	**II**	**III**
15	**I**	**I**	**I**	**II**	**II**	**II**	**III**	**III**
20	**I**	**I**	**II**	**II**	**II**	**III**	**III**	**III**
25	**I**	**II**	**II**	**II**	**III**	**III**	**III**	**IV**
30	**II**	**II**	**II**	**III**	**III**	**III**	**IV**	**IV**
35	**II**	**II**	**III**	**III**	**III**	**IV**	**IV**	**IV**
40	**II**	**III**	**III**	**III**	**IV**	**IV**	**IV**	**V**
45	**III**	**III**	**III**	**IV**	**IV**	**IV**	**V**	**V**
50	**III**	**III**	**IV**	**IV**	**IV**	**V**	**V**	**V**
55	**III**	**IV**	**IV**	**IV**	**V**	**V**	**V**	**V**
60	**IV**	**IV**	**IV**	**V**	**V**	**V**	**V**	**VI**
65	**IV**	**IV**	**V**	**V**	**V**	**V**	**VI**	**VI**
80	**IV**	**V**	**V**	**V**	**V**	**VI**	**VI**	**VI**

The results of statistical calculations to estimate the total growing stock are tabulated as follows.

Table 8 – 13 Statistical Calculation for Estimation of Total Growing Stock

Stratum	No. of Samples	Area	Total of Volume of Samples	Average Volume	Area by Stratum	Variance within Stratum	Total Average Variance
H	n_h	N_h	T_h	T_h/n_h	$W_h=N_h/N$	S_h^2	$(1/n_h-1/N_h)W_h^2S_h^2$
h \ Unit	No.	ha	m^3	m^3			m^3
I (1)	20	11,442	346.530	17.327	0.293	110.918	0.475
II (2)	21	12,206	545.000	25.952	0.313	89.509	0.417
III (3)	33	8,277	1,193.410	36.164	0.212	103.185	0.140
IV (4)	42	6,038	2,031.830	48.377	0.155	232.685	0.132
V (5)	14	767	874.420	62.459	0.020	170.133	0.005
VI (6)	3	274	202.320	67.440	0.007	1,004.080	0.016
Total	133	39,004	5,193.510	30.086	1.000	-	1.185

When the following variables are assumed, the statistical values in the above table can be described as follows.

h : Number of stratum

x_h : Volume of each plot

$\bar{x}$: Mean value of population

S_h^2 : Variance within each stratum

$S\bar{x}^2$: Variance of mean value

$$\bar{x} = \sum_{h=1}^{L} W_h \bar{x}_h$$

$$s_h^{\,2} = \sum_{i=1}^{n_h} \frac{\left(x_{hi} - \bar{x}_h\right)^2}{(n_h - 1)}$$

$$s_{\bar{x}}^{\,2} = \sum_{h=1}^{L} W_h^{\,2} s_h^{\,2} / n_h - \sum_{h=1}^{L} W_h s_h^{\,2} / N = \sum_{h=1}^{L} (1/n_h - 1/N_h) W_h^{\,2} s_h^{\,2}$$

Table 8 – 14 Calculation of Total Growing Stock by Stratification After Sampling

Parameter	Unit	Results	
Average volume	m^3	30.086	
Standard deviation of average volume (s)	m^3	1.185	
Number of sample plots (n)		133	
Confidence limit (p)		0.95	
t (p, n - L)		1.97	
Estimated error (t (p, n - L) * s)		2.334	
Confidence interval of the average volume	m^3/ha	30.086	± 2.334
Confidence interval of the grand total volume	1,000 m^3/ha	1,173	± 91
Estimated error ratio	%	8	

As stated above, the object precision for total growing stock was secured within 10% of the estimated error rate at the confidence level of 95%.

(3) Preparation of Stand Volume Tables Based on Aerial Photo Interpretation

Stand volume equations based on aerial photo interpretation were prepared to estimate

volume of each parcel classified through photo interpretation, and by using the equations stand volume tables (based on aerial photo interpretation) were prepared. The figures of stand volume tables were given by the equation obtained through the regression analysis of correlation between factors obtained through photo interpretation and stand volume. The flow of relevant works is shown in Fig. 8 – 6.

The factors obtained from the photo interpretation were tree height of upper story and canopy density which have a high correlation with volume. The stand volume equations were examined by adopting the following three model equations to compare the standard error ratio. The stand volume equations were prepared for both total volume and timber volume.

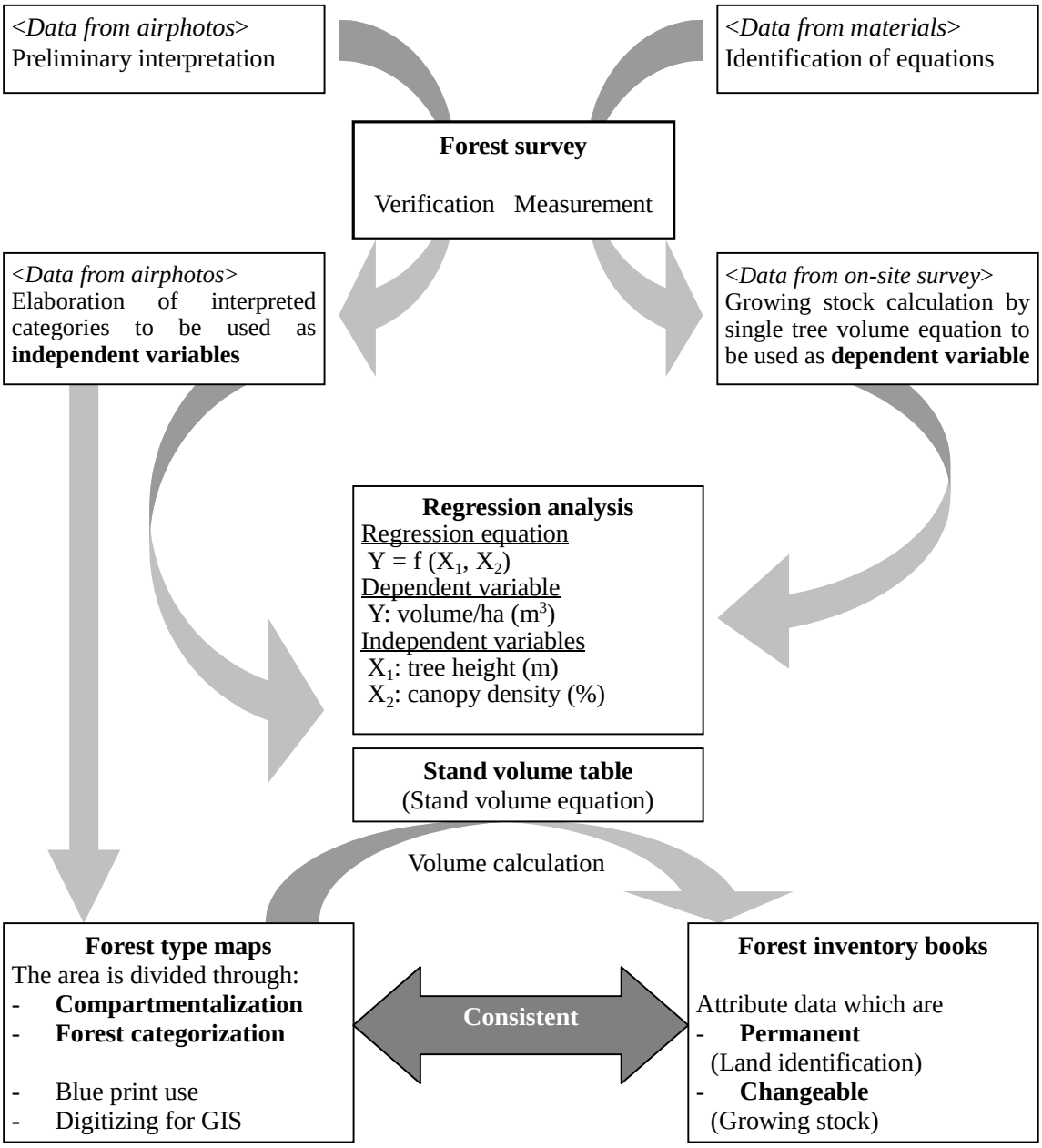


Fig. 8 – 6 Flow of Relevant Works for Stand Volume Table Preparation based on Aerial Photo Interpretation

Table 8 – 15 Comparison of Stand Volume Equations

Model	Equation	Total Volume		Timber Volume	
		Multiple Correlation Coefficient	Standard Error Ratio (%)	Multiple Correlation Coefficient	Standard Error Ratio (%)
1	*log* V = a * *log* H + b * *log* CD + c	0.78	**31.9**	0.56	**56.1**
2	V = a * H + b * CD + c	0.76	**31.8**	0.63	**55.4**
3	V = a * H * CD + c	0.74	**32.8**	0.57	**58.1**

Note: V: Volume H: Height (m) CD: Canopy Density (%) a, b, c: Constants

From the above the equations of Model 2 were selected for both total volume and timber volume due to the minimum standard error ratios. The constants are as follows.

Table 8 – 16 Adopted Equation and Constants for Stand Volume Equation

Type	Equation	a	b	c
Total Volume	V = a * H + b * CD + c	**3.8964**	**0.6704**	**-16.9829**
Timber Volume	V = a * H + b * CD + c	**3.7929**	**0.3093**	**-21.2440**

Note: V: Volume H: Height (m) CD: Canopy Density (%) a, b, c: Constants

The stand volume tables prepared by the said equation are as follows.

Table 8 – 17 Stand Volume Tables based on Aerial Photo Interpretation

Total Volume Unit: m^3/ha o.b.

CD \ H	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5	6	10	14	18	21	25	29	33
10	9	13	17	21	25	29	33	36
15	13	16	20	24	28	32	36	40
20	16	20	24	28	31	35	39	43
25	19	23	27	31	35	39	43	47
30	23	27	30	34	38	42	46	50
35	26	30	34	38	42	45	49	53
40	29	33	37	41	45	49	53	57
45	33	37	40	44	48	52	56	60
50	36	40	44	48	52	55	59	63
55	39	43	47	51	55	59	63	67
60	43	47	51	54	58	62	66	70
65	46	50	54	58	62	66	69	73
70	49	53	57	61	65	69	73	77
75	53	57	61	64	68	72	76	80
80	56	60	64	68	72	76	80	83

Timber Volume Unit: m^3/ha o.b.

CD \ H	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5	0	3	7	11	14	18	22	26
10	1	5	8	12	16	20	24	27
15	2	6	10	14	18	21	25	29
20	4	8	11	15	19	23	27	30
25	5	9	13	17	21	24	28	32
30	7	11	15	18	22	26	30	34
35	9	12	16	20	24	28	31	35
40	10	14	18	21	25	29	33	37
45	12	15	19	23	27	31	34	38
50	13	17	21	25	28	32	36	40
55	15	19	22	26	30	34	37	41
60	16	20	24	28	31	35	39	43
65	18	22	25	29	33	37	41	44
70	19	23	27	31	35	38	42	46
75	21	25	29	32	36	40	44	47
80	22	26	30	34	38	41	45	49

Note: CD: Canopy Density (%) H: Tree Height (m)

(4) Volume in Forest Inventory Books

The volume per ha for each parcel derived from aerial photo interpretation was obtained using the prepared stand volume equation by applying the interpreted values on aerial photos. The volume for each parcel was acquired by multiplying the volume per ha by the parcel area and is described in the forest inventory books. By summing up values of all parcels, total growing stock of the Intensive Area was calculated as 1,233,000 m^3.

Thus the total growing stock obtained by using the stand volume equation is within confidence interval (at confidence level of 95% and estimated error ratio of 8%) estimated by the results of the plot survey and is within the range of the target precision.

- Total growing stock obtained by summing up values of all parcels in the forest inventory books: 1,233,000 m^3

- Total growing stock estimated by the results of the plot survey: 1,173,000 m^3 ±91,000 m^3 (1,082,000 m^3～1,264,000 m^3)

(5) Volume of Each Block

The volume of each block is as shown in the following table.

Table 8 – 18 Volume of Each Block

Block	Total Area (ha)	Ratio (%)	Productive Area (ha)	Ratio (%)	Total Volume (m^3)	Ratio (%)	Total Volume per ha (m^3/ha)	Timber Volume (m^3)	Ratio (%)	Timber Volume per ha (m^3/ha)
Gwaai Forest Land										
C	1,812	3	775	2	22,436	2	29	12,006	2	15
G	5,500	10	4,029	10	152,220	12	38	81,048	12	20
H	12,107	22	9,419	24	277,090	22	29	148,072	22	16
J	14,604	26	11,272	29	370,147	30	33	203,476	30	18
K	13,332	24	5,625	15	142,999	12	25	72,656	11	13
Bembesi Forest Land										
B	8,157	15	7,884	20	268,148	22	34	156,667	23	20
Total	55,512	100	39,004	100	1,233,040	100	32	673,925	100	17

Note: Productive Area comprises woodland.

Moreover, since the timber volume is generally compiled by DBH classes in Zimbabwe, timber volume by DBH class was calculated for each block. The method applied was to multiply the growing stock for each block by the mean ratio of timber volume for DBH class of all plots.

Table 8 – 19 Mean Timber Volume Ratio for DBH Classes

Item	DBH Class	DBH Range (cm)	Mean Timber Volume Ratio (%)
All species	1	34 +	64.81
	2	26 – 33	35.19
Baikiaea plurijuga	1	34 +	33.17
	2	26 – 33	18.55
Guibourtia coleosperma	1	34 +	8.88
	2	26 – 33	5.16
Pterocarpus angolensis	1	34 +	10.89
	2	26 – 33	1.79

Table 8 – 20 Summary of Timber Volume for Main Species by DBH Class for Timber

				All Species			***Baikiaea plurijuga***			***Guibourtia coleosperma***			***Pterocarpus angolensis***		
Block	Area (ha)	Productive Area (ha)	Timber Volume (m^3)	DBH Class 1 (m^3)	DBH Class 2 (m^3)	Sub-Total	DBH Class 1 (m^3)	DBH Class 2 (m^3)	Sub-Total	DBH Class 1 (m^3)	DBH Class 2 (m^3)	Sub-Total	DBH Class 1 (m^3)	DBH Class 2 (m^3)	Sub-Total
			Ratio	64.81%	35.19%	100.00%	33.17%	18.55%	51.72%	8.88%	5.16%	14.04%	10.89%	1.79%	12.68%
Gwaai Forest Land															
C	1,812	775	12,006	7,781	4,225	12,006	3,982	2,227	6,210	1,066	620	1,686	1,307	215	1,522
G	5,500	4,029	81,048	52,527	28,521	81,048	26,884	15,034	41,918	7,197	4,182	11,379	8,826	1,451	10,277
H	12,107	9,419	148,072	95,965	52,107	148,072	49,115	27,467	76,583	13,149	7,641	20,789	16,125	2,650	18,776
J	14,604	11,272	203,476	131,873	71,603	203,476	67,493	37,745	105,238	18,069	10,499	28,568	22,159	3,642	25,801
K	13,332	5,625	72,656	47,088	25,568	72,656	24,100	13,478	37,578	6,452	3,749	10,201	7,912	1,301	9,213
Bembesi Forest Land															
B	8,157	7,884	156,667	101,536	55,131	156,667	51,966	29,062	81,028	13,912	8,084	21,996	17,061	2,804	19,865
Total	55,512	39,004	673,925	436,771	237,154	673,925	223,541	125,013	348,554	59,845	34,775	94,619	73,390	12,063	85,454

Note: DBH Class **1** 34 cm + Class **2** 26 – 33 cm

(6) Charasteristics of Timber Volume of Stands Dominated by *Baikiaea plurijuga*

By using the data of each plot, mean DBH in each plot, and tree vigor or fire damage were plotted on the graphs shown below. On both tree vigor and fire damage, the ratio for Class 1 and 2 occupying in timber volume was plotted in Fig. 8 – 7 and Fig. 8 – 8.

In terms of tree vigor, many volume percentages generally amount to zero with no relation to DBH size. The mean volume percentage for trees of Class 1 and 2 which would be valuable for timber is low at 9%.

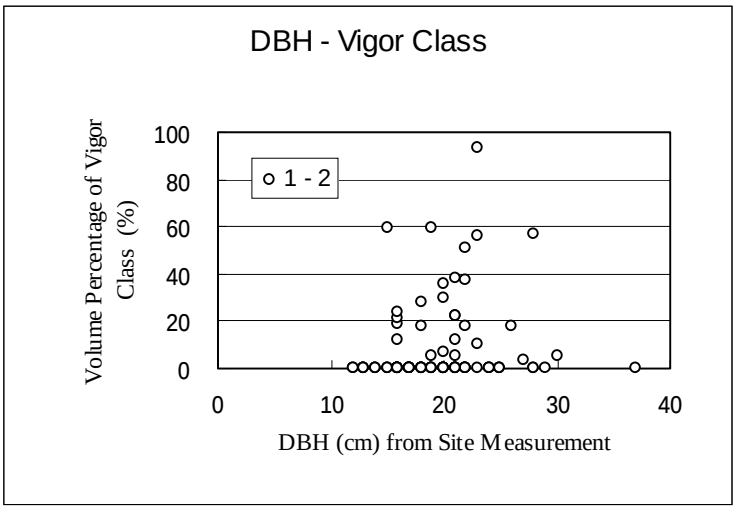


Fig. 8 – 7 Tree Vigor and Timber Volume of Stands Dominated by *Baikiaea plurijuga*

Note: The number of plots of 0 % amounts to 66 against all 93 plots.

In terms of fire damage, the mean volume percentage of Class 1 and 2 are generally high at 85%. In other words the large-diameter trees larger than 26 cm, which will be used as timber, mostly have rather slight fire damage.

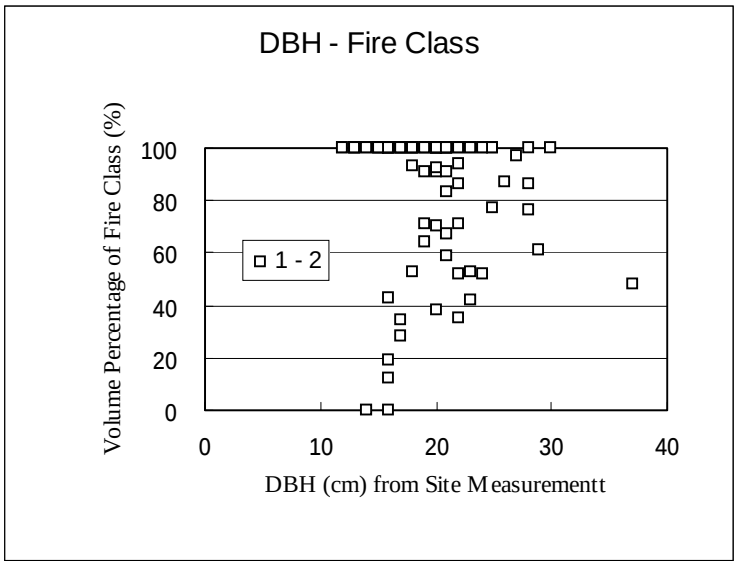


Fig. 8 – 8 Fire Damage and Timber Volume of Stands Dominated by *Baikiaea plurijuga*

Note: The number of plots of 100 % amounts to 55 against all 93 plots.

8.2 Natural Regeneration Survey

8.2.1 Survey Method

The trees regenerated in each plot of which DBH was less than 10 cm were surveyed by applying the Braun-Blanquet method. The abundance and coverage criteria of Braun-Blanquet method are as shown in Table 8－21. Abundance and coverage of each class was recorded by each tree species.

Table 8 – 21 Class Criteria of Braun-Blanquet Method (same as Table 8 – 4)

Class	Abundance and Coverage
+	Individuals of a species sparsely present in the stand; coverage very small
1	Individuals plentiful, but coverage small; Individuals rather few, but coverage large
2	Individuals very numerous if small; if large, covering 10-25% of area
3	Individuals few or many, collectively covering 26-50% of the area
4	Individuals few or many, collectively covering 51-75% of the area
5	Individuals few or many, collectively covering 76-100% of the area

8.2.2 Survey Results

(1) General Tendency (by simply summing up the collected data)

In order to compare the results from the forest survey for upper story trees of which DBH was 10 cm or more, and from the regeneration survey for regeneration trees of which DBH was less than 10 cm, the following items were simply counted by forest type.

i) Number of plots in which species appeared
ii) Frequency of plots in which species appeared relative to all plots in each forest type
iii) Ranking of the frequency

The summarized results are shown in Table 8 – 22. Tree use is shown at the left of the table for reference.

(a) Stand Dominated by *Baikiaea plurijuga* (Ba)

Baikiaea plurijuga as the upper story trees appeared at the highest frequency of 99% and the regenerations of the same species had the similar high ratio of 98%. Among the 93 plots in the subject forest type, there was one plot where there was no upper tree of *Baikiaea plurijuga*, though this plot was located in the subject forest type. This happened because the plot was located at a site where there was no *Baikiaea plurijuga* while many trees of *Baikiaea plurijuga* existed nearby. The same can be said about other plots which did not contain regenerations of *Baikiaea plurijuga*. The contents of regeneration was

extremely high in abundance and coverage. If regenerations of shrub species are ignored, regenerations that appear in a plot belong mainly to the highly ranked upper story trees. If the upper story trees have higher frequency of plots than their regenerations and the upper ones are ranked highly, in such a case there is the possibility of a decrease in the geographical range of the future regenerations. The trees of which such difference exceeded 10% consisted of *Combretum collinum* and *Pterocarpus angolensis*.

(b) Stand Dominated by *Guibourtia coleosperma* (Gc)

In this forest type both *Baikiaea plurijuga* and *Guibourtia coleosperma* were ranked highly and both upper story trees and regenerations appeared at 90% for the two species. The lineup of other species was similar to the case of stands dominated by *Baikiaea plurijuga*. However, there was no case that the upper story trees had a higher frequency of plots than the regenerations and the upper story trees were ranked highly, which indicates that there will be no problem with regard to regeneration in future.

(d) Stand Dominated by *Brachystegia spiciformis* (Br)

The upper story trees of *Brachystegia spiciformis* and *Baikiaea plurijuga* appeared in the higher rank while the regenerations of *Brachystegia spiciformis* showed a frequency of 100%. The species of which the upper story trees had higher frequency of plots (exceeding 10%) than regenerations, consisted of *Ochna pulchra*, *Combretum collinum*, *Commiphora mossambicensis*, *Guibourtia coleosperma* and *Pterocarpus angolensis*.

(e) Other Types

In the stands dominated by *Acacia* spp. (Ac), *Acacia karoo* was ranked highly in upper story trees followed by *Acacia nigrescens*. However, it might not necessarily represent a general trend since the number of plots were only two.

In the stands dominated by Combretaceae (Co/Ts), *Terminalia sericea* and *Combretum* spp. were ranked higly as well as *Burkea Africana*. *Baikiaea plurijuga* did not appear in upper story trees and as regenerations while the appearance of *Pterocarpus angolensis* and *Guibourtia coleosperma* was limited to their regenerations. Thus it can be said that valuable tree species for timber scarcely grow in the said stands.

In the stands dominated by *Colophospermum mopane* (Cm), *Colophospermum mopane* as well as *Acacia karoo* were ranked highly. Especially *Colophospermum mopane* appeared as nearly pure stand while its regenerations had an overwhelming abundance and coverage.

In the riverine forest (R), *Acacia* spp. and *Colophospermum mopanea* were ranked highly while their regenerations grew also.

In the planted area containing *Eucalyptus* spp. (Eu), regenerations of *Eucalyptus camaldulensis* did not exist. Except for *Eucalyptus camaldulensis*, other species appeared were *Baikiaea plurijuga*, *Combretum collinum*, *Guibourtia coleosperma*, *Diplorhynchus condylocarpon* and *Pterocarpus angolensis*.

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type

Forest Type : Ba (1 / 2)

Use of Trees									Species	Species Code	DBH≧10cm			DBH<10cm						Coinsident of Mother Tree and Regeneration
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits			No. of Plot in which species appeared	Frequency of Plot	Ranking	No. of Plots for: * 3	2	1	+	Frequency of Tota	Ranking	
	●	●	●			●			*Baikiaea plurijuga*	7	92	99	1	7	30	42	12	98	1	●
									Combretum collinum	13	63	68	2			7	42	53	3	●
		×							*Guibourtia coleosperma*	31	46	49	3		1	5	31	40	4	●
●		×	●				●		*Pterocarpus angolensis*	39	43	46	4			1	30	33	6	●
	●			●					*Terminalia sericea*	46	25	27	5		1	4	23	30	9	●
		×							*Ochna pulchra*	36	22	24	6			2	27	31	7	●
									Commiphora mollis	18	21	23	7	2	3	2	7	15	14	●
									Croton gratissimus	21	18	19	8	1		4	11	17	12	●
									Combretum fragans	14	13	14	9			3	18	23	10	●
									Diplorhynchus condylocarpon	24	12	13	10			5	29	37	5	●
		●	●		●				*Brachystegia spiciformis*	9	12	13	10		1	7	5	14	15	●
									Combretum zeyheri	17	12	13	10				8	9	22	●
									Burkea Africana	10	11	12	13		1		11	12	16	●
		×							*Pseudolachnostylis maprouneifolia*	38	9	10	14		1	1	19	23	10	●
									Baphia massaiensis	52	7	8	15		4	19	28	55	2	●
									Commiphora mossambicensis	19	7	8	15	1			4	5	26	●
	●								*Acacia nigrescens*	3	5	5	17			5	11	17	12	●
									Ricinodendron rautanenii	41	5	5	17							
									Commiphora pyracanthoides	20	4	4	19		4	2	5	12	16	●
								●	*Grewia occidentalis*	30	4	4	19			4	7	12	16	●
	●	●				●			*Combretum hereroense*	15	4	4	19			2	1	3	29	●
	●	×							*Ziziphus mucronata*	51	3	3	22			1	9	11	20	●
									Acacia ataxacantha	68	3	3	22			1	2	3	29	●
							●		*Dicoma anomala*	23	3	3	22				2	2	34	●
									Entandrophragma caudatum	27	3	3	22							
									Gardenia volkensii	53	2	2	26		2	2	5	10	21	●
								●	*Vitex payos*	48	2	2	26				7	8	23	●
									Cassia abbreviata	11	2	2	26							
									Combretum molle	67	1	1	29				6	6	24	●
									Euphorbia matabelensis	66	1	1	29			1	2	3	29	●
		×							*Afzelia quanzensis*	4	1	1	29			1		1	38	●
									Erythrophleum africanum	28	1	1	29				1	1	38	●
		×							*Lonchocarpus capassa*	35	1	1	29							
●									*Sclerocarrya birrea*	42	1	1	29							
									Securidaca longipedunculata	63	1	1	29							
									Bauhinia petersiana	57					4	10	15	31	7	
								●	*Strychnos cocculoides*	45						2	9	12	16	
								●	*Vangueria infausta*	47						1	5	6	24	
									Grewia monticola	64							5	5	26	
									Grewia flavescens	60						1	3	4	28	

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type : Ba (2 / 2)

Use of Trees									Species	Spcies Code	DBH≧10cm			DBH<10cm						Coinsident of Mother Tree and Regeneration
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits			No. of Plot in which species appeared	Frequency of Plot	Ranking	No. of Plots for: * 3	2	1	+	Frequency of Tota	Ranking	
	●								*Dichrostachys cinerea*	22							3	3	29	
								●	*Ximenia caffra*	50							3	3	29	
●									*Julbernardia globiflora*	32							2	2	34	
									Rhus dentata	71							2	2	34	
									Strychnos spinosa	59						1	1	2	34	
	●								*Acacia erioloba*	1							1	1	38	
	●								*Acacia karoo*	2							1	1	38	
●									*Albizia spp.*	5							1	1	38	
									Bridelia mollis	58						1		1	38	
									Gardenia volkensii	70						1		1	38	
									Parinari curatellifolia	54							1	1	38	
									Pavetta schumanniana	61							1	1	38	
								●	*Ximenia americana*	49							1	1	38	
										Total	93			Total No. of Plots				93		

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type : Gc

Use of Trees									Species	Spcies Code	DBH ≧ 10cm			DBH < 10cm						Coinsident of Mother Tree and Regeneration
														No. of Plots for: *						
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits			No. of Plot in which species appeared	Frequency of Plots (%)	Ranking	3	2	1	+	Frequency of Total Plots (%)	Ranking	
	●	●	●			●			*Baikiaea plurijuga*	7	18	90	1	1	4	13		90	2	●
		×							*Guibourtia coleosperma*	31	18	90	1		2	7	9	90	2	●
									Combretum collinum	13	8	40	3			1	12	65	7	●
									Burkea Africana	10	7	35	4			1	10	55	9	●
									Diplorhynchus condylocarpon	24	6	30	5			3	13	80	5	●
									Combretum fragans	14	5	25	6			3	14	85	4	●
		×							*Pseudolachnostylis maprouneifolia*	38	3	15	7		1		13	70	6	●
	●			●					*Terminalia sericea*	46	3	15	7		1	3	8	60	8	●
●		×	●				●		*Pterocarpus angolensis*	39	3	15	7				10	50	11	●
		×							*Ochna pulchra*	36	2	10	10		1		19	100	1	●
									Baphia massaiensis	52	1	5	11			5	4	45	12	●
									Commiphora mossambicensis	19	1	5	11				4	20	16	●
									Peltophorum africanum	55	1	5	11				2	10	21	●
	●	×							*Ziziphus mucronata*	51	1	5	11				2	10	21	●
									Combretum molle	67	1	5	11				1	5	25	●
									Combretum zeyheri	17	1	5	11				1	5	25	●
									Ricinodendron rautanenii	41	1	5	11				1	5	25	●
									Bauhinia petersiana	57						5	6	55	9	
								●	*Vitex payos*	48						1	6	35	13	
									Commiphora pyracanthoides	20				1	1	3	1	30	14	
								●	*Strychnos cocculoides*	45							6	30	14	
	●								*Acacia nigrescens*	3							4	20	16	
●									*Albizia spp.*	5							4	20	16	
								●	*Grewia occidentalis*	30						1	3	20	16	
									Euphorbia matabelensis	66						1	2	15	20	
								●	*Dovyalis caffra*	25					1		1	10	21	
									Gardenia volkensii	70							2	10	21	
		×							*Afzelia quanzensis*	4							1	5	25	
									Brachylaena rotundata	69							1	5	25	
							●		*Dicoma anomala*	23							1	5	25	
								●	*Vangueria infausta*	47							1	5	25	
										Total	20							20		

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type : Br

Use of Trees									Species	Spcies Code	DBH≧10cm			DBH<10cm						Coinsident of Mother Tree and Regeneration
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits			No. of Plot in which species appeared	Frequency of Plots (%)	Ranking	No. of Plots for: * 3	2	1	+	Frequency of Total Plots (%)	Ranking	
		●	●		●				*Brachystegia spiciformis*	9	7	88	1		1	4	3	100	1	●
	●	●	●			●			*Baikiaea plurijuga*	7	7	88	1		2	2	3	88	2	●
		×							*Ochna pulchra*	36	6	75	3			1	3	50	5	●
									Combretum collinum	13	5	63	4				2	25	8	●
									Burkea Africana	10	4	50	5				4	50	5	●
									Commiphora mossambicensis	19	3	38	6				2	25	8	●
		×							*Guibourtia coleosperma*	31	3	38	6				2	25	8	●
●		×	●				●		*Pterocarpus angolensis*	39	2	25	8				1	13	16	●
									Ricinodendron rautanenii	41	2	25	8							
									Baphia massaiensis	52	1	13	10			4	2	75	3	●
	●			●					*Terminalia sericea*	46	1	13	10			1	2	38	7	●
								●	*Strychnos cocculoides*	45	1	13	10				2	25	8	●
									Commiphora mollis	18	1	13	10				1	13	16	●
									Diplorhynchus condylocarpon	24	1	13	10				1	13	16	●
								●	*Grewia occidentalis*	30	1	13	10			1		13	16	●
	●	×							*Ziziphus mucronata*	51	1	13	10				1	13	16	●
	●								*Acacia karoo*	2	1	13	10							
									Combretum fragans	14						1	4	63	4	
									Acacia ataxacantha	68						1	1	25	8	
	●								*Acacia nigrescens*	3							2	25	8	
									Combretum zeyheri	17							2	25	8	
									Commiphora pyracanthoides	20					1		1	25	8	
									Bauhinia petersiana	57						1		13	16	
	●								*Dichrostachys cinerea*	22						1		13	16	
									Euphorbia matabelensis	66							1	13	16	
		×							*Pseudolachnostylis maprouneifolia*	38							1	13	16	
								●	*Ximenia caffra*	50							1	13	16	
										Total	8					Total No. of Plots		8		

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type : Ac

Use of Trees									Species	Spcies Code	DBH≧10cm			DBH<10cm						Coinsident of Mother Tree and Regeneration
											No. of Plot in which species appeared	Frequency of Plots (%)	Ranking	No. of Plots for: *				Frequency of Total Plots (%)	Ranking	
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits						3	2	1	+			
	●								*Acacia karoo*	2	2	100	1		1			50	1	●
	●								*Acacia nigrescens*	3	1	50	2			1		50	1	●
	●	●	●			●			*Baikiaea plurijuga*	7	1	50	2			1		50	1	●
							●		*Combretum imberbe*	16	1	50	2				1	50	1	●
		×							*Lonchocarpus capassa*	35	1	50	2				1	50	1	●
									Combretum collinum	13	1	50	2							
									Commiphora mossambicensis	19	1	50	2							
									Baphia massaiensis	52							1	50	1	
●	●	●		●					*Colophospermum mopane*	12							1	50	1	
									Combretum fragans	14							1	50	1	
									Euclea undulata	56							1	50	1	
										Total	2			Total No. of Plots				2		

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type : Co/Ts

Use of Trees									Species	Spcies Code	DBH≧10cm			DBH<10cm						Coinsident of Mother Tree and Regenerat
														No. of Plots for: *						
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits			No. of Plot in which species appeared	Frequency of Plots (%)	Ranking	3	2	1	+	Frequency of Total Plots (%)	Ranking	
									Burkea Africana	10	4	80	1			2	3	100	1	●
	●			●					*Terminalia sericea*	46	3	60	2		1	3	1	100	1	●
							●		*Combretum imberbe*	16	3	60	2				1	20	8	●
	●	●				●			*Combretum hereroense*	15	2	40	4	1	1			40	5	●
									Pericopsis angolensis	37	2	40	4				1	20	8	●
	●	×							*Ziziphus mucronata*	51	1	20	6				1	20	8	●
	●								*Acacia karoo*	2	1	20	6							
									Diplorhynchus condylocarpon	24						1	3	80	3	
									Euclea undulata	56						2	1	60	4	
		×							*Guibourtia coleosperma*	31						1	1	40	5	
									Peltophorum africanum	55						2		40	5	
	●								*Acacia nigrescens*	3							1	20	8	
									Combretum fragans	14							1	20	8	
									Lannea discolor	34							1	20	8	
		×							*Pseudolachnostylis maprouneifolia*	38							1	20	8	
●		×	●				●		*Pterocarpus angolensis*	39							1	20	8	
									Pterocarpus rotundifolius	40				1				20	8	
								●	*Strychnos cocculoides*	45							1	20	8	
										Total	5							5		

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type :	Cm

Use of Trees									Species	Spcies Code	DBH≧10cm			DBH<10cm						Coinsident of Mother Tree and Regeneration
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits			No. of Plot in which species appeared	Frequency of Plots (%)	Ranking	No. of Plots for: * 3	2	1	+	Frequency of Total Plots (%)	Ranking	
	●								*Acacia karoo*	2	2	100	1			1	1	100	1	●
●	●	●		●					*Colophospermum mopane*	12	2	100	1	1	1			100	1	●
	●								*Acacia erioloba*	1	1	50	3							
							●		*Combretum imberbe*	16							1	50	3	
							●		*Elephantorriza goetzei*	26						1		50	3	
		×							*Lonchocarpus capassa*	35							1	50	3	
	●	×							*Ziziphus mucronata*	51							1	50	3	
										Total	2							2		

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type :	R

Use of Trees									Species	Spcies Code	DBH≧10cm			DBH<10cm						Coinsident of Mother Tree and Regeneration
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits			No. of Plot in which species appeared	Frequency of Plots (%)	Ranking	No. of Plots for: * 3	2	1	+	Frequency of Total Plots (%)	Ranking	
							●		*Combretum imberbe*	16	2	100	1							
									Acacia ataxacantha	68	1	50	2			1		50	1	●
	●								*Acacia karoo*	2	1	50	2				1	50	1	●
●	●	●		●					*Colophospermum mopane*	12	1	50	2			1		50	1	●
		×							*Lonchocarpus capassa*	35	1	50	2				1	50	1	●
	●								*Acacia erioloba*	1	1	50	2							
								●	*Vitex payos*	48	1	50	2							
									Friesodielsia obovata	72							1	50	1	
									Rhus dentata	71							1	50	1	
									Strychnos madagascariensis	73							1	50	1	
										Total	2							2		

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type : Eu

Use of Trees									Species	Spcies Code	DBH≧10cm			DBH<10cm						Coinsident of Mother Tree and Regeneration
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits			No. of Plot in which species appeared	Frequency of Plots (%)	Ranking	No. of Plots for: * 3	2	1	+	Frequency of Total Plots (%)	Ranking	
									Eucalyptus camaldulensis	65	4	100	1							
	●	●	●			●			*Baikiaea plurijuga*	7	2	50	2		1		1	50	1	●
									Baphia massaiensis	52	1	25	3			1		25	4	●
									Combretum collinum	13	1	25	3				1	25	4	●
									Bauhinia petersiana	57					1		1	50	1	
		×							*Ochna pulchra*	36							2	50	1	
									Diplorhynchus condylocarpon	24							1	25	4	
		×							*Guibourtia coleosperma*	31							1	25	4	
●		×	●				●		*Pterocarpus angolensis*	39							1	25	4	
								●	*Strychnos cocculoides*	45							1	25	4	
										Total	4							4		

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type : All (1 / 2)

Use of Trees									Species	Spcies Code	DBH≧10cm			DBH<10cm						Coinsident of Mother Tree and Regeneration
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medcine	Fruits			No. of Plot in which species appeared	Frequency of Plots (%)	Ranking	No. of Plots for: * 3	2	1	+	Frequency of Total Plots (%)	Ranking	
	●	●	●			●			*Baikiaea plurijuga*	7	120	88	1	8	37	58	16	88	1	●
									Combretum collinum	13	78	57	2			8	57	48	3	●
		×							*Guibourtia coleosperma*	31	67	49	3		3	13	44	44	4	●
●		×	●				●		*Pterocarpus angolensis*	39	48	35	4			1	43	32	9	●
	●			●					*Terminalia sericea*	46	32	24	5		3	11	34	35	7	●
		×							*Ochna pulchra*	36	30	22	6		1	3	51	40	6	●
									Burkea Africana	10	26	19	7		1	3	28	24	12	●
									Commiphora mollis	18	22	16	8	2	3	2	8	11	19	●
									Diplorhynchus condylocarpon	24	19	14	9			9	47	41	5	●
		●	●		●				*Brachystegia spiciformis*	9	19	14	9		2	11	8	15	14	●
									Combretum fragans	14	18	13	11			7	38	33	8	●
									Croton gratissimus	21	18	13	11	1		4	11	12	17	●
									Combretum zeyheri	17	13	10	13				11	8	22	●
		×							*Pseudolachnostylis maprouneifolia*	38	12	9	14		2	1	34	27	11	●
									Commiphora mossambicensis	19	12	9	14	1			10	8	22	●
									Baphia massaiensis	52	10	7	16		4	29	35	50	2	●
									Ricinodendron rautanenii	41	8	6	17				1	1	48	●
	●								*Acacia karoo*	2	7	5	18		1	1	3	4	29	●
	●								*Acacia nigrescens*	3	6	4	19			6	18	18	13	●
								●	*Grewia occidentalis*	30	5	4	19			6	10	12	17	●
	●	×							*Ziziphus mucronata*	51	6	4	19			1	14	11	19	●
	●	●				●			*Combretum hereroense*	15	6	4	19	1	1	2	1	4	29	●
							●		*Combretum imberbe*	16	6	4	19				3	2	39	●
									Commiphora pyracanthoides	20	4	3	24	1	6	5	7	14	16	●
									Acacia ataxacantha	68	4	3	24			3	3	4	28	●
									Eucalyptus camaldulensis	65	4	3	24							
								●	*Vitex payos*	48	3	2	27			1	13	10	21	●
●	●	●		●					*Colophospermum mopane*	12	3	2	27	1	1	1	1	3	33	●
							●		*Dicoma anomala*	23	3	2	27				3	2	39	●
		×							*Lonchocarpus capassa*	35	3	2	27				3	2	39	●
									Entandrophragma caudatum	27	3	2	27							
								●	*Strychnos cocculoides*	45	1	1	32			2	19	15	14	●
									Gardenia volkensii	53	2	1	32		2	2	5	7	24	●
									Combretum molle	67	2	1	32				7	5	25	●
									Euphorbia matabelensis	66	1	1	32			2	5	5	25	●
									Peltophorum africanum	55	1	1	32			2	2	3	33	●
		·							*Afzelia quanzensis*	4	1	1	32			1	1	1	44	●
	●								*Acacia erioloba*	1	2	1	32				1	1	48	●
									Erythrophleum africanum	28	1	1	32				1	1	48	●
									Pericopsis angolensis	37	2	1	32				1	1	48	●
									Cassia abbreviata	11	2	1	32							
●									*Sclerocarrya birrea*	42	1	1	32							

Table 8 – 22 Species of Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type :	All (2 / 2)

Use of Trees									Species	Spcies Code	DBH≧10cm			DBH<10cm						Coinsident of Mother Tree and Regeneration
											No. of Plot in which species appeared	Frequency of Plots (%)	Ranking	No. of Plots for: *				Frequency of Total Plots (%)	Ranking	
Household items	Fencing	Firewood	Sledges	Poles	Bark	Shading	Medicine	Fruits						3	2	1	+			
									Securidaca longipedunculata	63	1	1	32							
									Bauhinia petersiana	57					5	16	22	32	10	
								●	*Vangueria infausta*	47						1	6	5	25	
●									*Albizia spp.*	5							5	4	29	
									Grewia monticola	64							5	4	29	
	●								*Dichrostachys cinerea*	22						1	3	3	33	
									Euclea undulata	56						2	2	3	33	
									Grewia flavescens	60						1	3	3	33	
								●	*Ximenia caffra*	50							4	3	33	
									Gardenia volkensii	70						1	2	2	39	
									Rhus dentata	71							3	2	39	
								●	*Dovyalis caffra*	25					1		1	1	44	
●									*Julbernardia globiflora*	32							2	1	44	
									Strychnos spinosa	59						1	1	1	44	
									Brachylaena rotundata	69							1	1	48	
									Bridelia mollis	58						1		1	48	
							●		*Elephantorriza goetzei*	26						1		1	48	
									Friesodielsia obovata	72							1	1	48	
									Lannea discolor	34							1	1	48	
									Parinari curatellifolia	54							1	1	48	
									Pavetta schumanniana	61							1	1	48	
									Pterocarpus rotundifolius	40				1				1	48	
									Strychnos madagascariensis	73							1	1	48	
								●	*Ximenia americana*	49							1	1	48	
										Total	136							136		

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

(2) Tendency by Plot

The appearance of upper story trees and regenerations was compared within each plot. The number of plots in which both upper story trees and regenerations appeared is shown in Table 8 – 23. The number of such plots was divided by the total number of plots for each forest type and named "Plot Ratio", and the level of appearance of the two (upper story trees and regenerations) was compared. When both upper story trees and regenerations appear in the plot of 0.1ha it could mean that the distribution density of mother trees and regenerations is high. Therefore, if the plot ratio is higher, the more possibility is expected for the sustainability of the subject species in the subject forest type.

In the stand dominated by *Baikiaea plurijuga* (Ba), both upper story trees and regenerations appeared at the plot ratio of 98%. On the other hand *Combretum collinum*, *Guibourtia coleosperma* and *Pterocarpus angolensis* showed a better regeneration, though the plot ratio was less than 50%. It should be noted that *Croton gratissimus* appeared only in the present forest type but not in other forest types.

In the case of stands dominated by *Guibourtia coleosperma*, *Baikiaea plurijuga* and *Guibourtia coleosperma* had plot ratios of 95% and 85%, respectively. The difference from the stands dominated by *Baikiaea plurijuga* was that *Burkea Africana* showed a rather high plot ratio.

Other forest types except the said two types and planted *Eucalyptus* spp. showed the relevant dominant species with plot ratio of 50% or more.

As the total of all forest types showed, five species with the highest plot ratio were: *Baikiaea plurijuga*, *Guibourtia coleosperma*, *Combretum collinum*, *Pterocarpus angolensis* and *Brachystegia spiciformis*. It should be emphasized that in the case of *Pterocarpus angolensis* the class of abundance and coverage is limited to " + ", which means that regeneration is not actively taking place, though the plot ratio is rather high.

Table 8 – 23 Number of Plots with Both Upper Story Trees and Regenerations by Forest Type

Forest Type: **Ba**		Regeneration Class*					Plot Ratio (%)
Species		**3**	**2**	**1**	**+**	Total	
Baikiaea plurijuga	7	7	30	42	12	91	98
Combretum collinum	13			5	27	32	34
Guibourtia coleosperma	31		1	5	21	27	29
Pterocarpus angolensis	39				23	23	25
Brachystegia spiciformis	9		1	7	5	13	14
Croton gratissimus	21	1		4	7	12	13
Commiphora mollis	18		1	2	7	10	11
Diplorhynchus condylocarpon	24			1	8	9	10
Terminalia sericea	46		1	2	5	8	9
Ochna pulchra	36				7	7	8
Burkea Africana	10				6	6	6
Baphia massaiensis	52			3	2	5	5
Acacia nigrescens	3			4		4	4
Combretum fragans	14			1	3	4	4
Pseudolachnostylis maprouneifolia	38				4	4	4
Combretum zeyheri	17				3	3	3
Ziziphus mucronata	51			1	2	3	3
Combretum hereroense	15			1	1	2	2
Combretum molle	67				2	2	2
Commiphora mossambicensis	19	1			1	2	2
Gardenia volkensii	53				2	2	2
Grewia occidentalis	30			2		2	2
Acacia ataxacantha	68				1	1	1
Combretum imberbe	16				1	1	1
Commiphora pyracanthoides	20		1			1	1
Dicoma anomala	23				1	1	1
Erythrophleum africanum	28				1	1	1
Vitex payos	48				1	1	1

Forest Type: **Gc**		Regeneration Class*					Plot Ratio (%)
Species		**3**	**2**	**1**	**+**	Total	
Baikiaea plurijuga	7	1	4	12	2	19	95
Guibourtia coleosperma	31		2	7	8	17	85
Burkea Africana	10			1	5	6	30
Combretum collinum	13			1	5	6	30
Combretum fragans	14				6	6	30
Diplorhynchus condylocarpon	24			2	3	5	25
Ochna pulchra	36		1		2	3	15
Commiphora mossambicensis	19				2	2	10
Pseudolachnostylis maprouneifolia	38				2	2	10
Baphia massaiensis	52			1		1	5
Peltophorum africanum	55				1	1	5
Pterocarpus angolensis	39				1	1	5
Terminalia sericea	46				1	1	5

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

Table 8 – 23 Number of Plots with Both Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type: **Br**		Regeneration Class*					Plot Ratio (%)
Species		**3**	**2**	**1**	**+**	Total	
Brachystegia spiciformis	9		1	4	1	6	75
Baikiaea plurijuga	7		2	2		4	50
Combretum collinum	13				3	3	38
Burkea Africana	10				2	2	25
Combretum fragans	14				2	2	25
Ochna pulchra	36			1	1	2	25
Baphia massaiensis	52			1		1	13
Commiphora mossambicensis	19				1	1	13
Diplorhynchus condylocarpon	24				1	1	13
Grewia occidentalis	30			1		1	13
Guibourtia coleosperma	31				1	1	13
Lonchocarpus capassa	35				1	1	13
Pterocarpus angolensis	39				1	1	13
Strychnos cocculoides	45				1	1	13
Terminalia sericea	46				1	1	13

Forest Type: **Ac**		Regeneration Class*					Plot Ratio (%)
Species		**3**	**2**	**1**	**+**	Total	
Acacia karoo	2		1			1	50
Acacia nigrescens	3			1		1	50
Baikiaea plurijuga	7			1		1	50
Combretum collinum	13				1	1	50

Forest Type: **Co/Ts**		Regeneration Class*					Plot Ratio (%)
Species		**3**	**2**	**1**	**+**	Total	
Terminalia sericea	46		1	2		3	60
Acacia karoo	2				2	2	40
Burkea Africana	10			2		2	40
Combretum hereroense	15	1	1			2	40
Combretum fragans	14				1	1	20
Combretum imberbe	16				1	1	20
Guibourtia coleosperma	31				1	1	20
Lonchocarpus capassa	35				1	1	20

Forest Type: **Cm**		Regeneration Class*					Plot Ratio (%)
Species		**3**	**2**	**1**	**+**	Total	
Colophospermum mopane	12	1	1			2	100
Acacia karoo	2			1		1	50
Guibourtia coleosperma	31				1	1	50

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

Table 8 – 23 Number of Plots with Both Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type: **R**		Regeneration Class*					Plot Ratio (%)
Species		**3**	**2**	**1**	**+**	Total	
Acacia ataxacantha	68			1		1	50
Colophospermum mopane	12			1		1	50
Diplorhynchus condylocarpon	24				1	1	50
Pseudolachnostylis maprouneifolia	38				1	1	50

Forest Type: **Eu**		Regeneration Class*					Plot Ratio (%)
Species		**3**	**2**	**1**	**+**	Total	
Combretum collinum	13				2	2	50
Terminalia sericea	46				2	2	50
Baikiaea plurijuga	7		1			1	25
Baphia massaiensis	52			1		1	25
Guibourtia coleosperma	31				1	1	25
Ochna pulchra	36				1	1	25

Note: * The number of plots is counted by each regeneration class (refer to Table 8 - 4).

Table 8 – 23 Number of Plots with Both Upper Story Trees and Regenerations by Forest Type (Continued)

Forest Type: **All**		Regeneration Class*					Plot Ratio (%)
Species		**3**	**2**	**1**	**+**	Total	
Baikiaea plurijuga	7	8	37	57	14	116	85
Guibourtia coleosperma	31		3	12	33	48	35
Combretum collinum	13			6	38	44	32
Pterocarpus angolensis	39				25	25	18
Brachystegia spiciformis	9		2	11	6	19	14
Burkea Africana	10			3	13	16	12
Diplorhynchus condylocarpon	24			3	13	16	12
Terminalia sericea	46		2	4	9	15	11
Combretum fragans	14			1	12	13	10
Ochna pulchra	36		1	1	11	13	10
Croton gratissimus	21	1		4	7	12	9
Commiphora morris	18		1	2	7	10	7
Baphia massaiensis	52			6	2	8	6
Pseudolachnostylis maprouneifolia	38				7	7	5
Acacia nigrescens	3			5		5	4
Commiphora mossambicensis	19	1			4	5	4
Acacia karoo	2		1	1	2	4	3
Combretum hereroense	15	1	1	1	1	4	3
Colophospermum mopane	12	1	1	1		3	2
Combretum zeyheri	17				3	3	2
Grewia occidentalis	30			3		3	2
Ziziphus mucronata	51			1	2	3	2
Acacia ataxacantha	68			1	1	2	1
Combretum imberbe	16				2	2	1
Combretum molle	67				2	2	1
Gardenia volkensii	53				2	2	1
Lonchocarpus capassa	35				2	2	1
Commiphora pyracanthoides	20		1			1	1
Dicoma anomala	23				1	1	1
Erythrophleum africanum	28				1	1	1
Peltophorum africanum	55				1	1	1
Strychnos cocculoides	45				1	1	1
Vitex payos	48				1	1	1

Note: * The number of plots is counted by regeneration class (refer to Table 8 - 4).

(3) Measures to Promote Natural Regeneration

(a) *Baikiaea plurijuga*

Baikiaea plurijuga was found to have a high degree of abundance and coverage and there were many regenerations even in the plots classified as "+". If the class of the abundance and coverage was more than "1", trees of DBH less than 10 cm were observed having a continuous and numerous distribution in DBH throughout the subject site. Additionally, *Baikiaea plurijuga* had an active coppice regeneration.

On the other hand artificial seeding showed positive results. According to the experience of the Forest Hill Office, the *Baikiaea plurijuga* seeds treated with hot-water can germinate in one week after sowing. This germination period which is shorter than other species, is advantageous in terms of a shorter time of exposure of regenerations to damage by animals.

Baikiaea plurijuga is highly adapted to the conditions of Kalahari sand. The higher dominance of this species will probably be maintained and promoted by the apt capacity to regenerate as well as by the successive dominance of upper trees. No problem was found with regard to the natural regeneration of this species.

(b) *Pterocarpus angolensis*

32% of all plots surveyed had regenerations of *Pterocarpus angolensis* while the remaining 68% of the plots did not have any. However, regenerations were frequently observed where upper story trees were *Pterocarpus angolensis*. The class of abundance and coverage was found mostly as "+" except for the only one plot with the class of "1". When the class was "+", trees of DBH of some 40 cm that were probably mother trees were found growing inside and outside the plots and there were a few regenerations with the height of a few meters around the mother trees. *Pterocarpus angolensis* did not show such a continuous and numerous distribution in DBH throughout the subject site as was observed with *Baikiaea plurijuga*.

Since the quality of timber from *Pterocarpus angolensis* is good and is sold at the highest price, it was cut intensively. Many trees of this species were selectively or illegally cutting until now and this is thought to have resulted in the decrease of future mother trees.

On the other hand artificial seeding shows rather negative results. According to the experience of the Forest Hill Office, the *Pterocarpus angolensis* seeds can germinate in

some two months after sowing. Germinating seeds could be destroyed by grazing animals during this period.

The DBH class distribution (refer to Fig. 8－2) shows a flat pattern which means that the regeneration is intermittent, even though currently there are regenerations. The trees eligible to be mother trees should be protected as much as possible.

(c) *Guibourtia coleosperma*

Guibourtia coleosperma showed better regeneration than *Pterocarpus angolensis*. Especially in the stand dominated by *Guibourtia coleosperma* (Gc), the plot ratio was 85%. The class of abundance and coverage of two plots was class "2", of seven plots was class "1" and of eight plots was class "+". The total of class "2" and "1" exceeded the number of class "+", which means that there is no problem with regard to regeneration of this species.

Some 44% of all plots in *Guibourtia coleosperma* contained regenerations while the remaining 56% of the plots did not have any. In comparison to *Pterocarpus angolensis*, *Guibourtia coleosperma* had a better regeneration. Such a situation of *Guibourtia coleosperma* could be due to the decreasing mother trees caused by numerous selective cutting because of its high value as timber, and possible animal damage to the seeds, which can germinate in two or three weeks after sowing. Another reason could be that the seeds of this species are used as food by the inhabitants.

8.3 Growth

The forests in the Survey Area have been cut several times since the early 1900s. An indication of the long history of logging in the area is the existence of numerous logging lines (tracks), beside the existing main management roads, as can be seen on the existing topographic maps at the scale of 1/50,000 (These logging lines are currently difficult to find on site because they are covered with bush.). These logging lines cover the whole Survey Area and in some places the density of the lines is as high as seven lines per km^2 which is equivalent to 70 m/ha of the road density. The average density of the lines is estimated at 40 m/ha since approximately four lines were observed in one km^2 area. This is a very high road network density and is an indication of the existence of a large volume of timber in these area, which have been selectively cut due to easy establishment of the lines in a flat topography.

If the unplanned cutting continues, the recovery of growing stock will take a long time and this will make sustainable production impossible. In order to estimate the growth of the forests in the Intensive Area, which can ensure a sustainable production, the following four sources were examined.

(1) The ecology and management of the Kalahari sand forest vegetation of south-western Zimbabwe (G. M. Calvert, 1986)

For *Baikiaea plurijuga*, Wightman(1967) calculated 127 years for fast-growing trees to reach 38 cm DBH and for slow growing suppressed trees over 400 years to reach the same size.
In other words the annual mean increment of DBH ranges from 2.99 mm to 0.95 mm.

On the other hand Calvert estimated that in average it will take some 200 years for most vigorous teak trees in Gwaai to grow from 2.5 cm DBH to 38 cm DBH.
In this case the annual mean increment of DBH is equivalent to 1.78 mm.

Incidentally a regeneration period to reach to 2.5 cm DBH is estimated at 30 years with a range of from 20 to about 50 years.
In this case the annual mean increment is calculated as 0.83 mm.

(2) "The Effect of Silvicultural Cleaning on Diameter Increment in Baikiaea plurijuga" in the booklet of The Ecology and Management of Indigenous Forests in Southern Africa (P.T. Mushouve, P.C. Gondo and C. Gumbie, 1993)

The mean annual increment in the control plots over the 25 year period from 1967 to 1992 was reported as 1.5 mm for Gwaai Forest Land while in the treatment plots removing tree species other than the main species like *Baikiaea plurijuga*, the mean annual increment was reported as 1.5 mm.

(3) The Ecology and Management of Indigenous Forests in Zimbabwe (SAREC,1996)

In this source mean annual increment for DBH is estimated for the following main tree species by using the data of over 44 years from the Permanent Sample Plots in the Gwaai forest land.

Table 8 – 24 Mean Annual Increments for DBH Increments for Four Commercial Indigenous Tree Species

Species	DBH Increment Range (mm/yr)
Baikiaea plurijuga	1.25～2.04
Pterocarpus angolensis	1.30～2.72
Guibourtia coleosperma	1.02～2.37
Terminalia sericea	0.98～2.24

(4) FAO Pilot Studies on Forestry Data Gathering and Analysis (C.M. Gumbie, 2000)

This source reports mean annual increments for DBH for the following main tree species.

Table 8 – 25 Mean Annual Increments for DBH for Four Commercial Indigenous Tree Species

Species	DBH Increment (mm/yr)
Baikiaea plurijuga	1.75 (0.19)
Pterocarpus angolensis	2.00 (0.45)
Guibourtia coleosperma	2.11 (0.25)
Terminalia sericea	1.78 (0.89)

Note: Figures in brackets are standard deviation.

As the above data indicate, the growth of the main tree species is very slow. The annual mean increment of these species is estimated at under 2 mm. It should be noted that the amount of 0.1 mm will become large to calculate a figure for thousands hectare, though this value is difficult to recognize on site.

The survey team counted the annual rings on stumps at cutting sites in the Gwaai Forest Land. If those annual rings are the true ones, the annual increment of DBH can be estimated as less than 2 mm.

The trees of the Intensive Area may have annual rings because the trees grow in rain-green forests where the rainy and dry seasons are clear and distinct. But it is hard to tell true annual rings from false ones. Thus the following issues should be researched in future.

i) Identification of annual rings

The relationship between the increment of DBH and annual rings should be investigated for a certain period to confirm whether the rings are true or false.

ii) Stem analysis

The growth should be investigated by stem analysis to see if the annual rings are identifiable.

iii) Follow-up of DBH growth

The follow-up should be conducted periodically at the permanent plots to identify the DBH growth.

8.4 Preparation of Forest Type Maps and Forest Inventory Books

8.4.1 Forest Type Maps

(1) Mapping Unit

Based on the survey results, the categories for forest type maps were decided as shown in Table 8 – 26. The categories for woodland and bushland used in land use and vegetation maps prepared in 1999 were subdivided by using dominant species (i.e. forest types). The dominant species are those which form the upper layer of the stand and are dominant in terms of tree number and canopy density.

For the aerial photo interpretation of stands, the dominant tree species were interpreted and tree height and canopy density of the upper layer of forests were calibrated by 1 m and 5% respectively. Tree height and canopy density were divided into the following classes. In the forest type maps the categories for dominant tree species, tree height class and canopy density class are shown by mapping symbols. The categories for dominant tree species are called "Parcel" and are marked with the serial number within each block. The same numbers used for parcels on the forest type maps were also used in forest inventory books when describing the parcels.

Table 8 – 26 Categories for Forest Type Maps and the Interpretation Criteria

	Category	Mapping Symbol	Criteria
Manmade Forest	Planted *Eucalyptus* spp.	Eu	The subject area is located to southwest to Kenmaur.
Managed Natural Forest	Stand dominated by *Baikiaea plurijuga*	Ba	Dominant species: *Baikiaea plurijuga*
	Stand dominated by *Guibourtia coleosperma*	Gc	*Guibourtia coleosperma*
	Stand dominated by *Brachystegia* spp.	Br	*Brachystegia* spp.
	Stand dominated by *Acacia* spp.	Ac	*Acacia* spp.
	Stand dominated by Combretaceae	Co/Ts	Combretaceae
	Stand dominated by *Colophospermum mopane*	Cm	*Colophospermum mopane*
	Bushland	B	Bushland mixed by several spp.
	Riverine Forest	R	Forests which specifically grow at riverside
Non-Forest	Bare Land	BL	Bare land
	Wet Land	WL	Wet land such as swamp and pond
	Vlei /Grassland	VG	Vlei or grasslands such as Insuza Vlei
	River	RI	Rivers such as Bembesi River
	Cultivated Land	CL	Cultivated land for crops such as maize
	Settlement	ST	Settlements clustered with small buildings that are found around St. Lukas and railway
	Others	OT	Roads, railways, power line, etc.

Note: Vlei means broad grassy depression.

Table 8 – 27 Height Class and Canopy Density Class

Height Class		Canopy Density Class	
1. ＜5m	(H1)	1. ＜25%	(D1)
2. 5m≦ ＜15m	(H2)	2. 25%≦ ＜50%	(D2)
3. 15m≦	(H3)	3. 50%≦ ＜75%	(D3)
		4. 75%≦	(D4)

(2) Tendency of Distribution and Typical Image (Tone) of Forest Types on Air Photos

The fact that the forests in the Intensive Area were continuously disturbed, mainly by cutting and forest fire, since the early 1900s, made it difficult to specify the tendency of distribution of forest types based on the natural conditions only. The tendency, however, was derived from the on site observation of the present condition and the deduction of the bias caused by the above human intervention. The tendency and typical image (tone) are described for each forest type as shown in Table 8 – 28.

Table 8 – 28 Tendency of Distribution and Typical Image of Forest Types on Air Photos

Forest Types	Tendency of Distribution	Typical Image on Air Photos
Eu	a. No specific tendency because the eucalyptus are planted for research. b. The largest parcel for this type is located near to Kenmaur. The site is mixed with other species such as *Baikiaea plurijuga*.	a. Eucalyptus has leaves, but appeared in whitish gray. *Baikiaea plurijuga* growing with the eucalyptus started dropping its leaves (at the time of photography) and, therefore, the total pattern ranged from whitish gray to dark gray. b. Each canopy was thin and small and had fine punctate pattern.
Ba	a. This type is distributed on the flat land over the whole Intensive Area, where the Kalahari sand is deep and *Baikiaea plurijuga* could be more competitive than other species. b. But rarely found distributed along the rivers, vleis and hillside.	a. *Baikiaea plurijuga* started dropping its leaves depending on the location and showed in whitish or dark gray. b. The size of the canopy varied from small ones of dwarf teak to large ones of large trees or multi-stemmed trees.
Gc	a. The distribution area of this type almost coincides with the distribution area of *Baikiaea plurijuga*. b. Possibly due to the low fire tolerance, the distribution range is decreasing where it is frequently affected by fire.	a. *Guibourtia coleosperma* did not drop its leaves and showed in dark gray or black. b. The *Guibourtia coleosperma* had a character of multi-stemmed form. Therefore there were many cases that it had relatively larger canopy even though it consisted of low and thin stems.
Br	a. This type is distributed along the Falls Road in the north area from Bembesi River. *Brachystegia* spp. grow with *Baikiaea plurijuga* or *Guibourtia coleosperma*.	a. Almost all of the stands had large trees higher than 10 m. b. *Brachystegia* spp. did not drop their leaves and showed in gray or dark gray.
Ac	a. These types are distributed along rivers, vleis and depressions. b. A few are found on hillside slopes. c. The distribution may be due to the natural conditions such as seasonal flooding and cool temperature.	a. *Acacia* spp. started dropping their leaves and showed in whitish gray or gray. b. The canopy was relatively dim.
Co/Ts		a. *Terminalia sericea* dropped its leaves and showed in whitish gray or gray. b. The canopy was very dim.
Cm		a. *Colophospermum mopane* did not drop its leaves and showed in dark gray or black. b. The canopy showed various sizes with close and equal distribution and clear punctate pattern.
B		a. Several species such as *Acacia* spp., *Terminalia sericea*, *Colophospermum mopane*, *Combretum* spp., *Burkea Africana* were mixed and showed similar patterns as Ac, Co/Ts and Cm above.
R	a. This type is distributed only on the alluvial deposits along the Bembesi River.	a. Some species forming the upper layer dropped their leaves. But other main component species did not drop leaves. Thus this type appeared in dark gray or black. b. The canopies were often contiguous.

8.4.2 Forest Inventory Books

Items described in the forest inventory books were agreed with the FC and are as follows.

Table 8 – 29 Items Described in the Forest Inventory Books

Item	Unit	Remarks
Administration Division		At the subject District level. (i.e. Lupane District and Bubi District)
Forest Land		Gwaai Forest Land or Bembesi Forest Land
Block Code		Gwaai Forest Land (C,G,H,J,K), Bembesi Forest Land (B)
Parcel No.		Each parcel is based on aerial photo interpretation.
Area	ha	
Soil Type		This item coincides with the mapping units of soil maps.
Category of Forest Type Maps		As shown in Table 8 – 27.
Dominant Species		The following dominant species were identified and described for the categories of woodland and bushland. i) *Guibourtia coleosperma* (Gc) ii) *Baikiaea plurijuga* (Ba) iii) *Brachystegia* spp. (Br) iv) *Acacia* spp. (Ac) v) *Terminalia sericea* (Co/Ts) vi) *Colophospermum mopane* (Cm) On the other hand, there are bushlands where the dominant species is not identifiable on aerial photos, or several species are found associated in mosaic patterns on site. Such bushland was described as "Bushland (B)".
Height and Height Class	m	Interpretation was based on the height of upper layer's trees and calibrated by 1 m. Tree height classes are as follows: i) ＜5m (H1) ii) 5m≦ ＜15m (H2) iii) 15m≦ (H3)
Canopy Density and Canopy Density Class	%	Interpretation was based on the canopy density of upper layer's trees and calibrated by 5 %. Canopy density classes are as follows: i) ＜25% (D1) ii) 25%≦ ＜50% (D2) iii) 50%≦ ＜75% (D3) iv) 75%≦ (D4)
Stand Volume	m^3 m^3/ha	a. Stand volume was estimated for woodlands and riverine forests by total volume and timber volume. Stand volume was not estimated for bushland. b. The stand volume is calculated by the stand volume equation prepared through multiple regression using the canopy density and tree height, and the stand volume acquired by the sample plots. c. The volume per ha is also calculated.

The forest inventory books were prepared as a separate volume.

Chapter 9

9. Soil Survey

9.1 Survey Method

The soil survey was conducted by soil profile description and reconnaissance of the Intensive Area while taking into consideration site conditions such as topography, geology, vegetation and land use. Soil profiles were dug to a depth of 100 cm, but when hard rocks or consolidated layers appeared, the profile depth was limited to those layers. The total number of soil profiles were 35. In order to understand the soil distribution and prepare the soil maps (scale of 1/20,000), in addition to soil profile survey, observations were conducted on simple soil pits, cutting and banking surfaces, and surface of dirt roads and bare lands.

The survey items for the soil survey were: site conditions such as location, topography, bearing, slope, altitude, land use and vegetation, as well as condition of A_0 (organic) horizon, limit of horizon, depth of horizon, nature of horizon limit, soil colour, humus, texture, structure, hardness, gravel and stone, pore, moisture content, leaching, accumulation, mottle and concretion, gleying, mycorrhiza and mycelium, roots, pH, other diagnostic properties, etc.

In order to prepare soil distribution maps, aerial photo interpretation was conducted for identifying the micro-topography and land use condition. The soil taxonomic criteria used are those of The Soil Map of the World Revised Legend (FAO/Unesco, 1990).

The results of profile survey are shown in Annex.

9.2 Taxonomy and Characteristics of Soils

A major characteristic of soils of the Intensive Area is that most part of the area except for its lower part along the Bembesi River is covered with deeply deposited quarziferous sand. According to "The Soils of Zimbabwe;Kingston Nyamapfene, 1991" and other sources, this sand is known as aeolian sand and originated from the Kalahari desert.

Iron cemented layer and its weathered products crop out at the footslopes and lands with low relief. These are a part of clayey paleo-soils that are formed through strong weathering. But the sands covering those soils are not well weathered and are immature soils. When the soils are formed from the same parent material at the same location, such soils comprise of lower layers being weakly weathered and upper layers being relatively

highly weathered, but this common characteristic is reversed in the survey area. Also there are some outcrops of fine-grained and dense rocks mainly formed by basalt, but such parent material usually forms clayey soils and not sandy soils. Moreover, the sands found in the Intensive Area are seem to be as new soils that were formed by deposition of quarziferous sands transported from other sites over the paleo-soils which are highly weathered. Evidences from the past climatic conditions and lithology show that the sands in the survey area originated in the Kalahari Desert and transported by wind to present location. The iron cemented layer crops out at the banks of Bembesi River within the altitude range of 1,020 - 1,030 m, located in the central and southern part of the Intensive Area, and in the banks of Bubi River within the altitude range of 965 - 975 m located at the northwestern part of the Intensive Area. In general the iron cemented layer is known to be formed by stable topographic surface. Therefore, the surfaces connecting both points of the iron cemented layer is thought to have been level grounds in the past. If the surface was flat (although there might have been some minor undulation) the maximum depth of the sand is estimated at 60 to 65 meters (refer to Fig. 9 – 1).

On the contrary, loamy or clayey soils, having entirely different parent materials from the sands, occur along both sides of the Bembesi River flowing in the central part of the Intensive Area from east to west. The spongy and reddish-brown rock cropping out on the riverbank of the Bembesi River is the basalt which becomes porous by spouting of gas at the time of extravasation and is reddish due to oxidization. Also at the hillside along the river fine-grained and dense basaltic rocks occur. Consequently the soils of lower lands at the both sides of the river are those formed from the same rocks as the parent materials.

As stated above, the Intensive Area can be characterized by the thickly deposited sands and the clayey soils along the river. The soils of the Intensive Area were classified into four major soil groups and a number of soil units. The major soil groups and soil units are as follows. The general distribution pattern of soils is illustrated in Fig. 9 – 1.

(1) Leptosols: Shallow soil on the hard rock or cemented layer. It occurs at footslope along rivers.
    (a) Eutric Leptosols: Shallow soil having high base saturation.
(2) Arenosols: Amorphic soil having deep sand layer. It covers the Intensive Area to the largest extent.
    (a) Albic Arenosols: Sandy amorphic soils having leached horizon.
    (b) Lubic Arenosols: Sandy amorphic soil containing clay.
    (c) Ferrali-luvic Arenosols: Sandy soil containing clay and having low activity.

(d) Cambi-luvic Arenosols: Sandy amorphic soil containing clay and having rather developed horizon

(3) Vertisols: Clay soil having high activity. It occurs on the lower land along the river.

(a) Eutric Vertisols: Active clay soil having high base saturation.

(4) Cambisols: Soil going through transitional stage of the development. It occurs on the lower land along the river.

(a) Eutric Cambisols: Transitional soil having high base saturation.

(b) Vertic Cambisols: Transitional soil containing active clay.

(c) Gleyic Cambisols: Transitional soil affected by water logging

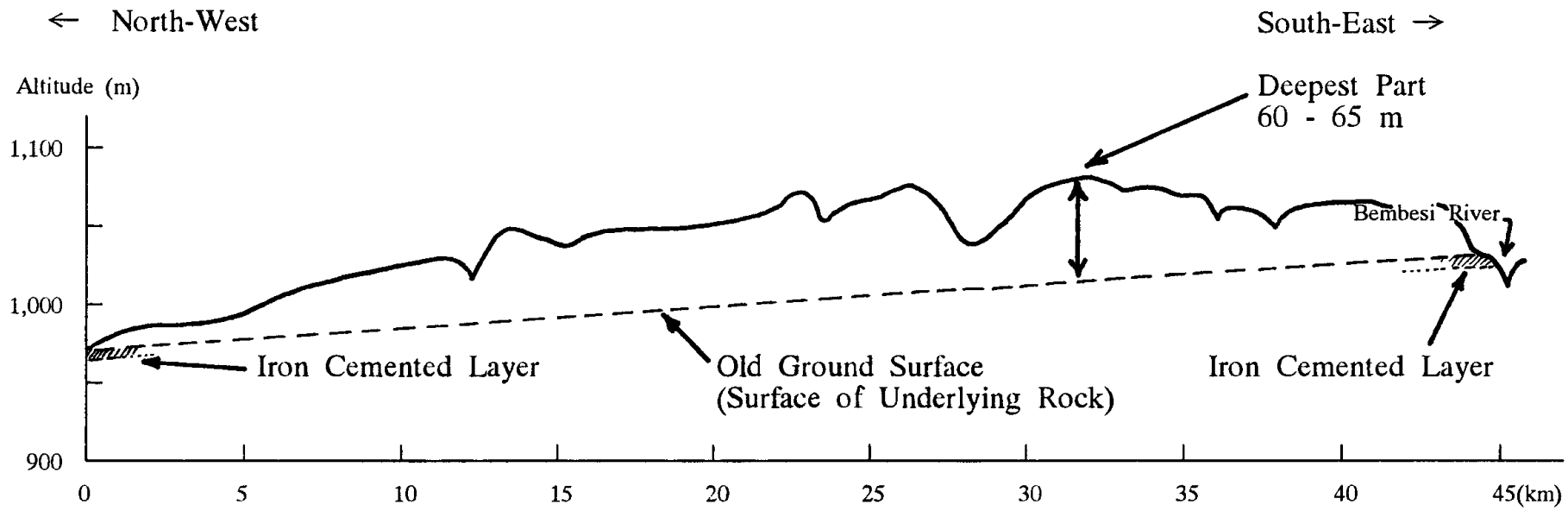


Fig. 9 – 1 General Distribution Pattern of Soils (Along Victoria Falls Road)

(1) Leptosols (LP)

The Leptosols are the soils the thickness of which is limited less than 30 cm by the presences of continuous hard rock or continuous cemented layer, or, are stony soils having the ratio of fine earth less than 20% from the surface horizon to at a depth of 75 cm. The Leptosols include various types of soils due to the above two simple criteria. The Leptosols found in the Intensive Area were classified into the following soil units.

(a) Eutric Leptosols (LPe)

This unit has an ochric A horizon and base saturation of more than 50% in all horizons. Ochric A horizon is the A horizon which lacks fully developed structure, large amount of organic materials, dark soil colour and adequate thickness.

In the Intensive Area the thickness of Leptosols was limited to less than 30 cm by the presence of iron cemented layer or underlying rock. A horizon of the unit had rather much humus and became brownish black when wet, its texture was loam or clayey-loam and its structure was blocky. When the amount of clay increased, it showed a hard angular-blocky structure with the sharp edge. The B horizon of the soil was dark brown and had clayey-loam texture, but sometimes lacked such a feature. The thin horizons of the unit also contained a large amount of ironstone and quartz gravel which are the weathered products of iron cemented layer. In the Intensive Area, outcrops of iron cemented layer and block of ironstone broken into 30 - 60 cm size were observed.

As a rule a stable land surface gets deep seated weathering, forms low activity clay and sesquioxide under the climate with high temperature and humidity and the sesquioxide accumulates at the lower part of subsoil by vertically fluctuating groundwater level. Then mixed materials of non-active clay and affluent iron and poor humus, quartz, etc. form plinthite which usually appears in the form of reddish mottles. But it suffer nonreversible changes into pea ironstone when it is exposed to the air through erosion of the upper layer or when it gets dry. If much sesqui-iron-oxide continuously cements, the iron bonds the cemented layer and form irregular clods. This cemented layer is the iron cemented layer which was known as laterites in the past. The subject layer occurring in the Intensive Area is the iron cemented layer or the weathered one. It can be said that iron cemented layer was formed under the climate with high temperature and humidity since climatic changes had often occurred in the old geologic age.

On the other hand, there was a stone layer which indurates with the clay to fill the gaps. This layer contained many quarziferous gravels larger than 2 mm in diameter from the

surface of land to a depth of 100 cm. Under the stone layer the profile having clayey subsoil and showing in reddish brown colour was observed. This profile also belongs to the unit of Eutric Leptosols with regard to the criteria of fine earth percentage. The A horizon of this soil was very thin, was dark reddish brown, contained sandy loam and had a single grain structure. But its B horizon lacked these features. It should be pointed out that a round gravel layer, that is to say a stoneline, having 10 cm thickness at the depth of 50cm from surface was observed. The stoneline indicates that the parent materials are different and the soil is polygenetic soil which means that the previously existed parent materials was moved.

As stated above, there were some variations in the pattern of profiles. These soils, however, are shallow or stony and could be put into the same soil unit as the Eutric Leptosols in terms of having ochric A horizon and base saturation more than 50%. A common feature of these soils is the presence of clayey subsoil. Also by taking the existence of iron cemented layer, weathered products and stone line into account, it becomes apparent that the origin of the sands on the upper hills is outside the Intensive Area.

The land containing Leptosols in the Intensive Area are covered with open woodland comprising *Colophospermum mopane*, *Terminalia sericea*, *Acacia* spp. and grassland at the footslope of hills and lands with low relief in lower area along the Bembesi River. The distribution area of these soils is not so large in the Intensive Area. The soils are not suitable for farming because of the presence of stones and boulders on the ground, and outcrops of iron cemented layer. The best use of the land containing these soils will be as forest land or grassland.

The Eutric Leptosols observed in the Intensive Area correspond to the Lithosol Group in the soil classification system in Zimbabwe.

(2) Arenosols (AR)

The Arenosols are the amorphic soils consisting of sand or loamy sand, of which texture are coarser than sandy loam at least within 100 cm depth from the ground surface. There soil did not have well developed horizons except for ochric A horizon or albic E horizon, and was without diagnostic horizons. The albic E horizon is a horizon of which iron-oxide or clay is leached by water. The colour of this horizon is not the colour of skin coating the sand but it is the colour of the sand grain itself. In other words oxides in the horizon are separated or lost to the extent that the colour depends on the quartz sands.

The Arenosols occurring in the Intensive Area are the aeolian sands originated in the Kalahari sands. The sands are carried by wind and deposited deeply over the paleo-soils. Generally the soils consist of fine to medium grain sand of which shape is frosted surface and round edge, and have no structure. The vertical section of the profile was very firm, but it was very prone to collapse by digging by fingers or becoming wet because of low stickiness. These soils, did not contain many gravels. However, there were some scattering cases of 10 cm-large blocks of iron cemented layer at specific sites. Besides such general characteristics, the Arenosols in the Intensive Area have minor difference in hue, texture, degree of the development of diagnostic horizon depending on the difference of micro-topography or position on the slopes. Such differences results in the following subdivisions.

All Arenosols occurring in the Intensive Area correspond to the Regosol Group in the soil classification system in Zimbabwe.

(a) Albic Arenosols (ARa)

These Arenosols have an albic E horizon within 125 cm of the surface, of which thickness is more than 50 cm. No effect of water logging was observed within 100 cm of the surface, though it was affected by horizontal water movement.

In the Intensive Area this unit occurred in places where a considerable amount of water flows in the rainy season such as in depressions on the hillside slopes or small valleys. When it becomes dry, the colour of the whole profile turns grayish white. The texture of this unit was loamy sand and was composed of a single grain with no structure. The soil section was soft. At sites where water flows at the surface, the albic E horizon developed throughout the profile and organic materials on the surface were washed away. However, where the land was relatively sloping and water flowed underground and in such sites as narrow valleys, A horizon was found having a dark brown colour or brownish black colour over the albic E horizon when the humus was abundant and it was wet. The texture was sandy loam since this A horizon contained much humus but was structureless, though it became very firm when it was dry.

In many places the area of Albic Arenosols was covered by open woodland dominated by *Combretum* spp. or *Terminalia sericea* and grassland dominated by poaceous grass. The unit contained little nutrient and clay, and had been significantly affected by water. Such conditions constrain the healthy growth of trees on this soil.

(b) Luvic Arenosols (ARl)

This unit is one of the Arenosols which does not have albic E horizon within 125 cm of the surface, of which thickness is more than 50 cm, but contains clay more than 3%.

In Luvic Arenosols occurring in the Intensive Area, no horizon except for A horizon developed. Just under the A horizon, mostly C horizon follows with the absence of the B horizon. The A horizon was 10 - 40 cm thick, had brownish black or brown colour, was abundant in humus and its texture was sand or loamy sand. The structure was hardly developed, and a very weak blocky structure was partially observed. This structure does not collapse easily when it is dry. But it easily collapses because of no stickiness when it contains water. The B horizon, when appeared, had the thickness of less than 30 cm, and had brown or bright brown colour, and contained no humus. The texture was loamy sand with no structure and composed of single grains. The C horizon was the sand which is very similar to the parent material at the previous level of soils. The colour was brown or bright brown. Deeper parts of this horizon showed the increase of chroma and value of the soil colour. In some surveyed profiles, sub-horizons having different hue than C horizon were observed and this might indicate that the parent materials of the C horizon are not homogeneous.

This soil unit occurred mainly at almost flat surfaces on hills and plateaus. With the next unit of Ferrali-luvic Arenosols, this unit covers the largest part of the Intensive Area. The area containing this unit was covered by woodlands dominated by *Baikiaea plurijuga* or *Brachystegia* spp. mixed with *Pterocarpus angolensis*. Agricultural use would be difficult in terms of the water availability. At the same time there are constraints of poor nutrient content, high permeability and low water retentivity, and since fertilizer will not have much effect, the possibility of growing crops in this unit is limited. Against such a background the trees like *Baikiaea plurijuga* has adapted highly to this unit through absorption of ground water by developing tap roots up to the lower aquifer.

(c) Ferrali-luvic Arenosols (ARlo)

This unit is one of the Arenosols which does not have albic E horizon within 125 cm of the surface, of which thickness is more than 50 cm, but contains clay more than 3%. The colour of this unit is strong red. This unit could be categorized into the said Luvic Arenosols with regard to the level of soil unit. But it was further subdivided by attaching the sub-unit symbol because there was a significant difference in hue of the profiles, and the distribution area differed considerably. The hue of the Ferrali-luvic Arenosols was

strongly red, ranging from 2.5YR to 5YR, while the hue of the Luvic Arenosols ranged from 7.5YR to 10 YR.

The Ferrali-luvic Arenosols which occurred in the Intensive Area had A horizon being dark reddish brown and C horizon being reddish brown. B horizon was reddish brown. But B horizon did not appear in many cases. Comparing with the Luvic Arenosols, the hardness of vertical section in the profile tended to be softer. The features such as the limit of horizon, texture and structure were same as those of Luvic Arenosols.

The Ferrali-luvic Arenosols occurred on the top area of hills with gentle relief and gentle slopes. This gentle relief is not recognizable on the ground, but it could be interpreted clearly on aerial photos or topographic maps. Such relief strongly affects the pattern of the soils. The relief might have resulted from the drainage situation after raining. In the Intensive Area this unit occurs over large area as much as the said Luvic Arenosols. The woodland on this unit is dominated by *Baikiaea plurijuga* and *Brachystegia* spp. It is worth to mention that the stand dominated by *Bracystegia* spp. appears only in this soil unit area. However, the reason is not clear whether it is due to soil condition or other factors. In terms of the land use capability it is the same as the Luvic Arenosols.

(d) Cambi-luvic Arenosols (ARlb)

This unit is one of the Arenosols which contains clay more than 3% within 125 cm of the surface, and shows a little developed B horizon. This unit could be categorized into the said Luvic Arenosols as well as to Ferrali-luvic Arenosols. But it was further subdivided by attaching the sub-unit symbol because there was a significant difference in the development level between horizons.

This soil unit occurring in the Intensive Area had a thin A horizon and a thick B horizon whose thickness reached to 80 cm or more. A horizon was brownish black, had a loamy sand texture and a weak blocky structure. These features of A horizon of this unit are similar to the A horizons of other units of Arenosols. But it differed by the existence of the B horizon of which the texture is sandy loam. This might have caused by the water influence with regard to topographical location. This horizon is developing by gathering fine particles.

Topographically the soil unit occurred on the gently sloping areas below the hill slopes or in broad concave sites among hills. Comparing with other units of Arenosols, this unit had low permeability and high water retentivity due to the finer soil texture. Owing to the

topographical location, the water condition was rather favorable. This unit occurring at the lower land along Bembesi River and Bubi River is mainly utilized as farmland. The area among hills is covered with dwarf teak and open woodland of *Combretum* spp. and *Terminalia sericea*. The dwarf teak is thought to have resulted from repeated forest fires. But there is a possibility of the influence of water condition also.

(3) Vertisols（VR）

This unit contains clay more than 30% in all horizons at least within 50 cm of the surface, and shows cracks in the dry season of which width is more than 1 cm and depth is more than 50 cm. The following units of Vertisols occurred in the Intensive Area.

(a) Eutric Vertisols (VRe)

The diagnostic properties such as accumulation of gypsum or lime could not be observed. This unit is one of the Vertisols having base saturation more than 50% within 20 - 50 cm of the surface.

The Eutric Vertisols occurring in the Intensive Area had large cracks which were some 10 cm or more in width and sometimes reaching to 100 cm in depth. This is due to the large content of active clay having the character of both expansion and contraction. These cracks appear only under dry conditions and disappear under wet condition. This soil unit had a loose top horizon (hereinafter referred to as "A_1 horizon") having clay loam and a granular structure within a few centimeters. Under this horizon, there was a dark-coloured horizon of which thickness reached to 100 cm or more (hereinafter referred to as "A_2 horizon"). The repetition of dryness and wetness contributes to the formation of a loose and thin top horizon which is known as self-mulching. These A horizons were black or brownish black, had a clayey texture, much humus and a strong wedge-shaped structure. This wedge-shaped structure is the angular blocky structure having the form of acute triangle. This structure is hard to collapse even in the wet condition because of its well developed stickiness. When it becomes dry, the vertical section of the profile becomes indurated excluding the thin top horizon.

When there are wide cracks from the dry season to the early rainy season, small soil clods on the surface fall in and fill these gaps created by the cracks. When the rainy season comes, a part of the soil is pushed up by the pressure inside the soil formed by the swollen clay absorbing the water. Such a phenomena of irregularly undulating ground surface is called “ gilgai micro-relief”. The area of the Vertisols in the Intensive Area has the gilgai micro-relief of which relief ranges from a few centimeters to over 10 cm. The pressure in the soils brings the change to the surface of the soil clods. More specifically these clods

show glossy surfaces with grooves called slickensides which is attributed to the polishing of the surface of the soil clods by the pressure. The upper materials are mixed mechanically so that dark-coloured deep horizons develop. There was a slight difference in colour between the surface, which was black, and the inside of the structure. This indicates that organic matter fall in through the cracks from the upper part.

The Eutric Vertisols, which are thought to have originated in the basaltic rocks, occured in the depressions some distance away from the hillside slopes in the lower lands along the Bembesi River. The areas containing this unit were covered with riverine forests (*Colophospermum mopane* or *Acacia* spp.), or were grasslands. Actually the Vertisols are very fertile soils, but become very hard under dry condition and very sticky under wet condition. Additionally Vertisols form swampy ground because the swollen clay decrease the drainage when it rains. Therefore, the agricultural use of the land containing this soil limited to a short period. Moreover the root system might be sheared when the soils shrink. In fact fine roots entirely stretched from both sides of the cracks were observed in the Intensive Area during the dry season. Accordingly reasonable irrigation farcilities to prevent dryness will be needed if the areas containing this soil are to be used for agriculture. Also, the clay of Vertisols is not suitable for brick production.

Eutric Vertisols occurring in the Intensive Area correspond to the Vertisols Group in the soil classification system in Zimbabwe.

(4) Cambisols（CM）

The Cambisols are the soils which have the Cambic B horizon. The Cambic B horizon shows development of the horizon having sandy loam or finer texture, though it does not develop to the extent to be recognized as a diagnostic horizon. This means that it is a B horizon which is at the transitional stage of the development. In other word, the Cambisols are the soils in the process of formation and have no diagnostic horizon to identify them as a major soil group. In terms of soil morphology, it is at the middle point between immature and developed soils. Both soil formation process and erosion continue where the unit is found, but it maintain its shape because of a constant supply of new parent materials. Since the Cambisols are transitional soils they appear in various forms and development stages.

In the Intensive Area the following three soil units are distributed in a mosaic pattern. In the soil maps areas containing mosaics of two or three units were shown as a mixed unit of the relevant two or three soil units.

All units of Cambisols occurring in the Intensive Area correspond to the Siallitic Group in the soil classification system in Zimbabwe.

(a) Eutric Cambisols (CMe)

This unit is one of the Cambisols having an ochric A horizon and a base saturation of more than 50% within at least 20 - 50 cm of the surface. There are no other diagnostic properties such as a B horizon affected by water logging and showing in brown to red colours.

There were two types of Eutric Cambisols in the Intensive Area. One type contains sands of which the parent material is basaltic rock and another type is of alluvial nature with fine grains leaching from sands. The former is clayey and the latter is rather sandy. Generally, the A horizon had a thickness of 20 to 40 cm, a brownish black colour, abundant humus and a sandy loam or clay loam texture. The structure was blocky in sandy soils and angular-blocky in clayey soils, and the vertical section of the profile was hard during the dry condition. The B horizon could be found in the depth of up to 100 cm or more. It had a brown colour, contained sandy loam or clay loam with no humus, had no structure and indurated massively. The moisture content was high, though the survey was conducted in August in the dry season, which may be linked to topographical condition of water and high water retentivity.

This unit occurred mainly at lower lands along Bembesi River and at broad and flat depressions among hills. The area containing this soil unit was covered with open woodland dominated by *Colophospermum mopane*, *Terminalia sericea*, *Combretum* spp. or *Acacia* spp. while the fertile part with relatively favourable water condition was used for farming.

(b) Vertic Cambisols (CMv)

This unit is one of the Cambisols containing a relatively large amount of clay having both characteristics of expansion and contraction. It shows seasonal crack or wedged structure. The unit does not develop diagnostic properties same as the previously mentioned Vertisols, and possesses transitional properties.

The Vertic Cambisols occurring in the Intensive Area had originated from the basaltic rocks. Some parts of clay removed due to the topographic condition mixed with the sand. This unit was more sandy than the previously mentioned Eutric Vertisols. The A horizon was black or brownish black with very abundant humus while the texture was sandy loam

or sandy clay loam and the structure was angular blocky. The B horizon could be found in the depth of up to 100 cm or more, was yellowish brown or brown, contained little humus, its texture was sandy clay and had no structure but indurating massively. In dry condition both A and B horizons indurate and cracks (width 1 cm or less) appear from the ground surface to the upper part of the B horizon. There was no loose surface horizon with granular structure.

This unit occurred mainly at footslopes of hills along Bembesi River, and in temporarily waterlogged broad and flat depressions among hills. The area containing this unit was covered with open woodland dominated by *Colophospermum mopane*, *Terminalia sericea*, *Combretum* spp. or *Acacia* spp.

(c) Gleyic Cambisols (CMg)

This unit had horizons affected by water logging within 100 cm from the surface. But it did not show diagnostic properties to be classified as the authentic Gleysols. It showed transitional properties instead of the diagnostic properties of the Gleysols.

The Gleyic Cambisols in the Intensive Area appeared particularly where water logging would occur for a long time in a year, in lower lands along the Bembesi River and in broad and flat depressions among hills. The A horizon of this unit was brownish black with abundant humus, had a sandy loam texture, a blocky structure and indurated under dry condition. The B horizon was generally brownish gray (containing a little brown iron mottle or black manganese mottle), contained no humus, had a sandy loam or sandy clay loam texture and a partially blocky structure which was indurated. When the field work was conducted, the soil profile had a high moisture content.

Most of the areas containing Gleyic Cambisols were grasslands or bare lands. The clayey soils of B horizon were not of good quality but those were used as materials for manufacturing bricks.

9.3 Distribution of Soils

The distribution of soils in the Intensive Area is summarized in the table below.

Table 9 – 1 Distribution of Soils in the Intensive Area

Major Soil Group	Soil Unit	Main Location of Distribution	Relative Productivity & Suitable Land Use
Leptosols (LP)	Eutric Leptosols (LPe)	Areas containing this soil unit were covered with open woodlands comprising *Colophospermum mopane, Terminalia sericea, Acacia* spp. or were grasslands. This unit was found on the footslope of hills and on lands with low relief in the lower areas along the Bembesi River.	Low productivity Suitable for forests or grasslands
Arenosols (AR)	Albic Arenosols (ARa)	This unit occurred on depressions on the hillside slopes or in small valleys mainly dominated by shrub or grass.	Low productivity Suitable for forests
	Luvic Arenosols (ARl)	This soil unit occurred mainly on almost flat surfaces on hills and plateaus, and occupied a large area. The areas containing this unit were covered with woodlands dominated by *Baikiaea plurijuga* mixed with *Pterocarpus angolensis*.	Low productivity Suitable for forests
	Ferrali-luvic Arenosols (ARlo)	This unit occurred on the top of hills with gentle relief and on gentle slopes, and occupied a large area. The woodland in this unit was dominated by *Baikiaea plurijuga* and *Brachystegia* spp.	Low productivity Suitable for forests
	Cambi-luvic Arenosols (ARlb)	This unit occurred on the gently sloping area below the hill slopes or on broad concave site among hills. The lands containing this unit were mainly used as farmlands.	Moderate productivity Suitable for forests or farmlands
Vertisols （VR）	Eutric Vertisols (VRe)	This unit occurred on flat land along downstream of the Bembesi River. The areas containing this unit were covered with riverine forests consisting of *Colophospermum mopane* or *Acacia* spp., or were grasslands.	High productivity Suitable for forests, orchards or farmlands
Cambisols （CM）	Eutric Cambisols (CMe)	This unit occurred on lower lands along the Bembesi River and on broad and flat depressions among hills. The areas containing this unit were covered with open woodland dominated by *Colophospermum mopane*, *Terminalia sericea* or *Acacia* spp.	High productivity Suitable for forests or farmlands
	Vertic Cambisols (CMv)	Same as above	High productivity Suitable for forests or farmlands
	Gleyic Cambisols (CMg)	This unit showed traces of influence of ground and the land use was mainly grasslands and bare land.	Low Productivity Suitable for forests

Chapter 10

10. Recommendations for Forest Conservation Plan Formulation

The recommendations are aimed to support the forest conservation plan to be formulated by the Zimbabwe Government based on the data and information about forest resources and soil distribution provided by this survey and the results of the socioeconomic survey conducted by DFID.

The forest survey and soil survey were conducted in the Intensive Area. Therefore, the recommendations assume the Intensive Area as the subject area while mentioning the Survey Area when necessary.

The contents of the recommendations are mainly technical because of the nature of information provided by this survey.

10.1 Existing Forest Management Plan

The forest management plan regarding the Survey Area is Forest Management Plan Area South, which was prepared by the FC in 1994. This plan consists of the forest management plans formulated for each forest land under the jurisdiction of Area South. The plan of the Gwaai and Bembesi Forest Lands is included in this plan. The planning period of the said plan was for five years (Phase 1) from 1995 to 1999, which had already expired. Currently the plan for the next five years (Phase 2) from 2000 to 2004 is under preparation and is scheduled to be finished at an early date. The plan for the Phase 2 is said to be very similar to the plan prepared in Phase 1. Basically, the plans for forest lands are prepared by the foresters who work in each forest land.

(1) Contents

Though there area some minor differences, generally the plans for forest lands contain uniform descriptions. Each plan consists of three parts: general background (Part A), management zones (Part B) and forest development (Part C).

Part A consists of the current conditions such as history, size and location, physiography (topography, climate, soil, vegetation, etc.), forest resources (timber, wildlife and other forest products), forest utilization (thatching grass, firewood, sand quarry, grazing land lease, commercial logging, hunting, safari, etc.), forest management (tenants and squatters, wildlife, fire management, research, tourism, poaching, etc.) and

administration.

Part B is the actual plan and consists of programmes for each zone having specific forest utilization.

Table 10 – 1 Zoning of the Forest Management Plan (Phase 1)

Zone	Gwaai Forest Land	Bembesi Forest Land
A	Hunting/Photographic safari operations	Relocation
B	Relocation	Consumptive and non-consumptive safaris (connected with Zone A of Gwaai)
C	Hunting safari operations	Timber belt
D	Grazing	—
E	Timber production	—
F	Hunting	—

With regard to the Gwaai Forest Land, the area for hunting/photographic safari of Zone C and hunting area of Zone F are also designated as the area for timber production.

The activities in each zone are described in terms of the target work amount or implementation area by fiscal year, but definite implementation methods are not mentioned. The area of each activity is indicated by block. The Gwaai Forest Land has 12 blocks while the Bembesi Forest Land has three blocks, and the area of each block ranges from 7,200 to 31,900 hectares (refer to Table 7 – 6). A block is a plan implementation unit. Though the subject forests are relatively homogeneous and the topography is with generally flat, the size of each block is rather large as an implementation unit of the plan. Measures with regard to fire fighting are mentioned by zones and not by specific area.

Part C describes annual forest development activities. The target work amount is described for operations such as seedling production, planting and tending by fiscal year.

(2) Progress in Phase 1 and Plan Contents for Phase 2

The information about the progress in Phase 1 and plan contents for Phase 2 was obtained through interviews with officers in charge of plan preparation for the Gwaai and Bembesi Forest Lands as shown in Table 10 – 2.

Table 10 – 2 Progress in Phase 1 and Plan Contents for Phase 2 of Forest Management Plan

By Zone or General	Main Plan Content by Zone	Blocks or Site	Progress in Phase 1 (1994～1999)	Plan Contents for Phase 2 (2000～2004)
Bembesi Forest Land				
A	a. Relocation	Part of A, B	Moderate achievement.	- The activities of Phase 1 will continue. - Relocation is a key issue.
B	a. Consumptive safari (Hunting) b. Non-consumptive safari (Photo)	Part of the vlei	Approximately 80% achievement.	- The activities of Phase 1will continue.
C	a. Timber production b. Grazing lease	B,C	Cutting targets were achieved, but only fences and boreholes were constructed for grazing lease.	- Timber production had ended. - Grazing lease will continue for relocated people.
General	Fire protection		Planned fire prevention and fire control activities were implemented.	- Planned fire prevention and fire control activities will be implemented.
General	Forest improvement		Planted area for 5 years totals to 5 ha which is less than 2% of the planned planting area. Arboretum was not established. No research was conducted.	- The activities of Phase 1 will continue. - Research on thinning and regeneration will restart.
Gwaai Forest Land				
A	a. Hunting b. Photographic safari	Insuza vlei	Improvement targets regarding bridges, game fences and game viewing platforms were achieved.	- The activities of Phase 1 will continue.
B	a. Relocation	East side Victoria Falls Road	Plan contents are being implemented.	- The activities of Phase 1 will continue.
C	a. Improvement of hunting safari site	Between 8 mile line and the Bembesi River	Plan contents are being implemented (The improvement work will start after finishing the end of relocation.).	- The activities of Phase 1 will continue.
D	a. Grazing	O	Targets not achieved.	- The activities of Phase 1 will continue.
E	a. Timber production	B,L,N,A,B, C,E,K,L,M ,N,H&J	Cutting was conducted in G, C and E blocks, amounting to some 27,000 m^3 more than the planned amount of 25,000 m^3 for 5 years.	- Grazing lease will be arranged for the people relocated. Additional planting or enrichment planting will be conducted.
F	a. Hunting		Targets almost achieved.	- The activities of Phase 1 will continue. - Incorporating grazing especially along the railway.
General	Fire protection		Planned fire prevention and fire control activities were implemented.	- Planned fire prevention and fire control activities will be implemented.
General	Forest improvement		Arboretum was established. But research and seed count were not conducted.	- Maintenance of arboretum - Research plots will be established and surveyed. - Implementation of seed counting

The cutting volume (timber volume of DBH≧31 cm) in the Gwaai Forest Land is shown in the table below.

Table 10 – 3 Current Cutting Volume in the Gwaai Forest Land

Year	Cutting Volume (m^3)
1996	2228.668
1997	4403.684
1998	6655.556
1999	8164.451
2000	5523.089

10.2 Current Task with Regard to the Forest Management

As can be seen from Table 10 – 2, except the delicate issue of relocation, other planned activities such as safari, timber production and fire protection were implemented. On the other hand, grazing lease and forest improvement targets were not achieved as planned.

In terms of fire protection, the fire prevention activities were implemented almost as planned. However, many fires broke out in the dry season. On the whole the FC staff are doing their best to implement the plan, though the number of personnel is limited and the area is very large. However, as was found out during this survey, the following three issues are of paramount importance regarding forest conservation in the Survey Area.

(1) Cutting Volume Based on Allowable Cutting Volume

Regarding the Gwaai Forest Land for which recent cutting data are available, 25,000 m^3 of timber was planned to be cut in five years, or 5,000 m^3 per year. As shown in Table 10 – 3, the cutting volume for five years from 1996 to 2000 amounted to 27,000 m^3 while the cutting volume in 1995 is not known. Thus the actual cutting volume can be said to be slightly above the planned figure of 25,000 m^3. This planned figure is said to be based on estimation by experienced persons.

Beside the said cutting volume, there is another cutting volume from the cutting , which started at the same time as the present forest resources survey, in Blocks H and J in the Gwaai Forest Land. The intention was said to be to cut commercial trees before such trees will be cut through poaching, which is frequently occurring in the area.

Since the decision on such cuttings is sometimes taken due to the social necessities or supply and demand condition, technical consideration play a minimum role. However, from a forestry technology point of view, the establishment of allowable cutting volume

is needed if production is to be sustained. If the cutting volume required due to social demand exceeds the cutting volume which is technically feasible, this situation will probably lead to the deficiency of timber resources in the future and environmental degradation. The allowable cutting volume with technical basis could be adopted to avoid such problems. The establishment of allowable cutting volume will require the identification of forest resources and increment. In the future, it is essential to establish the allowable cutting volume based on the results of proper surveys.

(2) Measures Regarding Forest Tending

In the Survey Area, there are numerous patches of bushland containing many dwarf teak trees of which height is around 1 m. A common explanation is that the *Baikiaea plurijuga* stands which existed in the area had turned into dwarf teak stands as the result of repeated cuttings and fires.

The dwarf teak stands contain of numerous sprouts of *Baikiaea plurijuga*. Without a proper treatment it will be difficult for these sprouts to develop into large and healthy individual trees. With a proper treatment such stands may become productive and produce timber. It is necessary to develop productive dwarf teak stands.

(3) Promotion of Fire Protection Measures

Fire is the most critical issue regarding the forest management in the Survey Area. A considerable amount of money is allocated in the budget for fire prevention and fire action annually. In the Survey Area, fires are caused mainly by human action such as poaching. Because of their direct or indirect involvement, the problems of forest burning and poaching could be solved only through the participation of the forest residents and people from the surrounding communities in the management of the forests. The Shared Forest Management Project was formulated to tackle these problems. In reality, however, many social issues have to be dealt with before attempts could be made at managing the forests in the area according to the principles of forest technology. From a technical viewpoint, however, practical fire protection measures should be developed and implemented.

10.3 Summary of the Current Condition

Prior to describing the concept of forest conservation plan, the current condition of forests in the Intensive Area is summarized as follows.

10.3.1 Conditions of Forests

(1) Tree Species Appeared

The rank and frequency of major tree species appeared in the plots surveyed were as shown in the table below.

Table 10 – 4 Rank and Frequency of Major Three Tree Species Appeared

Species	Rank	Frequency of Species Appeared (%)
Baikiaea plurijuga	1	42
Guibourtia coleosperma	2	12
Pterocarpus angolensis	8	3
Other species	—	41
Total	—	100

(2) DBH and Tree Height

DBH and tree height by forest type were as follows.

Table 10 – 5 Average and Maximum DBH by Forest Type

DBH/Forest Type	Eu	Ba	Gc	Br	Ac	Co/Ts	Cm	R	All
Average(cm)	14	18	20	19	14	14	14	30	18
Max(cm)	24	79	61	58	43	51	28	120	120

Table 10 – 6 Average, Maximum and Minimum Tree Height by Forest Type

DBH/Forest Type	Eu	Ba	Gc	Br	Ac	Co/Ts	Cm	R	All
Average(cm)	9	7	7	8	6	6	7	14	7
Max(cm)	17	18	15	14	9	11	10	31	31
Min(cm)	5	2	3	3	4	3	4	3	2

The per hectare DBH class distribution of the main tree species was as shown below.

Table 10 – 7 DBH Class Distribution of Main Tree Species Unit: No. of Trees / ha

DBH Range	Ba	Gc	Pt	Co c	Cm m	Cm	Br	Others	All
10 - 14	47.50	9.56	0.81	8.97	5.88	4.41	1.91	40.15	119.19
15 - 19	16.40	6.03	0.22	4.71	1.69	0.96	0.88	10.37	41.25
20 - 24	13.90	5.74	1.03	3.97	0.44	0.66	1.18	5.51	32.43
25 - 29	6.10	2.65	0.96	1.69			0.96	1.62	13.97
30 - 34	6.32	2.65	0.66	0.66			0.66	1.03	11.99
35 - 39	4.63	1.84	1.03	0.15		0.07	0.44	0.66	8.82
40 - 44	2.79	0.66	0.44				0.22	0.66	4.78
45 - 49	1.91	0.37	0.74				0.07	0.37	3.46
50 - 54	0.29		0.15				0.15	0.15	0.74
55 - 59	0.37						0.07	0.22	0.66
60 - 64	0.29							0.07	0.37
65 - 69									
70 -	0.07					0.07		0.22	0.37
Total	100.59	29.49	6.03	20.15	8.01	6.18	6.54	61.03	238.01

Note: Figures showing the number of trees are averages of all plot.

(3) Growing Stock

The average volume of trees of DBH 10 cm or more is calculated as approximately 30 m^3/ha. The value of 30 m^3/ha is estimated to be considerably lower than the potential figure as described later. The forests in the area had a rather uniform distribution and thus did not show sizable volume in specific sites, though there were minor differences. This might have caused by the selective cutting of large-diameter trees since the early 1900s. Additionally, it should be noted that the stands dominated by *Guibourtia coleosperma* and *Brachystegia* spp. had a large number of the same dominant trees as well as *Baikiaea plurijuga*. The volume by block and main timber species for the Intensive Area, and volumes for Blocks H and J in the Gwaai Forest Land are shown in Table 10 – 8 to Table 10 – 11.

Table 10 – 8 Volume of Block

Block	Total Area (ha)	Ratio (%)	Productive Area (ha)	Ratio (%)	Total Volume (m^3)	Ratio (%)	Total Volume per ha (m^3/ha)	Timber Volume (m^3)	Ratio (%)	Timber Volume Per ha (m^3/ha)
Gwaai Forest Land										
C	1,812	3	775	2	22,436	2	29	12,006	2	15
G	5,500	10	4,029	10	152,220	12	38	81,048	12	20
H	12,107	22	9,419	24	277,090	22	29	148,072	22	16
J	14,604	26	11,272	29	370,147	30	33	203,476	30	18
K	13,332	24	5,625	15	142,999	12	25	72,656	11	13
Bembesi Forest Land										
B	8,157	15	7,884	20	268,148	22	34	156,667	23	20
Total	55,512	100	39,004	100	1,233,040	100	32	673,925	100	17

Note: Productive Area consists of woodland.

Table 10 – 9 Timber Volume by Species

Total Figure (Unit: m^3)			
Species	Class1	Class2	Total
Baikiaea plurijuga	223,541	125,013	348,554
Pterocarpus angolensis	73,390	12,063	85,453
Guibourtia coleosperma	59,845	34,775	94,620
Others	79,995	65,303	145,298
Total	436,771	237,154	673,925

Figure of Volume per ha (m^3/ha)			
Species	Class1	Class2	Total
Baikiaea plurijuga	5.731	3.205	8.936
Pterocarpus angolensis	1.882	0.309	2.191
Guibourtia coleosperma	1.534	0.892	2.426
Others	2.051	1.674	3.725
Total	11.198	6.080	17.278

Table 10 – 10 Timber Volume by Species for Block H

Total Figure (Unit: m^3)				Figure of Volume per ha (m^3/ha)			
Species	Class1	Class2	Total	Species	Class1	Class2	Total
Baikiaea plurijuga	49,115	27,467	76,582	*Baikiaea plurijuga*	4.057	2.269	6.325
Pterocarpus angolensis	16,125	2,650	18,775	*Pterocarpus angolensis*	1.332	0.219	1.551
Guibourtia coleosperma	13,149	7,641	20,790	*Guibourtia coleosperma*	1.086	0.631	1.717
Others	17,576	14,349	31,925	Others	1.452	1.185	2.637
Total	95,965	52,107	148,072	Total	7.926	4.304	12.230

Table 10 – 11 Timber Volume by Species for Block J

Total Figure (Unit: m^3)				Figure of Volume per ha (m^3/ha)			
Tree Species	Class1	Class2	Total	Tree Species	Class1	Class2	Total
Baikiaea plurijuga	67,493	37,745	105,238	*Baikiaea plurijuga*	4.622	2.585	7.206
Pterocarpus angolensis	22,159	3,642	25,801	*Pterocarpus angolensis*	1.517	0.249	1.767
Guibourtia coleosperma	18,069	10,499	28,568	*Guibourtia coleosperma*	1.237	0.719	1.956
Others	24,152	19,717	43,869	Others	1.654	1.350	3.004
Total	131,873	71,603	203,476	Total	9.030	4.903	13.933

Note: DBH Class **1** 34 cm + Class **2** 26 – 33 cm

10.3.2 Natural Regeneration

Baikiaea plurijuga had a high degree of abundance and coverage as well as excellent sprouts in all stands dominated by *Baikiaea plurijuga, Guibourtia coleosperma* and *Brachystegia* spp., and no major problems existed with regard to natural regeneration of all species.

Pterocarpus angolensis was found moderately regenerating with a low degree of abundance and coverage wherever mother trees were found among upper story trees. The area where regeneration was taking place estimated at a third of the Intensive Area. Many mother trees had been selectively cut. In the future the remaining mother trees should be protected.

Guibourtia coleosperma had a high degree of abundance and coverage in the stands dominated by this species, and no problems existed with regard to its regeneration. However, the area of regeneration of this species was estimated at half of the Intensive Area. The mother trees of *Pterocarpus angolensis* also should be protected.

10.3.3 Growth

All tree species in the Survey Area are slow growing. The mean annual increment of the main timber species, in terms of the existing data, are estimated from 1 to 2 mm.

10.3.4 Soils

The results of the soil survey showed that Kalahari sand is an important factor with regard to the growth and development the stands dominated by *Baikiaea plurijuga*. The main reason for the excellent growth of *Baikiaea plurijuga* on Kalahari sand is that it develops tap roots which can penetrate up to the aquifer. But where the soil moisture content is high other tree species dominate. The stands dominated by *Baikiaea plurijuga* were similar to manmade forests in terms of the uniformity of species. An advantage of this tree species is that it produces large quantities of good quality commercial timber. But the standing trees had very slow growth which could be due to the sand containing small amount of nutrients. With this background, it can be said that after felling restoration of the forests in the Survey Area may take a long time. Therefore, the cutting cycle and cutting ratio should be carefully arranged.

10.3.5 Issues Concerned with Residents

The Gwaai Forest Land and all of the Bembesi Forest Land were demarcated as state land in 1930 and 1940. Before demarcation, people were living in the forests and were engaged in subsistence farming and livestock raising. As these people were providing a source of seasonal labor for forestry operations and were helping fight forest fires, the Forestry Commission allowed them to reside in the forests.

Over the years, however, the population of the forest residents expanded, due to in-migration and also naturally.

Accordingly the establishment of farmlands and tree cutting increased and affected forest management negatively. In spite of various measures taken by the government, the population had increased. The FC finally decided to evict the residents recently settled in the forest, and to resettle the remaining residents in neighboring communal lands. In addition to this, the FC established a relocation area in state forest land north-east of the Bulawayo-Victoria Falls Road to settle the remaining households. But the residents living along the downstream of the Bembesi River in Gwaai Forest Land refused settlement in relocation area.

To obtain the cooperation and participation of the forest residents and of the inhabitants

from the surrounding areas for an effective protection and management of the forests in the area, the FC initiated the SFM project with the assistance of the DFID in 1998. In 1999 socioeconomic surveys were conducted under the project. Based on the survey results several options were proposed with regard to the issue of forest residents and "Voluntary Relocation" and "Improved Status Quo" were recommended as the best alternatives for settlement of the forest residents. The "Improved Status Quo" will allow the forest residents to remain in their present location, with provisions made for secure tenure, improved infrastructure, and shared forest management agreements. According to interviews conducted by DFID, the "Improved Status Quo" was the most strongly preferred by the residents, followed by "Relocation", "Resettlement" and "No Change".

10.4 Contents of the Recommended Forest Management Plan

10.4.1 Basic Principles of Forest Conservation

Forests are indispensable to human life owing to their various functions such as wood supply, flood control, biodiversity conservation, carbon pool by CO_2 sequestration and recreation. It is important to promote these functions in a integrated manner through a sound forest management.

The existing forest management plan for the Survey Area divides the forests into zones based on the utilization goals mentioned below.

- Timber production
- Safari
- Grazing (combined with timber production area)
- Relocation

The current zoning is generally appropriate because it had been carried out according to the objectives of forest management plan. However, by taking into account site condition and promotion of forest functions, the following categories could be added to the current ones.

- Firewood production
- Restoration
- Protection of genetic resources for useful species
- Soil and water conservation

10.4.2 Necessity of Forest Conservation Plan

Promotion of forest functions in a sustainable manner is essential to establish and to maintain a sustainable society. To promote forest functions in a sustainable way, it is necessary to present a system of planned forest management technologies which can deal with each forest function, and to prepare regional forest management plans that include forest functions. Those needs are brought into shape of "forest conservation plan".

10.4.3 Contents of Forest Conservation Plan

(1) Categorization by Function

The categorization by function, as presented in Table 10 – 12 was carried out by weighing the importance of each function. Excluding the relocation area, the categories consist of

production area and other areas. Conservation and management activities concerning each function will be described later. The area for each function category will be adopted by conforming to and sub-dividing the existing zones on maps as well as by referring to the thematic maps and results of forest survey and soil survey.

Table 10 – 12 Categorization by Function for the Gwaai and Bembesi Forest Lands

Category by Area of Function	Sub-Category by Area of Function	Contents
Production area	Timber production area	Forests to be used for timber production.
	Grazing area	Forests to be used for timber production and grazing.
	Firewood production area	Forests to be used mainly for firewood production. Grazing and farming will be allowed to some extent.
	Restoration area	Dwarf teak stands, which will be incorporated into the timber production area after developing to woodland.
	Safari area	Forests to protect wildlife and to be used for recreation hunting and photographic safari purposes.
Protection area of genetic resources of useful species		Areas to protect genetic resources of useful but scarce tree species.
Soil and water conservation area		Area to conserve the headwaters and drainage systems from soil erosion and soil discharge.
Relocation area		Area to implement relocation in line with the existing policies.

Site selection should be decided after the division of forests by using block and compartment as well as analysis of those attributes.

(2) Division of Forests

The division of forests to proper sizes due to topographical conditions or forest conditions facilitates forest management.

Since the Gwaai and Bembesi Forest Lands are characterized by a flat and simple topography and the existence of *Baikiaea plurijuga* forests of a relatively uniform physiognomy, in spite of being uneven aged and mixed with other tree species, the difference in work method to be applied will be insignificant. Currently forest operations are conducted by using a block as a unit, the size of which is quite large. Therefore, the appropriate way would be to subdivide each block into compartments. The minimum unit of forest operation will be a compartment if this principle is applied.

Blocks H and J, where currently cutting is being conducted, were divided into 19 parts

and cutting is conducted in each part every four-month. The total area for both blocks amounts to some 27,000 ha of which productive area is estimated at 20,000 ha. Considering this situation, the compartmentalization by some 1,000 ha within the blocks could be considered as an option in order to conduct forest operations efficiently.

On the other hand, the timber production area could be divided into 30 compartments by assuming a cutting cycle of 60 years, which will secure a cutting of two compartments every tow-year. All compartments will be designed in such a way so that a rotation of 60 years is achieved. The timber production area could also be divided into 20 compartments which will secure a cutting of one compartment every three-year.

Roads and rivers will form compartment boundaries. It should be pointed out that demarcation by roads needs to be conducted in such a way so as to achieve nearly equal sizes for compartments and also to use the roads as effective fire guards. A higher density of roads can facilitate fire prevention and can provide access to fire action sites.

Commonly forest inventory books describing the forest status are prepared with compartments as units. But the present survey used a parcel based division of the forest types because compartments were not established in the Survey Area.

(3) Planning Period

Currently the forest management plan is prepared for a period of five years. However, it would be appropriate to formulate the plan for a period of ten-years accompanied by intermediate reviews at every fifth-year, while taking the next 50 or 100 years into account.

10.5 Target Stand Type for Each Function Category

In order to promote highly sustainable forest functions required by the people, the target stands should be determined, forestry operations suitable to the stands should be conducted and the stands should be maintained properly. The recommended target stand types for each function category are as shown in Table 10 – 13.

Table 10 – 13 Target Stand Types for Each Function

Category of Area by Function	Sub-Category of Area by Function	Target Stand Type
Production area	Timber production area	The stand will be uneven aged, will consist of useful tree species and will have a high ratio of good quality trees. The upper story trees will comprise trees reaching to usable DBH or of similar sizes. The stand will have good quality trees of DBH of at least 30 cm or more.
	Grazing area	The same target stand type as timber production area while grazing lease will be conducted as well.
	Firewood production area	The stand where selective coppice system will be applied to firewood trees such as *Colophospermum mopane*. A coppice stand having a DBH of 10 cm or more would be preferred. To the certain extent, grazing and farming will be allowed within the area.
	Restoration area	After restoration, the target stand type will be the same as the timber production area.
	Safari area	The stand will be kept under the natural condition unless there is a specific reason to act otherwise.
Protection area of genetic resources for useful species		The stand will have trees such as *Pterocarpus angolensis* and *Guibourtia coleosperma*. The high trees with good quality and their young regenerations should grow together.
Soil and water conservation area		The stand will be kept under the natural condition unless there is a specific reason to act otherwise.

The target stand types for timber production require a high composition ratio of useful tree species of good quality and utilizable DBH. In addition, various DBH-sizes of trees have to form the stand in order that the stand can restore or supplement the distribution gap caused by cutting large trees periodically.

As described later in 10.6.3, the firewood production will require trees with desirable DBH of 10 cm or less which are secured by repeated cutting through selective coppice system.

Safari area and soil and water conservation area will be kept under the natural condition as possible unless there is a specific reason to act otherwise. Protection area of genetic

resources for useful species will consist of useful tree species with usable quality of which number is decreasing. The size of this area will be as large as the subdivision of the existing blocks.

10.6 Forest Management by Function Category

The forest management technology necessary for the improvement and maintenance of the target stand types mentioned above should be examined and shown in the forest conservation plan.

10.6.1 Timber Production Area

The timber production mainly aims at the production of materials for construction and manufacturing of furniture. Commonly good quality trees with longer and larger stems have a higher commercial value. Therefore, useful trees of good quality such as *Pterocarpus angolensis*, *Guibourtia coleosperma* and *Baikiaea plurijuga* had been specially prioritized for cutting and this resulted in a considerable decrease in the number of high quality large trees. The DBH of 40 cm or more was the minimum DBH size allowed to be harvested from the early 1900s to 1973. Later this size was reduced to 35 cm and currently the DBH allowed to be harvested is 31 cm. In this way the cutting regulation on DBH size tends to move into the direction which allows the cutting of trees with smaller diameters. This trend is obviously not compatible with the forest conservation and management for a sustainable timber production. If the trend continues, the minimum DBH size allowed to be harvested may become even smaller, negatively affecting the forest resources of the Gwaai and Bembesi Forest Lands.

The fact that the cutting is obliged to focus on small-diameter trees due to decline of large-diameter ones could be evidence for that the total growing stock and the number of good quality trees have been decreasing. The average volume of 30m^3/ha obtained by the survey on trees of DBH 10 cm or more is considered to be quite lower than the potential figure.

Before starting commercial cutting in the early 1900s, there might have been many trees of the DBH range of 50 to 100 cm. The diameter increment of useful tree species is very small as stated in the chapter on growth. *Baikiaea plurijuga* is estimated to grow to the DBH of 40 cm in some 250 years. *Pterocarpus angolensis* and *Guibourtia coleosperma* also have a similar slow growth. Once DBH size of the stand is reduced to the range of 20 cm through cutting, it will require 50, 100 or even more years for the stand in question to grow to a DBH range of 30 to 50 cm. In the meantime, it will be difficult to prohibit

cutting during this period. Even if cutting regulations are somewhat relaxed in consideration of the reality in the field, from now on a forest conservation plan which prohibits the cutting of good quality trees having a DBH of 30 cm or less is needed.

The term sustainability means "satisfying the needs of present generation without jeopardizing the needs of the coming generations". The forest conservation plan should be formulated by taking into account our responsibilities to the coming generations.

The cutting cycle is currently set at 60 years, though it was 40 years formerly. The current cycle should be maintained firmly. A longer cutting cycle must be adopted if the forests in the area are to have a certain ratio of trees having good quality and a DBH size ranging from 30 to 50 cm. Under this condition, if the cutting cycle is set at 40 years, the cutting ratio will decrease. Formulation of guidelines to show duration of cutting cycle and cutting volume for each compartment will be indispensable for the forest conservation plan.

(1) Yield Regulation of Timber Production Area

(a) Concept of Cutting

As stated above, in the case of the forests aiming at timber production, the cutting volume should be decided to secure sustainability of forest resources by setting the appropriate production target because the timber production period is rather long. If the cutting is conducted in a haphazard manner without considering the growth, since there is currently much growing stock, the sustainable production will be impossible. Therefore, the concept of yield regulation should be incorporated in the forest conservation plan.

(b) Sustained and Regulated Yield

Basically selective cutting method has to be adopted regarding forests in the Survey Area because of the indigenous and uneven aged characteristics of these forests. Though it will be difficult to realize a normal distribution of tree sizes in the forests where selective cutting is practiced, nevertheless, creation of sustained yield forests should be aimed for. The yield regulation and the principle of no more cutting beyond the annual increment should be incorporated into the cutting plans, and whenever such plans are formulated this approach should be adopted. Conducting cutting every year will not be appropriate in terms of work efficiency and relation of supply and demand. A more efficient approach will be to conduct cutting by taking several years after the prior cutting.

(c) Targeted Production Diameter

Production diameter aimed for is commonly decided by considering factors such as the use of logs, mean annual increment and economic profitability. In the case of *Baikiaea plurijuga*, the DBH reaches to approximately 1 m at a mature stage which may take more than 500 years, and in view of the current situation it does not sound realistic to aim for such a DBH size. It would be appropriate to set the target production diameter at the approximate range of 40 to 50 cm.

(d) Cutting Age

The cutting age is designed to conform to the stand age reaching to the targeted production diameter. If the subject diameter is set at the range of 40 to 50 cm, the stand age will approximately range from 270 to 330 years. 300 years will be the medium and acceptable figure.

(e) Cutting Cycle and Selective Cutting Ratio

The cutting cycle is the duration between two cuttings conducted in the same stand under the selective cutting method. The duration is usually decided by taking into account the number of years required to restore the volume that was cut through selective cutting to the same level as just before the start of the said selective cutting. When the selective cutting ratio is high, the cutting cycle becomes longer. It can be vice versa.

When the current growing stock is considerably lower than the original volume, such as in the Survey Area, the target volume should be set by assuming mature forests. In such a case the decrease in selective cutting ratio will be unavoidable.

(f) Allowable Cutting Volume

The allowable cutting volume is commonly decided by the upper limit of stand increment of the timber production forests within the term of the forest management plan to secure a stable timber production with no hindrance to sustained yield. When calculating the allowable cutting volume of selectively cut forests, the cutting volume should not exceed the increment under the assumption of a certain cutting cycle and a selective cutting ratio.

The allowable cutting volume can be calculated by using the following equation.

$$R = \frac{(1+P)^L - 1}{(1+P)^L} \times 100 \times f$$

R: Selective cutting ratio (%)
f: Current volume ratio divided by the target volume $f = V_0 / V_1$
P: Increment ratio of the subject forest
V_0: Current volume per ha
V_1: Target volume per ha
L: Cutting cycle (year)

The above equation means as follows. In the case of the current volume as "m", the volume after the cutting cycle is expressed by " $m \cdot (1 + P)^L$ " which will reach to the amount of "m" with selective cutting of the ratio of "R". In other words, the volume by selective cutting after cutting cycle will become equivalent to the current volume of "m". This is described by the following equation.

$$(1-R) \cdot m \cdot (1+P)^L = m$$
$$(1+P)^L - R \cdot (1+P)^L = 1$$

Accordingly,

$$R = \frac{(1+P)^L - 1}{(1+P)^L} \times 100$$

This equation is adaptable if the stand is sufficiently mature and has a high volume. However, if the stand is still growing and the volume is not large, the said ratio should be multiplied by the ratio of the current volume divided by the target volume, which will be set properly.

Accordingly,

$$R = \frac{(1+P)^L - 1}{(1+P)^L} \times 100 \times f$$

(2) Estimation of Stand Increment Ratio

The stand increment is the total of the growth volume of each constituent tree of a stand

minus the volume of dead trees. It is very difficult to determine the stand growth volume in the Survey Area due to negative factors such as natural death, forest fire, elephant damage, poaching and the problem of determining the growth of a single tree. In order to estimate the allowable cutting volume, a certain stand increment ratio will have to be assumed, and determining this ratio should be a topic for the future research.

As was described in 8.3, the mean annual diameter increment of *Baikiaea plurijuga* was estimated at 1.6 mm from the existing sources such as SAREC report. Generally, the increment ratio of a single tree having a large diameter is small while that of a small diameter is large. Therefore, it is difficult to determine the average range of diameter growth. Moreover, the small-diameter trees are severely damaged by fire while large-diameter trees are prone to illegal cutting. Here a tree of DBH 30 cm and of a height of 12 m is assumed as the average tree since trees of DBH 31 cm or more are cut currently. The total volume of this average tree is calculated as 0.4764 m^3. If the DBH grows to 30.16 cm after one year, the volume will increase to 0.4815 m^3 which means an increment of 1.07%.

In the subject indigenous forests how the stand grows as a whole is unclear. However, it is commonly known that the climax forests have a zero increment ratio because in these forests increment is balanced by natural death. The forests of the Survey Area have a plus increment because these forests are growing. However, the actual growth figure is affected by negative factors such as forest fire, etc. In fact 18.6% of the Survey Area of some 200,000 ha is damaged annually. Assuming that one percent of the Survey Area, amounting to 2,000 ha, is completely destroyed by fire, the Area will show a negative increment. By assuming that negative factors such as natural death, forest fire, elephant damage and poaching reduce increment to half, an annual increment ratio of 0.5% is used to conduct the following calculations.

(3) Provisional Estimate of Allowable Cutting Volume

The annual increment ratio is presumed at 0.5% and the cutting cycle at 60 years. The selective cutting ratio is calculated as follows.

$$R = \frac{(1+P)^L - 1}{(1+P)^L} \times 100 = \frac{(1+0.005)^{60}-1}{(1+0.005)^{60}} \times 100 = 25.86$$

The selective cutting ratio of approximately 26% will be reduced to 23% by deducting 10% as the ratio of trees damaged during logging.

At Blocks H and J where the cutting is underway, the timber volume for the three main tree species of DBH of 31 cm or larger is estimated at 10.7 m^3/ha. The forest area of both blocks amounts to some 20,000 ha. Therefore, by multiplying these figures the allowable cutting volume of some 50,000 m^3 is obtained.

The current cutting operation is organized in 19 parts within Blocks H and J. Each part is cut in four months, totaling 76 months. The subject tree species are the three main species with DBH of 31 cm or larger. A total of 38,000 m^3 of timber will be cut, which amounts to a monthly cutting of 500 m^3. This value is estimated to be lower than the said allowable cutting volume if the cutting cycle is assumed at 60 years.

However, the cutting cycle can be calculated as 40 years by assuming an allowable cutting volume of 38,000 m^3. Accordingly the next cutting in the Blocks H and J should be conducted after 40 years in order to secure the current volume of 10.7 m^3/ha of DBH of 31 cm or more for the main tree species.

If the blocks are subdivided into compartments, as stated earlier, and a cutting plan is formulated for each compartment, though the cutting volume will not be large, cutting will be possible every several-years.

If the target volume is expected to increase at any level, the cutting cycle needs to become longer and the cutting ratio should be decreased.

(4) Need to Preserve Mother Trees

As stated in 8.2, regeneration seedlings of *Pterocarpus angolensis* and *Guibourtia coleosperma* did not have a high degree of abundance and coverage but had a favourable regeneration where mother trees were present.

For *Pterocarpus angolensis*, the ratio of plots in which the species appeared against the all plots was 35%. The ratio of plots with DBH of 30 cm or more accounted for 22% while the ratio of plots with the regeneration seedlings (height < 5 m) accounted for 32%. As the data indicate, both the upper story trees currently of high value and the regeneration seedlings to be used in the future show rather small frequency.

For *Guibourtia coleosperma*, the ratio of plots in which the species appeared against the all plots was 49%. The ratio of plots with a DBH of 30 cm or more was 26% while the

ratio of plots with the subject regeneration seedlings accounted for 44%. Therefore, it could be said that the number of upper story trees of *Guibourtia coleosperma* is rather small while the ratio of regeneration seedlings is less than half.

The number of *Pterocarpus angolensis* and *Guibourtia coleosperma* trees appeared was limited because high quality trees might have been preferentially cut, leaving only those of a low quality. With such a background, genetic degradation could be the main concern. Therefore, high quality trees of *Pterocarpus angolensis* and *Guibourtia coleosperma* should be preserved as mother trees by prohibiting cutting. It is essential to preserve the stands containing a sizable number of mother trees of a high quality as protection area of genetic resources of useful species by demarcating such areas as compartments. In that case the trees having poor quality might be removed when protection areas are established. Outside the protection areas, cutting of good quality mother trees should be prohibited and the cutting should be restricted to the poor quality trees. Clear marking and a strict supervision system will be necessary to prevent the cutting of mother trees.

The natural regeneration may be materialized through seeds produced by the mother trees , but when such regeneration fails to occur, the reasons and supplementary methods should be carefully examined. However, a positive consideration should be given to seed collection, sowing and plating in the forests. If such a method was found to be applicable, the companies involved in cutting should be obliged to conduct planting after cutting. By planting the decreasing tree species such as *Pterocarpus angolensis* and *Guibourtia coleosperma*, degraded forests could be improved.

Due to a high degree of adaptability to the condition of Kalahari sand, the *Baikiaea plurijuga* was the most dominant tree and had a favourable regeneration throughout the Intensive Area. But there were many large-diameter trees of a poor quality since high quality trees had been cut. In order to prevent genetic degradation of *Baikiaea plurijuga*, trees of a good quality should be preserved as mother trees. When protection stands of *Pterocarpus angolensis* or *Guibourtia coleosperma* are established by using compartments, good quality and useful mother trees of such species as *Guibourtia coleosperma* and *Brachystegia* spp. should also be protected.

In addition the elephant damage tends to concentrate on *Diplorhynchus condylocarpon* or *Pterocarpus angolensis* and becomes a factor to degrade and decrease those mother trees. The realistic measures could be to create the comfortable living environment for elephants in the wildlife area as well as to fence around the area, in order to restrict the range of the activities within the wildlife area.

10.6.2 Grazing Area

The grazing area is currently used as lease land for grazing. The forest residents and the inhabitants from the surrounding communities graze their livestock in the forest. The cattle eat grasses but not tree leaves of useful tree species such as *Baikiaea plurijuga*. There were no traces of hardened ground due to trampling by cattle because most of the area is covered with sand. Therefore, no significant damage to the trees by cattle was observed, and on the contrary, the dung may provide nutrients to the land.

In terms of the damage to the cattle from grazing in the area, it is said that there is a poisonous grass species that kills the cattle when eaten. However, currently, the damage is not significant. It is possible to prevent cattle poisoning by advising the persons involved to remove the poisonous grass species before grazing.

If cattle are grazed in the forests, it will have certain positive effects such as reducing the fuel load and thus mitigating the spread of fire. Additionally, the cattleman may discover fire accidents and participate in fire fighting.

Therefore, it can be said that grazing in the forest is a case of killing two birds with one stone, and could be adapted aggressively as a fire fighting measure. Currently the largest problem that the inhabitants are facing is the shortage of drinking water for their livestock. The FC could help alleviate this problem by providing livestock drinking water facilities.

10.6.3 Firewood Production Area

Since *Colophospermum mopane* is suitable for firewood production, coppice stands of this tree species could be a target stand type for firewood supply. *Colophospermum mopane* can grow at less fertile sites than *Acacia* spp. while both grow at fertile lands of Vertisols or Cambisols. Growing *Colophospermum mopane* in less fertile lands within or around the settlements could be an option for growing firewood trees since currently the farmers settle at fertile site in many cases.

Many trees of DBH less than 10 cm are cut for firewood. To maintain a high level of biological productivity and to promote energy efficiency, it would be desirable to grow stands to be cut at DBH of some 10 cm.

Firewood production area are also being used as the settlement, farming and grazing areas by the inhabitants. Therefore, the firewood production stand should be established within or near the areas where farming and grazing are permitted. On the contrary, settlement

and farming should be prohibited in the timber production area. The area of firewood production stand should be calculated by considering factors such as the history of land use, soil condition and population of approved inhabitants, and should be clearly demarcated.

10.6.4 Restoration Area

This area has to be set at stands of dwarf teak in order to restore the original stands which grew in the area, mainly those of *Baikiaea plurijuga*. It is said that the low height (roughly 1 m) of dwarf teak is because of repeated fires. The sprouts of *Baikiaea plurijuga* were numerous and in one place more than 30 sprouts were observed growing from a single stump. It is essential to prune low quality sprouts and to leave only a few sprouts of good quality.

After pruning the stand would have a high possibility of developing large trees if there is no fire damage afterwards. It is important to actually carry out the pruning and the necessary follow-up survey at the pruned stands, in order to establish a suitable tending method. In the meantime, as described in the chapter on soil survey, there is a possibility that soil could be a factors responsible for the formation of dwarf teak stands. This issue will be a subject for research in the future.

10.6.5 Safari Area

In principle the safari area should be protected as indigenous forest. It is important to protect the subject area as a core zone while taking the vicinities into account as buffer zone. In the buffer zone arrangements to minimize cutting activities will be required when the timber production is undertaken. From the viewpoints of both humans and wild animals settlement and farming should be prohibited in the buffer zone.

10.6.6 Protection Area of Genetic Resources of Useful Species

As stated in the section on timber production area, the useful tree species (*Pterocarpus angolensis* or *Guibourtia coleosperma*) of large-DBH sizes and a high quality had been cut preferentially. This has resulted in a significant decrease in the number of these trees and their young regenerations. Areas where these trees decreased significantly should be preserved as protection area in order to preserve useful species and prevent genetic degradation. In the protection area good quality mother trees should be protected and stands containing a large number of such mother trees should be demarcated and designated as protection area. If the protection area is set for *Pterocarpus angolensis* and *Guibourtia coleosperma*, other useful and good quality tree species such as *Baikiaea plurijuga* or *Brachystegia* spp. should also be protected. Protection should not be

restricted to *Pterocarpus angolensis* and *Guibourtia coleosperma* but many tree species having good genetic qualities should be protected too. In the compartments to be designated as the protection area, clearing of individual trees having bad genetic quality should be taken into consideration at the time of the designation. This is to insure that the trees will not have a negative influence on regeneration. Such operation aims to increase the ratio of individuals with good genetic quality.

The phenotype does not necessarily correspond to genotype. However, a better phenotype corresponds to a better genotype with high probability. The operation to leave individual trees having better phenotype by removing the trees of undesirable phenotype would conform to the conservation of good genetic qualities. After setting the protection area, the cutting should be prohibited unless it is necessary in terms of protection. Naturally commercial cutting should be prohibited.

10.6.7 Soil and Water Conservation Area

This area will be designated in forests growing along rivers, where the cutting is prohibited in principle. Whether specifically designated long compartments along rivers should form soil and water conservation area or it should be incorporated in blocks along rivers should be examined carefully.

10.6.8 Relationship of Functions

Seven categories of areas by function, categorized from the viewpoint of their important functions, were described in 10.4 and 10.5 for the Gwaai and Bembesi Forest Lands. But if the timber production area is managed in a sustainable way, other functions such as soil and water conservation, wildlife (biodiversity) and genetic resources protection could also be secured in a coexisting manner. On the other hand wildlife protection could be secured with soil and water conservation in a similar manner. It is important to organize the functions to coexist or tune without detriment to each function by taking mutual relationships between them into account. Therefore, the application of an appropriate method of forest management in timber production area is very important if forests are to function in an integrated manner. Such management will contribute to promotion of capability of sequestration and pool of carbon and mitigation capability with regard to climatic change. In any case the most important issue is not to decrease forest area and bring down the target quality of forests no matter which function is required first.

10.7 Fire Protection Measures

(1) Current Situation of Forest Fire

Forest fire is the main concern with regard to the management of state-owned indigenous forests. Human action is responsible for roughly 90% of fires on the Survey Area. Approximately 18.6% of the forest area in the Survey Area had been damaged by fire annually between 1990 and 1993 (refer to Table 4 – 1). If the Intensive Area suffers the same ratio of fire damage, it will mean the damage to some 10,000 ha (out of 55,000 ha Intensive Area) of forest annually.

As was observed in the field, forests throughout the Intensive Area are damaged by fire. It is said that ground fire is the main form of fire occurring in the area and it seldom develops to crown fire. The reason why the frequent ground fires do not cause severe damages in many sites is that fortunately most of useful tree species like *Baikiaea plurijuga* have a certain resistance to the fire. In the case of *Baikiaea plurijuga*, its thick stem bark protects it from fire. There were some trees that showed no traces of damage by ground fire because the newly grown barks may have replaced the burnt barks. However, there were many trees with scars on their stems near the ground due to fire. But probably many trees will not die even though they are severely damaged by fire.

(2) Influence on Volume Increment

One of the most significant effects of fire in the area is the damage to young trees of useful tree species. Though there is no exact data on the number of young trees burnt, it is assumed that young trees most vulnerable to fire are those with a height of 2 m or less. This means that tree of which age is up to 30 years are at a high risk of being damaged by fire.

Even in the case of trees of which the DBH was larger than 10 cm there were some trees which were seriously damaged by fire. The damaged trees will have a suppressed growth as the result of the loss of a part of their cambium.

(3) Fire Protection Measure

A key fire protection measure is not to cause fire in the first place and to have the people prevent fire because the main causes of forest fire in the area are human activities. From this viewpoint, the understanding by and cooperation of the residents, which were supposed to be obtained through SFM project are essential. In addition, the grazing lease could be used as a leverage to make fire protection mandatory in exchange for grazing

benefits.

The newly established roads for demarcating compartments should help facilitate fire protection by acting as fire guards and providing access for fire prevention and action. To enhance the firebreaking role of the roads, the enlargement of the roads width should be considered as an option.

10.8 Future Research Topics

As described in 10.2, the most important issues for forest management in the Intensive Area are allowable cutting volume, tending operation and fire protection. Specific measures regarding each issue were described earlier. Here the related issues to be researched in the future are examined as follows.

(1) A Correct Understanding of Increment

A correct understanding of increment is necessary to set the allowable cutting volume. This should be examined both in terms of a single tree and the stand.

(a) Single Tree

The stem analysis and the continuous monitoring at the permanent plots will necessary. Especially mean annual increment as well as current annual increment are to be measured.

(b) Stand

The permanent plots should be surveyed by applying control method periodically in order to identify stand growth, which is needed for setting allowable cutting volume.

(2) Understanding of Natural Regeneration Condition

Natural regeneration should be investigated in the same plots established for increment survey. The regeneration seedlings should be monitored with regard to yearly growth.

In the protection area of genetic resources of useful species, regeneration monitoring is stressed because the regeneration will take place only naturally. When the results of natural regeneration are not promising, investigation of the causes of failure and conducting supplementary operations should be considered.

(3) Establishment of Artificial Regeneration Technology

Followed by the establishment of seedling production technology for each tree species, silvicultural technology should be developed with regard to enrichment. This issue is of a particular importance for trees of which mother trees are decreasing such as *Pterocarpus angolensis* and *Guibourtia coleosperma*.

(4) Establishment of Tending Method

A continuous survey of the stands of dwarf teak is necessary following the sprout improvement operation in order to promote the development of mature forests. The possible factors responsible for the formation of dwarf teak stands are said to be fire and drainage condition. If the development to a mature forest is difficult by conducting only the sprout improvement operation, other tree species like *Pterocarpus angolensis* and *Guibourtia coleosperma* could be planted also. In that case the said artificial regeneration technology will be helpful.

(5) Possibility of Designating as Permanent Plots some of the Forest Survey Plot Established under this Survey

The whole Survey Area has been disturbed by cutting or forest fires since the early 1900s. Therefore, the current forest conditions are due to the mix of human intervention and natural conditions. If background / history of forests in the area is clarified more, it could be used as an important element for the design of permanent plots.

If forest conditions such as stand density, tree height and DBH prior to cuttings conducted in the past are known, the data could help identify the outline of target forest condition for the future. However, such data are unavailable.

The continuous survey on the forest survey plots having typical forest condition will be effective source for the said data.

In the forest survey plots, representing the current situation, extremely large, extremely small and average total volume, timber volume, average DBH and average height were as shown in Table 10 – 14.

Table 10 – 14 Plots Representing the Current Situation

Forest Factors	Extremely Large	Average	Extremely Small
Total Volume Timber Volume	H55, S67, H13,H56	H52, S01, S04, S29, S54	H59, H65, H68, S28, S30
Ave. DBH Ave. Height	H17, S52, H55, S48, S58, S59	H01, H07, H45, H54, S20, S23, S25, S39, S45, S47, S51, S54	H35, H39, H68, S08, S19, S30

Besides the above plots, the forest survey plots containing trees having highly abnormal barks, stems or leaves are the two plots mentioned in Table 10 – 15. Both plots are heavily grazed and are located along Victoria Falls road. These plots could be designated as permanent plots representing the stands where human intervention is strong.

Table 10 – 15 Plots where Human Intervention is Strong

Plot No.	Forest Conditions
S41	Stems of some standing trees of *Baikiaea plurijuga* had cracked bark in scaly manner on thin hollow. Or the cambium layer was almost dead.
S59	*Guibourtia coleosperma* trees were frequently observed affected by a certain disease resulting in sap exuding from their cracked stem barks, and black spots appearing on their leaves.

The permanent plots should be established in the locations that can be easily supervised and maintained by the FC personnel (or where human intervention can be excluded). Therefore, the area should be around the Forest Hill Office could be a suitable site.

10.9 Necessary Conditions for Implementation of the Recommended Forest Conservation Plan

(1) Creating a Common Understanding Between the Forest Residents and the Inhabitants from the Surrounding Communities

The involvement of the people living in forests and in the surrounding areas is indispensable for the successful management of forests in Gwaai and Bembesi Forest Lands. This is because these people are related to each other and to the forest in various ways. A part of the people from the surrounding communities were the former forest residents who migrated to the surrounding areas, or are the relatives of the forest residents. Moreover, they have similar customs, habit and values, and utilize the forest land as

grazing area for their livestock and procure thatching grass or firewood from the forest.

But there is a conflict of interest between the forest communities and the surrounding communities. Therefore, collaboration among the two communities will involve many thorny issues. The SFM project supported by DFID undertook the approach of shared forest management. A combination of "improvement of status quo" and "voluntary relocation" was proposed by the project. The forest residents use the social infrastructure in the communal lands or resettlement area around the forest lands because currently no infrastructure is available in the forest lands. Some people in the forest community tend to think the use of social infrastructure of the surrounding areas as the compensation for the use of forest resources by the people of the surrounding communities. If social infrastructure are provided to the forest residents under the SFM project, the residents may demand that people from the surrounding communities pay for the use of forest produces, or even they oppose the use of forest by the surrounding communities.

Up to now the people of the surrounding communities used and benefited from forest resources. If these people are not properly involved, the task of forest management will be complicated. Therefore, the FC needs to make efforts to reach into a common understanding with the people based on discussions involving the forest residents, the inhabitants from the surrounding communities and the officials from the FC. A common understanding among all stakeholders will facilitate forest management. The legal system needs to be strengthened to assist the development of a common understanding because the stakeholders may have different priorities and interests which could develop full-scale confrontation. Thus it may be useful to consider customary conflict resolution regimes and organizations.

(2) Improvement of Social Infrastructure

Currently the FC has neither financial capability nor expertise for infrastructure improvement. Donors may assist in building the needed social infrastructure for the forest residents, but the future improvement, development, maintenance and management of the infrastructures can be ensured only by involvement of the forest residents and relevant government bodies as well as the FC.

(3) Extension

A sustainable timber production is needed as the financial source for the maintenance and management of the said infrastructure. On the other hand, the residents should recognize the importance of such sustainable forest management and learn the relevant technical skills. Consistent extension and education activities should be conducted to achieve these

goals. The extension activities should cover not only forest management but also farming and livestock raising. Improving the living conditions of the residents through introducing improved production technologies, could generate insentives for stopping poaching of wild animals and trees. Also the cooperation of the residents could be obtained for prevention of poaching.

(4) Job Creation for the Inhabitants

The system to improve the livelihood should be strengthened to improve the living conditions by generating jobs through forest management, farming and grazing. It is very important to convince the inhabitants to protect forests themselves while providing them with income from jobs such as seedling cultivation, planting and cutting.

(5) Promotion of Forestry

The promotion of forestry is necessary for job creation for the residents. However, great efforts have to be focused on how benefits can be obtained from the forests which seem to lose high quality and large diameter trees that were already cut, while securing sustainable production. For this to happen the prices of timber produced from state forests should be raised and these products should be sold at those by higher prices.

Annex