EU – Forestry Support Programme in Zambia – 8 ACP/ 051

Zambia Forest Resource Assessment 2004

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Executive Summary

1. Based on 40 satellite images over Zambian land area, on total of 1908 new sample plots spread over all Zambian provinces, and on latest gazetted forest produce fees and prices, a new estimate for Zambian forest resource was produced.

2. The forest lands proper were stratified in the satellite images into High Density Forest, Medium Density Forest and Low Density Forest. They cover altogether 30.1 mill. ha, 40 per cent of the Zambian land area. Trees growing outside forests, mainly as agroforests, cover additional 3.4 mill. ha. The total forested and wooded area is 33.5 mill. ha (45 %).

3. The tree stocking varied from 325 trees / ha (Eastern Province) to 885 trees / ha (Northern Province). The most commonly encountered species was *Brachystegia boehmii* (for instance 98 trees / ha in Northwestern Province). The occurrence of high-valued species like *Pterocarpus angolensis, Baikiae plurijuga* and *Guibourtia coleosperma* was low, especially in the large diameter classes 30-40 cm and over 40 cm. *Pterocarpus angolensis* was found in all provinces except Lusaka, but its occurrence in the large diameter classes was only 1-2 trees / ha. This limits practical forest management possibilities in the near future.

4. The mean woody biomass volume in the forest sample plots varied from 36.1 m^3/ha (Low Density Forest in Eastern Province) to 157.3 m^3/ha (High Density Forest in Copperbelt Province). Sampling intensity was low (on average 0.0004 per cent). Variation in the sample plot data was on average high. The standard error of the mean volume varied from 3.6 per cent to 46.3 per cent.

5. Based on provincial forest areas and provincial mean wood volumes, the total wood volume in Zambian forests proper was calculated at 2683 mill. m^3. The low wood volume (95 % statistical probability) is 1738 mill. m^3 and the corresponding high wood volume 3634 mill. m^3. The wood volume in agroforest lands was estimated at additional 17 mill. m^3. The total woody biomass resource in Zambian forests and wooded lands was estimated at 2700 mill. m^3.

6. The wood volume in the forest lands proper (2683 mill. m^3) divides into boles (749 mill. m^3), poles (399 mill. m^3) and other assortments, mainly fuel wood (1535 mill. m^3). Using gazetted 2003 forest produce fees and prices for various wood assortments, the total value of all trees in the Zambian forest resource was estimated at 102 trillion Zambian kwachas. The corresponding average value of forest hectare is 3.40 million kwachas per hectare, or 563 Euro or 715 USD per hectare.

7. The total wood volume of the gazetted high-valued trees is 1105 million m^3, out of which the share of boles is 294 million m^3. Assuming that a) sustained annual takeover of boles can be one per cent, b) low volume (based on 95 % low mean) is used, c) national parks and other protected areas are left out, and d) all the license fees for high-valued bole wood are annually collected, the estimate for the potential annual wood resource revenue is about 100 billion kwachas per year, or about 20 million USD per year.

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Preface

Zambia Forest Resource Assessment 2004 was carried out during the period August 2003 – March 2004. The assessment consisted of satellite image interpretation, analysis of recent (1996-2002) forest sample plot data, field measurement of new (2003-2004) forest sample plots in several provinces, analysis of new and combined field data and reporting. The assessment contained two field missions to Zambia, the first between 29 August – 22 September 2003 and the second between 12 January – 31 January 2004.

The forest sample plot exploration missions were completed (in Northwestern Province) on 7 Jan 2004. After that the January 2004 computation round consisted of altogether 1908 sample plots. Based on the computation the first estimate for Zambia total woody biomass volume, allowable cut and sustainable forest revenue were calculated. The results were discussed in the debriefing seminar of 30 January 2004 in the Department of Forestry. Based on that seminar the first draft report was written on 14 February 2004. This version has been further developed from the first draft.

During my two field missions to Zambia valuable discussions were held in Lusaka with the forest inventory team of the Department of Forestry. I want to thank Mr. Abel Siampale especially, for the good co-operation in various computing stages of the forest resource assessment. Another set of thanks belongs to the field team leaders Ms. J. Masinja, Mr. J. Mukosha, Mr. J.K. Mulomba, Mr. H. Musitini, Mr. E. Nonde and Mr. Y. Nyirenda.

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1 Introduction

11 Background

Zambia is relatively richly forested country in the Sub-Saharan Africa. Among the SADC-countries (Southern African Development Community) it belongs to the same group with Angola, Mozambique and Tanzania that are well-known for their abundant *miombo*-type forests (SADC 1997). Original *miombo* –forests are well known for their biodiversity and ecological value in Zambia as well as in the neighboring countries (Chidumayo 1997).

Despite the abundant forest resource and its importance to the local and national economy, forest resource assessments over the Zambian land area are only few. This is depicted also by the Zambian National Forest Policy from 1998, which states that "it is indeed unfortunate that no comprehensive forest inventory has been undertaken in the last three decades".

A comprehensive forest resource assessment has three components: 1) the forest area, 2) the woody biomass quantity growing on it, and 3) the current financial value of the forest resource. The literature does not know a comprehensive assessment for Zambia. Most often the Zambian forest area only has been assessed, and just in a couple of cases the assessment into the quantity of the woody biomass has complemented the forest area estimate.

The extent of the total area of the Zambian forests and woodlands has been assessed regularly in the history. Frequently quoted "semi-official" figure for the Zambian forest area is 44.6 million hectares, from the Zambia Forestry Action Programme (ZFAP 1996, Chileshe 2001).

Zambia Forestry Action Programme estimated the total woody biomass volume at 4202 million cubic meters. The ZFAP-study assessed only the total woody biomass. No attempt was made to split the total volume within tree species, nor at least between the high-valued (in the sense of commercial and export quality saw timber) and the low-valued (others, suitable mainly for fuel wood only) species. Very little is known about the national occurrence of the high-valued timbers *Pterocarpus angolensis* (mukwa, African teak) and *Guibourtia coleosperma* (mushibi, African rosewood). For instance, in which provinces do they grow, what is the amount of their woody biomass and bole wood resource, and are the trees distributed soundly between the young (small) and old (large) trees?

The European Union Forestry Support Programme (EU-FSP) is supporting the transition of Zambian Forestry Department into a proposed Forestry Commission (ZAFCOM). Part of the Forestry Support Programme is to reassess the Zambian forest resource by its area and by its stocking of woody biomass.

The coming Forestry Commission has been planned to be self-sustained by its finance. The revenue basis for the financing is the Zambian woody biomass resource, especially the revenue from the high-valued tree species. An immediate channel of funding the new Forestry Commission would be to transfer the sales of harvesting licenses for the most desired species from the Treasury in the Government of Zambia to the Forestry Commission. The viability of such a plan assumes that the demand of good quality sawn timber from the high-valued tree species, for national consumption and for export market remains continuously high. A stabile revenue flow into the Forestry Commission is a prerequisite of the plan. A key question for planning the coming Forestry Commission is therefore: Is the annual revenue from the license fees sufficient and sustainable to cover the annual expected costs of the Commission?

In order to determine the potential of the revenue collection the current state of the forest resources and the sustainable level of utilization need to be assessed. The forest resource assessment directly provides information that serves the overall objective of the Forestry Support Programme, namely “Forest resource used in a sustainable way” by determining the amount, the value and the limits of sustained use of the forest resource. Comprehensive forest resource assessment provides also information on the current state of biodiversity conservation in Zambian forests. Valuable information is collected on the rare and vulnerable species: their occurrence and their regeneration in the forest areas exploited by harvesting, shifting cultivation and agroforestry practices.

The inventory results will be used by the proposed Forestry Commission as basic information for planning its financial base, and further in planning the forest management and utilization activities of the Commission. The Provincial forest offices and also other Province administration units and further District administration offices will benefit from the assessment, as they will have new information of the forest resources of the Province and Districts. Other interested parties of the inventory results will include the users of the timber i.e. pit sawyers, saw-millers and other industrial users.

12 Target and scope

The forest management and biological target of the forest resource assessment is to produce a new quantitative and qualitative estimate for Zambian forest resource. The assessment is to be comprehensive. It must estimate new total area for the Zambian forests and wooded lands. It must update the quantity of the Zambian total woody biomass volume, split into tree species. And it must assess the financial value of the Zambian forest resource.

By geography, ecology and biology the study is first targeted on the latest satellite image information in order to determine a new area of the forest cover of Zambia. Second, the study is to be based on new ground truth (forest sample plot) measurements to provide fresh field data from various land classes determined by the satellite imagery. Thirdly, the forest sample plot measurements must provide information on distribution of the woody biomass into different tree species, especially into high-valued tree species, in the sense defined by the Zambian Forests Act.

The economic target of the forest resource assessment is to convert the forest management and biological data into monetary units (primarily into Zambian kwachas, secondarily into Euros and US dollars). This is to assess the total monetary value of the Zambian woody biomass resource, the potential of the sustainable annual monetary takeoff from the resource, and finally, the annual revenue range from high-valued timber species based on which the financing of self-sustained Forestry Commission could be budgeted.

The geographical scope of the study is the whole land area of Zambia, first split into the nine provinces of the country and then summed up into the national level. The forest management and biological scope of the study is the whole woody biomass resource as distributed into different tree species and into different wood assortments. In a single tree level the scope of woody biomass is in all woody material above the stump: in the stem and the branches, but not in the leaves.

2 Review past forest resource assessments Zambia

Organized forestry and forest management in Zambia started in the beginning of 1930s (Fushike and Mukosha 2002b). As anywhere else in the Sub-Saharan Africa, the early interest was in plantation forestry. The magnitude of the indigenous *miombo* –forest was, however, in Zambia so vast and such a number of valuable tree species grew in the forest, that an early interest arouse also in determining the productivity of this already available resource.

The first forest mensuration and inventory attempt in the indigenous *miombo* –forest was to establish sample plots between 1932 and 1936 near Ndola in the Copperbelt Province. This was related to the mining industry, which was growing into economic backbone of the country. The mining industry in Copperbelt Province needed forest inventory information on the available timber volume to be used as construction poles in the mines.

The increasing need of information leaded also to the first large-scale forest inventory. It was carried out in Copperbelt Province between 1942 and 1944. Another large-scale forest inventory was carried out in the Western Province at the end of the decade (1949 – 1951). This was to locate and assess the availability of sawn timber for concession harvesting. A special interest was in the Zambezi teak (*Baikiaea plurijuga,* mukusi). Since Livingstone's times (1857) Zambezi teak had been the most valuable timber resource in the area. The role of Zambezi teak has been central as raw material for railway sleepers besides Zambia in whole Southern Africa (Löyttyniemi 1988).

During the period 1952 – 1967 the forest inventories became more systematic. They were aimed to cover also other parts of the country than Copperbelt Province and Zambezi teak areas. There was an overall process to decentralize the colonial administration and this affected also the forest management. District became the unit of Forestry administration, and the forest inventories were done at district level. The forest inventory information was gathered into voluminous and massive District Forest Management Books (Forest Department 1965). The books have later been archived in the new offices of Department of Forestry in Ndola and Lusaka. The detailed forest inventory information found in the District Forest Management Books has been the baseline data for almost all later forest resource assessments in Zambia.

The first rigorous assessment of the total woody biomass volume in Zambia was done in the mid 1980s (de Backer et al. 1986). This happened in conjunction with the Wood Energy Consumption and Resource Survey. De Backer et al. used forest area of 61.2 million hectares in 1965 from the District Forest Management Books, as a reference point. Using various assumptions for the annual decrease in the forest area since 1965, estimates for the forest (wooded) area and growing woody biomass stock were derived (Table 1).

Table 1. Estimates on total forest area and growing woody biomass stock in Zambia in 1985 (de Backer et al. 1986). The method is extrapolation from 1965, based on various assumptions about forest decimation.

Since reference point 1965	Wooded area, mill. ha	Growing stock, mill. m^3
Annual decrease 0.5 %	55.2	4100
Annual decrease 1.0 %	50.2	3700
Forest Department Report 1985	46.1	3400
“Lowest possible”	41.2	3000

The range of forested and wooded area was between 41.2 – 55.2 million hectares. The corresponding estimate for the total woody biomass volume, the growing stock, varied between 3000 – 4100 million cubic meters.

The second assessment on Zambian woody biomass resource was done outside Zambia, independently from District Forest Management Books. The assessment was based on large scale remote sensing and satellite imagery analysis. The satellite imagery was obtained to cover the whole Southern African SADCC-region.

A Dutch foundation, ETC, specialized on new satellite image technology, published a wood energy study on estimated woody biomass resources, country by country in the SADCC –region (Erkkilä 1989, ETC Foundation 1987). The study concluded that the Zambian share of the SADCC woody biomass resource was 2600 million dry tons. At average basic density of 714 kg/m^3 for Southern African indigenous forest trees the dry woody tons correspond to 3640 million cubic meters of wood volume. The independent ETC-estimate fell thus well in the woody biomass growing stock range of de Backer et al. (1986).

The third assessment of Zambian woody biomass resource was done in conjunction with the Zambia Tropical Forestry Action Programme (ZFAP 1996). The reference point was again the District Forest Management Books of 1965. Based on them, on other available information over the consequent 30 years and on computer simulations Alajärvi (1996) made a thorough analysis for ZFAP, province by province, on the Zambian forest areas and growing woody biomass stock. He concluded that the total area of forests and wooded lands is 59.5 million hectares. The total growing woody biomass stock would be 4202 million cubic meters (Table 2).

Table 2. Zambia Forest Resource Assessment 1996, prepared for Zambia Forestry Action Programme (ZFAP 1996).

Province	Forest lands proper, mill. ha	Forests and wooded lands total, mill. ha	Growing stock mill. m^3
Central	5.56	7.54	474
Copperbelt	1.75	2.41	274
Eastern	4.71	5.82	410
Luapula	2.50	4.52	115
Lusaka	1.38	1.74	70
Northern	8.81	11.94	376
Northwestern	7.38	9.01	1156
Southern	4.66	6.63	314
Western	6.89	9.92	1013
Zambia	43.64	59.53	4202

Out of the total 59.5 million hectares the forest lands proper cover 43.6 million hectares and the lands with "trees outside forest" 15.9 million hectares. The growing woody biomass stock in forest lands proper was 4122 million cubic meters and in the other wooded lands 80 million cubic meters.

Soon after Zambia Tropical Forestry Action Programme a new estimate for Zambian forest area was prepared for United Nations through Southern African Development Community. The conference report for the fifth session (April 1997) of the United Nations Commission on Sustainable Development states that coverage of Zambian forests is 39 per cent which equals to 29.4 million hectares (Strid 1997). The basis for the assessment has not been given in the report.

Chidumayo (1997) reports in his textbook on Miombo ecology and management that the total area of Zambian forests and miombo woodlands is 44.0 million hectares. There is an additional 9.6 million hectares of "savanna woodlands". Thus the total area of forests + miombo woodlands + savanna woodlands would be 53.6 million hectares. Also these area estimates are based on extrapolations from older sources (Chidumayo 1994) and thus related to ZFAP – estimates.

The latest estimate for the forest cover in Zambia was calculated for FAO Global Forest Resources Assessment 2000 (FRA 2000). Also this assessment originated partly in the District Forest Management Books of 1965, although also rough scale satellite imagery was used. Other reference points for extrapolations were given by de Backer and Chakanga 1986 (reference year 1974) and Mukosha and Wamunyima 1998 (reference year 1993).

FRA 2000 states that the Zambian forests cover 31.2 million hectares. The assessment is well documented and available in internet (www.fao.org). No information on woody biomass resource as per volume or dry ton basis is, however, given.

In the late 1990s and early 2000s a series of new forest inventories was initiated and carried out by three forestry co-operation programmes: Provincial Forestry Action Programme (PFAP), Environment Support Programme (ESP) and Forestry Support Programme (EU-FSF). In the beginning at least, these programmes did not aim at comprehensive national forest resource assessments. The PFAP interest, especially, was rather in provincial level and in the well-stocked Forest Reserves. In the course of time the inventories have widened the scope from Forest Reserves to cover also Open Areas and Game Management Areas. It was the Forestry Support Programme which again set a target to get forest resource assessment done also at national level.

The synopsis on the development of forest inventories over the period of past 70 years has been summarized in Table 3.

Table 3. Synopsis on the development of Zambian forest inventories 1932-2004.

Period	Inventory or activity
1932 – 1936	Sample plots established near Ndola to determine the productivity of *miombo* woodland.
1942 – 1944	The first large-scale forest inventory for locating and estimating the timber volume availability for the Copperbelt province mines
1949 – 1951	Large-scale forest inventory for locating and estimating the timber volume for the Western province concession harvesting.
1952 – 1967	Large-scale inventory for District Forest Management Books
1972	Copperbelt province woodland survey
1977	Timber and woodland survey of East Luangwa PFA No. 170
1984 – 1986	First estimate on Zambia woody biomass resource: Wood consumption and supply survey at National level
1987	Second estimate on Zambia woody biomass resource: SADCC-countries wood energy study based on large-scale satellite imagery
1994 – 1996	Forest resources management study for Zambezi teak forests in South-Western Zambia in co-operation with Japan International Cooperation Agency (JICA)
1996	Third estimate on Zambia woody biomass resource: forest resource assessment for
1996 – 1998	Forest inventories in Copperbelt, Luapula and Southern Provinces under Provincial Forestry Action Programme, Phase I (PFAP)
1997	SADC estimate for Zambian forest area: 29.4 million hectares
1999 – 2001	Forest inventories in Copperbelt, Luapula and Southern Provinces under Provincial Forestry Action Programme, Phase II (PFAP)
2000	FRA 2000 (FAO) for Zambian forest area: 31.2 million hectares
2001	Forest inventories in Central Province under Environment Support Programme (ESP)
2002 – 2003	Forest inventories in Copperbelt, Eastern, Luapula, Lusaka, Northern, Northwestern, Southern and Western Provinces under Forestry Support Programme (EU-FSP)
2004	Fourth estimate on Zambia woody biomass resource: Forestry Support Programme (EU-FSP)

The separate forest inventories have been reported in sub-reports under the concerned programmes. Altogether 16 subreports have been completed (Table 4). The most rigorous of the forest inventories was without doubt the one for Zambesi teak forests. That inventory has been documented in three volumes (JICA 1996a, JICA 1996b, JICA 1996c).

Table 4. Summary on separate, reported forest inventories carried out in selected Forest Reserves, Pilot Forests, or at reconnaissance level in selected Provinces 1996-2003. For complete report information see References.

Author or team	Inventory site
Chisanga et al. 2002	Katanino local forest, Copperbelt Province
Chisanga et al. 2002	Shibuchinga pilot forest, Copperbelt Province
JICA 1996	Zambezi teak forests, South-Western Zambia
Junnikkala et al. 2002	Western Province
Mukosha et al. 2002	Southern Province
Mukosha 1997	Chibwe Forest Reserve, Central Province
Mukosha 1997	Copperbelt Province
Mulomba et al. 2002	Dambwa local forest, Southern District
Musitini et al. 2003	Ndondi local forest, Southern Province
Nyirenda 1997	Luapula Province
Phiri 1996	Mulungushi West Forest Reserve, Central Province
Phiri 1996	Mwewa forest reserve, Luapalua Province
Siampale 2001	Lukangaba forest, Luapula
Siampale 2003	Western Province
Wamunyima 2001	Chaba forest, Central Province
Wamunyima 2001	Myafi forest, Central Province

Since compilation of the District Forest Management Books of 1965 the separate forest inventories were the first which gave also new information on the actual condition of forests in the field. They gave also other information than just forest areas.

The mean wood volume in cubic meters per hectare is the useful piece of information which can be drawn from the separate forest inventories for later comparisons between forests, provinces and between consecutive time points. The mean wood volume varied from 36.2 m^3/ha (Mulungushi in Central Province) to 270 m^3/ha (Mongu, Senanga Shangombo and Sesheke in Western Province), revealing the considerable variation inside the country (Table 5).

In some inventories the tree stocking, in stems per hectares, has also been presented. It varied in the reported cases between 350 – 2230 trees per hectare. In a typical well-stocked, mature *miombo* –forest the trees may grow on average four meters apart, that is, the trees stocking is 625 trees per hectare.

Table 5. Some average stand characteristics in the separate forest inventories of 1996-2003.

Forest name or inventory identification	Province	Mean volume	Stocking
		m^3 / ha	trees/ha
Chaba	Central	90.5	374
Chibwe	Central	101	
Mulungushi West No 423	Central	36.2	1920
Myafi	Central	108	352
Katanino	Copperbelt	186	
Shibuchinga	Copperbelt	114	
Lukangaba	Luapula	132	665
Mwewa P 174	Luapula	121	2150
Dambwa	Southern	38.4	
Ndondi	Southern	66.9	
Mongu, Senanga, Shangombo, Sesheke 1.	Western	95.5	
Mongu, Senanga, Shangombo, Sesheke 2.	Western	270	2230
Mulobezi / Sesheke, average	Western	67.6	
Mulobezi / Sesheke, forest proper	Western	95.3	
Mulobezi / Sesheke, woodland	Western	52.1	

All inventory field data, except in the Japanese funded Mulobezi / Sesheke measurements, were analyzed with the same software (ForestCalc). Thus the results are comparable and compatible with each other. This data was also included as original source information for the Zambia Forest Resource Assessment 2004.

3 Forestry Support Programme forest resource assessment

31 Assessment background

In 2003 Zambia had four donor-funded, on-going forestry-sector projects. All of these have been anticipated to collect some type of forest resource inventory data. The data sets that have been collected fall broadly into two groups: into those that have been targeted at large scale assessments (provincial and district level), and into the others that are at the single forest level – generally intended for community-linked management programmes. The forest information bits and pieces collected in that way are valuable additional source data. Based on such scattered information a comprehensive picture of the Zambian forestry resource in the beginning of 2000s cannot be formed. There are also large areas of Zambia, particularly the North-Western, Northern, Lusaka and Eastern Provinces, where there are few or no recent forest inventory records.

Since the beginning of 2002 the Forestry Support Programme has been working for a realistic appreciation of the status, value and sustainability of the Zambian national forest resource. A part of the programme is to support the development of forest resource inventory system for comprehensive forest resource assessment. In order to determine the potential revenue collection, the current status of the forest resources and a sustainable level of utilization need also to be assessed.

The time for a comprehensive forest resource assessment was limited so that the field work had to be ready by the end of 2003. Forestry Support Programme has been scheduled to prepare the final Forestry Commission plans by mid 2004, and the new Forestry Commission has been planned to be operational already by mid 2005 (FSP 2003). The time able set the frame for the forest resource assessment. Such a rapid forest resource assessment is by nature reconnaissance type.

32 Task Force 2002

The Forestry Support Programme mandated in the beginning of 2002 a Task Force in the Department of Forestry to prepare necessary preliminary steps in order to start comprehensive national forest resource assessment along with the Programme Document. The Task Force had first to assess the current sources and availability of forest inventory data and information. Next, the Task Force had to present in an action plan how to fill the existing gaps so that an effective management information system with all the necessary data and information is in place when the Forestry Commission starts functioning as an autonomous institution (Fushike and Mukosha 2002a). The work of the Task Force was summarized (Fushike and Mukosha 2002b) and it led to the next step, reconnaissance level forest resource assessment in Western Province (Junnikkala 2003).

33 Western Province reconnaissance survey 2002

Since there was very little provincial information on forest resources in the Western Province, it was selected as the site for reconnaissance level inventory. Based on the experience that could be collected in the reconnaissance level survey, the pilot inventory was to be followed later by more thorough forest inventory. Another justification for selecting Western Province was that there was basic remote sensing information available in the Department of Forestry. A set of already procured satellite images from 1990-1992 covered almost the whole Western Province.

Quite a substantial district level forest inventory had, however, been done on Western Province. The Zambesi teak (*Baikiaea plurijuga*) forests had been studied in 1994-1996 in the Sesheke district in a project funded by Japan International Cooperation Agency (JICA 1996a, JICA 1996b, JICA 1996c). Under that project a forest inventory book covering part of the Sesheke district was published. Also tree volume functions and yield tables as well as preliminary calculations on annual allowable cut were prepared. The Sesheke district forest inventory was a valuable reference point for later assessments in Western Province.

Forestry Support Programme implemented in November 2002 a reconnaissance survey in the Western Province, covering Mongu, Senanga, Shagombo and Sesheke districts. Altogether 26 new forest sample plots were measured and 15 ground truthing plots for satellite image interpretation were assessed in the field (Junnikkala and Siampale 2002). The mean forest inventory characteristics of the plots are shown in Table 6.

Table 6. Mean characteristics from the reconnaissance level forest inventory in Western Province in 2002. Number of plots 26.

	Low 95 %	Mean volume	High 95 %	Std error
	m^3/ha	m^3/ha	m^3/ha	per cent
Stand volume	4.6	95.5	325	93
Bole volume	0.9	28.6	134	109

The sample size, 26 plots was very small for the whole Western Province. The sampling intensity (total area of sample plots / total area of forests, in per cent) was only 0.0003 per cent. However the natural variation that exists in the forests, was captured quite well. Most of the vegetation classes of Western Province were visited during the reconnaissance mission.

The small sample size resulted also in a considerable high variation in the results. The relative standard error of the mean was 93 per cent for the mean stand volume and 109 per cent for the mean bole volume. Such high variation pinpointed that in the forthcoming inventories a special consideration is to be given for increasing the number of plots to reduce the standard error and to make the confidence limit narrower around the mean.

Based on the reconnaissance survey a Forest inventory plan for the whole Western Province was prepared (Junnikkala and Siampale 2002). The plan also recommended that a new set of Landsat 7 images out to be acquired for the inventory exercise to replace the old images from 1990-1992. Based on the plan another forest inventory exploration mission was sent to Western Province in the first half of 2003 (Siampale 2003).

34 Satellite image interpretation

341 Image source

Following the recommendation from the Forest Resource Assessment Task Force (Fushike and Mukosha 2002) and the Western Province reconnaissance survey (Junnikkala and Siampale 2002) a complete set of Landsat 7 images over Zambian land area was collected or acquired from various sources. Some of the images were already available in the Forestry Department through Provincial Forestry Action Programme (PFAP), Environment Support Programme (ESP) and Forest Resources Management Project (FRMP). Forestry Support Programme procured altogether 16 additional new images.

Following the numbering rule of Landsat 7 the images over Zambia fall into the paths 169 – 176 and into the rows 066 – 072 (Landsat 7, 2004). The land area of Zambia could be covered with altogether 40 images. The major part of the images was from 1999 – 2002 (the earliest from 9 Sep 1999, the latest from 9 Jul 2002). Four images were a decade older:

171-071 from 1989
170-070 from 1990
174-072 from 1990
170-067 from 1991

In order to get a complete cover over the land area the four older images were mosaiced with the 36 fresher images. The accuracy of the interpretation is lower in the older images than in the fresher images.

Satellite image –based estimation of the woody biomass in Zambia is most accurate when it is done from the images which have been photographed during the dry season, between late April and early December. The grass has then turned into yellow or brown or it can be grayish to black due to recent fires. Evergreen trees have still green leaves. Some *miombo* –trees keep all their leaves throughout the dry season while the others shred part of the leaves. Some amount of green leaves, however, stays in the canopy.

Most of the images were taken between May – October. The following four images are from outside this period. The accuracy of interpretation is lower in these images.

170-069 from 10 Apr 2001
175-072 from 10 Apr 2001
175-071 from 20 Nov 2001
170-066 from 19 Dec 2000

The complete flight and date information on the Landsat 7 satellite images used in the forest resource assessment is presented in Annex 1.

342 Classification

The satellite imagery analysis for determination of the new area for forested and wooded lands of Zambia was carried out in the Department of Forestry by Mr. Abel Siampale in the fall 2003. The analysis was based on the new collection of Landsat 7 satellite images.

The satellite imagery analysis used the Normalized Difference Vegetation Index – concept (NDVI). NDVI is directly related to the proportion of photosynthetically absorbed radiation. It is calculated from the atmospherically corrected reflectances at the visible and near infrared AVHRR channels as:

NDVI = (CH2 – CH1) / (CH2 + CH1)

CH1 is the reflectance in the visible wavelengths (0.58-0.68 um) and CH2 is the reflectance in the reflective infrared wavelengths (0.725-1.1 um). The principle behind the theory is that Channel 1 is in the part of the spectrum where chlorophyll causes considerable absorption of incoming radiation, and the Channel 2 is in the spectral region where spongy mesophyll leaf structure leads to considerable reflectance (NASA 2004).

The satellite images were taken (photographed) during the dry season, when agricultural crops had been harvested and the grasslands had turned from green into yellowish or brown. If dry season fires had occurred the grassland color was from grayish to black. It is fair to assume that practically all the green color, emitted from chlorophyll, came from trees (unless they had totally shredded the leaves, which situation is rare in Zambia). NDVI-techniques take this situation best into consideration. High NDVI-values belong to high leaf mass in the woody vegetation. Leaf mass is directly proportional to woody biomass volume.

As the magnitude of NDVI-value reflectance is directly proportional to the amount of woody biomass per hectare, a simple classification of the NDVI-range into five classes (also called strata), classifies the land areas into various woody vegetation, or woody biomass density classes, as shown in Table 7.

Table 7. Forest (land) classification into NDVI-based categories (strata).

NDVI / reflectance value	Forest or land class	Forest or land description
Highest reflectance	1	HDF - High Density Forest
Second highest	2	MDF - Medium Density Forest
Third highest	3	LDF - Low Density Forest
Some reflectance	4	Scattered trees, agroforestry
No reflectance	5	Treeless land

Modern Geographical Information System (GIS) softwares can perform the NDVI-classification. For the Zambian satellite images in the Forest Resource Assessment 2004 the ArcGIS –software package was used (ArcGIS 2004).

343 Forest areas

The area coverage of forests and wooded lands was determined province by province. First the neighboring satellite images were mosaiced to form a complete set for one province. Next the NDVI-analysis was performed through the province land area and the areas for various forest and land classes were determined. Finally, the separate province data were combined into national data.

The total land area of Zambia, 75.26 million hectares divides into five main NDVI-classes as shown in Table 8.

Table 8. Stratification of Zambian land area into five NDVI-classes (woody biomass density classes).

Forest or land class	Area, mill. ha	Per cent of land area
1 High density forest	13.00	17.3
2 Medium density forest	7.84	10.4
3 Low density forest	9.24	12.3
subtotal forests proper	***30.1***	***40.0***
4 Agroforestry land	3.42	4.5
subtotal forests and wooded lands	***33.5***	***44.5***
5 Treeless land	41.76	55.5
Zambia total land area	***75.26***	***100***

In the beginning of 2000s the Zambian land area divides roughly into two halves. Forested and wooded lands cover 44.5 per cent. Treeless lands (agriculture, grasslands and settlements) cover 55.5 per cent. The forest area proper (classes 1-3) is 30.1 million hectares. The total area of forests and wooded lands (classes 1-4) is 33.5 million hectares.

High Density Forests cover a considerable area, 13.0 million hectares. It is more than in the Medium Density Forest area (7.8 mill. ha) or Low Density Forests (9.2 mill. ha).

The relative abundance of High Density Forests is important for the forestry planning of Zambia Forestry Commission. As the high-valued trees typically occupy the High Density Forest, the expected forest revenue may theoretically come mostly from these areas. It must be noted that this type, satellite image –based classification does not separate national parks and other protected areas from other land use classes. Thus a good share of the high density forests may belong to national parks.

In the satellite interpretation the class 4 (stratum 4) describes lands, which give some NDVI –reflectance from the tree cover. Typically such lands are forests that have been partly opened for agriculture, or they are open agricultural lands that have been enriched with trees. Such lands can be grouped in class 4 under general term "agroforestry lands". In the satellite image interpretation the boundary between the class 3 "Low density forest" and class 4 is difficult to detect. There may be some agroforestry activities in Low Density Forest and on the other hand the very sparsely stocked savanna forests may have been interpreted in Class 4.

In the Province level the Zambian land area divides into stratification classes as shown in Table 9.

Table 9. Stratification of the Province land areas into five NDVI-classes (woody biomass density classes).

Province	High Density	Med. Density	Low Density	Agroforest	Non-forest	Total area
Central	1.57	0.72	1.23	0.58	5.34	9.44
Copperbelt	0.52	0.29	0.25	0.22	1.86	3.13
Eastern	1.26	1.00	1.33	0.12	3.22	6.91
Luapula	0.86	0.46	0.68	0.42	2.64	5.06
Lusaka	0.42	0.13	0.37	0.20	1.07	2.19
Northern	2.15	1.86	1.55	1.06	8.17	14.78
Northwestern	2.50	1.55	1.12	0.02	7.40	12.58
Southern	1.57	0.73	0.99	0.37	4.88	8.53
Western	2.16	1.13	1.75	0.43	7.18	12.64
Total	13.00	7.84	9.24	3.42	41.76	75.26

Most of the Zambian best forest resources are found in Northern, Northwestern and Western provinces which all have over two million hectares of High Density forests. The populated Lusaka, Copperbelt and Luapula provinces have less than one million hectares of High Density Forests.

344 Comparison to past forest area estimates

The determined new areas 30.1 million hectares for forest lands proper and 33.5 million hectares for forested and wooded lands fall into the same range as the FAO / FRA 2000 estimate of 31.2 million hectares. The FAO –estimate was based an extrapolation from the previous national data, based on 1965 District Forest Management Books. The early reference was supplemented with scattered information from various forestry projects in Zambia, especially from Provincial Forestry Action Programme (PFAP). Finally, the older reference information was extrapolated and scaled to year 2000 by assuming an estimated per cent for annual forest decimation. The FRA 2000 set of assumptions and extrapolations fitted well with the Forest Resource Assessment 2004 data, which was based on independent satellite image interpretation.

The "semi-official" forest area from 1996 Zambia Forestry Action Programme 44.6 million hectares (ZFAP 1996) is an apparent overestimate. As also being a figure based on extrapolation, it does not sufficiently take into consideration the recent rapid disappearance of Zambian forests. An apparent overestimate is also Chidumayo´s (1997) area of 44.0 million hectares for forests + miombo woodlands and 53.6 million hectares for forests + miombo woodlands + savanna woodlands.

Provided that the 1965 reference forest area 61.2 million hectares (Forest Department 1965, de Backer 1986) is correct, the average rate of annual forest decline to 33.5 million hectares in 2003 has been 1.6 per cent per annum. By hectares the forests have then declined between 540,000 – 980,000 hectares per annum. This corresponds well with the decimation estimate of 900,000 per annum of Chidumayo (1996) as well as with the estimate of 850,000 per annum of FAO (FRA 2000).

According to an earlier FAO (1992) study the estimate for annual deforestation between 1975 and 1990 was in the range of 290,000 hectares per annum. This was an apparent underestimate. Closer to the right track were Mukosha and Wamunyima (1998). They estimated that out of the total forest area 14.6 million hectares of Copperbelt, Central and Luapula Provinces 560,000 hectares per annum (3.8 per cent) had been deforested. The change was mainly caused by shifting cultivation and charcoal production.

35 Field data collection

351 Optimized sampling based on satellite image interpretation

In order to optimize the allocation of time and resources available by the end of year 2003 in the FSP forest resource assessment a new field data sampling procedure was developed. A number of forest sample plots had already been measured in some provinces, whereas other, large provinces had no measured sample plots at all. With the help of the optimized sampling it was possible to gain a reasonable sampling coverage for all provinces by the deadline.

The forest sample plots used in the final analysis belong into three broad groups:

Group 1 included sample plots that had been previously measured by other projects and programmes in Central, Copperbelt and Southern Provinces. The original sampling used for them did not follow any particular routine nor was it based on thorough satellite imagery analysis. It was rather done on Forest reserve by Forest reserve basis. Forest reserves were of particular interest for the inventories as there was need of information on possible forest exploitation possibility. Due to the time constraint no supplementary sample plots were measured in the FSP forest resource assessment in these provinces.

Group 2 included sample plots in Western Province. They had been measured in the FSP-reconnaissance survey (Junnikkala and Siampale 2002) and the subsequent more thorough forest inventory (Siampale 2003). The use of satellite imagery and sampling methods were tested in Western Province to gain experience for the remaining provinces.

Group 3 plots were sampled by FSP forest resource assessment on an optimized forest class (stratum) basis. Plots from such sampling were measured in Eastern, Northern and Northwestern Provinces. They had no earlier forest sample plots. In Luapula Province a supplementary sampling was done to increase the number of sample plots from the previous inventory carried out by the Provincial Forestry Action Programme.

Optimized sampling for group 3 provinces was based on satellite image mosaicing and land classification carried out for the new forest area and strata calculation. The sampling was done on a district basis, in advance, prior to the departure of the inventory teams to the field. The main target was that in each district at least one transect line of 5 – 7 sample plots falls in each of the three forest strata. The transect lines were located manually in the computer screen so that sufficient representation for the particular stratum was achieved but at the same time considering the accessibility to the site by roads or tracks.

An example of the mosaicing, classification and transect line demarcation process for District of Petauke in Eastern Province is given in Figure 1. After preliminary screening of the satellite image the land in Petauke District was classified only in the three forest classes (green for High Density Forests, brown for Medium Density Forests and yellow for Low Density Forests. One transect line was placed in each of the three forest classes. The access from the main road (marked in red) partly determined the transect line locations, as the time allocation for Petauke District was limited.

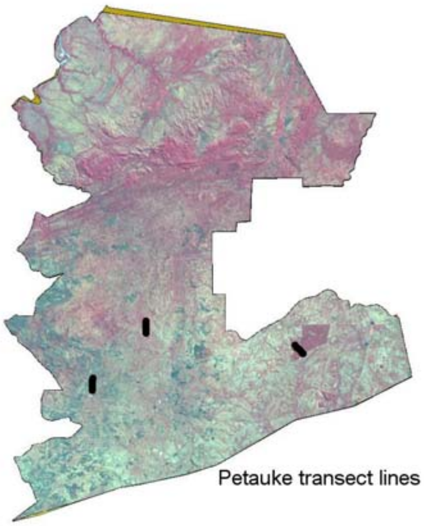


Figure 1a. Satellite image mosaic for Petauke

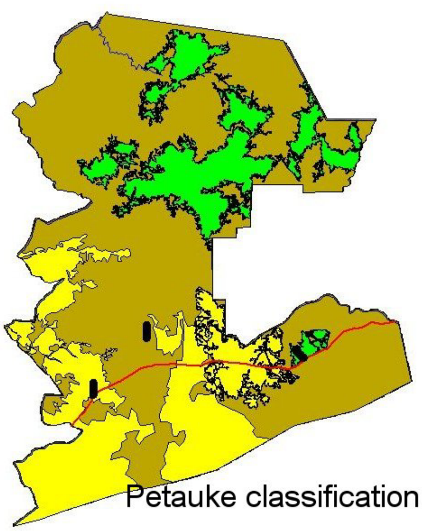


Figure 1b. NDVI classification for Petauke

Figure 1. Example of Landsat 7 satellite image mosaicing (1a), forest land classification and placement of transect lines, District of Petauke in Eastern Province

A typical transect line contained seven sample plots, 500 meters apart. Each sample plot was marked in the satellite image. GPS reading (X- and Y-coordinates) for the sample plots was determined from the satellite image or from topographic map. In the ideal case, before departing for field in a particular district, the inventory team field manager was equipped for each district with 1) an A4-sized colored print of the classified satellite image with three transect lines marked on it, 2) a corresponding topographic map with the same sample plots marked on it and 3) a set of GPS-ready coordinates for easy identification of the sample plot sites.

In the practical field work the field manager had to make the final decision where to locate the transect line and the sample plots. Accessibility to some sites was not as good as was anticipated during the advance satellite image and map work. In such a case the field team had to select manually a new transect line in similar forest class and measure the sample plots there. For each new sample plot the GPS-reading was recorded to facilitate later placing of the new transect line and sample plots into satellite image and topographic map. In every case and for every sample plot the forest class (High, Medium or Low Density Forest) was redetermined *in situ* by the field team leader and recorded in the field forms before the actual sample plot measurement.

352 Methodology

The kernel of the forest resource assessment is the forest sample plot and the trees growing on it. Each tree growing inside the plot is identified by species, tallied by breast height diameter (in cm) and measured by height (in meters). Based on these source data the key parameters to be calculated for each plot are the mean woody biomass volume (in m^3/ha) and the tree stocking (trees/ha).

Additional sample plot information is collected and recorded in the site, like forest condition, soil type and occurrence of fires. Also additional tree information is recorded, like bole height, health condition and occurrence of seedlings.

Each sample plot was circular, so called concentric plot. The concentric plot has several, normally two radii. For instance the inner radius is 3.0 meters and outer radius is 12.0 meters (Figure 2). The final radii are selected based on reconnaissance information: the radii are longer in sparsely stocked forest and shorter in densely stocked forests.

In the inner circle all the trees are measured which exceed by height the breast height limit of 1.3 meters. In the outer radius (between 3 – 12 meters) only big trees are measured. The tree size for big tree limit is determined by breast height diameter (dbh) for instance so that the big trees to be measured should be more than 5.0 cm by dbh.

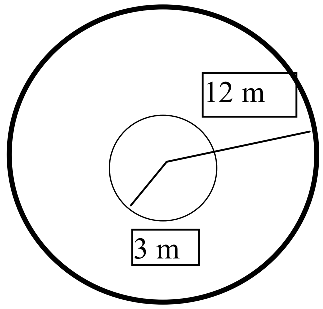


Figure 2. Concentric sample plot of forest inventory. All the trees are measured inside the inner radius of 3 meters. Only big trees (e.g. exceeding 5 cm dbh) are measured between 3-12 meters of the radius.

The method of concentric plots in forest inventory aims at increasing the accuracy of the measurement and sampling intensity of large trees, and simultaneously at saving time. It is a known fact in forest mensuration that the total woody biomass volume comes mostly from the big trees, but the time consumption per sample plot comes mostly from measurement of numerous small trees. Some amount of small trees must however be measured for reliable information on diameter distribution of various tree species. This information comes mostly from the smaller circle. The outer circle gives most of the volume information.

Every tree growing in the sample plot will potentially yield one, two or all three of the three possible assortments: fuel wood (cheapest assortment), poles (medium valued assortment) or boles (most expensive assortment). Their boundaries are defined based on the Forest Act and on the regularly updated, gazetted prices for forest produce (GRZ 2003), as follows:

First, every tree is a potential source of fuel wood. The smallest trees, less than 15 cm at butt height, give only fuel wood.

Second, when the tree is over 15 cm at butt height, it gives pole wood if the length of the pole is at least one meter and the upper diameter of the proposed pole is at least 10 cm. The pole starts from the stump. What remains above the pole height is additional fuel wood (partly in the stem, partly in the braches). If the pole conditions are not met (for instance the tree is bushy or heavily branched just above the butt height), also the over 15 cm trees at butt height give only fuel wood.

Third, when the tree is over 30 cm at breast height, it gives bole wood if the length of the bole is at least one meter and the upper diameter of the bole at least 10 cm. What is above the bole is additional fuel wood.

For every sample tree the total height and the length of the pole are recorded. Based on the sample trees, the software calculates how much bole wood, pole wood and fuel wood (in cubic meters) comes from every tree.

Another point of methodology is that the overall aim is to improve the reliability of the results in statistical terms. In every forest inventory the main result is some mean value, like mean woody biomass volume in cubic meters per hectare over the whole inventory area. As important, however, is the reliability of the mean. The reliability range is expressed with statistical standard error of the mean and with 95 per probability limits. Low 95 per cent mean volume and high 95 per cent mean volume is calculated around the arithmetical mean. One of the main aims in designing the forest inventory is to adopt such methodology that the reliability range minimizes, in other words the 95 per cent range becomes as narrow as possible.

For this target the method of sample plot clustering has been developed. The most time consuming part of the forest inventory is often just the walking to the sample plot site. After reaching the sample plot site it is more beneficial from the statistical point of view to measure several clustered small sample plots than to measure one big sample plot. The following example illustrates the case.

A miombo forest has stand density of 350 trees per hectare. A suitable circular sample plot radius could be 17 meters. There are 63 trees growing in the sample plot. The plot area is 1810 square meters.

If the sample radius is dropped into 8.5 meters, and four such smaller plots are measured the total number of trees to be measured is the same 63 trees. The total sampled area is 4 x 452.5 = 1810 square meters, i.e. the same.

Time consumption after walking into the forest is more or less the same when measuring 4 small sample plots instead of one big sample plot. The advantage comes from the increased statistical reliability of the results. The general rule is that the more plots are measured, the narrower becomes the reliability range, even if the size of one single plot is diminished. The small sample plots are located in the field in systematic form called cluster.

The method of clustering was adopted in the FSP Forest inventory after examining the reconnaissance level forest resource assessment in the Western Province. The FSP reconnaissance survey was done over only 26 big plots with radius of 17 meters: The standard error of the mean rose remarkably high, into 93 per cent. Consequently the reliability range was wide: low 95 % volume was 4.6 m^3/ha and the high 95 % volume 325 m^3/ha. This experience from Western Province alone justified a slight change of forest inventory methodology for the last Provinces to be assessed by Forestry Support Programme. Clustering of four sample plots instead of one big plot was adopted. The outer radius was dropped from 17 meters down to 12 meters.

After the field work is over the calculation of sample plot results is done with a suitable software. For Zambian conditions a tailor-made software package "ForestCalc" has been designed (ForestCalc 2003).

The methodology of **forest mensuration** based on forest sample plots and ForestCalc software has been well developed in Zambia during the field operations of Provincial Forestry Action Programme. Comprehensive manuals for the methodology have been given by Alajärvi (1996) and Vesa (2003a, 2003b).

353 Field guidelines

These forest inventory field guidelines have been updated from the Version 1 of 30 September 2003, prepared by Forestry Support Programme team leader Mr. Adam Pope (Pope 2003).

General Principles

The Forestry Support Programme national forest resource assessment is designed to provide rapid, reasonably accurate data on the sustainable productivity of Zambia's forests, and the financial value of the forest resources contained in it.

The national forest resource assessment will develop an inventory built up from field sample plot data collected from all provinces. The data collected will be analyzed in the Forestry Department using a ForestCalc software package. The national forest inventory will allow later planning and management at the national, provincial and district levels.

Each provincial inventory will be designed, planned, implemented and reported on by a Field Team Leader from the Forestry Department. Personnel who are skilled in satellite imagery mosaicing and classification, and in field sample design will support the Field Team Leader at the design stage. In the field the Field Team Leader will be supported by:

- i) one (1) individual from the Forest Management Unit at Headquarters;
- ii) one (1) representative of the provincial Forestry Department headquarters (if the sample period is more than two weeks this representative will be changed after two weeks in the field);
- iii) at least one (1) representative from each district; and
- iv) casual field support staff.

The provincial inventories all are planned to be completed by the end of November 2003. This will require concurrent field sampling of provinces. The remaining provinces to be sampled are (in order of sampling): Eastern, Northern, Luapula and Northwestern (Table 10).

Table 10. Work plan for field teams for provincial forest inventories in Eastern, Luapula, Northern and Northwestern Provinces.

	Sept		**October**				**November**				**December 2003**			
Eastern	X	X	X	X										
Northern		X	X	X	X	X								
Luapula						X	X	X	X					
N-Western							X	X	X	X				

Sample Design

In view of the short period (4 months at the end of 2003) available for the assessment the methodology to be used will be based on sampling within strata that are established through classification of orthorectified Landsat 7 imagery. The mapping scale for the forest resource assessment will be small and the results will therefore be of a reconnaissance nature only.

Mosaicing

The sample design process for each Province will start with the creation of a mosaic of adjoining Landsat 7 satellite images. The mosaic will be cut to produce a provincial mosaic upon which the district boundaries (and preferably principal roads and towns) will be overlaid.

Image classification

The mosaic will then be classified on the computer, and from hard copy eyeballing, into uniform strata on the basis of similar reflectance tones (NDVI-values). The emphasis will be on achieving the most detailed possible classification (i.e. strata with the smallest possible internal variation within the capacities of the software being used), using ground truth areas wherever possible.

The second stage of the classification process will involve reducing the number of strata to meet the overall time available for field sampling. This may involve grouping similar strata together until the timeframe is met.

If this reduction process is necessary it will also be necessary to ensure that the sampling process thereafter takes the variation within each stratum into account. To regularize this, a **district stratum sheet** will be developed at this stage. The sheet will be used in the field to record actual field stratum variation against the anticipated variation in the stratum.

Field Sampling Design

The allocation of sample plots (Figure 2) will be done on the following criteria:

i) an average of two sample days per district (larger districts may have more and smaller districts fewer, but the overall number should largely correspond to 2 x the number of districts);

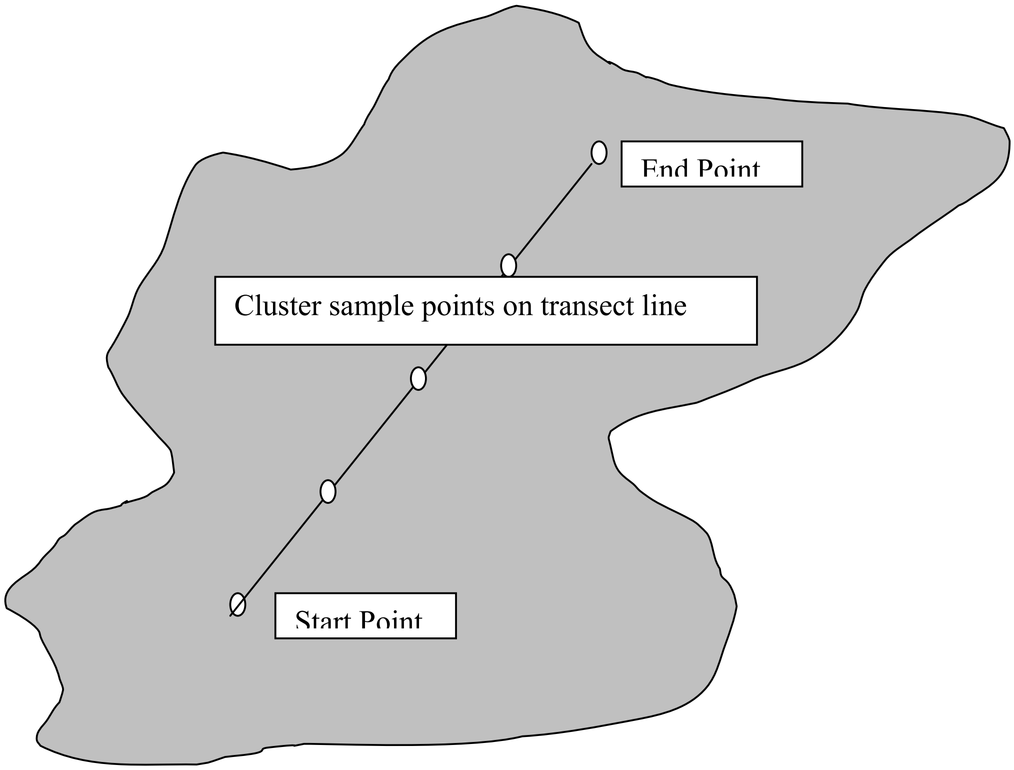
ii) it is assumed that there will be 1.5 transects per day, i.e. 3 transects per district;

iii) sampling will be based on the random placement of transects in strata;

iv) each transect will comprise:
   - a) five (5) cluster sample sites per transect, spaced at 500m intervals along the transect;
   - b) four (4) cluster plots per sample site, each comprising a 12m radius full count plot and a 3m radius concentric growth plot;
   - c) each cluster plot will be spaced 35m from the sample site centre point with each plot being located 90^{o} from the next and diagonally (45^{o}) to the transect line (see diagram);
   - d) four (4) 500m long by 10m wide rectangular plots, one between each cluster sample site centre point;

v) apparently identical strata need only be sampled once. If there is additional sampling time available those strata where variation is expected can be repeatedly sampled.

Stratum



Transect Line

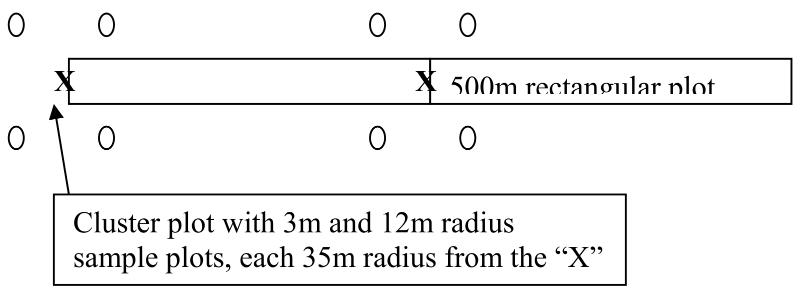


Figure 2. Principle of transect lines, rectangular plots and clustered sample plots

Logistical Plan

Once the location of transects has been decided, the Field Team Leader will establish a logistical plan for the provincial forest inventory. This will allocate time for driving and walking between each transect, plus a small amount of contingency time. The Field Team Leader will ensure that transport and a driver is available.

At this stage the Field Team Leader will contact the Principal Extension Officer in the Province to confirm the dates for the fieldwork and to ensure that the districts are advised and ready.

Budgets

Early in the planning process the Field Team Leader will present a request to the EU-FSP Team Leader for all preparatory costs. These will include:

- i) 1:250,000 and 1:50,000 mapping for the sampled areas;
- ii) gas for the field kitchen;
- iii) marker pegs and radius ropes;
- iv) data sheets copying;
- v) strata sheet copying;
- vi) replacing any field equipment that has been damaged or worn out.

Once the logistical plan has been finalized it should be costed, including the cost of all field allowances and costs and a preliminary budget presented to the EU-FSP Team Leader, for consideration.

Once everything is ready and the budget approved, the team will move to the field.

Fieldwork Procedures

When the team moves into the field it will have:

- i) a logistical plan;
- ii) an agreed point for handing over data sheets to return to Lusaka;
- iii) an agreed contact schedule so that FSP is fully informed of progress and can contribute to problem solving if necessary;
- iv) all transects marked onto 1:50,000 topographic sheets;
- v) all geographic coordinates for transect start and end points established for the GPS;
- vi) the compass directions for all transects;
- vii) all field equipment;
- viii) all field recording sheets.

Setting Up Transects

Transects will be set up from the mapping and using the GPS. If there is a problem in locating the start point then a new starting point will be established by setting out a 250m long offset towards the centre of the stratum being sampled. The new start point should then be recorded and marked on the map.

Once the first cluster sample point is located the following procedure will be used:

- i) set out the 4 sample plots from the sample centre point, using compass and standard length ropes;
- ii) set out each sample plot using 12m standard ropes and marked pegs;
- iii) set out the 3m growth plot in each of the sample plots;
- iv) measure and record all species above 5cm dbh in the 12m plots;
- v) records all species below 5cm dbh but above 1.3m height in the 3m plots;
- vi) record seedling count only in the first cluster plot;
- vii) record all data on field sheets and insert the species coding;
- viii) set off the rectangular plot from the cluster sample centre point in the direction of the transect (see diagram) (the rectangular plot is 500m long and 10m wide [5m either side of the center line of the transect]);
- ix) measure and record only the diameter of all economically important tree species (see list) with dbh greater than 30cm;
- x) record all data on field sheets and insert the species coding;
- xi) continue with the next cluster sample (not that the end point of the rectangular plot is the centre point for the next cluster sample);
- xii) repeat up to the fifth cluster sample;
- xiii) fill in the stratum variation form;
- xiv) end of transect – move to next transect.

Management of Fieldwork

All fieldwork will be under the overall control of the Field Team Leader. The Team Leader will also be responsible for setting out sample plots and for recording data. The other Head Office team member will be responsible for transect direction and distance measurement with the GPS and compass and for height recording with the hypsometer. Provincial and district staff will be responsible for diameter measurements and setting out the sample plots. All team members will participate in tree identification.

For all field inventory trips in excess of 2 weeks' duration the field data sheets will be sent back to Lusaka after two weeks, to allow those data to be entered into Forestcalc while the remaining field sampling is done.

Field Report

Once the field team is back in Lusaka a short provincial forest assessment report will be prepared by the Team Leader. The report will include:

i) a description of the classification and sampling design process (including the provincial satellite mosaic with the actual sample points located on it);
ii) details of the observed in-stratum variation, with recommendations for issues to be considered during the data analysis phase;
iii) a short description of the transect sampling process (the cluster plot details);
iv) a log of the field trip;
v) the actual costs of the provincial forest inventory work;
vi) preliminary results from Forestcalc.

Data Analysis

The analysis of data will be done using firstly a second examination of the satellite mosaic classification, and secondly the ForestCalc software. The review of the sampling classification system will be made in light of field observations. Where strata were grouped because of fieldwork time constraints, the strata will be un-grouped again if it is considered that in-stratum variations recorded in the field can be used to increase the accuracy of data extrapolation.

ForestCalc Ver. 4.2.5 software incorporates the following modules:

i) effective incorporation of cluster sample plots;
ii) incorporation of rectangular plots;
iii) calculation of allowable cut (using various decision criteria);
iv) flexible exchange of timber values.

Because of the reconnaissance scale/low sampling intensity of the inventory work outputs will only have real validity at the national level. Nevertheless, data will be analyzed at the provincial level, particularly after examining the uniformity of strata, and introducing in-stratum analysis using the observed variation with strata, as recorded in the stratum variation forms. In some case it may be possible to extract some district-level data. What must be appreciated is that there are several factors that will diminish the accuracy of extrapolated data, including:

a) the low sampling intensity;
b) the compilation on data from different data sets;
c) high in-stratum variation (because of the low sampling intensity);
d) grouping tendencies in the software (for example the diameter/height and diameter/form factors will be averaged over large areas);
e) the complexity of vegetation patterns, particularly in areas of past and present settlement; and so on.

Outputs

The Forestry Support Programme aims to produce the following data outputs at the national level, using standard ForestCalc outputs tables. The data will be reported in such a way that the statistical range of high, low and average data is recorded for parameters such as:

- i) the total allowable (sustainable) cut for important economic tree species;
- ii) the annual value of that off-take for all economically important tree species;
- iii) the standing stock (average number of trees per hectare) for all economically important tree species;
- iv) the total standing stock of all tree species above 30cm dbh;
- v) total non-timber forest product production (poles, fuelwood, etc).;
- vi) growth data for the standing stock, and so on.

It is expected that, because of the low sampling intensity, the coefficient of variation on these data will be high. Consequently, use of the results will require careful explanation and use.

The ForestCalc database is constructed so that data can also be extracted for the provincial and district levels, but these data will have greater limiting conditions attached to their use. Nevertheless, the data derived from this national forest inventory are expected to be sufficient to verify the approximate magnitude of the forest resource base and the estimated annual sustained allowable cut that can be extracted from it. In the first instance the key use for these data will be the verification of the likely financial sustainability of the Forestry Commission. Thereafter it will have two important functions:

- i) it will serve as a baseline condition, circa 2003, for the study of trends in the forest inventory;
- ii) more importantly, it will provide a better base for the planning and allocation of timber, fuel wood and charcoal concessions; and
- iii) it will provide the Forestry Department (later Forestry Commission) with a useful planning and management tool.

354 Sample plots

Altogether 1908 forest inventory sample plots were measured between 1996 and 2004. The last plots for Northwestern Province are from 7 January 2004. The distribution of sample plots in the provinces is shown in Table 11.

Table 11. Forest sample plot distribution in the Zambian provinces, field measurement period and source (programme) of inventory.

Province	Number of plots	Field period	Origin
Central	164	2001-2003	FSP, ESP
Copperbelt	79	1996-2002	PFAP, FSP
Eastern	152	2003	FSP
Luapula	305	2001-2003	PFAP, FSP
Lusaka	28	2003	FSP
Northern	370	2003	FSP
Northwestern	238	2003-2004	FSP
Southern	230	2001-2003	PFAP, FSP
Western	342	2001-2003	FSP
Total	1908		

Explanation: FSP = Forestry Support Programme, ESP = Environment Support Programme, PFAP = Provincial Forestry Action Programme,

Sample plots were measured by various teams and over varying plot sizes. Considerable time effort was used during the first half of 2003 for the important, forested, but poorly assessed Western Province. The reconnaissance survey (26 plots) and the consequent 2003 survey yielded altogether 342 sample plot. Effect of clustering is seen in Luapula, Northern and Northwestern provinces. Altogether 913 plots were possible to measure in remote areas during the latter half of 2003, roughly in same time as was used for Western Province.

The distribution of the sample plots between the forest classes is shown in Table 12. Most of the plots (1084 plots) were measured in Medium Density Forest. There were only 222 plots in High Density Forest. Proportionally this is less than the share of High Density Forests in Zambia. In other words: the sampling intensity of High Density Forests is especially low in the forest resource assessment 2004 data. The absolute number of sample plots was very low in Lusaka Province (7 plots) and Southern Province (4 plots). On the other hand, Low Density Forest was well represented in Northern Province: there were 217 plots.

Table 12. Allocation of sample plots into High, Medium and Low Density forests, per province, in the forest resource assessment 2004.

Province	HDF forest	MDF forest	LDF forest	Total
Central	11	104	49	164
Copperbelt	12	49	18	79
Eastern	11	86	55	152
Luapula	60	199	46	305
Lusaka	7	11	10	28
Northern	48	105	217	370
Northwestern	46	154	38	238
Southern	4	110	116	230
Western	23	266	53	342
Total	222	1 084	602	1 908

36 Data entry, accumulation and analysis

The field data was entered in a specially designed field form that is compatible to ForestCalc. All the other data is readily coded for computer entry in the field, except the tree species identification. For practical reasons the tree species are identified by their local names. The identification is greatly assisted by the local field assistants, which are always hired from the nearby villages to guide in the forest and to assist the field work. As the common local language is different in different parts of the country, the same tree species can have several different names. For data entry every recorded tree species must be re-identified by scientific name and then by the corresponding digital code. The species name verification is a laborious task, which can in principle be done in the field camp as evening assignment after the daytime field work. The species coding needs, however, such a concentration and effort that it is usually done after the field mission as office work. This causes easily delay in the data accumulation and analysis.

The sample plot measurement and data entry for Eastern, Lusaka, Northwestern and Western Provinces were done by one and same inventory team. This is the ideal case as it reduces data variation within a single province. After the data has been entered it must be verified by manual checking at the computer, again by the same inventory team, preferably by the Field Team Leader. He remembers best the field situation, visiting of each plots and general occurrence of various tree species. Obvious typing and illogical errors can also be minimized if the Field Data Manager himself enters the data into the computer..

For the Central, Copperbelt, Luapula, Northern and Southern provinces the forest inventories were done in several sets, with varying composition of field team leaders, members and data typists. Also the data verification and data entry were done by various compositions of field and office staff.

The coded and crosschecked field data is entried into ForestCalc. If the preliminary results look dubious, another field data verification can be done at the computer screen with ForestCalc. Again, this verification is most successful if the Field Team Leader himself carries it out.

An example of additional data verification was the occurrence of mukwa (*Pterocarpus angolensis*) trees in the forest inventory data. The first computation round with ForestCalc over the whole Zambian area showed that practically no mukwa (*Pterocarpus angolensis*) trees occurred in the sample plots. This was dubious and unlikely to be true with the observed field conditions. The crosschecking revealed that the species digital coding list had been changed in the course of whole inventory time (1996 – 2003). The coding list was rechecked and corrected by the main Field Team Leader (Mr. Abel Siampale). The next round of ForestCalc computation with corrected species coding list resulted in logical occurrence of mukwas.

The Zambia forest resource assessment was carried out as satellite image analysis and sample plot measurements on a Province basis. In one province several separate forest inventories could have been done, and each smaller inventory had produced one data set. The first target of the data accumulation was to combine all individual data sets belonging to a particular province, into one provincial data set. The combination can be done with ForestCalc. An example is given in Table 13 for Central Province.

Table 13. Combination of nine original field inventory datasets into one provincial dataset in Central Province

Inventory ID	Number of plots	Data source	Database file ID
Central 100	37	FSP	L0000100.mdb
Central 101	5	ESP	L0000101.mdb
Central 102	7	ESP	L0000102.mdb
Central 105	8	ESP	L0000105.mdb
Central 107	8	ESP	L0000107.mdb
Central 109	24	ESP	L0000109.mdb
Central 110	13	ESP	L0000109.mdb
Central 112	4	ESP	L0000112.mdb
Central 200	58	ESP	L0000200.mdb
Central 150	164		FC_Datainput_150.mdb

Nine different data sets were combined into one. Almost all the provinces had several forest inventory data sets. Only Lusaka Province and Northwestern Province forest inventories were done in one set, and each of them with one and the same field team. The full composition of sample plot original and combination data sets is shown in Annex 2.

After combination of the original data source files into nine provincial files, the remaining analysis was done with ForestCalc software-package.

37 Sampling intensity

The sampling intensity is calculated by dividing the total area of field sample plots in a particular forest class (stratum) by the total area of the forest class in question. The sampling intensity is presented in per cent. Therefore, if the whole forest area has been measured, the sampling intensity is 100 per cent. In large-scale inventories the sampling intensity is a fraction of per cent. In a small scale inventory the sampling intensity of one per cent can be targeted. In special biodiversity survey inventories the sampling intensity can be as high as five per cent.

The sampling intensity in the Zambia forest resource assessment 2004 has been presented in Table 14.

Table 14. Sampling intensity in the Zambia forest resource assessment 2004, calculated as the total sample areas divided by the forest class area, and expressed in per cent.

Province	HDF forest	MDF forest	LDF forest	Total
Central	0.000060	0.001281	0.000358	0.000415
Copperbelt	0.000164	0.001281	0.000358	0.000415
Eastern	0.000040	0.000391	0.000190	0.000193
Luapula	0.000349	0.002460	0.000391	0.000849
Lusaka	0.000150	0.000798	0.000248	0.000278
Northern	0.000119	0.000301	0.000745	0.000354
Northwestern	0.000083	0.000450	0.000153	0.000208
Southern	0.000023	0.001494	0.001112	0.000675
Western	0.000088	0.002004	0.000253	0.000574

The sampling intensity of the Zambian forest resource assessment 2004 was very low. It varied from 0.000023 per cent (Southern Province, High Density Forest) to 0.00246 per cent (Luapula Province, Medium Density Forest). Also the low sampling intensity pinpoints that the forest resource assessment 2004 was of reconnaissance nature.

4 Results

41 Mean wood volume and its confidence limits

411 Central Province

ForestCalc analysis produces from the provincial combination file readily the key forest stand characteristics: the mean woody biomass volume in cubic meters per hectare and its reliability range (Table 15).

Table 15. Mean volume, standard error of the mean and the 95 per cent confidence limits for Central Province

Forest class	Low 95%	Mean	High 95%	Std error
	m3/ha	m3/ha	m3/ha	per cent
High Density Forest	0.0	114.2	232.0	46.3 %
Medium Density Forest	80.0	94.3	108.5	7.6 %
Low Density Forest	18.4	56.2	94.0	33.6 %
All forests	**40.8**	**89.9**	**138.9**	**27.3 %**

The Central Province combination data was composed of nine different sample plot measurement sets. The different sample plot sets had been measured by different teams, during different times. This condition introduces unavoidably an additional source of variation into the data set. This can be seen in the standard error of the mean: it is high, overall in the forests 27.3 per cent. Especially high it is in the High Density Forests, 46.3 per cent. This is partly explained by low number of sample plots. There were only 11 plots. The method of clustering was not in use in Central Province.

On the other hand, the standard error of the mean volume was only 7.6 per cent in the plots belonging to Medium Density Forest. This again, is partly explained by the number of plots. There were 104 plots in the Medium Density Forest.

The high standard error of the mean is followed by wide reliability range. For instance it can be read that the mean woody biomass volume in High Density Forest is at 95 per cent probability between zero and 232 m^3/ha. Such a wide range has questionably value for making management decisions.

The situation is totally different in Medium Density Forest. At 95 per cent probability the mean woody biomass volume is between 80.0 – 108.5 m^3/ha, which clearly depicts the higher reliability of this data set than the one with High Density Forest.

The forest inventory results for Central Province correspond well with the estimate given by ZFAP forest resource assessment (1996). The mean volume in ZFAP is 83.5 m^3/ha, almost the same as the 2004 mean volume for all forests 89.9 m^3/ha. It may be just a coincidence, as the ZFAP assessment does not give 95 per cent confidence limits.

412 Copperbelt Province

The overall mean wood volume in Copperbelt Province, 141.0 m^3/ha (Table 16) is higher than in Central Province (89.9 m^3/ha). This observation is apparently true, since also the ZFAP assessment has the estimates in similar order (154.9 m^3/ha for Copperbelt, 83.5 m^3/ha for Central Province).

Table 16. Mean volume, standard error of the mean and the 95 per cent confidence limits for Copperbelt Province

Forest class	Low 95%	Mean	High 95%	Std error
	m3/ha	m3/ha	m3/ha	per cent
High Forest	107.8	157.3	206.8	14.3 %
Medium Forest	119.0	140.4	161.8	7.6 %
Low Forest	71.7	106.7	141.8	15.6 %
All forests	**116.6**	**141.0**	**165.3**	**8.7 %**

Although the total number of sample plots was only 79, the standard error of mean in Copperbelt Province (8.7 %) was clearly smaller than in Central Province (27.3 %). This may be a direct consequence for selection of the Forest Reserves (Katanino and Chibuchinga) for the assessment. By nature they are more homogenous than the forest areas selected for Central Province.

The low standard error of the mean can also be partly a consequence of homogenous inventory teams. Copperbelt provincial dataset is a combination of three separate forest inventories. Two of them: Katanino (Chisanga et al. 2002a) and Shibuchinga (Chisanga et al. 2002b) were done through local consultancy contract and one as regular field inventory by FSP team. Main part of the sample plots was measured by the same teams. This is the desired case which usually reduces the unnecessary variation between the measurement sets.

413 Eastern Province

The overall mean volume in Eastern Province, 50.4 m^3/ha (Table 17) is considerably lower than Central (89.9 m^3/ha) or in Copperbelt Province (141 m^3/ha). The present estimate is also less than the 1996 estimate from ZFAP (85.8 m^3/ha).

Table 17. Mean volume, standard error of the mean and the 95 per cent confidence limits for Eastern Province

Forest class	Low 95%	Mean	High 95%	Std error
	m3/ha	m3/ha	m3/ha	per cent
High Density Forest	30.9	55.6	80.4	20.0 %
Medium Density Forest	53.2	62.7	72.2	7.6 %
Low Density Forest	23.3	36.1	48.9	17.7 %
All forests	**40.9**	**50.4**	**59.9**	**9.3 %**

There is an odd phenomenon in the Eastern Province results. The mean wood volume is lower (55.6 m^3/ha) in the High Density Forest than in the Medium Density Forest (62.7 m^3/ha). The order should be opposite. This, again may be a consequence of low number of plots (11 plots only) and resulting wide reliability range (30.9 – 80.4 m^3/ha) in the High Density Forest plots. It overlaps the reliability range of Medium Density Forest mean volume (53.2 – 72.2 m^3/ha). Consequently, if the upper limits of the reliability range is compared the order is correct: HDF 80.4, MDF 72.2, LDF 48.9 m^3/ha. In any case, to improve the reliability of the forest resource assessment it is clear that more sample plots should be measured in High Density Forests of Eastern Province.

414 Luapula Province

The mean wood volume in Luapula Province (97.3 m^3/ha) is almost the same as in Central Province (89.9 m^3/ha). As compared to the 1996 ZFAP volume (42.0 m^3/ha) the new Luapula value is over two times higher. The ZFAP value is even lower than the Luapula low 95 % value (86.0 m^3/ha) (Table 18).

Table 18. Mean volume, standard error of the mean and the 95 per cent confidence limits for Luapula Province

Forest class	Low 95%	Mean	High 95%	Std error
	m3/ha	m3/ha	m3/ha	per cent
High Density Forest	111.5	130.9	150.3	7.4 %
Medium Density Forest	110.1	119.9	129.6	4.0 %
Low Density Forest	17.9	39.4	60.8	27.3 %
All forests	**86.0**	**97.3**	**108.6**	**5.9 %**

Of all the provinces the standard error of the mean was lowest in Luapula Province (5.9 % overall). This is near to the targeted reliability. The standard error of the mean in regular and thorough forest inventories in Finland has been between 1.5 – 5.9 per cent, varying from forest region ("province") to forest region (METLA 2003).

The low values in Luapula are without doubt related to high number of (total 305 sample plots). Such a high number of sample plots became possible when the clustering methodology in the Luapula Province forest inventory was adopted (see chapter 352).

415 Lusaka Province

Lusaka Province had the smallest number of forest sample plots, only 28 plots. Inevitably this resulted in relatively high standard error of the mean volume (19.9 % overall, Table 19). The method of sample plot clustering was not yet applied in Lusaka province. On the other hand all the plots were measured in one single forest inventory exploration mission and by one and the same field team. This stabilized the measurement and improved the reliability of the results.

Table 19. Mean volume, standard error of the mean and the 95 per cent confidence limits for Lusaka Province

Forest class	Low 95%	Mean	High 95%	Std error
	m3/ha	m3/ha	m3/ha	per cent
High Density Forest	38.3	89.7	141.2	23.4 %
Medium Density Forest	36.9	52.2	67.5	13.2 %
Low Density Forest	1.2	62.8	124.4	43.4 %
All forests	**43.7**	**73.8**	**103.9**	**19.9 %**

The 2004 mean wood volume (73.8 m^3/ha) for Lusaka Province was clearly higher than the 1996 ZFAP mean volume (49.3 m^3/ha). The mean volume in Medium Density Forest (52.2 m^3/ha) is higher than in the Low Density Forest (62.8 m^3/ha). On the other hand the order is correct in low 95 % values: 36.9 m^3/ha in Medium Density Forest and only 1.2 m^3/ha in Low Density Forest. This odd looking phenomenon follows from the small sample size. It is most likely that the reliability of Lusaka Province forest assessment improves radically if the number of sample plots could be increased by sending another inventory field mission and by applying the clustering method in the field inventory.

416 Northern Province

Northern Province had the biggest number of sample plots: altogether 370 plots. Sample plot clustering was adopted also there. Most of the sample plots, 217 plots, were located in Low Density Forest. Consequently, the standard error of the mean was the lowest there, 7.1 % (Table 20). On the other hand, the standard error of the mean in the Medium Density Forest was surprisingly high, 28.8 %, even if the number of sample plots was as high as 105.

Table 20. Mean volume, standard error of then mean and the 95 per cent confidence limits for Northern Province

Forest class	Low 95%	Mean	High 95%	Std error
	m3/ha	m3/ha	m3/ha	per cent
High Density Forest	55.9	71.9	88.0	11.2 %
Medium Density Forest	43.5	100.8	158.1	28.4 %
Low Density Forest	60.5	70.5	80.4	7.1 %
All forests	**60.9**	**81.2**	**101.5**	**12.6 %**

The irregularities in the standard error of the mean partly explain why the mean wood volume in High Density Forest (71.9 m^3/ha) was lower than in the Medium Density Forest (100.8 m^3/ha). It is apparent that in Northern Province either the advance forest classification into forest classes (strata) or the later field classification into the same classes failed. More probable is what happened in the field. The last word in the field inventory was always with the field team leader. He or she judged the condition of a particular sample plot *in situ*, irrespective of the transect line and its advance stratification. He or she denoted in the field for the forest condition (forest class) at and around the sample plot with a number 1, 2 or 3, denoting High, Medium or Low Density Forest. The field form is the basis for ForestCalc analysis, not the satellite image and the transect line definition in it. If there was a discrepancy between the advance forest classification and the forest classification in the field (*in situ*), the field observation superseded the advance classification in the ForestCalc analysis.

The 1996 ZFAP mean volume for Northern Province was 40.9 m^3/ha, only half of the 2004 assessment (81.2 m^3/ha). The ZFAP mean value was even lower than any of the Low 95 % values. This is another discrepancy in the Northern Province data. The mean volume level for Northern Province as whole can be too high. It leads to overestimate of woody biomass resource in Northern Province.

417 Northwestern Province

Northwestern Province is remote province which used to have abundant forest resources. The 1996 ZFAP estimate for the Northwestern Province mean wood volume was highest (155.7 m^3/ha) for the whole country. Also in 2004 assessment the mean volume was rather high, 110.9 m^3/ha (Table 21).

Table 21. Mean volume, standard error of the mean and the 95 per cent confidence limits for Northwestern Province

Forest class	Low 95%	Mean	High 95%	Std error
	m3/ha	m3/ha	m3/ha	per cent
High Density Forest	119.5	136.9	154.2	6.3 %
Medium Density Forest	78.5	85.4	92.3	4.0 %
Low Density Forest	27.7	88.1	148.6	34.3 %
All forests	**95.2**	**110.9**	**126.6**	**7.1 %**

Altogether 238 new sample plots were measured by one and the same FSP field inventory team. Sample plot clustering method was adopted. Consequently the standard error of the mean volume was under 10 per cent (7.1 %) overall, and very low, 4.0 % in the Medium Density Forest. In the Low Density forest the standard error of the mean was again high, 34.3 %, apparently due to low number (38) of the sample plots.

418 Southern Province

The forest sample plot data for Southern Province was combined from four separate field data files. Three of them were measured by the Provincial Forestry Action Programme field teams and one by the Forestry Support Programme field team. Combination of four different files into one dataset may be the reason why the standard error of the mean volume rose relatively high (14.4 % cent overall, Table 22) although total number of sample plots was as high as 230.

Table 22. Mean volume, standard error of the mean and the 95 per cent confidence limits for Southern Province

Forest class	Low 95%	Mean	High 95%	Std error
	m3/ha	m3/ha	m3/ha	per cent
High Density Forest	31.7	98.2	164.6	21.3 %
Medium Density Forest	46.5	67.7	88.9	15.6 %
Low Density Forest	22.3	39.0	55.8	21.4 %
All forests	**52.5**	**73.7**	**94.8**	**14.4 %**

Southern Province is almost as remote as Northwestern Province but the ecological conditions are drier. It is to be expected that the mean woody biomass volume is lower in Southern (73.7 m^3/ha) than in Northwestern Province (110.7 m^3/ha). The 1996 ZFAP value was 65.2 m^3/ha, near to the 2004 estimate.

419 Western Province

Altogether 342 sample plot were measured in Western Province. The field team remained the same through the sample plot measurements. The whole field inventory process was based on reconnaissance mission and managed by the same programme (FSP). Thus it could be expected that the standard error of the mean volume remained low. This was the case. The lowest standard error of the mean volume (3.6 %) was calculated for the Medium Density Forest in Western Province. Also the overall value was under 10 per cent (7.6 %). By all criteria the Western Province forest inventory woody biomass volume results are logical (Table 23).

Table 23. Mean volume and its 95 per cent confidence limits for Western Province

Forest class	Low 95%	Mean	High 95%	Std error
	m3/ha	m3/ha	m3/ha	per cent
High Density Forest	107.2	139.6	172.1	11.2 %
Medium Density Forest	101.7	109.5	117.4	3.6 %
Low Density Forest	28.8	50.0	71.3	21.2 %
All forests	**86.3**	**101.7**	**117.1**	**7.6 %**

The mean woody biomass volume in the Western Province (101.7 m^3/ha) was of same level as in Northwestern Province (110.9 m^3/ha). ZFAP assessment in 1996 estimated somewhat higher mean volume (144.9 m^3/ha) for the Western Province, than was the case with FSP forest resource assessment.

42 Total woody biomass volume

421 Central Province

The total volume for any particular province, for any particular forest class and for any particular reliability level (mean, low or high wood volume) is calculated by multiplying the mean woody biomass volume (m^3/ha) with the corresponding amount of hectares (ha). For instance the Central Province, High Density Forest the mean woody biomass volume is 114.2 m^3/ha (Table 15). The corresponding area is 1.57 million hectares (Table 9). Multiplication 114.2 x 1.57 gives total volume of 179 million cubic meters for High Density Forest (Table 24).

Table 24. The woody biomass volume, 95 per cent reliability range and the corresponding forest class area in Central Province

Forest class	Area	Low 95%	Mean total	High 95 %
	mill. ha	total mill. m3	mill. m3	total mill. m3
High Density Forest	1.57	0	179	364
Medium Density Forest	0.72	58	68	79
Low Density Forest	1.23	23	69	115
Subtotal forests	**3.52**	**80**	**316**	**557**
Agroforest land	5.81	3	3	3
TOTAL	**4.10**	**83**	**319**	**560**

The total woody biomass volume in the forest lands proper (3.53 million hectares) of Central Province is at 95 per cent probability in the range 80 – 557 million cubic meters. The arithmetic mean is 316 million cubic meters. This is somewhat lower than the 1996 estimate from ZFAP (464 million cubic meters). The ZFAP assessed only the mean wood volume, not the low and high wood volume confidence range.

The Central Province agroforest lands (class 4, scattered trees) have additional wood volume of 3 million cubic meters. As there were no sample plots on agroforest land, only a rough mean wood volume 5 m^3/ha was used throughout the agroforest lands (cf. ZFAP 1996). There is no reliability range for the woody biomass on agroforest land.

The overall Central Province total woody biomass volume was assessed at 319 million cubic meters (with 95 % reliability range of 83 – 560 mill. m^3). The corresponding ZFAP value for the total woody volume in Central Province is 474 million cubic meters.

The reliability range of the total woody biomass volume in Central Province is somewhat broad, for instance in High Density Forest between 0 – 364 m^3/ha. This direct consequence from the mean wood volume assessment (m^3/ha, see Table 15).

422 Copperbelt Province

The total woody biomass volume in Copperbelt Province was assessed at 149 million cubic meters in the forest lands proper. The 95 per cent reliability range is 108 – 189 million cubic meters (Table 25).

Table 25. The woody biomass volume, 95 per cent reliability range and the corresponding forest class area in Copperbelt Province

Forest class	Area	Low 95%	Mean total	High 95 %
	mill. ha	total mill. m3	mill. m3	total mill. m3
High Density Forest	0.52	56	82	108
Medium Density Forest	0.29	34	40	46
Low Density Forest	0.25	18	26	35
Subtotal forests	**1.05**	**108**	**149**	**189**
Agroforest land	0.22	1	1	1
Forests + wooded lands	**1.27**	**109**	**150**	**190**

The total woody biomass reliability range is relatively narrower in Copperbelt Province than in Central Province. It can be seen especially in the Medium Density forest (range as narrow as 34 – 46 million cubic meters). This follows again from the mean wood volume (m^3/ha) calculation (Table 16).

The ZFAP (1996) assessed the woody biomass stock considerably higher, almost twice as high (271 million cubic meters) as the FSP assessment (149 million cubic meters). This follows mainly the reduction in the forest area. It was 1.75 million hectares in the ZFAP assessment and 1.05 million hectares in the FSP assessment.

The agroforest lands contained only one million additional wood cubic meters in Copperbelt Province (compared to 3 million cubic meters in ZFAP assessment). Thus the total wood volume in Copperbelt is 150 million cubic meters whereas the ZFAP assessment total was 274 million cubic meters.

423 Eastern Province

The total woody biomass volume in Eastern Province forest lands proper was 180 million cubic meters with the reliability range of 123 – 238 million cubic meters (Table 26).

Table 26. The woody biomass volume, 95 per cent reliability range and the corresponding forest class area in Eastern Province.

Forest class	Area	Low 95%	Mean total	High 95 %
	million ha	total mill. m3	mill. m3	total mill. m3
High Density Forest	1.26	39	70	101
Medium Density Forest	1.00	53	62	72
Low Density Forest	1.32	31	48	65
Subtotal forests	**3.58**	**123**	**180**	**238**
Agroforest land	0.12	1	1	1
Forests + wooded lands	**3.69**	**123**	**181**	**238**

The earlier ZFAP assessment for Eastern Province was over twice as high (404 million cubic meters). Similar big difference exists in the total wood volume in the Province: 410 million cubic meters in ZFAP assessment and only 181 million cubic meters in FSP assessment.

424 Luapula Province

The forest lands proper in Luapula Province have total woody biomass volume of 196 million cubic meters (Table 27).

Table 27. The woody biomass volume, 95 per cent reliability range and the corresponding forest class area in Luapula Province.

Forest class	Area	Low 95%	Mean total	High 95 %
	million ha	total mill. m3	mill. m3	total mill. m3
High Density Forest	0.86	96	112	129
Medium Density Forest	0.46	51	55	59
Low Density Forest	0.68	12	27	41
Subtotal forests	**1.99**	**158**	**194**	**229**
Agroforest land	0.42	2	2	2
Forests + wooded lands	**2.41**	**160**	**196**	**232**

Luapula is the only Province in Zambia where the new FSP forest resource assessment gave higher total wood volume for forest lands proper (194 million cubic meters) than the older ZFAP assessment (105 million cubic meters). The same situation is seen in the total wood volume for forests and wooded lands. FSF assessed 196 million cubic meters whereas ZFAP assessed only 115 million cubic meters.

425 Lusaka Province

The total woody biomass volume, assessed by FSP (68 million cubic meters, Table 28) is exactly the same as the ZFAP assesses in 1996. The higher mean volume (73.8 m^3/ha) in FSP assessment compared to ZFAP assessment (49.3 m^3/ha) compensated the diminishment in forest area. It dropped from ZFAP assessment of 1.38 million hectares to FSP assessment of 0.91 million hectares.

Table 28. The woody biomass volume, 95 per cent reliability range and the corresponding forest class area in Lusaka Province

Forest class	Area million ha	Low 95% total mill. m3	Mean total mill. m3	High 95 % total mill. m3
High Density Forest	0.42	16	38	60
Medium Density Forest	0.13	5	7	8
Low Density Forest	0.37	0	23	46
Subtotal forests	**0.91**	**21**	**68**	**114**
Agroforest land	0.20	1	1	1
Forests + wooded lands	**1.12**	**22**	**69**	**115**

The reliability range in Lusaka Province is, however, rather wide (21 – 114 million cubic meters in forest lands proper) due to low number of sample plots.

The wood volume in Lusaka Province agroforest lands was low, one million cubic meters, both in ZFAP and FSP assessments.

426 Northern Province

Also in Northern Province the new FSF forest resource assessment gave higher total wood volume (451 million cubic meters, Table 29) than the older ZFAP assessment (360 million cubic meters).

Table 29. The woody biomass volumes, 95 per cent reliability range and the corresponding forest class areas in Northern Province

Forest class	Area	Low 95%	Mean total	High 95 %
	million ha	total mill. m3	mill. m3	total mill. m3
High Density Forest	2.15	120	155	189
Medium Density Forest	1.86	81	187	293
Low Density Forest	1.55	94	109	124
Subtotal forests	**5.55**	**295**	**451**	**607**
Agroforest land	1.06	5	5	5
Forests + wooded lands	**6.61**	**300**	**456**	**612**

Immediate explanation is the same as in Luapula Province. The Northern Province mean woody biomass volume (81.2 m^3/ha) was clearly higher in the FSP assessment than in the ZFAP assessment (40.9 m^3/ha). The diminishment was relatively smaller in forest area proper, from ZFAP 8.81 million hectares to FSP 5.55 million hectares.

The agroforest lands in Northern Province have about 5 million cubic meters in FSP assessment, whereas ZFAP assessment was more than 3 times higher, 16 million cubic meters. The total woody biomass (forests + wooded lands) in Northern Province is 456 million cubic meters (376 million cubic meters in ZFAP assessment).

427 Northwestern Province

In the large and traditionally well forested Northwestern Province the diminishment of total woody volume was drastic. It went down from ZFAP assessment of 1148 million cubic meters to FSP assessment of 573 million cubic meters (Table 30). The woody biomass volume halved.

Table 30. The woody biomass volumes, 95 per cent reliability range and the corresponding forest class areas in Northwestern Province

Forest class	Area	Low 95%	Mean total	High 95 %
	million ha	total mill. m3	mill. m3	total mill. m3
High Density Forest	2.50	299	342	386
Medium Density Forest	1.55	121	132	143
Low Density Forest	1.12	31	99	166
Subtotal forests	**5.17**	**451**	**573**	**695**
Agroforest land	0.02	0	0	0
Forests + wooded lands	**5.19**	**451**	**573**	**695**

This follows the simultaneous diminishment both in mean wood volume and in forest area. The mean wood volume went down from ZFAP 155.7 m^3/ha into FSP 110.9 m^3/ha. The forest area went down from ZFAP 7.38 million hectares into FSP 5.17 million hectares. The diminishment of the total woody biomass is apparently true as also the entire FSP 95 % reliability range (451 – 695 million cubic meters) is well below the ZFAP total volume (1148 million cubic meters).

In the FSP assessment there is very little agroforest land in Northwestern Province, only about 20,000 hectares. Consequently there is very little additional woody biomass in Northwestern agroforestry lands, less than one million cubic meters. The ZFAP assessment, instead, found more agroforest lands in Northwestern Province and altogether 8 million cubic meters growing on them. The total woody biomass volume in FZAP assessment was 1156 million cubic meters.

428 Southern Province

The mean wood volume in Southern Province (Table 31) is lower than in Copperbelt Province. Also the standard error of the mean is smaller.

Table 31. The woody biomass volumes, 95 per cent reliability range and the corresponding forest class areas for Southern Province

Forest class	**Area**	**Low 95%**	**Mean total**	**High 95 %**
	million ha	**total mill. m3**	**mill. m3**	**total mill. m3**
High Density Forest	1.57	50	154	258
Medium Density Forest	0.73	34	49	64
Low Density Forest	0.99	22	38	55
Subtotal forests	**3.28**	**105**	**242**	**378**
Agroforest land	0.37	2	2	2
Forests + wooded lands	**3.65**	**107**	**243**	**380**

The ZFAP total wood volume for forests proper is 304 million cubic meters and for forests and wooded lands 313 million cubic meters.

429 Western Province

Besides Northwestern Province the Western Province was the other well forested Province in ZFAP assessment (Northwestern total 1156 million cubic meters, Western total 1013 million cubic meters). In the FSP forest resource assessment the total woody biomass volume of Western Province had dropped into about half: into 514 million cubic meters overall and 512 million cubic meters for forest land proper (Table 32).

Table 32. The woody biomass volumes, 95 per cent reliability range and the corresponding forest class areas in Western Province

Forest class	Area	Low 95%	Mean total	High 95 %
	million ha	total mill. m3	mill. m3	total mill. m3
High Density Forest	2.16	231	301	371
Medium Density Forest	1.13	114	123	132
Low Density Forest	1.75	50	88	125
Subtotal forests	**5.03**	**396**	**512**	**628**
Agroforest land	0.43	2	2	2
Forests + wooded lands	**5.46**	**398**	**514**	**630**

The total woody biomass reliability range in Western Province is relatively small (as compared to other Provinces): 396-628 million cubic meters.

43 Zambia total woody biomass volume

The total area for each forest class and the total woody biomass for the whole country are calculated by adding the corresponding provincial values. The forest lands proper cover 30.1 million hectares and all the forests and wooded lands 33.5 million hectares (Table 33).

Table 33. The woody biomass volumes, 95 per cent reliability range and the corresponding forest class areas in the whole country of Zambia.

Forest class	Area	Low 95%	Mean total	High 95 %
	million ha	total mill. m3	mill. m3	total mill. m3
High Density Forest	13.0	907	1 433	1 966
Medium Density Forest	7.8	550	723	897
Low Density Forest	9.2	281	526	772
Subtotal forests	**30.1**	**1 738**	**2 683**	**3 634**
Agroforest land	3.4	17	17	17
Forests + wooded lands	**33.5**	**1 755**	**2 700**	**3 652**

The forest lands proper have total woody biomass of 2,683 million cubic meters. The corresponding 95 % reliability range is 1,738 – 3,634 million cubic meters. The agroforest lands have additional 17 million cubic meters. Thus the total woody volume of Zambia is in FSP assessment 2,700 million cubic meters.

The forest decimation from 1996 ZFAP values was rather drastic. The ZFAP area for forest lands proper was 43.6 million hectares and the total forested and wooded lands 59.5 million hectares. The FSP assessment shows that the total area of forests and wooded lands is now 44 per cent smaller than the previous estimate (area drop from ZFAP 59.5 into FSP 33.5 million hectares).

The drop in the Zambia total woody biomass volume was almost as drastic. The ZFAP total woody biomass volume was 4202 million cubic meters for forests and wooded lands. The FSP assessment is 36 per cent smaller (total volume drop from 4202 into 2700 million cubic meters). – The ZFAP total volume for forest lands proper is 4122 million cubic meters.

The total woody biomass growing on forest lands proper divides into three commercial assortments: bole wood, poles and other (fuel wood) as shown in Table 34. The share of bole wood, pole wood and fuel wood is calculated by the software, based on the methodology and conditions set in Chapter 352.

Table 34. Total woody biomass volume in Zambia, growing in forest lands proper, divided into assortments of bole wood, pole wood and other wood (fuel wood).

Forest class	**Total**	**Bole**	**Pole**	**Other**
	Mill. m3	**Mill. m3**	**Mill. m3**	**Mill. m3**
High Density Forest	1 433	376	234	823
Medium Density Forest	723	218	105	401
Low Density Forest	526	154	60	312
Total forests	**2 683**	**749**	**399**	**1 535**

Most of the woody biomass, 1535 million cubic meters of the tree volume, falls into the assortment “Other”, which in practice has the value of fuel wood to be used either as such or as a raw material in charcoal burning. The next in quantity is the bole wood, 749 million cubic meters. The pole wood is least, 399 million cubic meters.

5 Silvicultural and other forest management considerations

51 Principles

The overall target of sustained forestry in Zambia in general and in the Forest Support Programme especially, is to conserve the abundant forest resource and its rich biodiversity and at the same time utilize part of the annual growth by allowing planned amount of cuts in forest reserves, open and game management areas. The allowable cut calculation in Forestry Support Programme is linked to licensed harvests of bole wood, pole wood and other wood (fuel wood). The licensing is based on Forest Act and on the regularly updated, gazetted prices for forest produce.

52 Seed tree management

The seed tree management guideline for allowable cuts in the sustained forestry can be condensed in the current and desired diameter distribution as a whole in the forest, or species by species. The allowable cuts are practically always geared to the trees with large diameters, in Zambian conditions belonging to diameter classes of over 30 cm at breast height (in the management practice to classes 30-40 cm at dbh and over 40 cm at dbh).

In the desired case the forest stand has an abundant number of small diameter trees to ensure future growth and harvest of the large diameter trees. The large diameter trees, even the ones over 40 cm, cannot however, be cut to the last tree at the harvest, as they are the seed trees for future growth. The harvesting should thus be selective thinning, not clear cutting, as long as the silviculture depends on natural seeding not on nurseries and planting of seedlings.

In the situation of selective thinning, when some trees of large diameter are cut, there should be no problem in ensuring tree seeds as long as a big enough number of smaller trees are left alive. In some cases there has been a silvicultural problem in Zambian forestry in the past, in the cases when there is insufficient number of remaining, large-sized seed trees, and no small diameter trees (JICA 1996b).

The critical forest management question is: how many large diameter (over 30 cm) trees per hectare should be left in the harvest to ensure sufficient seeding for future trees? In seed tree ecology this is a matter of seed driftability after shredding, away from under the tree crown. The matter is best studied with mukusi (Zambezi teak, *Baikiaea plurijuga*). Mukusi is poor in seed driftability. The seeds do not fall over much wider range than the spread of the tree crown. About double the spread of the crown is considered to be the limit. The falling seeds thus intermix in the soil which is directly under the crown and outside the crown shade. Ideally, the rate of intermixing should cover 80 per cent of the forest soil, but a lower, practical management rule may target 50 per cent intermixing (JICA 1996b).

Assuming that one good mukusi seed tree shreds and drifts the seeds over an area of 90 square meters, there is a need for about 30 seed trees per hectare to allow 50 per cent intermixing. Accordingly, if 30 *mukusi* seed trees per hectare cannot be left standing in the selective harvest, the seed trees should not be harvested at all. If there are about 100 smaller *mukusi* trees per hectare to soon grow mature into seed tree diameter classes, time will take care of the *mukusi* regeneration. If there are less than 100 *mukusi* trees per hectare overall, the *mukusi* forest should be restocked by enrichment planting or the land should be reforested.

These management rules for *mukusi* can be generally applied for miombo – forest in the case when the overall seed driftability is similar to *mukusi* seeds. Many tree seeds are drifting longer from the mother trees as is the case with *mukusi*. Over half (59 %) of the miombo trees have explosive pods which throw the seed only a little longer than mere gravity drop. Next common (22 %) are the trees the seeds of which are driven by wind. Animals (birds and mammals) transport seed longer. This is the case with 19 per cent of miombo trees (Chidumayo 1997). If the seed dispersal rules are known, the seed tree management can be modified from *mukusi* management. The *mukusi* – rule, however, is a suitable starting point for sustained *miombo* – forest management.

53 High-valued trees

The management of Zambian indigenous forests is especially centered in the gazetted high-valued trees. The tree species have originally been listed in the Forest Act (Table 35). The list of Zambian high-valued species is necessary from two management angles. First, they are biologically valuable trees, part of the rich biodiversity in Zambia. The high-valued trees are constantly under heavy commercial harvesting pressure and they must be in regular monitoring in order to conserve the biodiversity for future human generations.

Second, the harvesting of the allowable cut of high-valued trees has in monetary terms the biggest potential forest revenue in Zambia. The revenue has national impact through saw-milling, furniture industries and export of valuable forest industries products. The revenue has local impact through farmers and small entrepreneurs by providing regular employment and wealth through private forestry and small scale forest industries. And third, he high-valued trees have direct impact onto financial planning of the coming Zambian Forestry Commission. The license fees of allowable cut of high-valued trees have been planned to be channeled and managed by the new Commission.

Table 35. High-valued tree species in Zambian indigenous forests.

Afzelia quanzensis
Albizia adiantifolia
Albizia amara
Albizia antunesiana
Albizia gummifera
Albizia harveyi
Albizia versicolor
Baikiaea plurijuga
Brachystegia allenii
Brachystegia boehmii
Brachystegia bussei
Brachystegia floribunda
Brachystegia longifolia
Brachystegia manga
Brachystegia microphylla
Brachystegia spiciformis
Brachystegia stipulata
Brachystegia taxifolia
Brachystegia utilis
Brachystegia wangermeaana
Daniellia alsteeniana
Entandrophragma caudatum
Entandrophragma delevoyi
Entandrophragma excelsum
Erythrophleum africanum
Faurea saligna
Guibourtia coloesperma
Khaya anthoteca
Mitragyna stipulosa
Pericopsis angolensis
Pterocarpus angolensis

Commercially the top three high-valued species in Zambia are (in alphabetical order)

Baikiae plurijuga (mukusi)
Guibourtia coleosperma (mushibi)
Pterocarpus angolensis (mukwa)

They are the most desired for saw-milling and furniture industries. They are the most valuable in the sense of bringing licensing revenue for the planned Forestry

Commission. They are the ones, which must especially be monitored, Province by Province in the Forest Resource Assessment.

54 Fire management

The diameter distribution of the observed miombo – trees is a guiding tool also for fire management. Regular fires always change the species composition so that the species which benefit the fires will become more abundant and the species which suffer from fires become rare in the diameter distribution. Especially this is seen in the small diameter class of 0-9 cm by breast height diameter.

Strong late dry season fires may kill all the seedlings irrespective of tree species. If the late season fires are regular this is later seen in the diameter distribution. The small trees (0-9 cm) are underrepresented or lacking throughout. Early season fires are more selective. They reduce the number of small diameter trees with high fire susceptibility, only. Investigation of the diameter distribution patterns between various Provinces and inside one Province between the tree species gives thus information on the severity of fires. Such information can be used in guiding the fire management in different Zambian provinces.

55 Species occurrence and diameter distribution

551 Central Province

The diameter distribution of high-valued and other species in Central Province is shown in Table 36. The average tree stocking in Central Province is reasonable, 714 trees per hectare. It is near to a sufficient reference stocking in miombo –forest, when trees are on average 4 meters apart (625 trees/ha). Most of the sample trees (406 trees per hectare) belong to fuel wood species. There are altogether 308 high-valued trees per hectare.

Following the management recommendation from Chapter 52, the overall number of seed trees (total 29 trees per hectare in diameter classes 30-39 cm and over 40 cm) is below 30 trees per hectare. Roughly speaking, about half of the forests in Central Province are understocked for sustained regeneration. Thus only about half of the Central Province forests could be carefully exploited.

The occurrence of the most valuable tree, mukwa (*Pterocarpus angolensis*) is low. On average, there are no seed trees. There are totally only 18 trees per hectare, and they are in the small diameter classes 0-9 cm and 10-19 cm only. It is doubtful if any licensing on mukwa harvesting in Central Province is possible.

Table 36. Occurrence of high-valued and other species by diameter class in Central Province. Unit: trees per hectare per diameter class. Diameter at breast height.

Species	0-9 cm	10-19 cm	20-29 cm	30-39 cm	40- cm	Total
Afzelia quanzensis	31	0	0	0	0	31
Albizia antunesiana	37	13	1	0	0	51
Brachystegia boehmii	50	30	21	8	0	109
Brachystegia floribunda	16	1	1	1	1	20
Brachystegia longifolia	1	2	2	1	0	6
Brachystegia manga	0	0	0	0	0	0
Brachystegia spiciformis	17	7	9	2	0	35
Brachystegia utilis	0	1	0	0	0	1
Erythrophleum africanum	4	6	2	0	0	12
Faurea saligna	0	8	0	0	0	8
Pericopsis angolensis	1	12	3	1	0	17
Pterocarpus angolensis	12	6	0	0	0	18
High-valued species, total	**169**	**86**	**39**	**13**	**1**	**308**
Other species, total	**225**	**141**	**25**	**11**	**4**	**406**
All species, total	**394**	**227**	**64**	**24**	**5**	**714**

The most abundant high-values species is *Brachystegia boehmii* (109 trees per hectare). It is one of the typical miombo – species in Zambia, and gives medium quality bole wood. *Brachystegia* – species dominate in Central Province.

From the fire management point of view the Central Province tree diameter distribution is sound. There is a good number of small trees in the small diameter classes (394 in 0-9 cm and 227 in 10-19 cm class). At least in the sampled areas the Central Province forest fires have not deteriorated the miombo –forest structure.

There are no *Baikiae plurijuga* – trees in Central province, which is expected outside Kalahari sands area. One would have expected that *Guibourtia coleosperma* occurs in Central Province, but there was none.

552 Copperbelt Province

There are on average 617 trees per hectare in Copperbelt Province (Table 37). The stocking is almost the same as in Central Province (714 /ha), but the number of seed trees is bigger (altogether 49 in diameter classes 30-40 cm and above 40 cm). This gives somewhat more space for selective harvesting in Copperbelt Province than in Central Province.

Table 37. Occurrence of high-valued and other species by diameter class in Copperbelt Province. Unit: trees per hectare per diameter class. Diameter at breast height.

Species	0-9 cm	10-19 cm	20-29 cm	30-39 cm	40- cm	Total
Afzelia quanzensis	1	0	0	0	0	1
Albizia adianthifolia	0	1	0	0	0	1
Albizia antunesiana	1	3	0	0	0	4
Brachystegia boehmii	5	3	2	2	0	12
Brachystegia longifolia	0	2	1	1	1	5
Brachystegia spiciformis	6	7	8	7	3	31
Brachystegia stipulata	3	18	8	3	2	34
Brachystegia wangermeaana	1	5	2	0	2	10
Erythrophleum africanum	1	0	1	0	0	2
Faurea saligna	1	0	0	0	0	1
Pericopsis angolensis	8	11	1	0	0	20
Pterocarpus angolensis	6	1	1	0	0	8
High-valued species, total	**33**	**51**	**24**	**13**	**8**	**129**
Other species, total	**222**	**191**	**47**	**20**	**8**	**488**
All species, total	**255**	**242**	**71**	**33**	**16**	**617**

Of the high valued species *Brachystegia* –species dominate also in Copperbelt province. The most abundant was *Brachystegia stipulate* (34 trees /ha). There were no *Baikiae plurijuga* –trees (as expected), neither *Guibourtia coleosperma* – trees (partly unexpected) in Copperbelt Province. Occurrence of *Pterocarpus angolensis* was again low: only 7 trees per hectare and all of them in small diameter classes 0-9 and 10-19 cm.

From the fire management point of view the sampled plots did not show anything alarming in Copperbelt Province. Most of trees (255 trees in 0-9 cm and 242 trees per hectare in 10-19 cm) were in small diameter classes.

553 Eastern Province

Only 7 high-valued tree species were found in Eastern Province (Table 38) out of classified 31 high-valued species in Zambia. The overall tree stocking (676 trees per hectare) was reasonable, but the number of high-values trees small (117 trees per hectare). Eastern Province seems to be heavily harvested as no large trees, over 40 cm were found in high-values trees and only 5 trees / ha in fuel wood trees. The overall total number of seed trees, 17 trees per hectare, is too low for sustained management. High-valued tree harvesting in Eastern Province should be carefully considered case by case.

Table 38. Occurrence of high-valued and other species by diameter class in Eastern Province. Unit: trees per hectare per diameter class. Diameter at breast height.

Species	0-9 cm	10-19 cm	20-29 cm	30-39 cm	40- cm	Total
Albizia antunesiana	9	4	0	0	0	13
Brachystegia boehmii	39	14	4	2	0	59
Brachystegia longifolia	10	1	1	0	0	12
Brachystegia spiciformis	10	6	2	1	0	19
Entandrophragma delevoyi	1	0	0	0	0	1
Pericopsis angolensis	1	2	1	0	0	4
Pterocarpus angolensis	6	2	0	1	0	9
High-valued species, total	**76**	**29**	**8**	**4**	**0**	**117**
Other species, total	**412**	**97**	**37**	**8**	**5**	**559**
All species, total	**488**	**126**	**45**	**12**	**5**	**676**

There were no *Baikiae plurijuga* –trees (as expected), neither *Guibourtia coleosperma* – trees (partly unexpected) in Eastern Province. Occurrence of *Pterocarpus angolensis* was again low: only 9 trees per hectare and 8 out of them in small diameter classes 0-9. There was one lonesome seed tree in diameter class 30-39 cm (but no trees in the next smaller class 20-29 cm).

From the fire management point of view the sampled plots showed sound diameter distribution. There were 488 trees per hectare in the smallest diameter class (0-9 cm.

554 Luapula Province

The tree stocking is Luapula Province was somewhat lower (576 trees per hectare, Table 39) than in many other provinces. The number of seed trees was, however, a little over the desired 30 trees per hectare (total 40 trees per hectare in two large diameter classes).

Of the high-values tree species *Brachystegia* sp. dominated again. The most abundant species was *Brachystegia spiciformis* (60 trees per hectare). There were altogether 25 mukwas (*Pterocarpus angolensis*) per hectare, 2 trees /ha of them in the seed tree classes. There were no *Baikiae plurijuga* –trees (as expected), neither *Guibourtia coleosperma* – trees (partly unexpected) in Eastern province. There were 266 trees per hectare altogether in the lowest diameter class 0-9 cm, which is sufficient from fire management point of view.

Table 39. Occurrence of high-valued and other species by diameter class in Luapula Province. Unit: trees per hectare per diameter class. Diameter at breast height.

Species	0-9 cm	10-19 cm	20-29 cm	30-39 cm	40- cm	Total
Albizia antunesiana	1	2	1	1	0	5
Brachystegia boehmii	20	10	5	2	2	39
Brachystegia longifolia	0	0	1	0	0	1
Brachystegia spiciformis	21	21	10	5	3	60
Brachystegia taxifolia	0	1	0	0	0	1
Brachystegia utilis	0	2	1	0	0	3
Erythrophleum africanum	2	3	2	1	0	8
Faurea saligna	1	1	0	0	0	2
Pericopsis angolensis	8	4	3	1	1	17
Pterocarpus angolensis	16	5	2	1	1	25
High-valued species, total	**69**	**49**	**25**	**11**	**7**	**161**
Other species, total	**197**	**148**	**48**	**13**	**9**	**415**
All species, total	**266**	**197**	**73**	**24**	**16**	**576**

555 Lusaka Province

The tree stocking in Lusaka Province was low, only 322 trees per hectare (Table 40). Partly the low stocking can be sampling error, as there were only 28 sample plots in the Province. No *Pterocarpus angolensis*, no *Guibourtia coleosperma*, no *Baikiae plurijuga* trees were recorded in Lusaka Province sample plots. The stocking of seed trees was very low, only 17 trees per hectare. Not much sustained harvesting can any more counted on Lusaka Province. Also the fire seems to be problem. The diameter distribution has only 90 trees per hectare in the smallest class (0-9 cm) and 120 trees per hectare in the next diameter class 10-19 cm, which frequencies are both too small for good stand regeneration.

Table 40. Occurrence of high-valued and other species by diameter class in Lusaka Province. Unit: trees per hectare per diameter class. Diameter at breast height.

Species	0-9 cm	10-19 cm	20-29 cm	30-39 cm	40- cm	Total
Albizia antunesiana	0	1	1	0	0	2
Brachystegia boehmii	3	10	4	0	0	17
Brachystegia floribunda	0	3	1	0	0	4
Brachystegia longifolia	6	21	4	1	0	32
Faurea saligna	1	0	0	0	0	1
Khaya anthoteca	0	1	0	0	1	2
Pericopsis angolensis	1	7	4	0	0	12
High-valued species, total	**11**	**43**	**14**	**1**	**1**	**70**
Other species, total	**79**	**120**	**38**	**12**	**3**	**252**
All species, total	**90**	**163**	**52**	**13**	**4**	**322**

556 Northern Province

Northern Province had altogether 882 trees per hectare and a good number of them (536 trees per hectare) in the smallest diameter class (Table 41). This shows good recovery from dry season fires. The number of seed trees was however low, only 33 trees per hectare. This shows that the Northern Province forests have been under heavy harvesting pressure.

There were altogether 15 *Pterocarpus angolensis* trees per hectare, out which on average of two were in the seed tree diameter classes. This gives some space for mukwa harvesting, but not much. There were no *Baikiaea plurijuga* trees as expected, but one would have expected occurrence of some *Guibourtia coleosperma.*

Table 41. Occurrence of high-valued and other species by diameter class in Northern Province. Unit: number of trees per hectare per diameter class. Diameter at breast height.

Species	0-9	10-19	20-29	30-39	40-	Total
	cm	cm	cm	cm	cm	
Albizia antunesiana	3	3	1	0	0	7
Brachystegia boehmii	1	0	0	0	0	1
Brachystegia floribunda	11	9	1	1	0	22
Brachystegia longifolia	27	12	4	2	1	46
Brachystegia microphylla	1	1	0	0	0	2
Brachystegia spiciformis	20	17	10	5	2	54
Brachystegia utilis	18	4	2	2	0	26
Erythrophleum africanum	2	3	2	0	0	7
Faurea saligna	8	3	1	0	0	12
Pericopsis angolensis	3	4	2	1	1	11
Pterocarpus angolensis	4	7	3	1	0	15
High-valued species	**98**	**63**	**26**	**12**	**4**	**203**
Other species	**438**	**181**	**43**	**12**	**5**	**679**
All species	**536**	**244**	**69**	**24**	**9**	**882**

557 Northwestern Province

As could be expected the number of large diameter trees per hectare is higher in the remote, forested Northwestern Province than in the other Provinces. There were altogether 55 trees per hectare in the seed tree classes 0-9 and 10-19 cm (Table 42). By far the most abundant high-valued tree species was again *Brachystegia boehmii* (98 trees per hectare, out of which 15 trees per hectare in the seed tree classes).

Pterocarpus angolensis was the second most abundant, 28 trees per hectare but only one of them belonged to seed tree diameters. This may tell about heavy selecting harvesting of large trees with *Pterocarpus angolensis*, in any case heavier than with *Brachystegia boehmii*. One could have expected occurrence of both *Baikiaea plurijuga* and *Guibourtia coleosperma* in Northwestern Province, but they were none in the sampled plots.

As to the fire damage the diameter distribution is healthy. There are altogether 412 trees per hectare in the smallest, 0-9 cm diameter class.

Table 42. Occurrence of high-valued and other species by diameter class in Northwestern Province. Unit: number of trees per hectare per diameter class. Diameter at breast height.

Species	0-9 cm	10-19 cm	20-29 cm	30-39 cm	40- cm	Total
Albizia adianthifolia	1	1	0	0	0	2
Albizia antunesiana	4	2	1	0	0	7
Brachystegia boehmii	46	24	13	8	7	98
Brachystegia floribunda	7	3	2	1	1	14
Brachystegia longifolia	2	1	1	1	0	5
Brachystegia spiciformis	7	3	4	3	2	19
Erythrophleum africanum	1	5	5	1	1	13
Faurea saligna	1	1	0	0	0	2
Pericopsis angolensis	4	2	3	2	1	12
Pterocarpus angolensis	22	3	2	1	0	28
High-valued species, total	**95**	**45**	**31**	**17**	**12**	**200**
Other species, total	**317**	**135**	**36**	**15**	**8**	511
All species, total	**412**	**180**	**67**	**32**	**20**	**711**

558 Southern Province

Baikiaea plurijuga (6 trees per hectare) and *Guibourtia coleosperma* (1 tree per hectare) were finally found in Southern Province, although their occurrence was low (Table 43).

The total number of seed trees per hectare in Southern Province was rather low, 30, which again mean that, from sustained forest management point of view, half of the forested area should not be harvested at this point but should be left for regeneration and recovery.

Most (49 trees per hectare) of the high-valued trees (80 trees per hectare) were *Brachystegia longifolia* trees. *Pterocarpus angolensis* was found, 6 trees per hectare, but none of the found trees belonged to seed tree diameter classes.

From fire management point of view the overall diameter distribution in Southern Province was healthy. Smallest diameter class had half (256 trees per hectare) of the found trees (516 trees per hectare).

Table 43. Occurrence of high-valued and other species by diameter class in Southern Province. Unit: number of trees per hectare per diameter class. Diameter at breast height.

Species	**0-9 cm**	**10-19 cm**	**20-29 cm**	**30-39 cm**	**40- cm**	**Total**
Afzelia quanzensis	1	0	0	0	0	1
Albizia antunesiana	1	0	0	0	0	1
Baikiaea plurijuga	1	3	2	0	0	6
Brachystegia boehmii	2	2	3	1	0	8
Brachystegia longifolia	16	11	11	8	3	49
Brachystegia spiciformis	1	1	0	0	0	2
Erythrophleum africanum	0	2	2	1	0	5
Faurea saligna	1	0	0	0	0	1
Guibourtia coleosperma	1	0	0	0	0	1
Pterocarpus angolensis	3	2	1	0	0	6
High-valued species, total	**27**	**21**	**19**	**10**	**3**	**80**
Other species, total	**229**	**151**	**39**	**14**	**3**	436
All species, total	**256**	**172**	**58**	**24**	**6**	**516**

559 Western Province

Of all the provinces Western Province had the highest tree stocking, 816 trees per hectare (Table 44).

Guibourtia coleosperma was found in abundance (46 trees per hectare) which was expectable. *Baikiaea plurijuga*, instead, was not found in the sampled areas at all, which was totally unexpected, and calls for sampling verification mission to the Province. *Pterocarpus angolensis* was found similarly to the other provinces: rather many in small diameter class (11 trees /ha in 0-9 cm class) but very few in the harvestable, but seed tree classes (only one per hectare in Western Province). The most abundant high-valued tree belonged again to *Brachystegia* sp. (*B. spiciformis*, 52 trees per hectare).

From fire management point of view the species distribution was healthy: over half (472 trees per hectare) belonged to the smallest diameter class.

Table 44. Occurrence of high-valued and other species by diameter class in Western Province. Unit: number of trees per hectare per diameter class. Diameter at breast height.

Species	0-9 cm	10-19 cm	20-29 cm	30-39 cm	40- cm	Total
Albizia antunesiana	6	5	3	1	0	15
Brachystegia boehmii	11	7	2	1	1	22
Brachystegia spiciformis	14	24	7	4	3	52
Brachystegia taxifolia	0	2	1	0	0	3
Brachystegia utilis	0	2	2	0	0	4
Erythrophleum africanum	12	9	2	1	1	25
Faurea saligna	1	1	0	0	0	2
Guibourtia coleosperma	35	5	3	2	1	46
Pericopsis angolensis	1	4	1	0	0	6
Pterocarpus angolensis	11	10	1	1	0	23
High-valued species, total	**91**	**69**	**22**	**10**	**6**	**198**
Other species, total	**381**	**182**	**41**	**9**	**5**	**618**
All species, total	**472**	**251**	**63**	**19**	**11**	**816**

6 Valuation of Zambia woody biomass resource

61 Fees for Indigenous Forest Produce

Valuation of Zambia woody biomass resource is based on the forest resource assessment in which the amount of bole wood, pole and fuel wood for each Province were calculated. The quantity in million cubic meters is multiplied by the unit price in Zambian kwachas per cubic meter. Thus the end result will be in Kwachas. Due to low value of the currency, the units of million Kwachas (1E06), billion (1E09) or even trillion (1E12) kwachas need to be used.

The valuation is also based on a principle that the sum of license fees for harvestable boles, poles and fuel wood as such describes the market value of the forest. There is no value estimate for land in this calculation. The valuation method is somewhat arbitrary, but it describes the potential revenue value of Zambian forest for the planned Zambia Forestry Commission. According to the financial plan for the Commission it could get its main revenue just for selling the timber harvesting licenses for bole wood, pole wood and fuel wood.

The valuation of the forest resource has two steps. In the first step the capital value, i.e. the standing value of the Zambian forest resource is assessed. In the second step the sustainable takeover from the standing stock is assessed. This is based on allowable cut. The allowable cut in turn is based on the growth of various trees in various parts of Zambia. The accuracy of growth computation is best if predetermined growth functions for various trees are available. Such detailed growth functions, however, do not exist for Zambian forests.

Without predetermined growth functions an overall growth per cent must be used. Alajärvi (1996) estimated for Zambia Forestry Action Programme (ZFAP) that the regular indigenous Zambian forests grow 1.5 per cent per year, the forests in national parks 1.0 per cent per year and the trees outside forest (agroforest trees) 2.0 per cent per year, all calculated from the standing stock.

In the Forestry Support Programme assessment 2004 it is assumed that the Zambian forests grow on average 1.0 per cent per year.

The unit values for various trees and various assortments like bole wood, pole wood and fuel wood have been given by the Forest Act or Zambia and they are regularly updated through the official Government Gazette. The last update is from 23rd October 2003 (GRZ 2003) (Table 45).

Table 45. Value of Zambian Forest Produce for different species and various assortments. Source: Government Gazette 23rd October 2003.

Tree species	Fee units	Fee ZMK	Per
Afzelia quanzensis	550	99 000	ZMK / m3
Albizia adiantifolia	500	90 000	ZMK / m3
Albizia amara	500	90 000	ZMK / m3
Albizia antunesiana	500	90 000	ZMK / m3
Albizia gummifera	500	90 000	ZMK / m3
Albizia harveyi	500	90 000	ZMK / m3
Albizia versicolor	500	90 000	ZMK / m3
Baikiaea plurijuga	750	135 000	ZMK / m3
Brachystegia allenii	600	108 000	ZMK / m3
Brachystegia boehmii	600	108 000	ZMK / m3
Brachystegia bussei	600	108 000	ZMK / m3
Brachystegia floribunda	600	108 000	ZMK / m3
Brachystegia longifolia	600	108 000	ZMK / m3
Brachystegia manga	600	108 000	ZMK / m3
Brachystegia microphylla	600	108 000	ZMK / m3
Brachystegia spiciformis	600	108 000	ZMK / m3
Brachystegia stipulata	600	108 000	ZMK / m3
Brachystegia taxifolia	600	108 000	ZMK / m3
Brachystegia utilis	600	108 000	ZMK / m3
Brachystegia wangermeaana	600	108 000	ZMK / m3
Daniellia alsteeniana	650	117 000	ZMK / m3
Entandrophragma caudatum	650	117 000	ZMK / m3
Entandrophragma delevoyi	650	117 000	ZMK / m3
Entandrophragma excelsum	650	117 000	ZMK / m3
Erythrophleum africanum	600	108 000	ZMK / m3
Faurea saligna	700	126 000	ZMK / m3
Guibourtia coloesperma	750	135 000	ZMK / m3
Khaya anthoteca	550	99 000	ZMK / m3
Mitragyna stipulosa	550	99 000	ZMK / m3
Pericopsis angolensis	550	99 000	ZMK / m3
Pterocarpus angolensis	750	135 000	ZMK / m3
Other species	450	81 000	ZMK / m3
Poles not exceeding 14 cm butt diameter	30	5 400	ZMK / pole
Poles between 15 and 19 cm butt diameter	40	7 200	ZMK / pole
Poles between 20 and 24 cm butt diameter	50	9 000	ZMK / pole
Poles between 25 and 30 cm butt diameter	60	10 800	ZMK / pole
Fuelwood stacked in cubic meters	200	36 000	ZMK / m3
Fee conversion factor 23 October 2003	180	ZMK / unit	

62 Value for all species

Based on FSP Forest Resource Assessment woody biomass volume results (million cubic meters for every Zambian province), as per forest class and wood assortments, and on the Government Gazetted fees for Forest Produce, it is possible to calculate the capital value of the standing stock. The capital value is first calculated Province by Province and then summed up into Zambian national level (Table 46). The unit is trillion kwachas (trillion has 12 zeros).

Table 46. Estimated total value of Zambian forest resource, trillion Zambian kwachas.

Total Kwacha	**Total**	**Bole**	**Pole**	**Other**
Forest class	**Trill. ZMK**	**Trill. ZMK**	**Trill. ZMK**	**Trill. ZMK**
High Density Forest	54.9	15.7	1.8	37.5
Medium Density Forest	27.0	6.5	0.7	19.8
Low Density Forest	20.2	5.0	0.4	14.9
Total forests	102.2	27.2	2.9	72.1

Most of the capital value in Zambian forests is in the fuel wood (column "Other"), 72.1 trillion kwachas. The second biggest value is in bole wood (27.2 trillion kwachas). This order comes partly from the finding, that in many Provinces the number of large diameter bole wood trees was low. Most of the resource gives only fuel wood and raw material for charcoal burning.

The total, estimated capital value for Zambian forest resource (as per total woody biomass volume) is 102.2 trillion Zambian kwachas (102,200,000,000,000 kwachas). As the woody biomass resource is still considerably large and as the monetary value of one kwacha is low, their product is difficult to understand by the quantity. The capital value of the woody biomass becomes easier to understand when it calculated as per hectare basis (Table 47).

Table 47. Average per hectare value of Zambian forests, million kwachas per hectare.

Kwacha / hectare	**Total**	**Bole**	**Pole**	**Other**
Forest class	**Mill. ZMK**	**Mill. ZMK**	**Mill. ZMK**	**Mill. ZMK**
High Density Forest	4.23	1.21	0.14	2.88
Medium Density Forest	3.45	0.83	0.09	2.53
Low Density Forest	2.19	0.54	0.04	1.61
Total forests	3.40	0.90	0.10	2.40

The overall average value for Zambian forest hectare is 3.40 million kwachas per hectare. To make comparisons for forest hectare value in Euros and US dollars, the corresponding forest hectare values have been calculated in Table 48 (euros) and Table 49 (US dollars). The exchange rates are from 19 February 2004.

Table 48. Average per hectare value of Zambian forests, in Euro per hectare. Exchange rate Euro to kwacha 6038.

Euro / hectare	**Total**	**Bole**	**Pole**	**Other**
Forest class	**Euro**	**Euro**	**Euro**	**Euro**
High Density Forest	700	200	23	477
Medium Density Forest	571	137	16	419
Low Density Forest	363	89	7	267
Total forests	563	149	16	397

Table 49. Average per hectare value of Zambian forests, in USD per hectare. Exchange rate USD to kwacha 4750.

USD / hectare	**Total**	**Bole**	**Pole**	**Other**
Forest class	**USD**	**USD**	**USD**	**USD**
High Density Forest	890	254	29	606
Medium Density Forest	726	174	20	532
Low Density Forest	461	114	9	339
Total forests	715	190	20	505

The average forest hectare in Zambia is valued (without land) at 563 euros per hectare, or 715 US dollars per hectare. The value compares well to international standards. In a forested country of Finland, for instance, the value of forest hectare in 2003 was between 1000 – 2000 euros per hectare (including the land value).

63 Valuation for high-valued species

The capital value of high-valued species only is of more interest for the coming Zambia Forestry Commission. The high-valued species, and especially the licensed bole wood from them is the planned main revenue for the Commission. Thus, the capital value of the high-valued trees species boles can be interpreted as a capital in bank from which to draw annually for the expenses to the Forestry Commission. Such a “bank balance” capital value was calculated for the high-valued bole wood at 18.1 trillion kwachas (Table 50).

Table 50. Share of high-valued trees of Zambian forest resource, trillion Zambian kwachas.

Total Kwacha	Total	Bole	Pole	Other
Forest class	**Trill. ZMK**	**Trill. ZMK**	**Trill. ZMK**	**Trill. ZMK**
High Density Forest	27.6	11.0	0.8	15.8
Medium Density Forest	10.7	3.8	0.3	6.5
Low Density Forest	8.9	3.3	0.2	5.5
Total forests	47.2	18.1	1.3	27.8

The corresponding per hectare values in Zambian kwachas, Euros and US dollars are given in Tables 51 - 53.

Table 51. High-valued trees, average per hectare value of Zambian forests, million kwachas per hectare.

Kwacha / hectare	Total	Bole	Pole	Other
Forest class	**Mill. ZMK**	**Mill. ZMK**	**Mill. ZMK**	**Mill. ZMK**
High Density Forest	2.12	0.85	0.06	1.21
Medium Density Forest	1.36	0.49	0.04	0.83
Low Density Forest	0.96	0.36	0.02	0.59
Total forests	1.57	0.60	0.04	0.92

Table 52. High-valued trees, average per hectare value of Zambian forests, in Euro per hectare. Exchange rate Euro to kwacha 6038.

Euro / hectare	Total	Bole	Pole	Other
Forest class	**Euro**	**Euro**	**Euro**	**Euro**
High Density Forest	352	140	10	201
Medium Density Forest	225	81	7	138
Low Density Forest	160	59	3	98
Total forests	260	100	7	153

Table 53. High-valued trees, average per hectare value of Zambian forests, in USD per hectare. Exchange rate USD to kwacha 4750.

USD / hectare	Total	Bole	Pole	Other
Forest class	**USD**	**USD**	**USD**	**USD**
High Density Forest	447	178	13	256
Medium Density Forest	286	102	9	175
Low Density Forest	203	75	4	125
Total forests	330	127	9	194

Thus, in euros, the average capital value of the high-valued species boles in one forest hectare is on average 100 euros per hectare. It is highest in High Density Forest (140 Euro / ha) and lowest in Low Density Forest (59 Euro / ha). Such a capital value can be used in forest economy planning for instance when planning future harvests in forest reserves at district and province level.

64 Allowable cut

The allowable cut calculation (in cubic meters per annum) is based on three conservative principles. The calculation is done in three rounds (Table 54).

Table 54. Allowable cut calculation for all tree resource in Zambia, the three rounds explained in text.

All trees, volume	Total	Bole	Pole	Other
	mill. m3/a	mill. m3/a	mill. m3/a	mill. m3/a
Round 1	26.8	7.5	4.0	15.4
Round 2	17.4	4.8	2.6	9.9
Round 3	**15.6**	**4.4**	**2.3**	**8.9**

In the first round the growth rate (maximum allowable cut) is estimated at one per cent per year, calculated from the total woody biomass volume (see Chapter 61). This would allow total harvesting of 26.8 million cubic meters per year from the Zambian forest resource.

In the second round the allowable cut is dropped to low 95 per cent reliability level. The reduction factor is 0.647. This round would allow total harvesting of 17.4 million cubic meters in a year.

In the third round the National parks and other protected and strictly conserved areas are left out from allowable cut. Their share is 10 per cent, thus the reduction factor is 0.90. The third round thus gives the allowable cut of 15.6 million cubic meters per annum for the whole country (and for all trees). The biggest share (8.9 million cubic meters per annum) of the allowable cut is in fuel wood ("other"). The allowable cut for bole wood is 4.4 million cubic meters and for pole wood 2.3 million cubic meters, per annum.

Similar allowable cut calculation can be done for high-valued trees only (Table 55), which forms a share of the total allowable cut.

Table 55. Allowable cut calculation for high-valued trees in Zambia. The calculation rounds as in Table 54.

High-valued, volume	Total	Bole	Pole	Other
	mill. m3/a	mill. m3/a	mill. m3/a	mill. m3/a
Round 1	11.1	2.9	1.7	6.4
Round 2	7.1	1.9	1.1	4.2
Round 3	**6.4**	**1.7**	**1.0**	**3.7**

The most interesting part of the high-valued trees allowable cut are the boles. The calculation shows that 1.7 million cubic meters of high-valued species can be harvested in sustained manner per annum. Such amount of high-valued bole wood gives the frame for annual licensing fees in the planned Forestry Commission.

65 Sustainable revenue

The calculation of sustainable revenue follows the calculation of allowable cut. The cubic meters are substituted with kwachas (or euros or US dollars) through multiplication with unit value (ZMK / m^3). The sustainable revenue in kwachas (or euros or us dollars) can be interpreted as the interest rate which can annually be drawn from the bank account (= capital value of Zambian forests).

The sustainable revenue calculation, after three consecutive calculation rounds, gives for all trees 595 billion kwachas per annum, or 99 million euros or 125 million US dollars per annum (Tables 56 – 58). This is the theoretical maximum which assumes that all allowable cut is harvested per annum, and that all the licensing fees for boles, poles and fuel wood can be sold and collected (and that there is no illegal, non-licensed harvesting).

Table 56. Sustainable revenue from Zambian forests, all trees, kwachas

All trees, Kwachas	Total	Bole	Pole	Other
	Bill. ZMK/a	Bill. ZMK/a	Bill. ZMK/a	Bill. ZMK/a
Round 1	1 022	272	29	721
Round 2	661	176	19	467
Round 3	**595**	**158**	**17**	**420**

Table 57. Sustainable revenue from Zambian forests, all trees, Euros

All trees, Euro	Total	Bole	Pole	Other
	Mill. euro/a	Mill. euro/a	Mill. euro/a	Mill. euro/a
Round 1	169	158	17	420
Round 2	110	29	3	77
Round 3	**99**	**26**	**3**	**70**

Table 58. Sustainable revenue from Zambian forests, all trees, US dollars

All trees, USD	Total	Bole	Pole	Other
	Mill. USD/a	Mill. USD/a	Mill. USD/a	Mill. USD/a
Round 1	215	57	6	152
Round 2	139	37	4	98
Round 3	**125**	**33**	**4**	**88**

For the financial planning of Zambia Forestry Commission it might be more realistic to study the high-valued trees species only, and the potential bole wood licenses only. Assuming again, that all the allowable cut is harvested, all the licenses are sold and collected and that there is no illegal harvesting, the sustained annual revenue from high-valued tree species boles is of the order of 106 billion Kwachas, or 17 million euros, or 22 million US dollars per annum (Table 59-61).

Table 59. Sustainable revenue from Zambian forests, high-valued trees, boles only, kwachas

High-valued, Kwachas	Total	Bole	Pole	Other
	Bill. ZMK/a	Bill. ZMK/a	Bill. ZMK/a	Bill. ZMK/a
Round 1	472	181	13	278
Round 2	305	117	8	180
Round 3	**275**	**106**	**7**	**162**

Table 60. Sustainable revenue from Zambian forests, high-valued trees, boles only, Euros

High-valued, Euro	Total	Bole	Pole	Other
	Mill. euro/a	Mill. euro/a	Mill. euro/a	Mill. euro/a
Round 1	78	30	2	46
Round 2	51	19	1	30
Round 3	**45**	**17**	**1**	**27**

Table 61. Sustainable revenue from Zambian forests, high-valued trees, boles only US dollars

High-valued trees, USD	Total	Bole	Pole	Other
	Mill. USD/a	Mill. USD/a	Mill. USD/a	Mill. USD/a
Round 1	99	38	3	58
Round 2	64	25	2	38
Round 3	**58**	**22**	**2**	**34**

The annual budget of the planned Zambia Forestry Commission might be of order 3-5 million euros per annum. The budget would be in balance if about one third of the potential license fees for allowable cut of high-valued boles can be annually collected.

7 Discussion

71 General

The Zambia Forest Resource Assessment 2004 was carried in a rather short period: the main part of the assessment during one year. As the country is vast and its forests and wood lands cover various, large ecological zones in altogether nine Provinces, such a rapid forest resource assessment must still be regarded as a reconnaissance survey. It gives way and basis for a more systematic, thorough and comprehensive national woody biomass inventory and forest resource assessment which is in the planning pipeline for Zambia as assisted by FAO.

For the first time since 1965 District level forest management planning and combined national forest assessment the FSP Forest Resource Assessment 2004 was an independent assessment that did not rely only on old measurements. Modern satellite technology, powerful computers and advanced software made it possible to rely mostly on new data: satellite image interpretation over whole country and new forest sample plots measured in every Province of the country. Thus the FSP Forest Resource Assessment aimed to go far beyond than for instance the forest resource assessment that was done for Zambia Tropical Forestry Action Programme (ZFAP 1996).

Compared to all past assessments the FSP Forest Resource Assessment 2004 had more comprehensive scope. In addition to forest land areas and the wood volume growing on them, information was collected and computed on tree species spectrum, their diameter distribution and division into the three main assortments: bole wood, pole wood and fuel wood. This information connected with the recent Zambian gazetted fees and prices for Forest Produce, made it possible to compute the capital value of the Zambian forest resource both as a whole and as per hectare basis. Such calculation is not known from the past.

Finally, the capital calculation made it possible to estimate the annual sustained revenue, based on license fee approach, from the Zambian forest resource. Such a calculation, as compared to annual budgeting needs for new Zambia Forestry commission, has been one of the ultimate objectives of the Forestry Support Programme. The Forest Resource Assessment analysis shows that it is possible for the planned Forestry Commission, at least in potential terms and based on available forest resource and its sustained use, to count in her budgeting on the annual revenue coming from the resource itself.

72 Degree of variation in the results

There are several inaccuracies and uncertainties in the results which lower the reliability of the calculated results. The first of them relates to the low sampling intensity, which was low, only about 0.0004 per cent on average. The second is the degree of variation in the results, which is best depicted by the standard error of the mean, in the mean volume calculation, and the wideness of 95 per cent reliability range. In general, they both were too high or wide. This follows from use of several field measurement teams, with varying level of forest mensuration training and experience. The general observation was that the more different teams were used, the higher the standard error of the mean became.

73 Implication of confidence limits

The 95 percent confidence limits are important in the later stage of the forest resource assessment analysis. For conservative calculations of allowable cut or sustained revenue, to be on a safe side, the lower 95 per cent limits are normally used instead of arithmetic mean values. Therefore, the wider is the reliability range of the results, the smaller is the basic value for financial calculations.

74 Probable sources of error

The errors in the field measurement are of two kinds. Less harmless are the random errors. Each individual error deviates from the true value, either up or down. But by repeated measurements and big enough number of observations the positive and negative errors cancel each other. With large enough number of observations, the mean value becomes correct.

The more harmful are the systematic errors. For instance the tree diameter can be constantly read by some field team member as too high. There will biased error, biased upwards which will give an overestimate in the field data.

In the field sampling some consideration is left with the field team and its leader. There is a continuous danger that selection of sample plots will be done in favor of better than worse plots. For instance, when the transect line has been demarcated in the field and later located in the field, the first plot may be empty. There is always temptation to walk some distance to get the first plot into forest. The empty plot may stay unrecorded, although it should be recorded.

75 Lack of, or insufficient data

There was a considerable variation between the provinces in the amount of sample plots. Northern Province had 370 plots but Lusaka Province had only 28 plots. There was definite insufficiency in the data of Lusaka Province. Another Province where there was insufficient data was Copperbelt Province.

76 Recommendation for future assessments

A number of improvements for the next forest resource assessment can be made based on FSP assessment 2004.

First, full cover of fresh satellite imagery could be obtained. At least the four older images (from about 1990) could be replaced with fresh, dry season images.

Second, the Zambian lands could, after having full set of fresh satellite images, be reclassified with new, more powerful computers and more modern software.

Third, the GPS coordinates of the already measured 1908 sample plots could be marked to satellite images and the forest class for each plot could be rechecked.

Fourth, another field sample plot measurement could be sent to Lusaka Province to increase number of sample plots. Other possible field missions could be selected for such provinces and forest classes in them which have high standard error of mean.

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91 Annex 1.

Satellite images data – Zambia: Landsat 7 Images Index

PATH	ROW	DATE	OWNERSHIP
169	067	10 / 09 / 2001	FD / FSP
169	068	10 / 09 / 2001	FD / FSP
169	069	05 / 05 / 2000	FD / FSP
169	070	05 / 05 / 2001	FD / FSP
170	066	19 / 12 / 2000	FD / FSP
170	***067***	***Old Image 91***	***FD / AMS***
170	068	14 / 09 / 2000	FD / ESP
170	069	10 / 04 / 2001	FD / ESP
170	***070***	***Old Image 90***	***FD / AMS***
171	066	22 / 05 / 2002	FD / FSP
171	067	09 / 07 / 2002	FD / FSP
171	068	23 / 10 / 2000	FD / ESP
171	069	23 / 10 / 2000	FD / ESP
171	070	22 / 07 / 2001	FD / FSP
171	***071***	***Old Image 89***	***FD / AMS***
172	066	13 / 05 / 2002	FD / FSP
172	067	13 / 05 / 2002	FD / FSP
172	068	13 / 05 / 2002	FD / FSP
172	069	14 / 10 / 2000	FD / ESP
172	070	11 / 08 / 2000	FD / ESP
172	071	12 / 10 / 2000	FD / PFAP
172	072	22 / 05 / 2001	FD / PFAP
173	068	01 / 05 / 2001	FD / FRMP
173	069	01 / 05 / 2000	FD / FRMP
173	070	05 / 10 / 2000	FD / ESP
173	071	05 / 10 / 2000	FD / PFAP
173	072	22 / 05 / 2001	FD / PFAP
174	068	22 / 06 / 2000	FD / FRMP
174	069	28 / 08 / 2000	FD / FRMP
174	070	24 / 09 / 1999	FD / ESP
174	071	09 / 08 / 2000	FD / ESP
174	***072***	***Old Image 90***	***FD / AMS***
175	068	03 / 08 / 2001	FD / FRMP
175	069	02 / 05 / 2002	FD / FRMP
175	070	02 / 05 / 2002	FD / FSP
175	071	20 / 11 / 2001	FD / FSP
175	072	10 / 04 / 2001	FD / FSP
176	069	03 / 05 / 2002	FD / FRMP
176	070	25 / 07 / 2001	FD / FSP
176	071	25 / 07 / 2001	FD / FSP

Old images highlighted (bold)
Source: Mr. Abel Siampale, Forestry Department, Zambia, January 2004

92 Annex 2. Forest sample plots.

Inventory ID	Plots	Source	Original database file	New or combination file
Central 1	**164**			FC_Datainput_150.mdb 1700 kb
Central 100	37	FSP	L0000100.mdb 452 kb	
Central 101	5	ESP	L0000101.mdb 240 kb	
Central 102	7	ESP	L0000102.mdb 222 kb	
Central 105	8	ESP	L0000105.mdb 194 kb	
Central 107	8	ESP	L0000107.mdb 188 kb	
Central 109	24	ESP	L0000109.mdb 196 kb	
Central 110	13	ESP	L0000110.mdb 238 kb	
Central 112	4	ESP	L0000112.mdb 186 kb	
Central 200	58	ESP	L0000200.mdb 578 kb	
Copperbelt 2	**79**			FC_Datainput_250.mdb 876 kb
Copperbelt 9	32	PFAP	L0000009.mdb 322 kb	
Copperbelt 78	38	PFAP	L0000078.mdb 302 kb	
Copperbelt 120	9	FSP	L0000078.mdb 120 kb	
Eastern 3	**152**			FC_Datainput_350.mdb 1452 kb
Eastern 301	152	FSP	L0000301.mdb 706 kb	
Luapula 4	**305**			FC_Datainput_450.mdb 3388 kb
Luapula 22	123	PFAP	L0000022.mdb 1252 kb	
Luapula 400	182	FSP	L0000400.mdb 738 kb	
Lusaka 5	**28**			FC_DataInput_550.mdb 492 kb
Lusaka 501	28	FSP	L0000501.mdb 288 kb	
Northern 6	**370**			FC_DataInput_650.mdb 4924 kb
Northern 600	8	FSP	L0000600.mdb 230 kb	
Northern 601	362	FSP	L0000601.mdb 2612 kb	
Northwestern 7	**238**			FC_DataInput_750.mdb 4160 kb
Northwestern 702	238	FSP	L0000702.mdb 962 kb	
Southern 8	**230**			FC_DataInput_850.mdb 1808 kb
Southern 40	12	PFAP	L0000040.mdb 188 kb	
Southern 302	81	PFAP	L0000302.mdb 626 kb	
Southern 303	54	FSP	L0000303.mdb 298 kb	
Southern 304	83	PFAP	L0000304.mdb 536 kb	
Western 9	**342**			FC_DataInput_950.mdb 3236 kb
Western 900	120	FSP	L0000900.mdb 914 kb	
Western 901	110	FSP	L0000901.mdb 746 kb	
Western 909	112	FSP	L0000901.mdb 708 kb	
TOTAL plots	**1908**			

10 List of acronyms and abbreviations

AVHRR	Advanced Very High Resolution Radiometer
ESP	Environment Support Programme
EU-FSP	European Union – Forestry Support Programme
HDF	High Density Forest (forest class based on NDVI-classification)
FRMP	Forest Resources Management Project
FSF	Forestry Support Programme
JICA	Japan International Cooperation Agency
LDF	Low Density Forest (forest class based on NDVI-classification)
MDF	Medium Density Forest (forest class based on NDVI-classification)
NDVI	Normalized Difference Vegetation Index
PFAP	Provincial Forestry Action Programme in Central, Copperbelt and Luapula Provinces
SADC	Southern African Development Community
SADCC	Southern African Development Coordination Conference
ZAFCOM	Zambia Forestry Commission
ZFAP	Zambian Forestry Action Programme
ZMK	Zambian kwacha