National Biomass Study

Technical Report

September 21, 2002

Forest Department, Ministry of Water Lands and Environment.

National Biomass Study Technical Report of 1996-2002

Paul Drichi,

Project Manager
National Biomass Study Project
Forest Department, P.O. Box 1613, Kampala, Uganda
21 September 2002

Foreword

Uganda like any other developing country has continued to rely mainly on biomass derived energy (firewood, charcoal and agricultural residues) for most of its domestic requirements. Biomass energy is derived from trees and agricultural residues from the surrounding land cover such as farmlands, bushlands, woodlands, forests or grasslands. Apart from energy, other products such as timber and poles are also obtained from trees occurring in these various land cover types collectively referred to as the biomass resource.

However, this resource is now threatened by increased human activities and competing demands from the same resource. For instance, increasing population, which in turn requires increased food production and energy is putting undue pressure on the surrounding land cover. The consequences among others are increasing deforestation, forest degradation and woodfuel scarcities in many parts of the country. The worsening situation on the biomass resource has been of concern to foresters, environmentalists, decision-makers and the general public.

In spite of the concern and awareness of the problem, it was realised in the late 80's that there was no up to date data and information for planning and sustainable management and use of this otherwise crucial resource. It is for this reason that the National Biomass Study NBS, project was created in 1989 to fill in the information gap by providing up to date data/information on the biomass resource.

Since then, the project has been implemented by the Forestry Department in collaboration with the Norwegian Forestry Society under the then Ministry of Environment Protection, now Ministry of Water, Lands and Environment. The project has undergone through three phases. The first phase (Phase I) was implemented from 1989-1992 covering nine peri-urban areas in Uganda with perceived woodfuel scarcities. The findings of this phase were published in 1992. This was followed by Phase II from 1992-1996 and finally Phase III from 1996- 2002. Phase III was followed by bridging period from 2001 to 2002. The Norwegian Agency for International Co-operation, NORAD has been the main financier of the project throughout its more than 10 year life span.

In the assessment of the biomass resource, the NBS employed the latest state of the art technology in Remote Sensing, RS, Geographical Information system, GIS and Global Positioning System, GPS. These latest techniques have several advantages over the traditional and out dated methods of mapping and resource assessment. For instance reduced costs through timesavings, easy data storage, retrieval and analysis with better accuracy, easy to update etc.

For the first time in Uganda, the National Biomass Study has been able to provide the most comprehensive information on the biomass resource at national, regional and district administrative units up to parishes. Information presented covered area and extent of land cover, status of protected areas (deforestation and forest degradation), biomass density and standing stock, growth and dynamics, and, future scenarios on land cover and biomass supplies. It is hoped that if properly used in planning, management and utilisation of the biomass resource, the goal of improved and sustainable use of this otherwise threatened resource should become a reality rather than a dream.

Ambrose Kyaroki

Ag. Commissioner for Forestry,

Forestry Department, Kampala

Acknowledgements

A project with a national coverage running for many years such as the National Biomass Study project would not have gone far without financial support. Luckily, for NBS the Norwegian Agency for International Co-operation (NORAD) has offered this support throughout since its inception in 1989. NBS is deeply indebted to the continuous leadership and guidance from the respective Permanent Secretaries of previous and present Ministries under whom the Forest Department has been oscillating over the years. Similarly the good management and guidance from the respective Commissioners who headed the Forest Department during the lifespan of NBS are acknowledged. Without their leadership, support and guidance, the project would not have achieved its targets on time. Special gratitude is extended to the Commissioner and staff of the Department of Surveys and Mapping for their warm and excellent co-operation in data sharing and participation in the mapping process. The Staff of the Statistical Department especially those of the 1991 Census Office are thanked for their donation of the population data and the raw data on administrative layers.

The Forest Department would like to thank in a special way the Chief Technical Advisor Mr. Calle Hedberg who particularly built the NBS from its first pilot phase in the early 90s to its present status as a leading institution in Environmental Information System in the country. Without his expertise and wisdom the project would not be where it is today. The project is grateful to Mr. Paul Drichi who ably took over the leadership from Calle Heberg and steered the project on course till to the end.

Deep appreciation and gratitude is extended to all the project staff members of NBS for their contribution in varying capacities to the successful implementation of the project especially the following: Forestry Officers/GIS specialists Amadra Ori-Okido, Ayongera John, and Diisi John for their perseverance, skills and hardwork. Ali Karatunga and Mpungu Lwanga, for their initial participation in the project. System Administrator/GIS Specialist, Christopher Balyeidhusa for his stamina, dedication and hardwork. Assistant Forest Officers/Team Leaders: Erong Komaler Augustine, Damulira Edward, Macapili Alfred and Mukwaya Christopher; Assistant Team Leaders Ongodia John, Enyel, Aber Judith and Edward Senyonjo for their tirelessness and dedication to the field work. This group literally combed the countryside while searching for the raw data. Data entry Clerks: Stella Kabasemeza and Firidah Basemera for their concentration and hardwork; Cartographers Osubia Peter and Mubiru George for their contribution in the cartographic field. David Walugembe for his contribution as editor, without his effort, the document would not be what it is now.

Special thanks is extended to all the District Chief Administrative Officers, Resident District Commissioners, District Forest Officers, Local Council V Chairmen, and Local Councillors, right down to the village level for their kind support and co-operation in their respective districts during the field work. Without their kind support and protection of our field staff, the data collection would have been rendered impossible.

It is not possible to mention every one by name, however all those who contributed in one way or the other during the execution of this project are sincerely acknowledged in their respective capacities.

Table of Contents

List of Tables

List of Figures

Acronyms

DEP	Directorate of Environment Protection (one of 3 directorates within MNR)
DFO	District Forest Officer
ESD	Energy for Sustainable Development
ESMAP	Energy Sector Management and Assistance Program (UNDP/World Bank)
FAO	Food and Agriculture Organization
FD	Forest Department, Kampala (under DEP within MNR)
FO	Forest Officer
FORI	Forestry Research Institute (within NARO)
FRP	Forestry Rehabilitation Project, Uganda (coordinated by World Bank - 1988-94)
GIS	Geographical Information System
GDP	Gross Domestic Product
GoU	Government of Uganda
GPS	Global Positioning System
IUCN	World Conservation Union (previously International Union for the Conservation of Nature)
IPCC	Intergovernmental Panel on Climate Change
MWLE	Ministry of Water, Lands and environment
MFEP	Ministry of Finance and Economic Planning
M.Sc.	Master of Science
NARO	National Agricultural Research Organisation
NBS	National Biomass Study
NFS	Norwegian Forestry Society
NGO	Non-Governmental Organisation
NOK	Norwegian Kroner
NORAD	Norwegian Agency for Development Cooperation
PUP	Peri-urban Plantations project
UEB	Uganda Electricity Board (defunct)
UNDP	United Nations Development Program
UPTC	Uganda Posts and Telecommunications (defunct)
USD	United States Dollars
Ush	Ugandan Shillings
UTSP	Uganda Tree Seed Project (financed by DANIDA/UNSO)

Executive Summary

This technical report presents the findings of a 7-year assessment of the national biomass resource in Uganda (1995-2002) as a response to the goal and objectives of the National Biomass Study Phase II and Phase III.

Approach.

The assessment was based on mapping and biomass survey (stock, growth and dynamics).

Mapping: Uganda's land cover/use were stratified into 13 main strata as shown in the table below.

Class	Land cover and Land use
1.	Plantations and woodlots – deciduous trees/broadleaves ("hardwood")
2.	Plantations and woodlots – coniferous trees
3.	Tropical High Forest (THF) – normally Stocked
4.	Tropical High Forest (THF) – depleted/encroached
5.	Woodland – trees and shrubs (average height > 4m)
6.	Bushland - bush, thickets, scrub (average height < 4m)
7.	Grassland – rangelands, pastureland, open Savannah; May include scattered trees shrubs, scrubs and thickets.
8.	Wetlands – wetland vegetation; swamp areas, papyrus and other sedges
9.	Subsistence farmland – mixed farmland, small holdings in use or recently used, with or without trees
10.	Uniform commercial farmland – mono-cropped, non-seasonal farmland usually without any trees for example tea and sugar estates
11.	Built up area – Urban or rural built up areas
12.	Open water – Lakes, rivers and ponds.
13.	Impediments (bare rocks and soils)

* Classes 1 – 10 (Land cover), 11. 12, 13 (Land use)

Remote sensing data from SPOT satellite imageries (of early 1990s) were used to interpret the above strata and use of Geographical Information System to capture and process the data to produce an up to date land cover/use map of Uganda. The main output of this activity was to produce quantitative data on land cover areas at national, district; county and other lower administrative units although this report covers up to district level.

Biomass Survey: Since it is not possible to survey all the tree parameters in the country a systematic sampling technique was adopted. Over 4,000 sample plots located at 5 by 10 km grid intersections were marked on the ground after which tree parameters such as diameter at breast height, tree heights, bole heights and crown width were measured for computation of single tree weights here termed as the biomass. From this, statistical analyses was carried out to estimate the mean standing stock of biomass (tons per hectare for each land). The standing stock of biomass when multiplied with area of the land cover yields the quantities of biomass.

Biomass growth and dynamics: Sub-samples of the above plots were revisited for periodic measurements of tree parameters in order to determine the biomass from undisturbed plots and monitor biomass dynamics (removals/growth).

Findings

The findings are summarised at national level in the following categories

- Area and extent of land cover
- Biomass stock
- Growth and Dynamics
- Future Scenarios of land cover and biomass stock

Area and Extent of land cover

Uganda has a total area of about 241,551 km^2, out of which, farmland is the most extensive, followed by grasslands, woodlands, water bodies, bush land, tropical high forest (normally stocked), tropical high forest (degraded) and others in that order. The land area excluding water is about 20.5 million ha, out of which 4.9 million ha (about 24%) is covered by forests (plantations both hard and softwoods) tropical high forests (normal and degraded), and woodlands.

The distribution by each land cover is shown in the table below.

Stratum	**Area(Ha)**	**Percentage1**
Plantations Hardwoods	18,682	0%
Plantations Softwoods	16,384	0%
THF- Normal	650,150	3%
THF - Degraded	274,058	1%
Woodlands	3,974,102	16%
Bushlands	1,422,395	6%
Grasslands	5,115,266	21%
Wetlands	484,037	2%
Subsistence Farmlands	8,400,999	35%
Commercial Farmlands	68,446	0%
Built up areas	36,571	0%
Water	3,690,254	15%
Impediments	3,713	0%
Total	**24,155,058**	**100%**

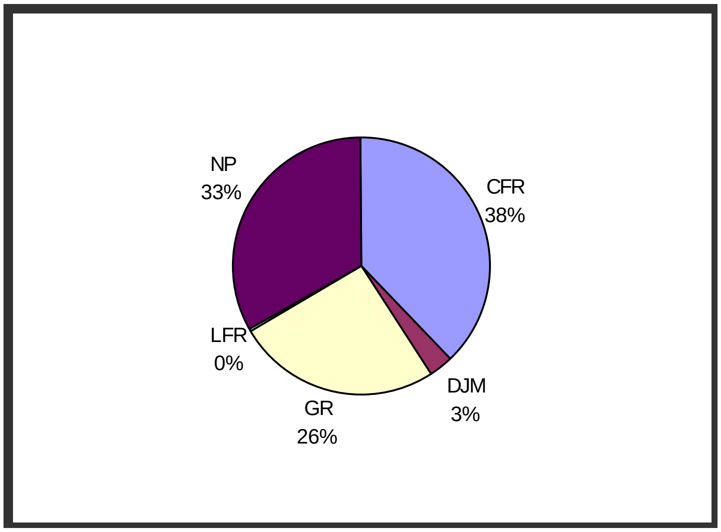
Land Cover Distribution in Protected and Private Lands - Out of the 241,551 km, 490 sq km (13%) is under protected areas owned and managed by the Forest Department (5%) and Uganda Wildlife Authority (8%*).* The balance (87%) is under private ownership.

Protected areas and ownership are as follows:

- Central Forest Resrves, CFR (under the Forest Departemnt)
- Local Forest Resrves, LFR (under Local Government)
- National Parks, NP and Game Reserves, GR (under Uganda Wildlife Authority)

Their relative share is shown below.

Figure 1-1: Types of protected areas and relative occurrence



The overall distribution in Protected areas shows that forestland (plantations, tropical high forests and woodlands) is the most extensive (47%), followed by grasslands (37%).

Status of Forest Reserves – The Forest Department aims at achieving a balance between the supply and demand of forest products, protection and conservation needs for present and future generations. However, FD also faces management challenges such as forest degradation which is the deterioration of the productive capacity of forests from high to low productivity due to human influence and deforestation the complete clearing of tree formations (closed or open) and their replacement by non-forest land uses. The findings are as follows:

Degradation - Out of 1.17 million ha of Central Forest Reserves in the country, 58,000 ha (5%) have been degraded or depleted. On a reserve level the most affected forests are South Busoga Forest Reserve now in Mayuge District where out of 16,000 ha, 12,500 ha (76%) is degraded. This is followed by Mabira Forest Reserve, where out of 29,570 ha, about 7,000 ha (24%) is depleted or encroached. In all, the results revealed that 14 Forest Reserves out of 500 CFRs in the entire country were seriously degraded by over 1000 ha each.

Deforestation - Unlike forest degradation, deforestation is more in Local Forest Reserves than in Central Forest Reserves. Out of the 500 CFRs, 30 is totally deforested. In Local Forest Reserves 65 out of 192 reserves are completely deforested. In relative terms 9% and 43% of the total CFRs and LFRs respectively are deforested in Uganda. At forest reserve level, the most affected areas are Buyaga Dam (over 12,000 ha), Luwunga (5,000 ha), Nyangea-Napore (4,000 ha), and Moroto over 3,000 ha deforested.

Biomass Stock

The findings from the biomass survey revealed the following:

Gross biomass stock - A total of 468 million tons of air-dry biomass above ground is available in Uganda out of which 155 million tons is held in protected areas as shown in the table below.

Land Cover (use)	Standing Stock (000, Tons)	Prot. Areas (000, Tons)	Private (000, Tons)
Hardwood Plantations.	1,682.7	623	1,059.6
Conifers Plantations.	2,457.6	2,354	103.6
Tropical Hgh Forest (Normal Stocked	136,491.2	104,648	31,843.3
Tropical Hgh Forest (Depleted)	27,596.2	9,546	18,050.2
Woodlands	126,014.2	24,942	101,071.7
Bushlands	14,007.6	2,594	11,413.3
Grasslands	46,852.4	9,858	36,994.3
Wetlands	236.3	6	230.0
Subsistence Farmlands	111,824.9	1,311	110,513.6
Largescale Farmlands	154.2	4	150.5
Builtup areas	862.8	13	850.2
Water	0.0	0	0.0
Impediements	0.0	0	0.0
Totals	**468,180**	**155,900**	**312,280**

In protected areas topical high forest (normally stocked) are most stocked followed by woodlands, depleted tropical high forest and grasslands.

More than half the total biomass in protected areas is held in Central Forest Reserves (82 million tonnes of biomass), followed by National Parks, Game Reserves and Local Forest Reserves with only 196 thousand tons.

Land Cover (Use)	**Forest Department, FD**		**FD/UWA**	**Uganda Wildlife Authority**		
	Central Forest Rserves (,000 tons)	Local Forest Reserves (,000 tons)	DepartmentalJoint Management (,000 tons)	Game Reserves (,000 tons)	National Parks (,000 tons)	Total (,000 tons)
Hardwood Plantations.	566	54		0	3	623
Conifers Plantations.	2,013	0			341	2,354
Tropical Hgh Forest (Normal Stocked)	57,118	56	4,598	621	42,255	104,648
Tropical Hgh Forest (Depleted)	5,898	29	184		3,436	9,546
Woodlands	12,924	19	295	3,963	7,741	24,942
Bushlands	940	5	61	770	818	2,594
Grasslands	2,022	5	226	3,640	3,966	9,858
Wetlands	1	0		2	4	6
Subsistence Farmlands	1,105	27	3	77	99	1,311
Largescale Farmlands	4	0			0	4
Builtup areas	8	0		1	4	13
Water						0
Impediements						0
Total	**82,597**	**196**	**5,366**	**9,073**	**58,667**	**155,900**

National Biomass Growth and dynamics - Uganda can ideally expect a total annual growth of 50 million tons of biomass per year, out of which 15 million tons is in protected areas.

Biomass dynamics reveal that tropical high forests (normally stocked) have the highest rate of loss estimated at 24 tonnes (air-dry biomass)/ha/yr followed by degraded tropical high forest with a net reduction of 8 tonnes/ha/yr.

Future Scenarios

Through scenarios based on the above findings, auxiliary data, and, certain assumptions it was possible to predict the likely trends of some land cover and biomass supplies. Examples are:

Impact of population growth on forest land - NBS predicted that there will be a steady decline from 0.3 ha in 1991 to 0.1 ha per capita of forest area by the year 2025,

Impact of population growth on Subsistence farmland - This was considered under three scenarios. In the first scenario, assuming 0.6 ha per capita farmland in 1991 was maintained, subsistence farmland would increase from 8.4 million ha to 23 million ha which is more than the total land area of Uganda. Since this is impossible, there is need for optimal use of available land in order to ensure food security and prevent conflicts. In the second scenario, assuming that the subsistence farmland remains fixed (which is a reality), as the population increases the per capita subsistence farmland of 0.6 ha in 1991 would reduce to 0.2 ha by the year 2025 thereby leading to land fragmentation. In the third scenario assuming that rural communities lose interest in farming as an economic activity due to low prices and poor incomes, the result would be migration of rural communities to urban areas in search of better alternatives. This implies that land would be abandoned as fallow land and left to absentee landlords. Whichever direction a given scenario takes, the country's forest and agricultural lands are at risk of being depleted with dire consequences. Therefore strategic policies and natural resource management plans need to be put in place right away.

Future biomass supplies (business as usual scenario) - The present 312 million tons of biomass in private lands will face a deficit of 846,000 tons by the year 2025. Most of the biomass to be lost will be in tropical high forest. By the year 2025, all the present land cover would have been cleared. On the other hand, biomass in farmlands will increase from the present 110 million tons to about 123 million tons by the year 2030.

In protected areas, based on estimated growth rates under ideal management conditions, the present supply of 167 million ton in 2000 would increase to 536 million tons by the year 2025. The deficit from private lands would likely be offset by the positive growth in the protected areas.

In view of the above, it can be concluded that the information gap on land cover/use and biomass standing stock has now been filled by the results of this study. However, in order to realise the full value of this information, all stakeholders concerned need to know about the existence and use of this information in planning, management and use of the biomass resource. Until this is done, then the goal of improved sustainable management and use of our natural resources as envisaged in the forestry sector program would not be realised. It is also hoped that the future scenarios should be of interest to stakeholders because whichever direction it takes, it means that there must be an appropriate response today rather than tomorrow.

1. Introduction

Uganda, a landlocked country is located in East Africa, bordered by Kenya in the East, Tanzania in the South, Rwanda in the South West, the Democratic Republic of Congo, (DR-Congo) in the West and the Sudan in the North. Earlier estimates indicate that it has a total land area of 243,000 square kilometres of which nearly 40,000 sq. km is open water (National Biomass Study Project Document, 1988). Most of the country lies between 900 and 1500 m above sea level.

The country has two rainy seasons in April -May and September – November mainly in the South and one long rainy season in the North starting July to November. The yearly precipitation ranges between 900 mm in the North to 1500 mm in the South and West and temperatures range between 22 degrees in the south and 28 degrees in the North.

The vegetation is sparse and shrubby bush in the North East (Karamoja) and north, but species richness and diversity increase in the south and west where grasslands and woodlands give way to Tropical High Forests.

1.1 Political and Economic developments

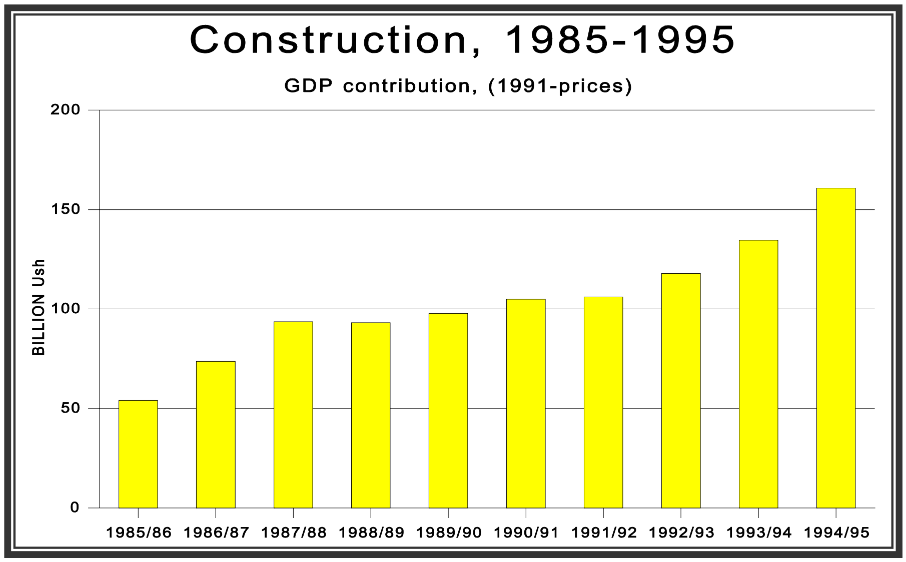
Uganda was under British colonial rule from 1888 to 1962 when it attained independence. During 1960s, the country's economy was vibrant, but between 1970 and 1985, the economy almost collapsed due to military rule and wars. In 1986, when the NRM took over government Uganda experienced rapid economic recovery from 1987 to 1995 with average real Gross Domestic Product (GDP) growth rates of about 6.5% per year. This is high by international standards. Presently the economic activity, including utilisation of forestry products, is considerably higher compared to the economic activities in the sixties. However, GDP *per capita* is still approximately 25% lower compared to that of 1970.

The annual GDP growth rate was 8.4% in 1995 but dropped to about 5 % in 1999. Nevertheless, the annual average growth rate of 6.2 % from 1995 up to 1999 (GoU a, 2000) if maintained, in addition to continued stability, democratisation, economic liberalisation and diversification, one can expect similar growth rates for the next ten years. Some traditional key sectors like tea and cotton will require consistent high economic growth rates for many years if they are to attain the production levels of the sixties.

Population growth rate in the past had been only 2.5% (Censuses 1969, 1980 and 1991) which corresponds with roughly the period of civil strife. In mid-96 the population was officially estimated to almost 20 million and was projected to 25.7 million by the year 2005 (growth rate of 3% per year). The urban population was about 2.8 million (14%) in 1996 and was projected to about 3.5 million in 2000 and 4.8 million in 2005 (GoU, 2000). The rural population was 17.1 million (86%) in 1996 and was projected to rise to 18.5 million in 2000 and 20.2 million by 2005.

The combined effect of high economic growth and high population growth has had and will continue to have a dramatic impact on the forestry sector. After 15 years of civil war and very little construction activity, there has been a building boom between 1985 and 1995, during which period alone, the sector experienced annual growth rates of 10-20 %. (Figure 1-1).

Figure 1-1: Building Construction Trends



Source: Ministry of Finance and Economic Planning

Similar growth rates were observed in other industrial sectors where wood is the main source of energy. For example, lime, tiles, bricks, tobacco, tea, and hotels.

Another sector which will affect the biomass resource is urbanisation. By the year 2006, 20% of the population will be urbanised. This combined with higher household incomes will mean a transition from using firewood to charcoal. In addition, people will have more hot meals per day, better housing and more furniture per household. All these indicate that the use of forest products in general and woody biomass derived energy in particular will grow *faster* than the growth in population and/or growth in the economy for many years. This is *as long as the resource base allows it.*

1.2 Forestry Sector

Uganda still has considerable forest and biomass resources. However this resource is being heavily 'mined' through rapid expansion of agricultural land. Official estimates of land being cleared in 1994 ranged from as low as 70,000 ha (Ministry of Agriculture, World Bank) to 200,000 ha (Ministry of Finance and Economic Planning).

Agricultural expansion will continue to be a major source of woody biomass derived energy i.e. fuelwood, agricultural residues (coffee husks, maize stalks), although deficits can be expected for other forest products like timber. However, since the extent of land cover distribution was not accurately known, nor was there any analysis of future scenarios affecting most of the remaining bushlands, grasslands and woodlands, the National Biomass Study was initiated to address these aspects.

Nevertheless, for many years, the Government considers ‘environment and forestry’ as one of its Priority Programme Areas, PPAs. For instance in recent times the government has put in place legislation i.e. the National Environmental Statute (1995), the 2001 Forest Policy, the Forest Act (Bill) 2002, the Wildlife Statute (1996), Local Government Act (1997), Water Act (1999) and the Land Act (1998). However, their impact has been small since political emphasis is largely on environment and conservation where ‘environment protection’ is construed to be synonymous with *planting of* trees, and environmental destruction with *cutting* of trees.

1.2.1 Forestry and the Economy

Official statistics have so far seriously under-estimated the contribution of the forestry sector to the national economy for example 2% (GoU a, 1996). This is partially due to insufficient empirical data on forestry products and services (monetary and non-monetary). However studies conducted by the Forestry Department and Department of Energy revealed that the contribution of the Forest Sector to GDP is about 6% though 23% was by FAO, (1998).

A political and cultural bias towards ‘modern’ forms of energy like electricity and petroleum make them appear important energy sources, but compared to charcoal and firewood, these forms of energy are less important for economic growth and public welfare. For example, the Public Investment Plan (PIP) 1995/96 - 1997/98 showed a high disparity between public investments in electricity production and forestry sector. For instance, the Government of Uganda (GoU) in 1995/96, spent almost Ush 214 billion in generating and distributing electricity yet only 11 billion was spent on the forestry sector.

Table 1-1 shows the current estimated consumption and demand for forestry products, with extrapolations to the year 2006. The figures and growth rates have been rounded off.

Table 1-1: Consumption of Forest Products and extrapolation to the year 2006

Product	1995/96	Growth	2006
	Ush bn	rate p.a.	Ush bn
Charcoal, 400,000 tons @ 120,000/=	48	7%	96
Firewood (monetary), 3.6 mill tons @ 20,000/=	72	7%	144
Firewood (non-monetary), 9 mill tons @ 5,000/=	45	2.50%	58
Sub-total biomass for energy	165	6.00%	298
Sawn timber, 200,000 m³ @ 200,000/=	40	7%	80
Electricity poles, 8,000 @ 100,000/= (retail)	0.8	10%	2
Telephone poles, 25,000 @ 40,000/= (retail)	1	10%	2.6
Poles (monetary), 500,000 m³ @ 50,000/=	25	7%	50
Poles (non-monetary), 250,000 m³ @ 20,000/=	5	2.50%	6.4
Other products (monetary), 1,000/= per capita	20	5%	33
Other products (non-monetary), 2,000/= per capita	40	2.50%	52
Total	**296.8**	**6%**	**524**
Momentary	206.8		407.6
None-monetary	90.0		116.4

Note: Monetary items are those bought from the market while non-monetary are freely acquired from source. Data sources are: World Bank, Statistics Dept., Uganda Electricity Board, UEB, Uganda Posts and Telecommunications, UPTC, the Energy for Sustainable Development, ESD, Study of Woody Biomass Derived Energy & the National Biomass Study, Forest Department, Carvalho & Pickles (1994).

The term ‘other products’ denotes all non-wood forest products like medicines, bamboo shoots and other edibles, shear butter oil, honey, gum arabic, fodder, tourist trade in curios, matches, plywood, weaving materials and so on.

The estimates in Table 1-1 are considerably higher than earlier estimates, which were based on extrapolated old data. Thus the need for new empirical data and information in this sector is urgently needed.

Woody biomass energy plays a vital role in Uganda’s energy sector. Table 1-2 shows Uganda’s energy consumption in1994 from biomass, petroleum and electricity in TerraJoule (TJ).

Table 1-2 : Uganda's Energy Consumption in 1994- (End use energy demand in terrajoules)

Sector - 1994	Biomass	Petroleum	Electricity
Urban Household	3,338	122	853
Rural Household	130,685	305	95
Sub-total household	134,023	427	948
Industrial	7,087	915	1,193
Commercial	4,341	508	597
Sub-total industry/commercial	11,428	1,423	1,790
Institutional	3.377	152	281
Transport	0	381	0
Total	148,828	2,003	3,019

Sources: The ESD study on Biomass Derived Energy, MFEP, UEB, Forest Department, ESMAP/World Bank, Statistics Department.

Biomass supplies thirty times as much energy as petroleum and electricity combined on an end use basis. That is, excluding for instance transmission losses and nearly four times as much final energy to industrial and commercial sectors as petroleum and electricity combined (Table 1-2). Note that whereas petroleum and electricity are efficiently utilised and generate manufactured goods of higher value, they provide fewer jobs and are costly in terms of foreign currency. For instance 90-95% of petroleum, and, 60-70% of electricity expenditure are in foreign currency. Although the efficiencies of firewood and charcoal are generally low, in Uganda they provide tens of thousands of jobs. *Sustainable* utilisation of the woody biomass resource is vital because this woody biomass additionally helps in maintaining soil fertility, controlling agro-climate, and in conserving a better environment and biodiversity in general.

The main challenge in the energy sector is therefore how to develop Uganda's considerable hydro-electric potential (and possibly its petroleum resources), and *simultaneously* increase the biomass resource base as well as use the present resources more efficiently. Such a challenge cannot be tackled without data and information on the biomass resource base.

1.3 Review of Data availability and reliability

The main source of data and information on biomass resources has been the Forest Department, a few individuals and organisations. Most of the available data such as area, productivity and sustainable yield of biomass have been produced from gazetted forests with hardly any from forests outside gazetted areas or agricultural lands. This data though useful as a baseline is obsolete and therefore needs updating. The next three sections will review available data and its reliability to the forestry sector, agriculture and general land uses with a focus on the biomass resource.

1.3.1 Forestry

There are three types of forests in Uganda i.e. tropical high forest, woodlands, and plantations.

Originally tropical high forests covered most parts of central and western regions especially the stretch from Lake Victoria to Lake Albert. Others are found on high altitude such as Mount Rwenzori and Mount Elgon. Savannah woodlands and bushlands are found in most of the drier parts of the north, east and some of the Mid-Western region. Plantations of softwoods (conifers) and hardwoods (mainly *Eucalyptus*) are scattered in forest reserves throughout the country. Forest Department records and individual studies are the main sources of data on the acreage, extent and the status of forests in Uganda.

Tropical High Forests (THF). Several sources have indicated the following areas for THFs in Uganda .

The Atlas of Uganda of 1967 estimates THFs to be 689,000 ha and Bamboo-grassland 73,000 ha.

Lockwood Consultants in 1972 estimated THFs to be 732,000 ha.

FAO in 1987 estimated THFs to be 765,000 ha.

The Forest Department in 1987 estimated THFs to be 730,000 ha. This figure is for all gazetted tropical high forests, but takes no account of land lost to encroachment since 1972, nor additional areas of High Forest on private land and/or public land.

The World Bank in 1987 estimated non- reserved forests to be 125,000 ha and the gazetted High Forest Reserves to be 700,000 ha, out of which 160,000 ha are protected forests, 110,000 ha are proposed nature reserves and 430,000 ha are production forest. Due to encroachment, the actual forests on gazetted land might be less than the figures given above in potentially productive area. Besides, the volume and condition of growing stock were unknown.

Savanah Woodlands. Very little information exists on the Savannah woodlands. Recent area estimates vary a lot, and were as follows: The Atlas of Uganda in 1967 quoted savanah woodland area at 699,000 ha. Lockwood Consultants in 1973 put it at 776,000 ha and FAO in 1985 estimated it at 5,250,000 ha. Most likely the two lower figures were referring to gazetted Savannah woodlands. FAO estimates represent nearly 22% of Uganda's total area, or nearly 26% of its land area excluding the country's wooded areas. However, this discrepancy is likely due to the differences between woodlands, bush land and savannah, which in many cases are practically difficult to distinguish from one another. Data on the country's woodland productivity, standing volumes and condition of growing stock were not available.

Plantations. In 1978 The Forest Department estimated the area of plantations to be 24,000 ha out of which 10,000 ha were softwoods and, 14,000 ha hardwoods. The World Bank in 1987 estimated the plantation area to be 24,300 ha out of which 13,400 ha were softwoods and 10,900 ha were peri-urban plantations for fuelwood and poles. In addition, there were 7,690 ha of fuelwood plantations for tobacco and tea processing outside the control of the Forest Department. In 1987, the area of softwood plantations was estimated by the Forestry Department to be 79,000 ha, out of which 27,500 ha were planted and 51,500 ha unplanted. The area of eucalyptus plantations was 20,000 ha out of which 14,000 ha belonged to the Forest Department and 6,000 ha to the former British American Tobacco, BAT (Forest Department, 1987).

In addition, a number of scattered small private woodlots (plantations) are found in many areas especially in parts of central and western Uganda. The most widely planted species is *Eucalyptus* mainly for production of poles and firewood at short rotation. Nonetheless, there is no reliable data available on the areas and number of seedlings planted, growth performance and productivity.

Miscellaneous sources. A number of inventory reports on the forest resource existed at the beginning of the National Biomass Study. For instance Lockwood Consultants 1971-73 on Kashyoha-Kitomi Forest Reserve, GITEC Consult (1985) on Budongo Forest Reserve, the British Overseas Development Administration (ODA) with the Forest Department on inventories of softwood plantations in southwestern Uganda in 1984. In addition, two other sources of up to date information on some forest reserves were by Howard (1986) and Otte (1985). Howard assessed the status of six Forest Reserves: Semliki, Itwara, Ruwenzori Mountain, Kasyoha-Kitomi, Kalinzu and Maramagambo, while Otte conducted ground surveys in Mt. Elgon Forest Reserve (then) to establish the nature, extent and ecological consequences of forest destruction on the mountain. In early 1990s the World Bank funded Forest Rehabilitation Project, FRP, provided detailed information on the standing stock, species, and growth/yield on gazetted forest reserves, but no inventories were carried out on non-gazzetted areas.

1.3.2 Deforestation

Hamilton (1982) assessed deforestation in Uganda from the Forestry Department records, satellite imagery and through interviews using questionnaires. Based on these sources, Hamilton documented the causes and developments that have led to the reduction of Uganda’s forest cover. Aluma (1987) produced a list of High Forest Reserves and Savannah in Uganda, with draft notes on their condition. He estimated that over 100,000 ha were cleared between 1976 and 1986 with only one exception: Kashoya-Kitoma reserve in Bushenyi which was saved by its remoteness and difficult terrain. The rate of deforestation estimated at 10,000 ha/year by Aluma (1987) was consistent with that of FAO in 1980. Among the worst cases reported was on the slopes of Mount Elgon, where about 7,200 ha of the original Mount Elgon Forest reserve was degazetted, and an additional 20,000 ha within the Forest Reserve was lost to cultivation during the late seventies and eighties (Aluma, 1987).

Finally, no geographically referenced digital datasets existed on forestry, agriculture, land use and other attributes such as productivity, status etc. The only datasets available then, albeit more general in nature, was by UNEP/GEMP/GRID based on a case study of an environmental database for Uganda (UNEP/GEMP/GRID, 1987). It contained basic, national datasets on land, climate, and infrastructure but lacked recent data. Most of the basic datasets were digitised from the Atlas of Uganda (1964 and 1967 editions), as more recent data for the whole country in many cases were then not available.

1.3.3 Agriculture and land use

Agriculture contributes 65% to the national economy of Uganda and employs almost 80% of the population. This means that the country still remains essentially an agrarian state with sufficient food supplies to feed its people. This is in spite of occasional natural calamities such as poor weather and socio-political upheavals, which normally lead to hunger and starvation. Apart from the food production, agriculture contributes a considerable amount of biomass derived energy in form of wastes and residues. Therefore, data and information in this sector is crucial in developing strategic plans and policies for the sustainable utilisation of energy in the country.

Some of the data given in recent years on the agricultural sector were based on projections of the comprehensive Agricultural Census of 1963-64 and Livestock Census of 1963, and on general trends since then. The census published detailed data on type of crops grown, areas and production on a District basis. From that time up to 1982, that is nearly 20 years, there was no such comprehensive data collection done until when the Arid Lands Information Center, University of Arizona, USA, presented a "Draft Environmental profile of Uganda". This study documents trends in land-use practices for the whole country between 1961 and 1977, and gave information on arable land under temporary crops and permanent crops, permanent meadow and pastures, forests and woodlands, other lands including potentially productive land. The next most reliable and up-to-date records on land use were given in a survey carried out by USAID in August 1984 of four selected areas; Kigezi, Masaka, Teso and Busoga. This survey provided information on staple and cash crops planted, planted acreage, land tenure practices and marketing.

In June 1986 the Department of Animal Industries and Veterinary Services, DAIVS initiated a nation-wide sample survey to gather information about numbers of livestock, total grazing area, number of dips, spray pumps, major livestock diseases, etc.

A UNDP/FAO supported National Census of Agriculture and Livestock was carried out from 1986 to 1990. The survey aimed at, among other things, conducting a nation-wide sample for census of agriculture and livestock; establishing a data bank for storage and retrieval of information; and strengthening the survey, forecasting, and remote sensing capabilities of the staff at the Ministry of Agriculture, Animal Industry and Fisheries. However, the findings of this survey have been highly disputed and have remained unpublished to date.

Conclusion: In view of the foregoing, it is evident that there is inadequate data on the current status of Uganda's forestry resources in general and woody biomass situation in particular. It is worth noting that the above data and information are now obsolete. Therefore there is need to update it.

It is with this background in mind that the National Biomass Study was conceived in 1989 to address the issue of providing data and information for better planning and use of biomass derived energy at national, regional and local levels, details of which are discussed in the next chapter.

2. Background to the National Biomass Study

The National Biomass Study, (reference number: NR 12 (A) / UGA 003), was originally part of the Second Power Project within the then Ministry of Energy, which included a number of woodfuel-related studies. In 1987, it was decided that the Forestry Department, FD, and the Norwegian Forestry Society, NFS, implement this project with close links to the Forestry Inventory Project of the Forestry Rehabilitation Programme, FRP. The Norwegian Agency for Development Co-operation, NORAD, provided the funds through 100% grant, which was channelled through the Norwegian Forestry Society. The project has had several Phases i.e. Phase I (1989-1992), Phase II 1992-1996 and Phase III 1986-2000.

Phases I and II, were initially planned to take four years, but it soon became evident that this was over-optimistic. A considerable expansion of the scope of the project in Phase II made it necessary to extend it, up to a total of 6.5 years that is until June 1996 which was followed by Phase III.

2.1 Phase I: Overview of objectives and achievements

Phase I (1989-92) was a detailed study of the woody and non-woody biomass (trees, bush, crop residues), which are potential woodfuel in nine peri-urban areas. Phase II (1992-1996) though slightly less detailed was broadened to cover the whole country. It had several additional and/or enhanced components related to natural resource mapping and analysis in general.

As already mentioned, Phase I aimed at providing a more detailed overview of the woody biomass situation in nine peri-urban areas of Kampala, Jinja, Kamuli, Mbale, Kumi, Moroto, Arua, Mbarara, and Kabale. The area coverage in each varied from 920 km^2 in Mbarara to about 3,000 km^2 in Kampala. The total area was about 14,000 km^2. The basis for their selection was regional representation and perceived woodfuel deficits.

The land cover/land use stratification for the nine areas was carried out in collaboration with the Department of Surveys and Mapping using 1:25,000 scale aerial photographs with minimum field surveys (*ground-truthing*). This required about two person-years, with another person-year for manual digitizing and interpretation. These maps served the purpose in Phase I, but were clearly sub-standard for Phase II and therefore not used further.

Activities in Phase I were related to collecting and processing vast amounts of empirical data such as:

(a) *Sample Plots:* A total number of 19,866 plots each measuring 50 m by 50 m were classified using aerial photos. A sub-sample of 3,417 plots were physically measured or assessed on the ground.
(b) *Trees:* A total of 2,721 single trees, (123 different species), were measured for volume or weight. This is termed destructive sampling.
(c) *Tree Species Specimens:* A total of 4,556 specimens,

representing 112 different tree species were weighed under green and air dry conditions.

(d) *Bush Plots:* A total of 38 plots classified as bush each measuring 10 m by 10 m were weighed to establish their woody biomass weights.

(e) *Sample Plots for agricultural residues:* A total of 64 plots each measuring 10 m by 10 m were assessed for specific crop residues.

All measurements were "*above ground biomass*" only in accordance with the original project description. A request from an international research group working with carbon sinks ('greenhouse gases') in 1991 to include "*under ground biomass*" (roots and biomass remnants in and on the soil) was turned down due to lack of resources.

For details of classification system, methodology and results from Phase I the reader is referred to the National Biomass Study Technical Report Phase I (1992).

In 1993, after in-depth analysis of Phase I data, the key assumption that the total biomass is closely related to crown cover was proved incorrect, thus leading to discarding considerably various aspects relating to methods and results. Nevertheless, most of the basic data collected is still useful and formed an important part of the biomass data used in Phase II. Below are some examples:

(a) About 2,500 of the trees destructively sampled in Phase I are still used for developing single tree biomass functions, together with an additional 600 mainly big trees sampled in 1993. Another 300 trees sampled in West Nile by Biometrics section of FD in late 1995 were incorporated. The project continued to use tree groups based on a combination of species and morphology. However, this was changed after Knut (1997) reviewed and recommended the use of models based on tree size.

(b) All basic research done on moisture content, dry or wet weight ratios and basic densities, for a number of species which were not scientifically investigated before are still valid (National Biomass Study Technical Report, Phase I, 1992).

(c) All the field plots measured in Phase I have been geo-referenced by the project staff. Around 2,000 of these 3,500 field plots were re-used in the analysis for the whole country. This data set was complemented by new field plot measurements collected from May 1995 to May 1996 from areas around Masaka, Mityana, Bushenyi, Masindi Port, Moyo, and Soroti.

The developments in techniques and understanding which have occurred and continue to occur in the National Biomass Study *should be regarded as a result of a normal research process.* Little or hardly any relevant information was available in this field when the project started.

2.2 Phase II Objectives

The initial objective of Phase II (National Biomass Study Project Document, 1988) was simply to extend Phase I objectives to cover the whole country, though in less detail. The project was revised considerably as a result of a project Review Mission in January-February 1992. The following objectives were adopted, expanding the scope of the project to cover dynamic assessment of woody biomass, broader digital mapping and systematic user interaction.

(1) To develop land cover/land use stratification in scale 1:50,000 with estimates of woody and non-woody biomass, which are potential woodfuel for the whole of Uganda, using a combination of multi-spectral satellite imagery and extensive ground surveying.
(2) To initiate monitoring of woody biomass dynamics (growth, removals and land cover (use) change) through re-measurement of about 1,000 field plots from Phase I, as a first experimental step in establishing a system for monitoring of land cover / land use and woody biomass change and growth in Uganda.
(3) To develop a full-fledged Environmental Information System (EIS)[2], incorporating data sets like land cover / land use stratification, administrative boundaries, infrastructure, rivers, boundaries of all protected areas, and contour lines (Digital Elevation Model). All basic data sets will be in scale 1:50,000.

2.3 Phase III: Goal and Objectives

The goal is to promote economic, environmentally sound and sustainable management and development of natural resources in Uganda, while simultaneously providing knowledge, information, and data sets necessary to increase the resource base. The project shall provide knowledge, information, data sets, analyses, and scientific/political scenarios to all relevant users within and outside Uganda, and in particular to the Forest Department and other actors in the forestry sector.

The following broad objectives have been defined for the National Biomass Study, Phase III:

(1) To establish a firm framework for continuous dynamic monitoring of land cover / land use and woody biomass in Uganda; partially through establishing up to 6,000 field plots in a regular grid covering the whole country in 1995-98, and starting to re-measure them in 1999.
(2) To maintain and update the Environmental Information System
(3) To transfer responsibility for some of these data sets to other agencies while ensuring continuous user access to quality and develop new channels for information dissemination enabling users in the public and private sectors to have easy and affordable access to updated and reliable information in analogue or digital form.
(4) To collaborate with other professional groups within or outside the Forestry Department in research and analysis, aiming at maximising the use of the biomass data sets for various purposes.

---

2 The term EIS is used in a *technological* sense, representing a computer system with many software tools surrounding a spatial database, and not in a *data set* sense, i.e. representing all data sets needed for "environmental" analysis.

In view of the above, it should be noted that data collection, processing and analysis constituted the core activity of NBS and thus the methodology adopted is presented in the next chapter.

3. Methodology

This chapter presents the methodology adopted by NBS in the assessment of biomass resources in Uganda. Basically the assessment is to determine the area and extent of land cover, which combined with the biomass survey data (tree parameters), results in the quantification of biomass standing stock in Uganda.

It starts with a presentation of stratification and mapping (stratification system, interpretation of satellite imageries, ground-truthing, final delineation and data capture in section 3.1 followed by biomass survey (sampling technique, plot location, tree parameter measurements, and data capture) in 3.2. Monitoring of biomass growth and dynamics is presented in 3.3. Finally the synthesis of the mapping and biomass survey is presented in 3.4.

3.1 Stratification and Mapping

It is obviously impossible to carry out one hundred percent inventory of the woody biomass of such a large area without applying sampling theory. In sampling theory, a population is used to denote the aggregate from which a sample is chosen. In Phase I, the population refers to all sample plots within the whole project area (Phase I) while in Phase II it refers to the whole country. The population was sub-divided (stratified) into sub populations (strata) comprising of plots in, for instance, one district or plots within a land Cover / Use. The main purpose of sub-dividing the population into sub populations is to produce results/estimates within cost-effective levels for the entire population with minimum variance. In other words the aggregate variance of these sub populations should be lower than the variance of the whole population without stratification.

Existing land use or land cover stratification or classification schemes were found to be silviculturally and economically oriented and thus less suitable for biomass inventory. Therefore the project developed its own classification system, based on a combination of land cover and land use given in (Table 3-1).

Table 3-1: Stratification System

Class	Land cover and Land use
1.	Plantations and woodlots – deciduous trees/broadleaves ("hardwood")
2.	Plantations and woodlots – coniferous trees
3.	Tropical High Forest (THF) – normally Stocked
4.	Tropical High Forest (THF) – depleted/encroached
5.	Woodland – trees and shrubs (average height > 4m)
6.	Bushland - bush, thickets, scrub (average height < 4m)
7.	Grassland – rangelands, pastureland, open Savannah; May include scattered trees shrubs, scrubs and thickets.
8.	Wetlands – wetland vegetation; swamp areas, papyrus and other sedges
9.	Subsistence farmland – mixed farmland, small holdings in use or recently used, with or without trees
10.	Uniform commercial farmland – mono-cropped, non-seasonal farmland usually without any trees for example tea and sugar estates
11.	Built up area – Urban or rural built up areas

Note: A stratification system in practice is not only for the assessment of biomass but is to a large extent a multipurpose classification system. The great majority of users are not specifically interested in biomass or wood fuel alone, but rather in a wide range of spatial and non-spatial data and information related to land use, land degradation, environment, urban and rural economic developments.

Plantations (Classes 1 and 2) - These are man-made tree plantations comprising of two main classes. Class 1 consists of broad-leaved trees mainly *Eucalyptus spp.,* (Figure 3-1), *Maesopsis eminii, Acacia mearnsii* (Black Wattle) and some *Markhamia lutea.* Class 2 includes the *Conifers*; *Pine spp.* and *Cypress spp*.(Figure 3-2).

Figure 3-1: Eucalyptus Plantation in Namanve Forest Reserve

Figure 3-2: Coniferous Plantation: Katugo Forest Reserve

Figure 3-3: Tropical High Forest (normally stocked): Mabira Forest Reserve

Tropical High Forest (THF) (Classes 3 and 4) - These are natural forests rich in species biodiversity i.e. flora and fauna. THF were grouped into Class 3 (Figure 3-3) i.e. normally stocked forest, for example Mabira Forest along Kampala-Jinja Highway, and, Class 4 (Figure 3-4) i.e. depleted or encroached with reduced species richness and composition dominated by secondary growth of bush and shrubs, in particular *Solanum gigantea*.

Figure 3-4: Depleted or encroached Tropical High Forest: Mabira Forest Reserve

Woodlands (Class 5) - Wooded areas where trees and shrubs are predominant. There are wet and dry types. The wet type occurrs as a zone along wetlands (riverine forest) and the dry type is found on grass-covered upland areas. To qualify as woodland the average height of the trees must exceed 4 m.

Figure 3-5: Woodland (trees and shrubs): Nakasongola District

Bushlands (Class 6) - refers to vegetation dominated by bush, scrub and thicket growing together as an entity, but not exceeding an average height of 4m (Figure 3-6).

Figure 3-6: Bushland (bush, thickets and scrubs): Nakasongola District

It is common to find bushlands in abandoned farmland under late fallow, or forestland. The vegetation rapidly progresses to bush with many different pioneer species as the first phase of succession. In dry, grass-covered areas they appear to be permanent, for example normally taller growing species *Acacia hockii* in Mbarara and *Commiphora africana* in Moroto.

Common bushlands species include: *Securinega virosa, Acanthus pubescens, Lantana camara, Rhus natalensis, Rhus vulgaris, Harisonia spp., Acacia gourmensii, Solanum spp., Ziziphus africana, Xymenia americana, Securidaca longipendiculata, Dovylis macrocalyx* (Wild Kei apple), *Maytenus senegalensis, Maesa lanceolata* and *Alchomea cordifolia.*

Common grass often found within bushlands are: *Cloris spp.*, *Panicum spp*, *Imperata cylindricum* (Spear grass) and *Hyparrhenia ruffa*.

Grasslands (Class 7) – Rangelands, grazing grounds, improved pastures and natural savannah grassland. Various trees - bush/woody vegetation frequently occur on this land, but grass dominates the landscape (Figure 3-7).

Figure 3-7: Grassland/Rangelands: Bare hills of Mbarara District

Grasslands normally have some trees, but many areas cleared for pasture were devoid of trees and therefore had little woody biomass. Under the circumstances, a sub-qualifier ‘i’ was introduced in class 7 (grassland) to represent ‘Improved Pasture’.

Wetlands (Class 8) - comprises of a) permanent wetland - usually with papyrus and reeds (Figure 3-8) and b) seasonally flooded areas.

Figure 3-8: Papyrus wetland: Mpologoma River along Iganga-Tirinyi road

Wetlands are found along lakeshores and in valleys with impeded drainage. Various vegetation types may occur although grass tends to be the most frequent and dominant species. Common trees include *Acacia siberiana* and palms such as *Phoenix reclinata.*

Farmland Area (Class 9) - Scattered trees are frequently found in the vicinity of the homesteads. Examples include fruit trees and various multipurpose trees integrated in the farming system (agroforestry), (Figure 3-9). Farmland areas including small holder subsistence farm units cover 50-90% of the land cover of Uganda. The cropping systems include mono- and mixed cropping.

Figure 3-9: Subsistence farmland near Mwiri SSS in Jinja District

Large scale or Commercial farmlands (Class 10) - Sugar Estates, (Figure 3-10), tea estates for instance in Western Uganda and Coffee Estates in Central Uganda.

Figure 3-10: Large-scale commercial farmland: Kakira sugar estates

Built up area (Class 11) – Urban areas, towns, village trading centres, quarries, homesteads, school compounds, roads, and recreational grounds

However, urban areas were most common and considerable biomass was noted in various compounds (Figure 3-11).

Figure 3-11: Built up area: Kampala City Centre

Open Water (Class 12) – Lakes, Rivers and Ponds (Figure 3-12).

The distinction between open water and flooded wetland is sometimes difficult to draw especially in situations where for instance floating vegetation such as water hyacinth blurs their boundaries.

Figure 3-12: Open water body: View of L. Victoria from Mwiri SSS

Impediments (Class 13) – Bare rocks and soils without vegetation cover (Figure 3-13).

Figure 3-13: Impediments: Bare rock near Bukedea Trading Centre

3.1.1 Sub-stratification system

The 13 strata were further modified by sub-stratification based on biomass density, soil moisture and bush types as described below:

Sub-stratification by biomass densities - Due to variability within a given stratum, it was later realised that the original thirteen strata did not give adequate information for calculation of woody biomass. For example, in Masaka, the standing stock in class 9 (subsistence agricultural farmland) was much less than that in Iganga. This variation within classes would lead to wrong estimates if the same stocking level were used to calculate the total biomass for the two districts. Thus three methods were tried to address this problem.

The first method was based on subjective assessment of the satellite imageries by NBS interpreters based on their knowledge of these land cover/use and how it resembled the earlier stratification in Phase I. For instance, farmland or woodland similar to Arua farmland even if located in Mpigi would be referred to as Arua farmland. However, this technique became more complex with new types of land cover strata. Moreover, most mensurational experts consulted also criticised it as being too subjective and prone to "deviations" as the teams moved from one area to another.

The second method tried to resolve the above problem by estimating tree basal areas as a basis for sub-stratification of the land cover/use. The quickest way of achieving this was to use a relascope (a forest mensurational tool) which calculates single tree basal areas on the basis of angles subtended by the trees and their relation (distance) to the point of observation. The estimated basal areas were then used to sub-stratify the land cover/use into high, medium or low biomass density categories. However, dense undergrowths hampered the relascope visibility of observations, and, combined with high variability in subsistence farmland, woodland, bushland and tropical high forests this method was also found unreliable and consequently abandoned.

The third method was a generalised variation of the first in that the land cover in Phase I was further subdivided into substrata (categories) on the basis of biomass stocking densities ranging from Very Low (VL), Low (L), Medium (M), High (H), or Very High (VH) see further in Table 3-2.

Table 3-2 : Substratification based on stocking densities

Land Use/Cover	Substrata					
	Very Low (VL) Tons/Ha	Low (L) Tons/Ha	Medium (M)Tons/ Ha	High (H) Tons/Ha	Very High (VH) Tons/Ha	Comments
Plantations and woodlots	<10	10-20	20-40	40-100	>100	
Plantations (Softwoods)						NA*
Tropical High Forest		<150	150-350	>350	>102	
Tropical High Forest (Degraded)		<50	50-100	>100		
Woodlands		<40	40-80	>80		
Bushlands		<10	10-20	>20		
Grasslands		<10	10-20	>20		
Wetlands						NA
Subsistence Farmlands		<10	10-20	20-30	>30	
Commercial Farmlands						NA
Built up areas						NA
Water						NA
Impediments						NA

NA = Not Applicable or data not available.

Sub-stratification by soil moisture - Other modifications were made to describe the land cover types in wetlands, grasslands and bushlands. Three sub-classes were created within waterlogged areas to describe the wetness:

- Permanently waterlogged is denoted by ‘P’;
- Seasonally waterlogged is denoted by ‘S’ and
- Dry ground is denoted by ‘N’.

Sub-stratification of bushlands - The data analysis of the previous bush measurements in Phase I revealed that bushlands as stratified earlier on the basis of 40% minimum canopy closure and a maximum height of 5m was insufficient to estimate the standing biomass stock. This was due to the existence of various species and varying ecological conditions that make bushlands vary in both species composition and biomass density. Accordingly, two bushland groups were identified as Bush 1 (B1) and Bush 2 (B2). The biomass density in B1 is on average, half that of B2.

B1 consisted mostly of species which whenever conditions allow, saplings grow from shrubs to trees i.e. *Acacia spp, Combretum and Solanum spp*. The average fresh weight of this bush type is about 25 tons per ha.

B2 was composed of climbers, lianas, and species with non-defined numerous stems that form a dense network of mostly undergrowth vegetation cover. Examples include *Lantana camara,* and *Harisonia spp*. The average fresh weight of this bush type is about 45 tons per ha.

Note that the above sub-stratification and its range were preliminarily used on a work basis only. This was because, at that time, it was not known whether this sub-stratification would turn out to be significant by reducing the variance for better accuracy especially before enough additional plots were measured and all data analysed.

3.1.2 Satellite image interpretation

SPOT XS satellite imageries were used for preliminary interpretation, “ground truthing” and final delineation in preparation for data input or capture in the Geographical Information System.

Preliminary interpretation - The theory behind satellite image interpretation is that different land cover types reflect different quantities of the sun’s incidence rays into space. The reflected incidence rays are captured by sensors aboard a satellite vessel plying at over 800 km in space and then relayed to ground receiving stations as remotely sensed raw data. The raw data is then processed through several steps into a final product either in digital or hardcopy format referred to as remote sensing data or satellite imageries (sometimes called pictures).

The differences in the amounts of reflected sun’s incidence rays as captured by the satellite sensor give the imagery a particular characteristic texture colour and tone for each vegetation type or object. A combination of these characteristics is termed *spectral signature*.

It is these spectral signatures which the interpreter used to identify and delineate homogenous areas belonging to one land cover/ use on satellite paper prints or film diapositives. The following were the steps involved:

- A transparency was fixed firmly on to the paper print using an adhesive tape,

- Corner points were then marked carefully to act as guides even after removing the transparency,
- Interpretation of the spectral signatures and delineation of homogeneous areas belonging to the same land cover / use were carried out and finally,
- The land cover/use codes were labelled onto the delineated polygons, lines or points (features).

During interpretation of the satellite imageries, problems encountered were:

Spectral signatures - Issues which created difficulties in distinguishing between one land cover and another were *similar spectral signatures* for different land cover/use, *different spectral signatures* for the same land cover/use and *different dates of satellite imagery acquisition*.

Similar spectral signatures for *different* land cover/use included woodlots and banana fields, open cultivation and sandy soils, high forest and bush/woodlots/woodland, open cultivation in wet areas, and farmland with trees in dry areas.

Different spectral signatures for the *same* vegetation led to wrong conclusions. For example bush in valleys has a bright red signature but is green on hilltops due to dry soil conditions, which could wrongly be interpreted as bare soil instead of bush land. Similarly, woodland in burnt areas with its black spectral signature due to lack of green vegetation could be interpreted as bush land or grassland instead of woodland.

Different dates of imageries resulted in varying spectral signatures due to seasonal changes in the land cover. For example, burning in the northern savannahs led to loss of vegetation but rapid growth in the rainy season caused variations which became possible sources of confusion and / or erroneous interpretation.

These anomalies make digital image classification unreliable and therefore justify a need for intensive ground truthing to establish the reality of observations made in the satellite imagery on the ground as discussed further below.

Minimum Size – The minimum size of a polygon to be delineated from satellite imageries determines the level of detail required. For instance big sizes lead to many generalisations with possibilities of losing important information, while small sizes meant crowded maps with many details some of which were irrelevant. Without general guidelines which was the case at the beginning of the study, variations between one interpreter and another were so common that this showed how subjective the approach was.

To resolve this, general guidelines on minimum sizes were developed based on imagery resolutions, socio-economic values of different vegetation types, modelling flexibility, extent and accuracy of ground truthing, and, readability of the produced maps. For details see Table 3-3.

Table 3-3 Minimum sizes per Land Cover/ Use

Land Cover use	Minimum Area (Ha)	Map Dimension in mm (at scale 1:50,0000).
Plantations and woodlots	4	4 by 4
Plantations (Softwoods)	4	4 by 4
Tropical High Forest	4	4 by 4
Tropical High Forest (Degraded)	4	4 by 4
Woodlands	10	6 by6
Bushlands	25	10 by 10
Grasslands	50	14.14 by 14.14
Wetlands	4	4 by 4
Subsistence Farmlands	25	10 by 10
Commercial Farmlands	25	10 by 10
Built up areas	1	2 by 2
Water	4	4 by 4

3.1.3 Ground-Truthing

The preliminary interpretation was followed by checking and truth verification of observations from satellite imagery on the ground through field surveys of the resulting stratification. The team leaders used topographic sheets and paper copies of the imagery to navigate their way by driving around through existing roads and motor able tracks. During the process the land cover types interpreted and boundaries of polygons from the office were crosschecked and necessary changes made accordingly. Control sweeps usually involving at least 3 team leaders including the project managers were organised during the first twelve months. The purpose of the control sweeps was to develop a common understanding of the classification system and thereby reduce potential biases from the assessments.

Some problems encountered during ground truthing were:

- Inadequate time and resources limited the progress of checking all the interpretations on each sheet within the given time since all the sheets could not be verified. So, for realistic and representative checking and verification of each topographic sheet (Scale 1:50,000), at least three to four days of ground-truthing were necessary.
- Discrepancies were noted between "image truth" and "ground truth" due to land cover changes during between satellite imagery acquisition and field surveys. However, in some cases the changes were so small that common sense sufficed, and, in others changes were simply ignored because they did not affect the accuracy of the biomass assessment.
- Abandoned farmland and others under fallow were difficult to classify. For instance some sugar and tea estates in Jinja and western Uganda in the early 1990s were being rehabilitated. In this case it was resolved to classify them as farmlands or plantations.

3.1.4 Final Delineation

On completion of ground truthing, delineation of the land cover and uses was carried out in the office through the steps below.

A satellite film diapositive, with better visibility than a paper print was fixed over a light table. Thereafter, with the aid of a fine drawing pen (0.25 mm nib), all relevant information with the changes made from the field were drawn on the final sheet. The edges of each map sheet were *'edge matched'* in order to make sure that the lines on adjacent sheets connect to each other. In addition all polygons were checked to ensure that they were all closed and joined.

Rectification – Marking corners and trigonometric points on the final sheet with real world geographical co-ordinates acts as a control and this process is termed rectification. The purpose of rectification was to avoid gaps between two or more adjacent layers when they were eventually entered into the Environmental Information System (EIS).

A lot of collaboration took place between NBS and the Department of Surveys and Mapping (DSM) of the Ministry of Water, Lands, and Environment during the rectification process. DSM availed all its cartographers and provided original layers of the 1:50,000 map series and trigonometric points for use in this exercise.

3.1.5 Capture and processing of spatial data

The products from the final delineation are spatial data sets ready for capturing and processing in the GIS. Two methods of data capture were used i.e. digitising and scanning.

Digitising – Digitising is a process of tracing features (polygons, lines and points) from a map sheet fixed on a digitising tablet and capturing them into a computer. As a line, polygon or point is traced, the system registers a continuous series of x, y co-ordinates of each feature, in digital format. It is these x, y co-ordinates which when transformed into real world geographical co-ordinates of latitude or longitudes make the system recognise the position of a given feature in its real world geographical location. Thereafter additional information or attributes (see Appendix 1) related to each feature could be entered and stored for further analysis. PC-ArcInfo and ArcView software were used for the data capture.

This technique was appropriate for layers with relatively few features, for layers with many features scanning was preferred.

Scanning – A scanner is an instrument using a beam of light in a predetermined pattern over (a surface or region) to obtain, capture and store information especially for ease of reproducing it later as an image. The process is similar to photocopying and therefore very fast and is preferred for sheets with numerous and complex features. However, a scanner reproduces images termed raster which are not based on x, y co-ordinates (vectors). Therefore, in order to generate x, y co-ordinates from scanned images, a process called vectorizing is necessary when converting them into real world geographical information system.

Analysis – Spatial data analysis was done in Arc-info software system. The process involves overlaying six layers (land cover/use, contours, rivers, administrative boundaries, infrastructure and gazetted areas) at 1:50,000 scale and joining these 1:50,000 sheets with each other, to cover the whole country. The system then automatically generates area, length, perimeter and general relationships of one feature to another. Below are some examples:

Area statistics of land cover distribution by administrative units were generated at district, county and parish level. Similarly area statistics were generated for protected areas. The statuses of gazetted areas were similarly assessed generating statistics of encroached areas represented by either degraded forests or farmlands occurring within the Forest Reserves. Line features such as roads, railways, (when similarly analysed) generate statistics on forest boundaries and length of roads by administrative units.

Impact Assessments based on relational analysis of a given land cover to one feature and another. For instance how many hectares of forest will be destroyed by a new road construction project in a given area?. Similarly, how far are other river resources to neighbouring settlements or likely areas to be affected by floods.

Contour layers were used to develop Digital Elevation Models, DEM to analyse and visually display a three-dimensional view of land forms, actual ground distance, visibility, location and planning of forest roads, and soil erosion risk areas.

3.2 Biomass Survey

This activity involved measurement of tree parameters from sample plots in order to obtain single tree weights, aggregation of standing stock of biomass per unit area/ (ha), and ultimately quantification of the total standing biomass stock for each land cover. This was achieved through appropriate sampling techniques since it was not possible to enumerate all trees in the entire country.

3.2.1 Sampling Techniques

Sampling is a statistical method of estimating population variables from sample plots. Two sampling techniques applied in the biomass assessment were double sampling and systematic sampling. Double sampling was applied in Phase I because of its efficiency when dealing with large areas, although it did not adequately yield the expected results and was replaced by systematic sampling in Phase II as discussed further below.

Double Sampling – This was mainly used to determine the potential relationship between crown cover as assessed from the photos and actual biomass on the ground through regression analysis. The two stages involved in this technique are:

Crown cover assessment through photo-interpretation i.e. approximately 20,000 photo plots (2 by 2 mm each), were sampled stereoscopically for crown cover percent scores and land cover / use in the office.

Tree parameters were measured from 3,417 sample plots on the ground out of the 20,000 photo-plots. This is to determine the actual biomass on the ground using regression equations developed for 38 species groups based on 2,700 test trees destructively sampled for wet weight.

Results from the field were then correlated to the crown cover percent scores in order to derive regression equations, which were then used to predict or estimate wet weight (biomass) from all the 20,000 photo plots.

However, there were some limitations associated with this technique. It was initially assumed that crown cover scores from photo sampling, is directly correlated to the woody biomass in the field plot, since studies in other countries, for example, in Sudan and many others in Europe, show that crown cover is a good indicator of woody biomass. However, NBS analysis proved beyond doubt that crown cover is a poor indicator of the woody biomass in countries with complex tropical vegetation patterns like Uganda. The correlation coefficient (R^2) was very low, with values ranging from 0.2 to 0.4 compared with other countries where values attained exceed 0.7.

In addition to the low correlation between crown cover and the field biomass, the logarithmic regression model applied when analysing the 2,700 test trees was later found to under-estimate the actual biomass by 10-15%, a clear bias. This necessitated further improvements on the regression models by cutting of additional (mainly large) test trees. For example, power regression models such squaring of independent variables and application of certain statistical correction factors (e.g. halving of the mean square error of the regression estimate) were incorporated.

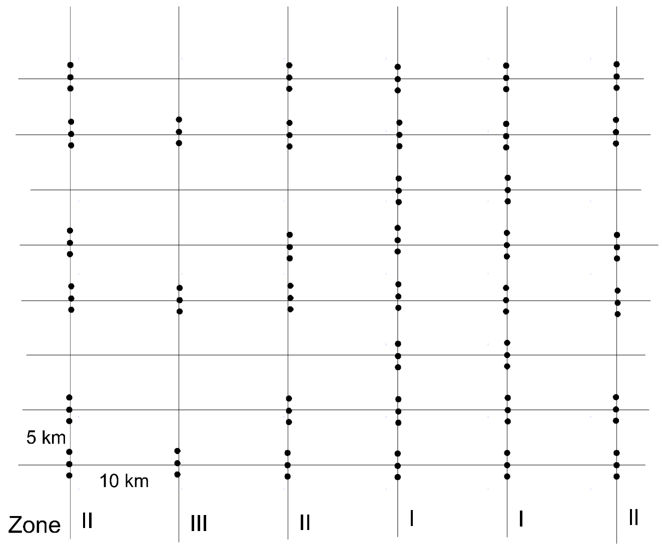
All these improvements reduced the bias to near zero levels and therefore gave better results than the original models. The large variations, in for instance tree morphology (tree shape), and the large number of species encountered still posed a major challenge for researchers, but even then, NBS is of the opinion that the present biomass functions are sufficiently accurate for a nation-wide biomass inventory.

The initial aim of Phase I (1989-1992) was to establish baseline data sets of the average growing stock for each land cover / use (open water and impediments have no relevant biomass). The estimated mean biomass (air-dry biomass) per hectare for each land cover was to be linked to the satellite imagery interpretation for quantifying total biomass countrywide. Because of the high variability in the land cover within, between, and, in the different regions in the country, this approach had to be abandoned.

Systematic Sampling – In view of the above experiences, a systematic sampling technique was adopted in Phase II. In this technique, 5 by 10 Km Grid intersections were generated for the whole country. At each intersection, clusters of three sample plots were located for tree parameter measurements.

Uganda has an effective area of 180,000 sq. km (excluding water and large swamps) and therefore needed approximately 3,000 grid intersections. With 3 sample plots at each intersection, a total of 9,000 sample plots were generated. See Figure 3-14.

Figure 3-14: Sample plot design



The black dots at each grid intersection represent a cluster of three sample plots. The columns and rows (5 by 10 km) are the grids generated on each topo-sheet in UTM coordinates

3.2.2 Sampling intensity

The total number of sample plots out of the gross population determines the sampling intensity. In order to achieve reliable estimates, the sampling intensity was varied according to population density and agro ecological zones as discussed below.

Population density and priority zones – Population density has a direct impact on land cover and biomass density. In principle high population density areas have low biomass density due to either, high consumption or expanded agricultural activity, whereas low population density areas have high biomass density due to low consumption and agricultural activity. Based on these assumptions, a review mission (1994) recommended that Uganda should be classified into priority zone I, II and III as follows:

Priority Zone I - High population density (over 100 persons per square km covering approximately 64,013 km^2), i.e. Kampala, Jinja, Kisoro, Mbale, Kabale, Tororo, Pallisa, Mpigi, Iganga, Mukono, Masaka, Bushenyi, Rukungiri, Kamuli, Kasese, Nebbi, Rakai, Kumi, Mbarara and Kapchorwa districts.

Priority Zone II - Medium population density (50 – 100 persons per square km covering approximately 56,375 km^2), i.e. Kabarole, Arua, Lira, Mubende, Apac, Hoima, Bundibugyo and Soroti districts.

Priority Zone III - Low population density (Less than 50 persons per square Km covering approximately 76,708 km^2), i.e. Kibale, Kiboga, Moyo, Kalangala, Masindi, Gulu, Kitgum, Kotido and Moroto districts.

Since greater biomass changes are expected in priority Zone I, than in priority zone II and priority III, a sampling intensity at a ratio of 3:2:1 was adopted. This means that three intersections (9 plots) were measured in Zone I, two intersections (6 plots) in Zone II, and one intersection (3 plots) in Zone III. In all, 1,500 grid intersections (4,500 plots) were required for priority zone I, 1000 intersections (3,000 plots) for Zone 2 and 500 intersections (1,500 plots) for zone 3. See (Figure 3-14). Theoretically totalling to 9,000 sample plots.

However in practice some plots were inaccessible physically (for example swamps, remoteness), socially (for example the owner refuses access) and due to insecurity. This led to fewer plots being located and measured in the field than previously targeted.

3.2.3 Agroecological zones

Tree growth is heavily dependent on soil quality and climatic conditions (such as precipitation, evapo-transpiration, and temperature). The climatic regimes together with agricultural systems determine the ecology of a given area, agro-ecological system or zone. The Ministry of Agriculture and Forestry in 1987 divided the country into 11 agroecological zones. Considering the time and scope of the study, NBS re-grouped the eleven zones into 4 as shown in Figure 3-15.

Agroecological zone 1, i.e. High altitude areas covering south western corner of Uganda (Kigezi/Kabale) and Mt. Rwenzori in Kabarole district; Mt. Elgon (Mbale, Kapchorwa in the east, and a small part of Nebbi and Arua districts. These areas produce temperate zone like crops e.g. wheat, irish potatoes, and coffee arabica.

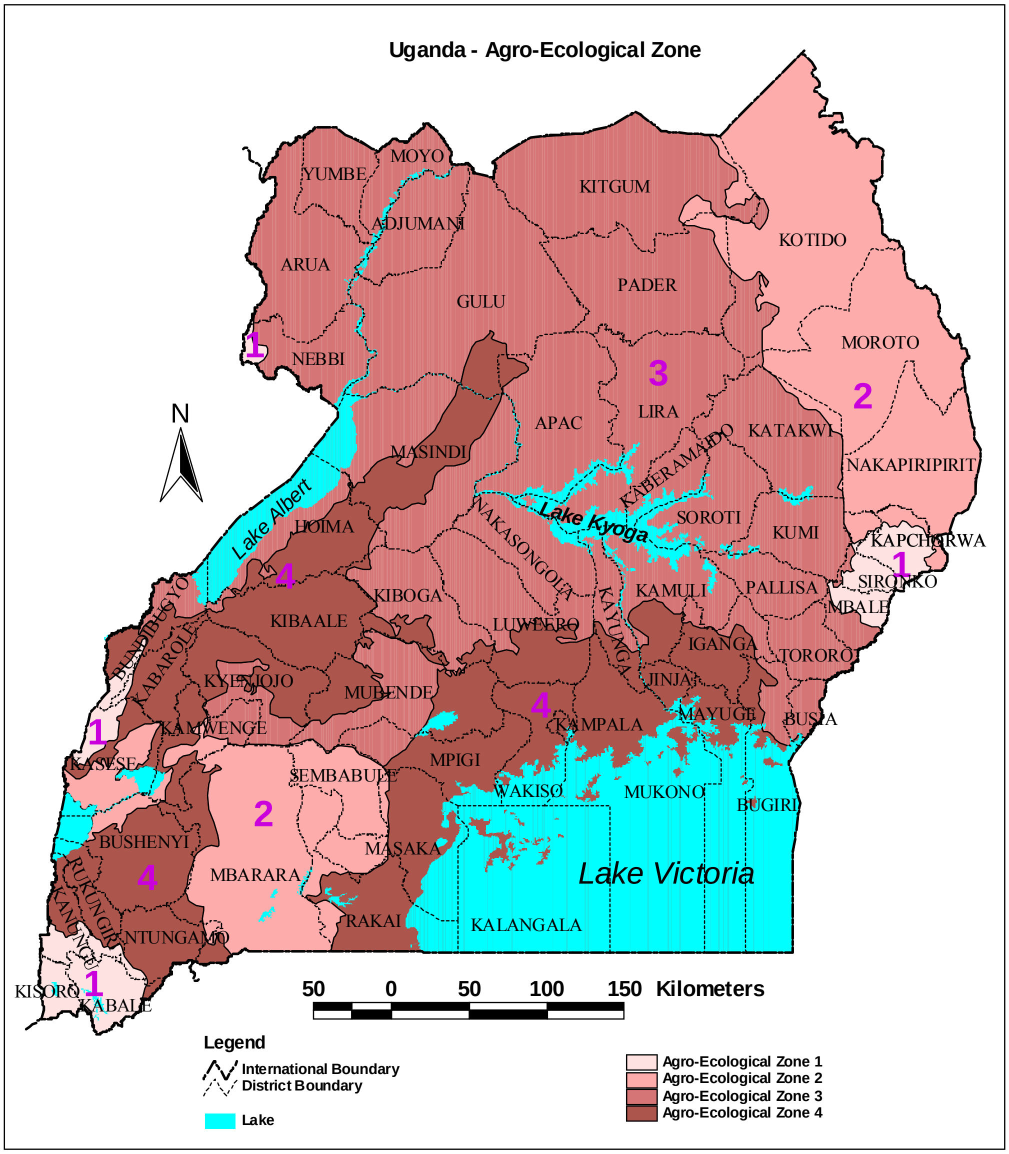
Agroecological zone 2, i.e. Pastoral dry to Semi Arid rangeland areas covering: Mbarara and Western Masaka in the south west and Moroto and Kotido in the north east. The dominant agricultural system is pastoralism.

Agroecological zone 3, Semi-moist lowland Savannah areas covering Northern and Eastern Uganda districts e.g. Arua, Adjumani, Moyo, Nebbi, Yumbe, Gulu, Kitgum and Lira characterised by short grass and growing of cotton, millet and sorghum.

Agroecological zone 4, i.e. Moist lowland and medium altitude areas covering most of Southern and Western Uganda in the Districts of Mpigi, Masaka, Kabarole, Hoima, Kabale, Kisoro, Nebbi and Mbale.

This agroecological zoning is particularly important not only in ensuring that sample plots or the sampling intensity cover all ecological systems but also improves the precision of estimating the biomass stock.

Figure 3-15: Agro-ecological zones of Uganda



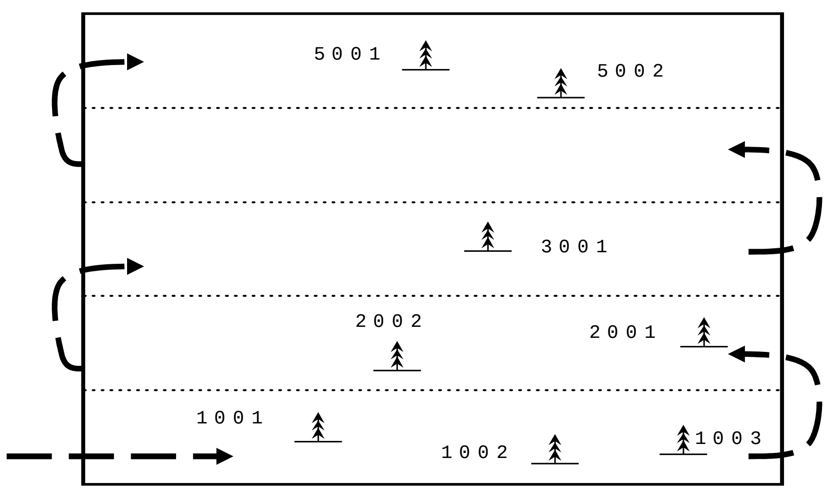
3.2.4 Plot Size

Plot sizes have to be carefully determined because they influence both cost and precision of the survey. A big plot implies many trees, longer movements, therefore more time spent which all translate into higher costs in human and material terms. The plot size influences the precision of the survey through reduction or increase of the coefficient of variation (CV). Knut (1997) carried out statistical tests on various plot sizes and found that in general increasing the plot sizes reduces the CV in most land cover types except plantations, where increasing plot sizes had the opposite effect due to low variability within the plantations. Accordingly he confirmed that the use of 50 by 50m plots should be continued for most land covers except plantations where he recommended the use of 20 by 20 m plot sizes.

3.2.5 Plot location and establishment

Topographic maps, land cover maps (1:50,000) and Global Positioning System (GPS) were used to locate the field plots on the ground. After locating the plots, 50 x 50-m plots were demarcated on the ground. For consistency and future revisits, the south-western corner of each plot was registered by the GPS as a reference point in real world geographical co-ordinates. The readings were recorded on a field form in Universal Transverse Mercator (UTM) or Latitude-Longitude. From the reference point the plot was always established eastwards and northwards in order to re-locate it easily in future, and, other descriptive information like distance and the angle of proximity to any conspicuous landmark were noted on the field form. See illustration, Figure 3-16.

Figure 3-16: Plot strips within the 50m by 50m plot



Arrows in the figure show direction of movement within the plot and numbers refer to tree numbers.

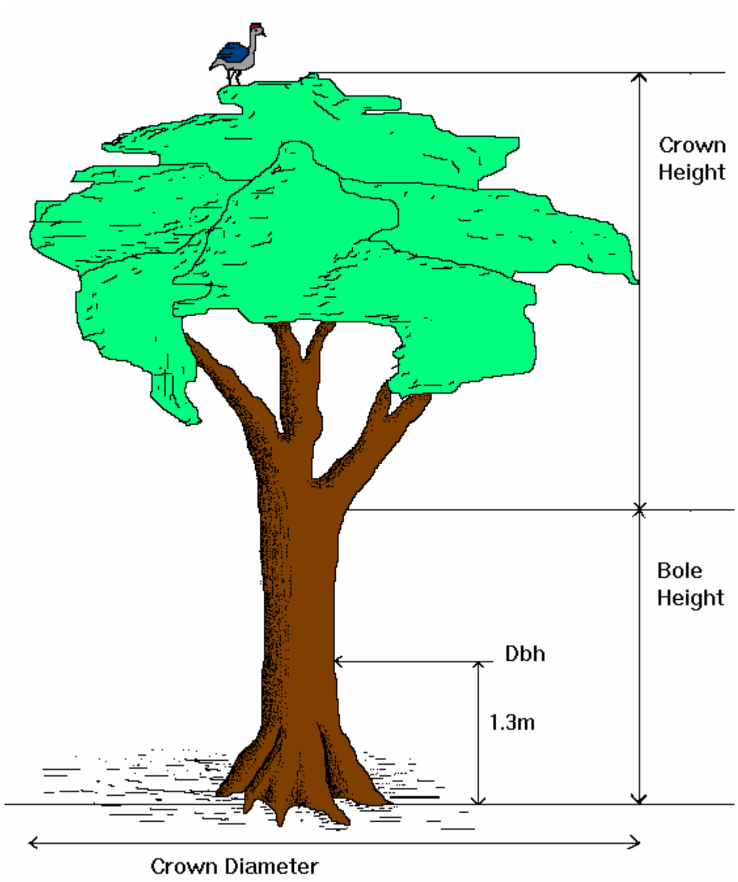
After demarcating the 50 by 50 m plot it was divided into 10 by 5 m wide strips running alternately east or west from the reference point. Within each strip trees were measured systematically from one end of the strip to the other and different numbers were given to each tree for ease of identification (Figure 3-16). In addition plot number, grid reference, crown cover assessment of trees, bush, grass and land cover were recorded.

3.2.6 Measurement of tree parameters

On completion of demarcating and establishing the plot, the team then proceeded to identify tree species within the plot. For every tree within the sample plot, parameters such as diameter at breast height (dbh), tree height, bole height, and crown width were measured.

Diameter at breast height, – Diameter at breast height is the diameter of a tree located at a standard height of 1.3 m above ground. The height at 1.3 m normally corresponds to the position of the chest or breast of an average person, hence the term 'Diameter at breast height or dbh'. It is measured by a diameter tape or calliper, which is calibrated to give readings in diameter or girth. If it is in circumference or girth, it has to be converted to diameter by dividing circumference by *pi* (*pi or* π = 3.1428). The measurements are normally to the nearest centimetre.

Figure 3-17: Tree parameters



Total Tree Height - The total height of a tree is the height from the ground to the top of the crown or highest growing point (Michael, 1983). It is measured by hypsometers, which are instruments for measuring heights based on either geometric or trigonometric principles, calibrated to give readings of the height directly in meters or degrees.

Bole Height – This is the height of a tree from the ground up to the first branching. This part is what foresters refer to as 'merchantile or timber height'. It is measured in the same way as the total height of a tree.

Crown Width - This is the distance on the ground covered by the crown of a tree. It is measured by a distance-tape and readings made to the nearest meter. Since trees normally have irregular crown shapes, two diagonal readings are normally taken and the average mean recorded as the crown width.

In addition to the above parameters, more information from the plot such as land cover/use, percentage of bush coverage and stocking density levels were assessed and recorded on the field form (Appendix 2).

3.2.7 Capturing and processing of field plot data

Tree parameters recorded on the filed forms were entered into appropriate databases for processing and analysis as discussed below.

Data entry program - A program in Dbase (*plot-ent.prg)* was developed and used for capturing the raw data from the field forms. The data was divided into two sections. The first section describes plot characteristics such as Plot number, Map reference, GPS readings, Land cover, types of crops etc... The second section describes tree parameters such as tree diameter, height, bole height, crown width and species. For details of the program refer to Appendix 3.

As a routine, the data was edited regularly in order to ensure consistency and quality control before analysis.

Data analysis – The analysis of single tree weights was based on regression models developed from destructive sampling of trees for the prediction of single tree weights (as the dependent variable) and tree parameters (as independent variables) as shown in equation 3.1 below:

Equation 3.1

$$\text{Ln (WSUM)} = a + (1/_2\text{MSE}) + b^* \text{Ln (D)} + c^*\text{Ln (HT)} + d+ \text{Ln (CR)}$$

Where: a, b, c and d are regression coefficients

MSE = Mean Square Error (Residual error of the regression)

WSUM = predicted weight of tree

D = Diameter at breast height

HT = Height of the tree

CR = Crown Width

Ln = Natural logarithm

From the above model, 40 different regression models were developed from 3,477 sample trees felled through destructive sampling. The 40 models representing 40 species groups were based on genera, morphological and ecological characteristics. In all, 123 species were covered but Knut (1997) discouraged this approach by arguing that grouping species on morphological characteristics was subjective and statistically not significant. As an alternative, he recommended the use of tree size in intervals of 20cm diameter classes as a basis for grouping. Accordingly, he came up with the following models in Equation 3.2 below:

Equation 3.2

These regressions models were then incorporated in a dBase program for

Dbh < 20cm:

$$Ln(w) = 0.5 * 0.09937 \quad 0.909575 + 1.544561 * (ln.d) + 0.50663 (ln.ht) + 0.33346 * ln(cr)$$

Dbh $>= 20$ cm .AND. < 60cm

$$Ln(w) = 0.5 * 0.0892 \quad 1.795491 + 1.943912 * (ln.d) + 0.47371 * (ln.ht) + 0.245776 * ln(cr)$$

Dbh $>= 60$cm

$$Ln(w) = 0.5 * 0.05222 \quad 2.192612 + 2.032931 * (ln.d) + 0.31292 * (ln.ht) + 0.436348 * ln(cr)$$

estimating single tree weights from the tree parameters.

The programme performs the following tasks:

Selects the location (from area file), then opens appropriate tree-data file and calculates wet-weight of single trees using the relevant coefficients of the biomass regression models (Equation 3.2).

The results from above (weight of single trees per plot) were summed up per plot and then converted to weight of trees per hectare using appropriate conversion factors.

The resulting file could be imported into other statistical or data base management packages for further statistical and other analysis.

The statistical analysis was carried out in order to assess the accuracy and quality of the estimated mean standing stock by looking at statistics of Variance, Coefficient of Variation (CV) and Sampling Error (SE). These were further aggregated by each land cover, agro-ecological zone and substrata.

Simple random sampling was preferred to the stratified systematic cluster sampling, because of its simplicity. See further in the following formulae:

Equation 3.3

Mean, $\acute{w} = \Sigma w_i / n$

Where $\hat{w}$ is the estimated mean weight, w individual plot weight per plot i, n is the number of sample plots

Equation 3.4

Variance $= \acute{s}^2 = \Sigma(w_i - \acute{w})^2 / n-1$:

The sum of squared deviations of individual plot weights w_i , from the sample mean, $\acute{w}$ divided by the number of sample plots.

Equation 3.5

Standard Deviation $s = \sqrt{\acute{s}^2}$: Square root of Variance

Equation 3.6

Standard Error of the Mean $s_x = s/\sqrt{n}$:

Standard Deviation divided by the square root of n.

Equation 3.7

Sampling Error (SE) = $t * s_x$

Where: t is the student t value at 95%. The SE measures the upper and lower limits of where the true population mean should lie unless a 5% chance occurs that one is wrong. This is also termed as the confidence limit.

The output above focused on the static assessment of the biomass resource. However, it was recommended (Review Mission, 1992) that dynamic assessment of the resource would yield more valuable information for planning and understanding of changes and trends in the resource. This is covered below under monitoring and land cover change.

3.3 Monitoring biomass growth and dynamics

Biomass Growth - During location and measurement of plots (see 4.2.1), some plots were demarcated as growth plots for monitoring of biomass growth. Apart from the sample size, the procedures of plot location and tree parameter measurements remained the same as described in the previous sections. However there were some exceptions below.

A small proportion (about 400 plots) were revisited and re-measured as growth plots. This was out of the 6,000 plots measured in the first round in mid 1990s. These 400 plots were spread with a minimum of 12 plots per land cover per agro ecological zone, so as to obtain a representative number of sample plots across the country. For purposes of ease of relocation, each growth plot was specially marked such that all trees in the plot were laid in a matrix form by reading the distance from the reference point in the x-axis and the y-axis direction. For example, a tree could be marked on the plot as tree No. 1 and the matrix marked as 5 x 4, meaning that it is located 5 metres from the South-West corner Eastward (x-axis) and 4 metres from the South-West corner Northwards (y-axis).

The data processing and analysis for growth estimation was based on two sets of measurements on undisturbed plots over a certain time interval because of growth being continuous throughout the year. The calculation of biomass growth per year had to be from date to date in years (expressed in decimal years) covering the time interval.

The initial measurements (Visit 1) were used to calculate biomass of all trees larger than 3-cm diameter breast height at the beginning of the time interval. The second measurements (Visit 2) were used to estimate the biomass at the end of the time interval. The final biomass consists of:

Equation 3.8

B2 = B1 + GB1 + I

Where B1 = initial standing stock

B2 = final standing stock

GB1 = growth of initial standing stock

I = ingrowths of trees below 3 cm to trees over 3 cm diameter

The growth rate estimator is the growth per year in percentage of the initial standing stock. From this the growth could be generated from initial standing stock as shown in equation (3.9):

Equation 3.9

$$GB1 = B2 - B1 - I$$

The increment percentage is then:

Equation 3.10

$$GB1\% = GB1*100/ (B1*T)$$

Where T = time interval in years (expressed in decimal years)

Time interval between the first measurements and the second was on average 3 years whereas the average percentage within a stratum was estimated as the weighted biomass percentage of all plots within the stratum.

Other analyses covered growth among tree sizes by grouping trees into specified diameter class intervals. Thereafter, the sum of growth of all trees in a diameter class was divided by the number of plots to yield average biomass per diameter class. Likewise, the count of all trees per diameter class divided by number of plots gave the number of trees per diameter class. Note that recruits or ingrowths were treated as a special diameter class. Figure 3-18 gives a schematic presentation of yield assessment.

Figure 3-18: Schematic illustration of growth assessment

PLOTNO	TREENO	DBH	BOLE	HEIGHT	CROWN	SPECIES	PWS_AIRDRY
112028	1001	4	1.3	3.0	1.5	Persea americana	3.8
112028	1002	7	1.4	4.0	2.5	Persea americana	12.3
112028	1003	6	1.3	4.0	1.0	Citrus nobilis	8.7
112028	1004	5	1.7	4.5	1.0	Citrus nobilis	7.0
112028	1005	6	1.3	4.0	1.0	Citrus nobilis	8.7

PLOTNO	TREENO	DBH	BOLE	HEIGHT	CROWN	SPECIES	PWS_AIRDRY
112028	1001	5	1.3	3.5	1.5	Persea americana	5.8
112028	1002						Cut
112028	1003	6	1.3	4.3	1.0	Citrus nobilis	9.0
112028	1004						dead
112028	1005	6	1.3	4.3	1.0	Citrus nobilis	9.0
112028	R101	3	1.3	3.0	2.5	Mangifera indica	3.5

PLOTNO	TREENO	DB	BOL	HEIGHT	CROWN	SPECIES	PWS_AIRDRY
112028	1001	4	1.3	3.0	1.5	Persea americana	3.8
112028	1003	6	1.3	4.0	1.0	Citrus nobilis	8.7
112028	1005	6	1.3	4.0	1.0	Citrus nobilis	8.7

Biomass dynamics – The overall biomass growth, which is a net result of biomass growth at the end of the second visit and the stock at the first visit, can be either positive or negative. This is determined by how much biomass is removed due to human activities or natural causes and how much is left to grow undisturbed. The impact of removals and growth on the net biomass stock is referred to as biomass dynamics. This has been assessed through re-visiting and re-measurement of nearly 1180 sample plots out of the total 5000 sample plots. The procedures of locating the plots, measuring of tree parameters and data processing are the same as described in 3.2.

Land cover change - The importance of land cover change and monitoring of trends was realised during the process of assessment and was incorporated in the biomass monitoring program by recording the land cover class in each polygon during the first visit. In addition, the local land cover /use (class 11, 12, 13) around the plot was noted. This may often differ from that of the polygon because of natural variations across the delineated area.

During the second visit to the sample plot, the land cover (use) was also noted and recorded for comparison with the first visit. The comparison of the land cover (use) changes at the two different time periods was done in a crosswise table as shown in Table 3-4.

Table 3-4 : Change in Land Cover

Land cover (use) class.	**Land cover (use) class.**					
	Time 2					
Time 1	Plantations Hardwood	Plantations softwood	Tropical High Forest	…	n	Sum
Plantations Hardwood	x11	x12	x13	x14	..	x1.
Plantations softwood	x21	x22	x23	x24	..	x2.
Tropical High Forest	x31	x32	x33	x34	..	x3.
...	...	...	...	...	...	...
n						
Sum	x.1	x.2	x.3	x.4	...	

From such a table the change in land cover classes can be seen. Likewise the change between classes would be clearly indicated. Note that a land cover/use class may appear relatively stable in total but can actually be undergoing tremendous change.

If there are areas of great change, the original map will be out of date. The land cover change table will probably be of considerable help when updating the maps. The main efforts here should be applied to classes of considerable change and not to stable classes.

3.4 Synthesis and products

Information from the mapping, biomass survey, monitoring of biomass and land use change were synthesised to yield the following main products:

The extent and distribution of land cover at national, regional or district level with possibilities of going down to the lowest administrative unit i.e. parish.

The total biomass in tons per land cover/strata, which can also be aggregated at national, regional and district levels.

The status of gazetted areas such as extent of deforestation, degradation and forest or non-forest areas within for instance Forest Reserves, National Parks and Games reserves.

Biomass annual growth (increments) and land cover change

Conclusion - This chapter presented the methodology applied in the stratification, mapping, biomass survey and monitoring. The results from this exercise are presented in the next two chapters.

4. Land Cover Area and Distribution

The previous chapter described the methodology for mapping the land cover, field data collection, processing and analysis. In this chapter the results of the mapping exercise which primarily aimed at determining the area and extent of land cover distribution at national, regional and district level is presented. The overall distribution of land cover is further dis-aggregated by ownership i.e. gazetted and non-gazetted (private) land in order to determine the actual biomass resource base and establish its current status in protected areas especially in Forest Reserves.

4.1 Area and Extent of land cover

The area and extent (distribution) at national, regional and district levels are presented for the 13 classes in Table 4-1 and sub-classes in Table 4-2.

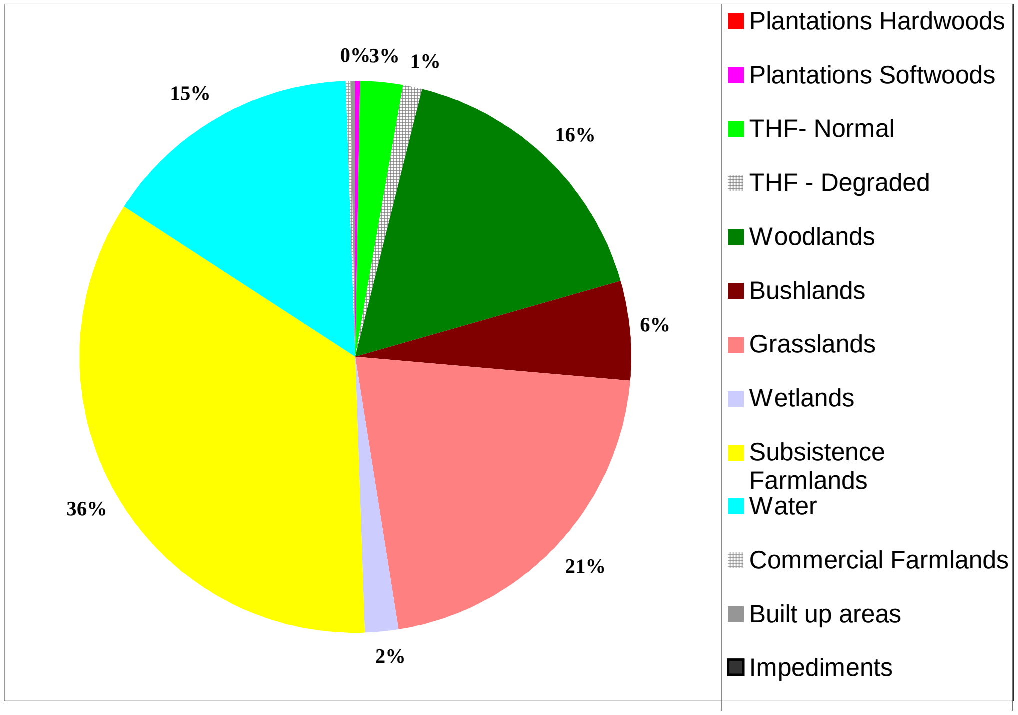
National Distribution (Main stratification) – Uganda has a total area of about 241,551 km^2, out of which, farmland is the most extensive, followed by grasslands, woodlands, water bodies, bushlands, tropical high forest (normally stocked), tropical high forest (degraded) and others in that order.

Table 4-1 : National Land Cover/Use distribution

Stratum	Area(Ha)	Percentage3
Plantations Hardwoods	18,682	0%
Plantations Softwoods	16,384	0%
THF- Normal	650,150	3%
THF - Degraded	274,058	1%
Woodlands	3,974,102	16%
Bushlands	1,422,395	6%
Grasslands	5,115,266	21%
Wetlands	484,037	2%
Subsistence Farmlands	8,400,999	35%
Commercial Farmlands	68,446	0%
Built up areas	36,571	0%
Water	3,690,254	15%
Impediments	3,713	0%
Total	**24,155,058**	**100%**

[3] Note the zeros are due to rounding and represent values less than 1%

Figure 4-1: Relative Land Cover Distribution



The land area excluding water is about 20.5 million ha, out of which 4.9 million ha (about 24%) is covered by forests (plantations both hard and softwoods) tropical high forests both normal and degraded, and woodlands. The rest (76%) is non-forested i.e. comprising of other land cover types such as bushlands, grasslands, wetlands, subsistence farmland, commercial farmland, built up areas and impediments as shown in Figure 4-1 and Annex 1 for national distribution and extent of land cover.

National Land Cove Distribution (with sub-stratification) – As described in section 3.1.1, the thirteen main classes had to be sub-stratified on the basis of biomass stocking densities which ranged from low, medium, high to very highly stocked as shown in Table 4-2. The first column is land cover represented by codes 1 to 13 as explained in 3.1 and the others represent the substratum classification.

The area by sub-stratum (Table 4-2) shows that majority of the sub-classes are found within low and highly stocked biomass density classes. However, others such as wetlands, water and impediments were ignored because of the assumption that they do not represent significant woody biomass.

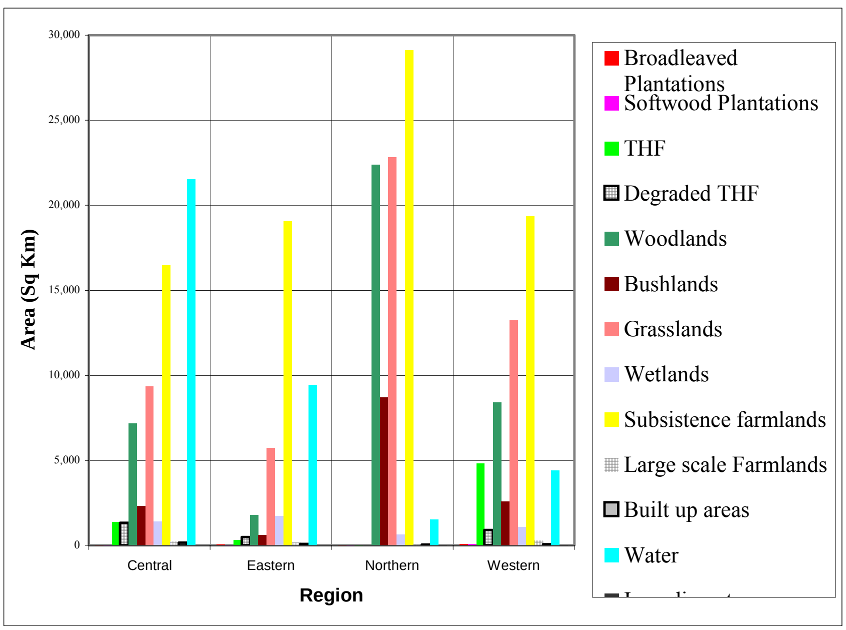
Table 4-2 Land Cover Areas by substrata (Units in Ha)

Strata	Non-Stratifie	0	AV	BA	BH	BL	HI	LO	ME	NO	VH	VL	Total
1	721.97		1541.28				5900.37	1727.88	6212.03	15.22	2350.98	211.96	18681.69
2	6735.84		411.22				5908.38	924.44	36.04	2367.91			16383.83
3							92622.42	242422.69	315105.33				650150.44
4	25.83						68815.31	75686.89	123978.17	5551.31			274057.50
5				7061.54	8268.63	2846.72	588676.39	1473176.85	1894072.29				3974102.43
6		16.81					227412.79	771229.52	422358.73	1377.52			1422395.37
7							1498838.52	2005610.22	1282054.69	328762.47			5115265.90
8			484027.50							9.46			484036.95
9							1272311.74	2258342.30	3700534.23	46576.95	135617.75	987616.13	8400999.11
10	31761.44						4101.62	8143.10	3167.82	21272.08			68446.06
11	83.85		34311.23				721.56	10.66	1318.73	125.15			36571.17
12										3690253.84			3690253.84
13										3713.30			3713.30
													24155057.58

AV (Average), HI (High) ME (Medium) and LO (Low). Bamboo a special woodland category is classified as BH (Bamboo High) which is in the same category as HI in woodland or BL (Bamboo Low also same as LO in woodlands).

Regional Distribution – For purposes of NBS study, Uganda was divided into four regions i.e. Central, Eastern, Northern and Western (Figure 4-2).

Figure 4-2 Land Cover Distribution by Region



In Central, water bodies occupy the largest area (mainly Lake Victoria), otherwise the most extensive land cover is farmland, followed by grasslands, woodlands, tropical high forest (degraded) and tropical high forest (normal) in that order.

In Eastern Uganda, farmland is the most extensive land cover followed by water bodies and grasslands, with tropical high forests and woodlands coming last.

Western Uganda is similarly dominated by farmland, followed by grassland, woodland, tropical high forest, water bodies and others (bushland, degraded tropical high forest and plantations).

Northern Uganda like other regions has more farmland than any other land cover, followed by grassland, woodland, bushland, water bodies and wetland in that order. Note that there is hardly any tropical high forest in this region.

The description above focused on variations within each region, however cross-regional variations can also be compared with each other.

Land cover/Use distribution by districts - Table 4-3 shows the detailed distribution of land cover by district.

Table 4-3 : Land Cover/Use Distribution by districts (Units are in Ha)

District	Hardwood Plantations	Softwood Plantations	Tropical High Forest (Normal)	Tropical High Forest (Depleted)	Woodlands	Bushlands	Grasslands	Wetlands	Subsistence Farmlands	Commercial Farmlands	Built up Areas	Water	Imped-iments	Sub-total
ADJUMANI			1,268		149,850	1,630	43,257	9,428	96,706	605	320	5,615	19	308,698
APAC	176				68,912	10,054	92,752	11,462	433,321	1,257	457	35,533	201	654,123
ARUA	1,837	395			176,607	26,526	33,961	8,061	295,736	116	574	3,738	72	547,624
BUGIRI	5		1,435	1,602	23,090	5,092	5,388	10,537	108,192	1,181	321	410,168	84	567,094
BUNDIBUGYO			37,539	1,912	34,633	2,245	84,956	10,290	36,516		58	18,016		226,166
BUSHENYI	1,067	16	67,798	3,259	17,300	14,507	62,930	9,197	214,665	1,004	503	36,982	26	429,254
BUSIA	8	16	431	1,861	7,606	4,484	2,450	2,908	52,835	159	326	2,852	5	75,940
GULU	272	484			468,628	35,894	162,380	7,156	485,842	346	794	9,664	87	1,171,546
HOIMA	47	432	48,440	26,703	84,890	8,558	71,564	5,817	118,324	1,289	345	226,869		593,277
IGANGA	156		575		4,837	4,672	3,706	14,618	218,754	86	546	266	16	248,232
JINJA	3,256	186	34	255	264	2,502	442	1,215	49,121	8,192	1,825	4,975		72,267
KABALE	1,809	1,868	8,138	340	466	557	16,447	1,501	136,178	19	580	5,061		172,962
KABAROLE	805	782	33,134	6,478	14,225	279	21,509	2,175	96,338	5,274	632	813		182,444
KABERAMAIDO					17,546	2,255	19,579	6,155	89,864		52	26,944		162,395
KALANGALA			21,972	55	4,756	867	11,469	26	7,664		13	860,004		906,826
KAMPALA	31			491	30	736	80	1,453	6,904	123	8,150	1,685	19	19,700
KAMULI	286	21			27,601	10,442	33,783	39,682	252,490	242	586	64,916	102	430,151
KAMWENGE	38		24,387	1,026	27,124	3,986	53,375	7,517	119,932	73	70	6,414	2	243,942
KANUNGU	215	1,485	19,002	326	14,117	2,680	11,515	742	76,918	299	103	1,808		129,209
KAPCHORWA	14	1,492	19,372	13,987	27,731	6,377	58,447	1,042	44,022	541	137		9	173,172
KASESE	196	1	39,437	2,254	66,868	18,361	55,306	6,578	103,012	4,253	1,231	40,971	489	338,958
KATAKWI	6				17,721	283	241,003	6,593	225,409		472	9,912	47	501,444
KAYUNGA	593	142	61	433	13,916	13,579	28,150	18,407	82,898	326	280	11,453		170,238
KIBAALE	31		79,671	34,430	72,910	2,434	52,106	10,547	171,872		274	26	303	424,605
KIBOGA	2	491	3,148	3,826	161,213	10,816	90,703	12,276	121,825	111	118	20		404,548
KISORO	202	3	10,287	290		86	2,831	980	55,246		214	2,825		72,965
KITGUM					475,309	28,827	177,606		281,026		334	309	37	963,448
KOTIDO	17				232,120	284,117	686,396		121,427		120	16	298	1,324,512
KUMI	122				8,056	9,673	77,149	10,641	166,807	369	379	11,574	44	284,813
KYENJOJO	227	1,993	42,403	11,838	85,600	2,995	66,389	9,176	181,256	2,908	155	5	489	405,437
LIRA	77	298			68,409	8,052	90,938	11,063	461,059	606	1,052	78,332	185	720,073
LUWEERO	76	32	137	5,565	231,639	6,665	123,071	24,007	177,173	388	508	126	3	569,390
MASAKA	1,252	6	6,013	9,599	5,120	9,056	89,834	8,331	225,677	369	945	112,967		469,169
MASINDI	281	112	50,966	1,980	393,058	27,089	201,460	13,042	164,511	10,892	942	79,956	12	944,302
MAYUGE	129	139	1,282	14,486	6,960	3,856	7,017	5,710	67,822	660	173	355,597	24	463,855
MBALE	557		4,758	10,541	9,987	1,574	7,381	515	100,738		1,222	3	7	137,282
MBARARA	1,046	1,233	3,700	171	17,836	170,482	493,087	20,311	284,548	285	1,102	7,938	170	1,001,909
MOROTO					68,366	251,959	455,513		75,585		268		70	851,759
MOYO	18	2		5	70,694	4,710	56,653	10,226	37,561		205	8,995	1	189,070
MPIGI	93		20,839	19,462	31,556	10,767	83,464	8,274	150,863	1,056	383	33,801		360,559
MUBENDE	707	137	4,917	23,950	94,446	26,046	99,109	16,002	335,634	2,884	473	15,428	35	619,768
MUKONO	497	216	54,673	45,953	6,641	12,919	32,120	17,232	149,693	15,137	1,441	928,966	84	1,265,571
NAKAPIRIPIRIT					45,855	195,372	310,352	1,443	30,029	83	110		138	583,381
NAKASONGOLA	1	1,707			127,051	48,865	78,091	15,806	54,729	67	793	23,884	1	350,994
NEBBI	163	2,057	190		24,358	22,897	62,755	3,184	167,692	115	82	8,228		291,723
NTUNGAMO	295	333			1,927	312	97,107	6,997	98,034		128	415		205,549
PADER	3	2			252,701	1,377	67,355		370,297		326	578	287	692,924
PALLISA	39				927	429	13,458	31,210	145,977	212	266	6,628	26	199,173
RAKAI	704		18,292	3,206	14,102	30,551	192,837	8,859	146,172	161	329	75,531	125	490,869
RUKUNGIRI	569		16,929		8,552	4,060	33,314	925	80,278		168	11,882		156,677
SEMBABULE	91				15,749	54,639	85,211	3,600	72,483	7	58	77		231,915
SIRONKO	60		2,100	6,092	17,176	3,456	24,943	3,009	52,148	228	177			109,390
SOROTI	9	287			6,477	3,024	72,383	22,519	180,922	429	1,347	50,370		337,767
TORORO	207		1	44	2,853	3,763	5,577	17,857	149,897	3,692	1,014	8	14	184,926
WAKISO	322	16	6,823	21,638	9,229	4,620	20,910	6,474	115,086	2,401	3,085	90,109	61	280,773
YUMBE	65				138,508	339	43,699	1,263	55,292		5	1,002	124	240,298
Totals	***18,682***	***16,384***	***650,150***	***274,058***	***3,974,102***	***1,422,395***	***5,115,266***	***484,037***	***8,400,999***	***68,446***	***36,571***	***3,690,254***	***3,713***	***24,155,058***

Highlighting all aspects on a district by district basis is not possible. However in brief, tropical high forests exist in Kibaale, Bushenyi, Mukono, Hoima, Masindi and Kyenjonjo in western region, and no tropical high forests for districts such as Gulu, Pader, Arua, Lira and Apac in the north.

Woodlands mostly occur in Kitgum, Gulu, Masindi, Pader and Kotido. Kisoro is the only district without any woodland.

4.2 Land Cover Distribution in Protected and Private Lands

Land in Uganda is either Government or Private owned. Government land consists of mainly gazetted or protected areas i.e. for purpose of forestry (Forest Reserves) or wildlife conservation (National Parks and Game Reserves). Other gazetted areas for institutions (schools, prisons, police and the army) are insignificant. Private land is under freehold, leasehold, customary, communal and 'mailo' land. Appendix 4 shows the location of each Protected Areas, PA.

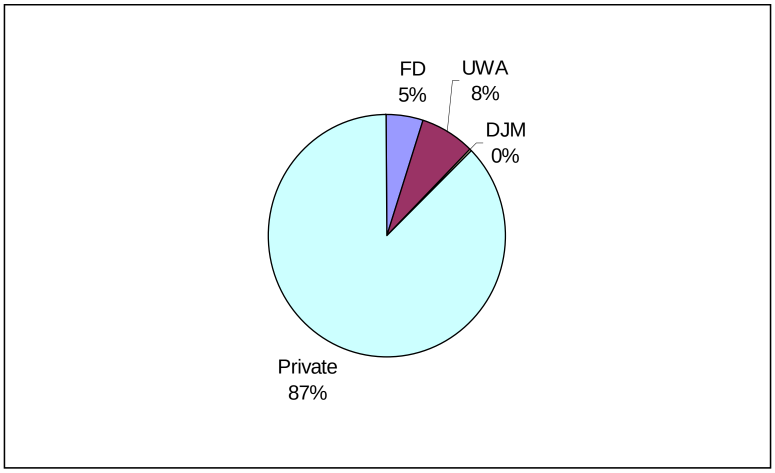
The gross national land cover distribution between the two main categories is shown in Table 4-4. The purpose of separating the gross land cover is due to differing management objectives, which also have a bearing on accessibility and availability of biomass. For instance all the biomass in private land is assumed to be accessible and therefore available, whereas that in protected areas is assumed to be inaccessible and unavailable. With this point of view, more attention will be given to protected areas because of their management status.

Table 4-4 : Land Cover in Uganda

Land Cover/Use	Gross Area by Land Cover/U	PA (excluding HA)	Private
Plantations Hardwoods	18,682	6,658	12,024
Plantations Softwoods	16,384	15,693	690
THF- Normal	650,150	477,068	173,083
THF - Degraded	274,058	97,011	177,047
Woodlands	3,974,102	875,854	3,098,248
Bushlands	1,422,395	296,111	1,126,285
Grasslands	5,115,266	1,149,967	3,965,299
Wetlands	484,037	32,598	451,439
Subsistence Farmlands	8,400,999	137,931	8,263,068
Commercial Farmlands	68,446	1,287	67,159
Built up areas	36,571	1,982	34,589
Water	3,690,254	14,713	3,675,541
Impediments	3,713	745	2,968
Total	**24,155,058**	**3,107,618**	**21,047,440**
Relative to Total area		**13%**	**87%**

Overall, 13% of Uganda's land is under government as protected areas and the balance (87%) is under private ownership (Figure 4-3).

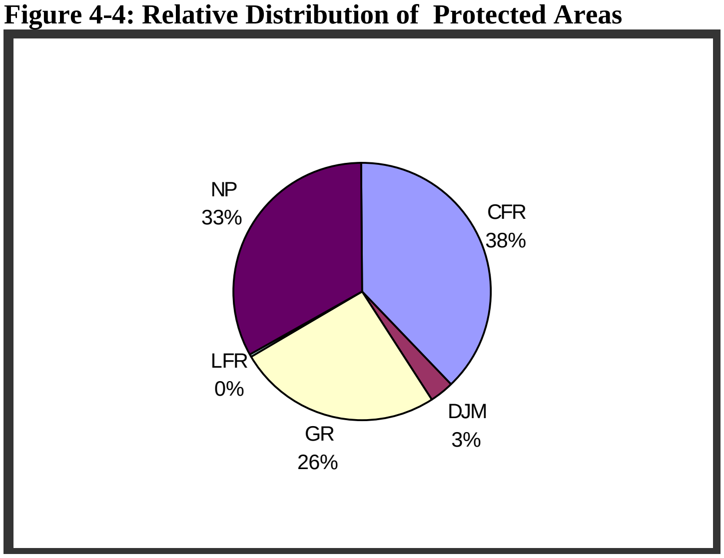
Figure 4-3: Relative Share of Land by Ownership



Types of Protected Areas and Management/ownership - Protected Areas, (PAs) in Uganda comprise of Forest Reserves which are further categorised into Central Forest Reserves, (CFRs) or Local Forest Reserves, (LFRs). The Forest Department (FD) and Local Government are responsible for the management of Forest Reserves, while Uganda Wildlife Authority (UWA) is responsible for the management of National Parks, (NPs), Game Reserves, (GRs), and Animal Sanctuaries, (ASs). Departmental/Joint Management, DJMs are jointly managed by FD and UWA. A summary of Protected Areas by ownership and type of reserve at District level is shown in Appendix 5.

Figure 4-4 shows the relative share of land by ownership in protected area.

Figure 4-4: Relative Distribution of Protected Areas



CFRs take the biggest share of protected areas, followed by NPs and GRs. LFRs are almost insignificant.

4.3 Land cover distribution in Gazetted Areas

The distribution of land cover classes within Protected Areas has been summarised at national level as shown in Table 4-5.

Table 4-5 : Distribution of Land Cover by type of Protected Areas

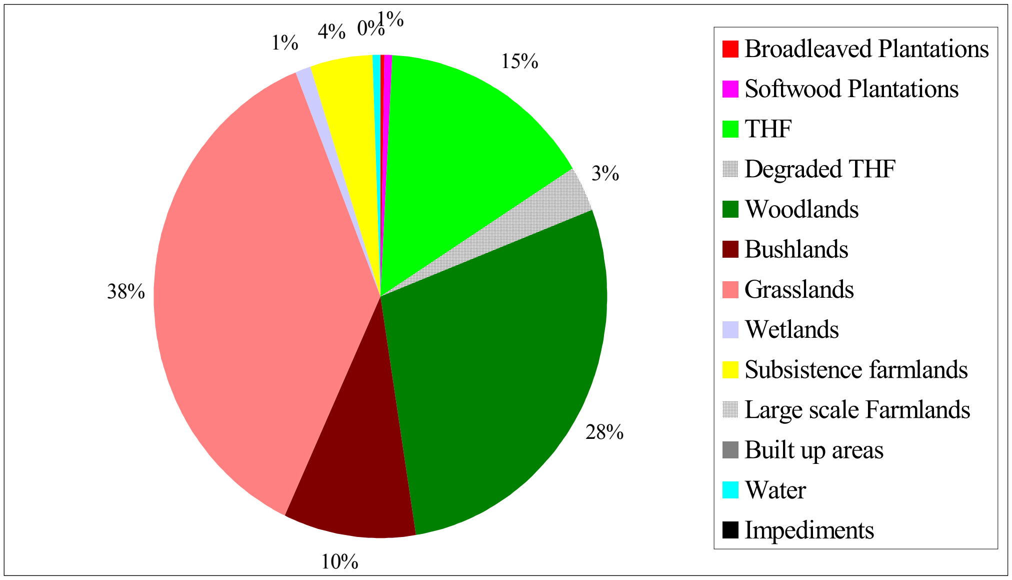
	Forest Department, FD		FD/UWA	Uganda Wildlife Authority			
Land Cover/Use	Local Forest Reserves	Central Forest Rserves	Departmental Joint Management	Animal sanctuary	Game Reserves	National Parks	**Total**
	(Ha)	**(Ha)**	**(Ha)**	**(Ha)**	**(Ha)**	**(Ha)**	**(Ha)**
Plantations Hardwoods	575	6,045		10	0	27	6,083
Plantations Softwoods	3	13,418				2,273	15,691
THF- Normal	309	261,924	24,175		3,057	187,602	476,759
THF - Degraded	235	57,886	2,304	114		36,473	96,776
Woodlands	512	414,066	11,864	181	144,905	304,327	875,342
Bushlands	371	107,298	9,026	31	103,179	76,207	295,740
Grasslands	602	200,828	41,164	1,330	523,848	382,196	1,149,366
Wetlands	177	5,965	318	20	4,862	21,256	32,421
Subsistence Farmlands	2,136	103,525	1,421	1,470	15,505	13,874	135,795
Commercial Farmlands	4	1,202	0			81	1,283
Built up areas	11	321		1,448	33	169	1,971
Water	22	899	113	2,269	902	10,508	14,691
Impediments	1	377		21	10	336	745
Total	**4,957**	**1,173,753**	**90,386**	**6,894**	**796,302**	**1,035,327**	**3,107,618**
Forest	1,634	753,339	38,343	305	147,962	530,701	1,470,650
Forest %	**33%**	**64%**	**42%**	**4%**	**19%**	**51%**	**47%**

The overall distribution shows that forestland comprising of plantations, tropical high forests and woodland is the most extensive (47%), followed by grasslands (37%). Further details of land cover distribution within the protected areas are discussed below for Central Forest Reserves, Local Forest Reserves, National Parks and Game Reserves.

Central Forest Reserves: Out of 1.17 million ha of Central Forest Reserves, woodlands take the greatest share, followed by tropical high forest and depleted tropical high forest. Together, the forested areas in the central forest reserves total 64%. The balance is shared between non-forested land cover/uses e.g. grasslands (17%), bushlands (9%) and others, (Figure 4-5).

Appendix 6 shows a summary of the land cover distribution within Central Forest Reserves by Districts.

Figure 4-5: Relative Land Cover Distribution in Central Forest Reserves



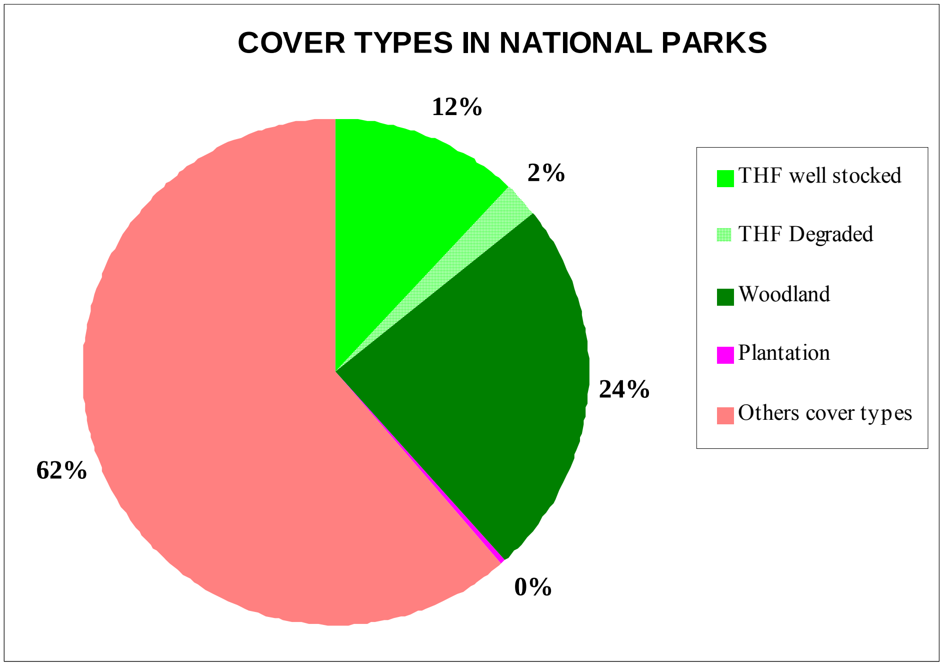
Local Forest Reserves - Within Local Forest Reserves, the dominant land cover is subsistence farmland followed by grasslands and woodlands. Most plantations are hardwoods (eucalyptus). For details of land cover distribution within Local forest Reserves refer to appendix 7.

The distribution above is useful for Forest Planning and Management. For instance it is now easy for FD to identify the actual area covered by forests and non-forests within gazetted area. When planning for tree planting programs, assuming the areas presently occupied by grasslands and bushlands were to be planted with high quality and fast growing species, the plantation area would be increased from the present 20,000 ha to over 300,000 ha. This is 15 times more than the current acreage, even though it would take some years (probably 10 years at an annual planting rate of 30,000 ha per year) to achieve such a target. The impact of such a program, notwithstanding the economics of it, would be great improvement or rise in the biomass supply situation in the country.

National Parks - The forested area in National Parks amounts to about 38% of the land area in National Parks, leaving a balance of 62% to rangeland (bush and grassland (Figure 4-6).

Appendix 8, 9 and 10 show the details of land cover distribution within National Parks, Game Reserves and Departmental Joint Management areas in the districts respectively. It should be noted that Districts, which are not shown, do not have these Pas.

Figure 4-6: Land cover distribution in National Parks



4.4 Status of Forest Reserves

As already stated, FD is responsible for the management of forests in Central Forest Reserve while District Local Governments are responsible for management of forests in Local Forest Reserves. The management objectives as outlined in the forest policies are to achieve a balance between supply and demand for forest products, protection and conservation for the needs of present and future generations. However, FD in the management of the forest estate has faced management challenges such as forest degradation and deforestation, both of which have impacted negatively on forest productivity.

Forest Degradation - This is the deterioration of the productive capacity of forests from high to low productivity due to human influence such as uncontrolled logging, overgrazing, over exploitation, repeated fires, encroachment for agricultural activities and others such as diseases (FAO, 1995). The distribution of degraded tropical high forest has been used as a proxy for assessing the extent of forest degradation in forest reserves in Uganda.

The assessment revealed that out of the total 1.17 million ha of Central Forest Reserves in the country, 58,000 ha (5%) have been degraded or depleted (See Appendix 11). On a reserve by reserve basis, the most affected forests are South Busoga Forest Reserve now in Mayuge District where out of 16,000 ha, nearly 12,500 ha (76%) have been degraded. This is followed by Mabira Forest Reserve, where out of 29,570 hectares, about 7,000 ha (24%) are depleted or encroached. In all, the results revealed that 14 forest reserves out of 500 CFRs in the entire country were seriously degraded by over 1000 ha in each.

A list of Districts heavily affected by forest degradation show Mayuge leading with over 12,000 ha, followed by Mukono, Mpigi, Masaka and Hoima (Table 4-6). For details in each district refer to Appendix 11.

Table 4-6 : Degradation and deforestation in Central Forest Reserves

District	Total CFR area (ha)	Degraded area(Ha)	Deforested area	percent
MAYUGE	26,025	12,770	1,958	8%
MUKONO	51,027	11,856	2,232	4%
MPIGI	30,304	6,056	3,198	11%
MASAKA	19,982	4,930	6,098	31%
HOIMA	59,536	4,624	2,055	3%
KIBOGA	38,327	3,105	8,781	23%
BUSHENYI	48,312	2,949	1,393	3%
KYENJOJO	30,483	2,325	1,070	4%
WAKISO	6,409	2,253	959	15%
MUBENDE	36,806	2,024	10,668	29%
BUSIA	3,795	1,631	503	13%
KIBAALE	31,755	1,164	1,115	4%
BUGIRI	2,421	765	143	6%
RAKAI	38,264	589	6,715	18%
JINJA	6,131	222	1,538	25%
KABALE	4,993	156	424	8%
KAYUNGA	8,220	120	490	6%
MBARARA	12,852	102	599	5%
MASINDI	100,341	100	2,473	2%
KASESE	2,029	52	347	17%
BUNDIBUGYO	4,572	49	1,656	36%
KABAROLE	4,390	46	250	6%

Deforestation - This is the complete clearing of tree formations (closed or open) and their replacement by non-forest land uses (FAO, 1995). Subsistence farmlands, commercial farmland and built-up areas occurring within Forest Reserves have been used as a proxy for assessing the extent of deforestation within the Forest Reserves.

The findings indicate that, unlike forest degradation, deforestation is more in Local Forest Reserves than in Central Forest Reserves. The results revealed that out of the 500 CFRs 30 have been totally deforested. In Local Forest Reserves 65 out of 192 reserves have been completely deforested. In relative terms 9% and 43% of the total CFRs and LFRs respectively have been deforested in Uganda. At forest reserve level, the most affected areas are Buyaga Dam (over 12,000 ha), Luwunga (5,000 ha), Nyangea-Napore (4,000 ha), and Moroto over 3,000 ha deforested.

Comparison of deforestation in Central Forest Reserves by districts revealed that Mubende, Kiboga, Gulu, Kotido, Rakai, Masaka, Sembabule, Apac, Moroto, Mpigi and Kitgum are worse off than other districts (Table 4-6). In Local forest reserves, the leading districts in deforestation are Arua, Lira, Pallisa, Jinja, Mpigi and Apac with over 400 ha deforested. Districts like Adjumani, Bundibugyo, Gulu, and Sembabule have totally cleared their Local Forest Reserves (Table 4-7). The details by each reserve are shown in Appendix 12.

Table 4-7: Degradation and deforestation in LFRs by Districts

District	Total Area	Degraded area	Deforested area	Percent
ARUA	646		461	71%
LIRA	298		247	83%
PALLISA	271		146	54%
JINJA	150		135	90%
MPIGI	330	86	112	34%
APAC	105		84	80%
IGANGA	169		82	49%
NEBBI	176		65	37%
KASESE	78		61	78%
ADJUMANI	56		56	100%
MUBENDE	85		50	59%
MASAKA	199		46	23%
KATAKWI	58		45	77%
LUWEERO	178		41	23%
PADER	61		41	67%
MBALE	68		40	60%
BUNDIBUGYO	39		39	100%
TORORO	63		36	57%
KUMI	191		35	18%
SOROTI	324		33	10%
KITGUM	30		30	100%
KOTIDO	40		27	66%
GULU	25		25	100%
KANUNGU	36		24	67%
RAKAI	85		24	28%
SEMBABULE	23		23	100%
SIRONKO	110		22	20%
KABAROLE	23		20	88%
MOYO	19		17	91%
KAMULI	82		17	21%
BUSHENYI	22		12	54%
KAYUNGA	57		11	19%
MUKONO	499	135	7	1%
WAKISO	128	15	7	5%
MASINDI	70		6	9%
KABERAMAIDO	11		5	45%
KYENJOJO	14		4	30%
KIBAALE	27	0	4	16%
HOIMA	32		4	13%
RUKUNGIRI	9		4	46%
MBARARA	61		1	1%
KAMWENGE	5		1	10%
KAPCHORWA	3		0	15%

What is clear though is that while on an individual Forest Reserve basis deforestation issues might be serious, it is worth noting that at national level the extent of deforestation within forest reserves and apparent destruction have been exaggerated at least during the early 90s.

Conclusion – This chapter presented the areas and distribution of land cover at national, regional and district level. In addition, the status of protected area was also given. However, the above information is only part of the overall biomass assessment. In order to complete the assessment, the results from tree measurements from field sample plots are needed for the quantification of the biomass resource. Turn to chapter 5 for details.

5. Biomass Stock, Growth and Dynamics

This chapter presents biomass structure (species composition and tree size characteristics), mean standing stock per hectare (biomass density), growth, yield and dynamics. These variables were, with the area data in chapter 5 used to quantify the biomass standing stock which were further aggregated at national, regional and district levels.

5.1 Biomass Structure

The biomass structure was assessed through analysis of tree parameters from the field sample plots as described below.

Tree Species Composition and Distribution - As expected numerous tree species were encountered during the field surveys. For clarity, the distribution of the commonest 20 species in farmland woodland, bushland and grassland were examined in their respective agroecological zones (See 3.2.3), because of their importance as the nearest source of woodfuel supply.

The species distribution in Agro-ecological zone 1 i.e. high altitude areas especially in Kabale and Nebbi Districts - showed that in woodlands, bushlands and grasslands the commonest species are *Acacia mearnsii, Eucalyptus grandis* and *Ficus natalensis.* Whereas *Eaucalytus grandis, Erithrina abyssinica* and *Ficus natalensis* are mostly found in farmlands.

In Agro-ecological zone 2 i.e. semi-arid areas commonly known as the ‘cattle corridor’ covering the districts of Mbarara, Moroto, Kotido and Nakasongola - the commonest species are *Acacia hockiii, Rhus vulgaris* and *Grewia bicolor* in woodlands, bushlands and grasslands. In farmlands, *Eaucalytus grandis, Erithrina abyssinica* and *Ficus natalensis.*

In Agro-ecological zone 3 i.e. covering all the semi-moist lowland areas in the Northern and Eastern Districts are *Combretum collinum, Acacia hockii* and *Combretum molle,* in woodland while *Acacia hockii, Combretum collinum* and *Markhamia lutea* are found in farmlands.

And finally in Agro-ecological zone 4, which covers most of moist lowlands in Central and Midwestern regions of Uganda has *Combretum collinum, Acacia hockii* and *Sapium ellipticum* and in farmland areas *Markhamia lutea, Cassia spectabilis* and *Ficus natalensis*..

The frequencies do not only show species commonly found in a given agroecological zone but also give an indication of what is readily available for human utilization i.e. fuelwood, planting of seeds of that species. For example in agroecological zone I, the two commonest tree species (*Eucalyptus grandis* and *Acacia mearnsii*) are exotic species planted mainly for poles and firewood respectively. Other species such as *Erythrina abysinca* and *Ficus natalensis* are planted as live fences for demarcating land parcels.

For illustrations of the commonest 20 species found in woodlands, bushlands and grasslands in the different agroecological zones, see Figure 5-1 to Figure 5-4 below.

Figure 5-1: Species distribution in Agro-Ecological Zone 1

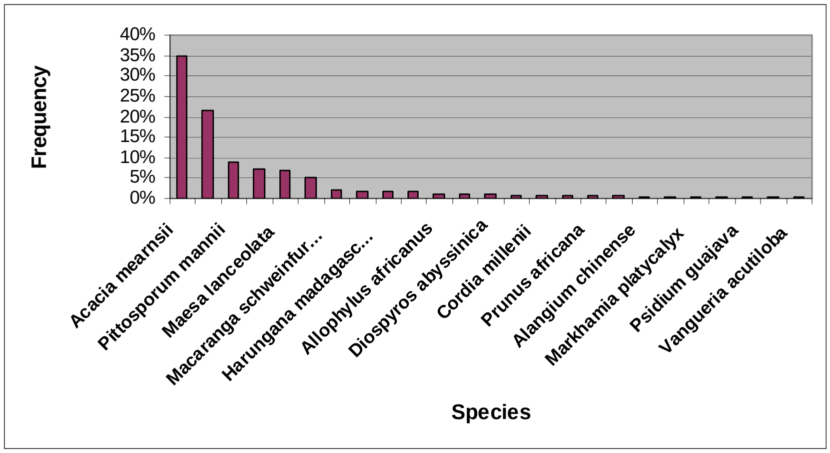


Figure 5-2: Species distribution in Agro-Ecological Zone 2

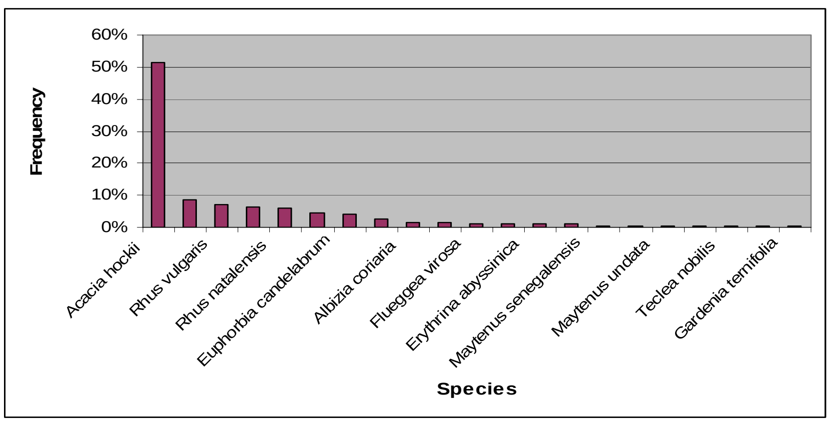


Figure 5-3: Species distribution in Agro-Ecological Zone 3

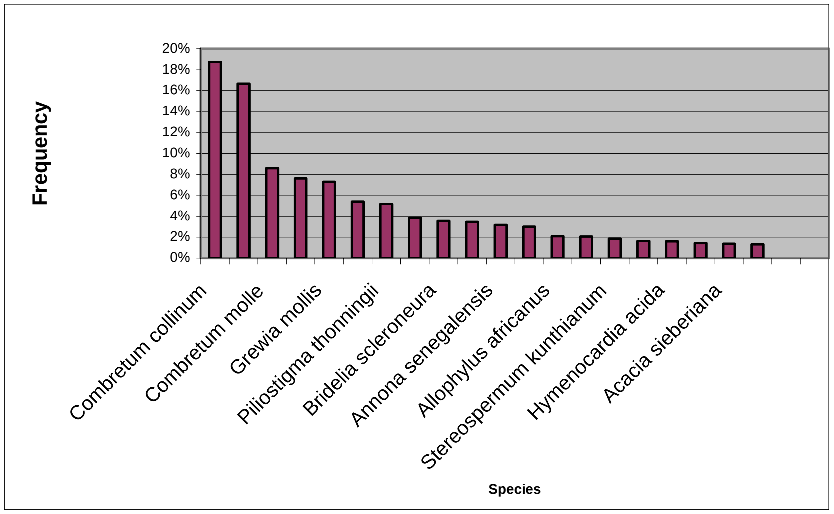


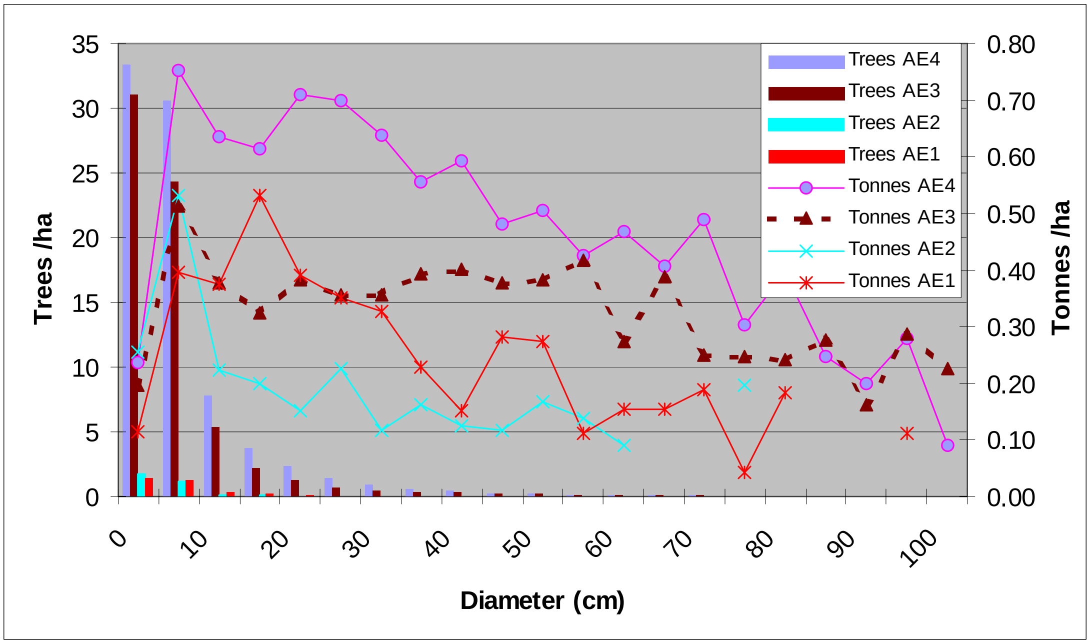
Figure 5-4: Species distribution in Agro-Ecological Zone 4

Tree Sizes - The diameter at breast height determines the size of each tree and therefore expected tree biomass i.e. the bigger the tree; the more biomass expected. Equally important is the number of trees in a given area, the more the trees per unit area the more the biomass expected. Tree sizes can also reveal a lot about the presence of 'mother trees' for supplying seeds or for regeneration.

Since trees measured were numerous, it is practically impossible to run a summary of the data for each area where samples were taken. Instead, the frequencies for woodlands and farmland classes aggregated by agroecological zones is given. The reason for selecting them is that they are the most extensive and main sources of fuel wood in the country.

The results are illustrated in Figure 5-5 and Figure 5-6. In each figure, there are two graphs. The first one is a bar graph showing the frequency of trees per hectare against diameter (tree size) while the second is a line graph showing the distribution of biomass in tonnes per hectare against diameter in cm.

Figure 5-5 : Biomass And tree distribution in woodlands by AEZone

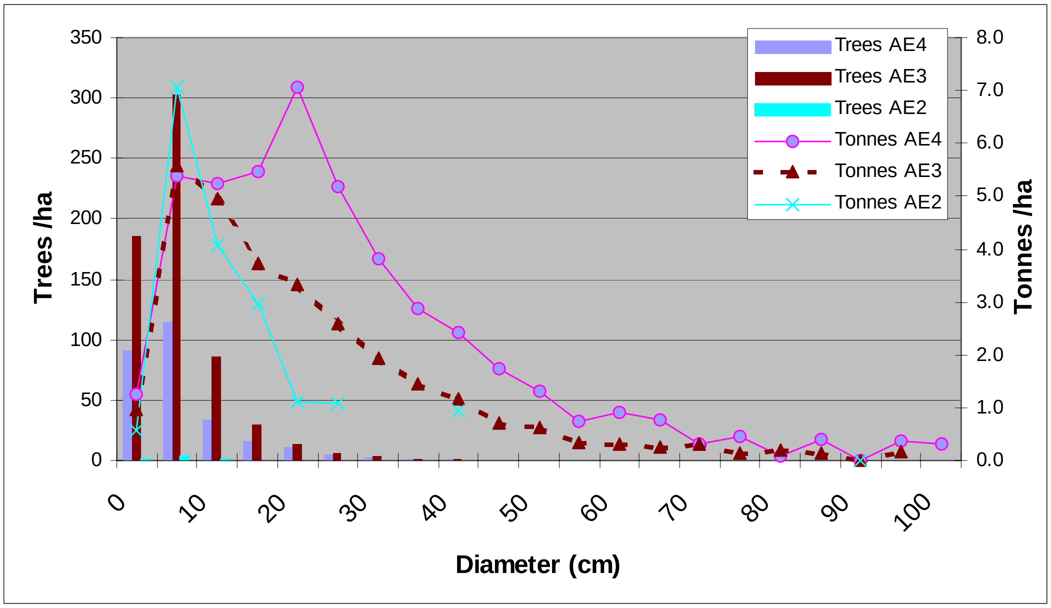


Note: There are two graphs combined in both figures. The Bar graph shows the frequency of trees per hectare (Left hand y-axis) against diameter whereas the line graph shows the distribution of biomass in tonnes per hectare (Right-hand y-axis) against diameter in cm. The four agroecological zones are abbreviated as AE1 to AE4 for Agroecological zones I to 4 respectively. See further Figure 3-15

Distribution of trees by diameter class - The results showed that generally the frequency of trees in both farmland and woodlands have the typical distribution curve of a 'reverse J – shape' or sometimes called negative exponential curve. In other words there are more small trees in the lower diameter range (small trees) than there are in the upper diameter range (big trees) as shown by woodlands occurring in all the four agroecological zones (Figure 5-5).

Agroecological zone 1 (highlands) and 2 (semi-arid lands) have barely any trees left while agroecological zones 3 (semi-moist lowlands) and 4 (moist lowlands) have the highest number of trees in the 5 to 10 cm diameter class with 300 and 100 stems per hectare respectively. It is interesting to note that in all agroecological zones, there are fewer trees in the 3-cm class than in the 5cm-diameter class. This implies poor regeneration due to natural factors like seasonal fires in the dry season, which periodically scorch trees within this diameter class. The sudden jump (from 3-cm to 5-cm) with high number of trees implies that the tree saplings over that range were able to withstand the seasonal fires. A similar curve was observed in subsistence farmland in all four-agroecological zones, for example, agroecological zones 3 (semi-moist lowlands) and 4 (moist lowlands) still showed negative exponential curve although agroecological zones 1 (High altitude) and 2 (Semi-arid) have fewer trees in all diameter classes (Figure 5-6). The numbers of trees fall from a high of over 16 trees per ha in the 3-cm diameter class to almost zero in the 20-cm diameter class.

Figure 5-6: Biomass and tree distribution in Subsistence Farmland areas by agroecological zones



Distribution of single tree weights - The distribution of single tree weights by tree sizes per hectare showed similar patterns as for tree size distribution.

Similarly, biomass in woodlands has a distribution pattern like that of trees by size (Figure 5-5). For example, agroecological zone 1 and 4 peak at over 7 tons per ha, in the 10-cm dbh class and 20-cm dbh class respectively while agroecological zone 3 peak at less than 6 tons per ha. It is evident that most of the biomass is found in the 10-cm to 30-cm diameter classes in all agroecological zones. Another interesting observation is the sharp difference between agroecological zone 4 (moist lowland) and agroecological zone 2 (semi-arid) since the former is wetter than the latter, it is not suprising that agroecological zone 4 has more biomass in all the diameter classes than agroecological zone 3. Refer to Figure 5-5.

In farmlands (Figure 5-6) the highest weight or biomass per ha is found in the lower diameter classes peaking in the 10-cm dbh class (all agroecological zones except agroecological zone 1). However within this peak, there are variations in the agroecological zones. For example agroecological zone 4 has the highest amount of biomass (over 0.7 tons per ha) in the 10-cm dbh class, while agroecological zone 1 has the least with less than 0.4 tonnes per ha. From the lower diameter classes, the high biomass per size class drops to less than 0.3 tonnes per ha up to the 100-cm dbh class. See further details in Figure 5-6 above.

5.2 Biomass standing stock

Estimate of the mean standing stock - A major analysis of the field plot data is the estimation of the mean standing stock in tons or kgs per hectare sometimes called biomass density. This estimate is vital in the quantification of the total biomass standing stock.

However prior to using the estimated mean standing stock for the quantification of biomass, the reliability of the estimate has to be assessed through analysis of the following related statistics: Standard Deviation (StDev), Coefficient of Variation (CV), Sampling Error, Number of sample plots, N and Confidence Limits.

The StDev and CV measures the variation of individual weights of trees around the estimated mean of the standing stock, whereas the sampling error measures the variation between sample plots. The variations among samples depend primarily on the inherent variability within the population mean and the size of the sample (n) (Freese, 1984). The lower the dispersion around the mean, the higher the precision of the estimate. The closeness to the estimated mean (whether below or above) is determined by the confidence limits at a given probability.

Below, is the estimated mean standing stock and related statistics for the main land cover classes (strata) Table 5-1 and for the substrata Table 5-2.

Table 5-1 presents the statistical results (mean, standard deviation, coefficient of variation, and number of sample plots, N) for land cover classes without sub-stratification, where the estimated mean standing stock showed varying biomass densities for the 13 main classes. The variation ranged from less than 1,000 kgs (1 ton) in wetlands to 223,672 kgs (approx. 224 tons) in tropical high forests.

Table 5-1 : Estimated mean standing stock per ha (without sub-stratification)

Class	Mean	Min	Max	StDev	CV	N
1	84935.16	0.00	226122.50	56753.54	67	66
3	223672.07	46674.40	605258.00	110750.62	50	79
4	93720.41	14590.80	306985.20	65026.17	69	76
5	34997.76	0.00	193548.00	26333.33	75	377
6	13505.81	0.00	55243.60	11250.23	83	126
7	8022.34	0.00	62638.40	8534.14	106	752
8	460.40	0.00	1202.00	631.46	137	5
9	11036.57	0.00	326227.60	20443.58	185	2577
10	3457.20	0.00	26802.40	8544.23	247	10
11	22740.52	0.00	116635.20	30733.24	135	30
					sum	4098

Note: Some land cover classes are missing due to absence of sample plots or were mainly associated with auxiliary data sources.

In spite of the variations, the estimates of the mean standing stock are within the expected ranges for the various land cover in the country. The corresponding CV also ranges from 50% in tropical high forest to 247% in commercial farmlands. A CV of 25% was recommended in the National Biomass Study project document (1996), however from the results, it became apparent that without sub-stratification, this target (of 25%) could not be achieved hence the sub-stratification as presented below.

Estimated mean standing stock for the sub-strata – The results of the statistical analyses for the land cover by substrata are presented in Table 5-2. As mentioned in 3.1.1, the 13 classes presented above were further sub-stratified on the basis of biomass density (low, medium, high and very high) and agroecological zones (High altitude (1), semi-arid, lowland (2) moist lowland (3) and semi-moist lowland.

Table 5-2: Estimated mean standing stock per ha (with sub-stratification).

Aezone	Stratum	Sub-stratum	Mean	Stdev	N	CV	SE (95%) Kg	Lower Limit (Kg)	Upper Limit (Kg)
1	9	LO	3,996.50	1,650.40	17	41%	800.6	3,195.90	4,797.10
1	9	ME	10,027.30	3,949.50	18	39%	1,861.80	8,165.40	11,889.10
1	9	VL	417.3	810.9	77	194%	184.8	232.5	602.1
2	6	LO	6,368.50	2,880.00	11	45%	1,736.70	4,631.80	8,105.20
2	7	HI	15,297.60	4,848.30	16	32%	2,424.20	12,873.50	17,721.80
2	7	LO	2,588.20	1,700.20	47	66%	496	2,092.20	3,084.20
2	7	ME	8,925.90	2,826.70	25	32%	1,130.70	7,795.20	10,056.60
2	9	VL	1,004.20	732.7	20	73%	327.7	676.5	1,331.90
3	1	ME	96,846.10	25,833.90	11	27%	15,578.40	81,267.70	112,424.60
3	5	HI	57,532.20	29,734.50	37	52%	9,776.60	47,755.60	67,308.80
3	5	LO	17,181.90	10,998.60	128	64%	1,944.30	15,237.60	19,126.20
3	5	ME	37,766.10	13,582.00	106	36%	2,638.40	35,127.70	40,404.50
3	6	HI	30,431.60	7,917.70	12	26%	4,571.30	25,860.20	35,002.90
3	6	LO	4,869.00	2,944.10	25	60%	1,177.60	3,691.40	6,046.60
3	6	ME	14,707.10	6,223.50	27	42%	2,395.40	12,311.70	17,102.60
3	7	HI	18,994.80	8,567.30	105	45%	1,672.20	17,322.60	20,666.90
3	7	LO	2,414.30	2,265.70	190	94%	328.7	2,085.60	2,743.10
3	7	ME	10,276.50	4,082.90	116	40%	758.2	9,518.40	11,034.70
3	9	HI	29,787.20	7,863.20	88	26%	1,676.40	28,110.70	31,463.60
3	9	LO	4,966.80	2,445.40	279	49%	292.8	4,674.00	5,259.60
3	9	ME	14,331.40	6,697.10	255	47%	838.8	13,492.60	15,170.20
3	9	VH	75,198.20	29,526.90	64	39%	7,381.70	67,816.50	82,579.90
3	9	VL	593.2	863.8	599	146%	70.6	522.6	663.8
4	1	ME	113,391.40	49,386.10	14	44%	26,398.00	86,993.50	139,789.40
4	3	HI	328,885.70	112,876.00	28	34%	42,663.10	286,222.60	371,548.80
4	3	LO	154,992.40	50,931.40	37	33%	16,746.20	138,246.20	171,738.60
4	3	ME	194,755.30	42,194.10	14	22%	22,553.70	172,201.70	217,309.00
4	4	HI	155,374.10	39,316.00	19	25%	18,039.40	137,334.70	173,413.50
4	4	LO	38,962.70	11,515.70	25	30%	4,606.30	34,356.40	43,569.00
4	4	ME	99,893.00	66,653.20	32	67%	23,565.50	76,327.50	123,458.50
4	5	HI	73,364.30	35,797.90	43	49%	10,918.30	62,446.00	84,282.50
4	5	LO	17,605.00	7,256.30	17	41%	3,519.80	14,085.20	21,124.80
4	5	ME	33,066.10	13,537.60	41	41%	4,228.40	28,837.70	37,294.50
4	6	LO	9,447.60	9,990.70	17	106%	4,846.20	4,601.40	14,293.80
4	6	ME	14,504.20	7,685.00	16	53%	3,842.50	10,661.60	18,346.70
4	7	HI	19,240.30	7,544.70	38	39%	2,447.80	16,792.50	21,688.10
4	7	LO	1,788.00	2,864.80	145	160%	475.8	1,312.20	2,263.80
4	7	ME	12,966.10	8,959.40	58	69%	2,352.90	10,613.20	15,318.90
4	9	HI	31,776.80	12,938.50	138	41%	2,202.80	29,574.00	33,979.60
4	9	LO	4,821.30	4,306.10	319	89%	482.2	4,339.10	5,303.40
4	9	ME	13,167.80	6,675.30	324	51%	741.7	12,426.10	13,909.50
4	9	VH	85,927.40	56,649.80	53	66%	15,562.90	70,364.50	101,490.30
4	9	VL	740.1	828	303	112%	95.1	645	835.2

(AeZone= Agro-ecological Zone, Class numbers refer to LUC Codes, Substrata: Biomass standing stock: LO, Low; ME, Medium, HI, High; VH, Very High).

The table is organised as follows. The first column represents agro-ecological zones (in codes 1 – 4 for agroecological zones one to four) followed by strata (classes also in codes 1 to 13) and sub-strata (sub-classes) in the second and third column respectively. The fourth, fifth, sixth, seventh and eigth columns represents the estimated mean in kilograms per hectare, Standard Deviation (StDev), number of sample plots, Coefficient of Variation (CV) and Sampling Error respectively. Finally, columns nine and ten present the lower and upper confidence limits of the estimated mean at the given sampling errors in column eight.

As explained earlier, the purpose of sub-stratification was to help improve on the accuracy of the estimates of the mean standing stock of biomass. Whether this is true or not can be judged by comparing Table 5-1 with Table 5-2. For example, the estimated mean standing stock for tropical high forest in moist lowland without sub-stratification is 224 tons per hectare in Table 5-1, whereas after sub-stratification i.e. low stocked is 155 tons per ha, 195 tons for medium stocked, and 329 tons for highly stocked. (Table 5-2). The corresponding CV for the main classes is 50% (Table 5-1) whereas with sub-stratification it ranged from 22% to 34% (Table 5-2). This confirmed that sub-stratification improved the accuracy of the estimates. Similarly for woodlands without sub-stratification is approximately 35 tons (Table 5-1), whereas with sub-stratification for example in moist lowlands ranged from 17 tons (low stocked) to 57 tons (highly stocked), (Table 5-2).

The reduced CVs noted in the sub-stratification implied that the estimates are more reliable than in the main classes. However note that some land covers do not have sample plots (thus no estimate). This is because the more common a land cover is, the higher the chances are for more sample plots to be located.

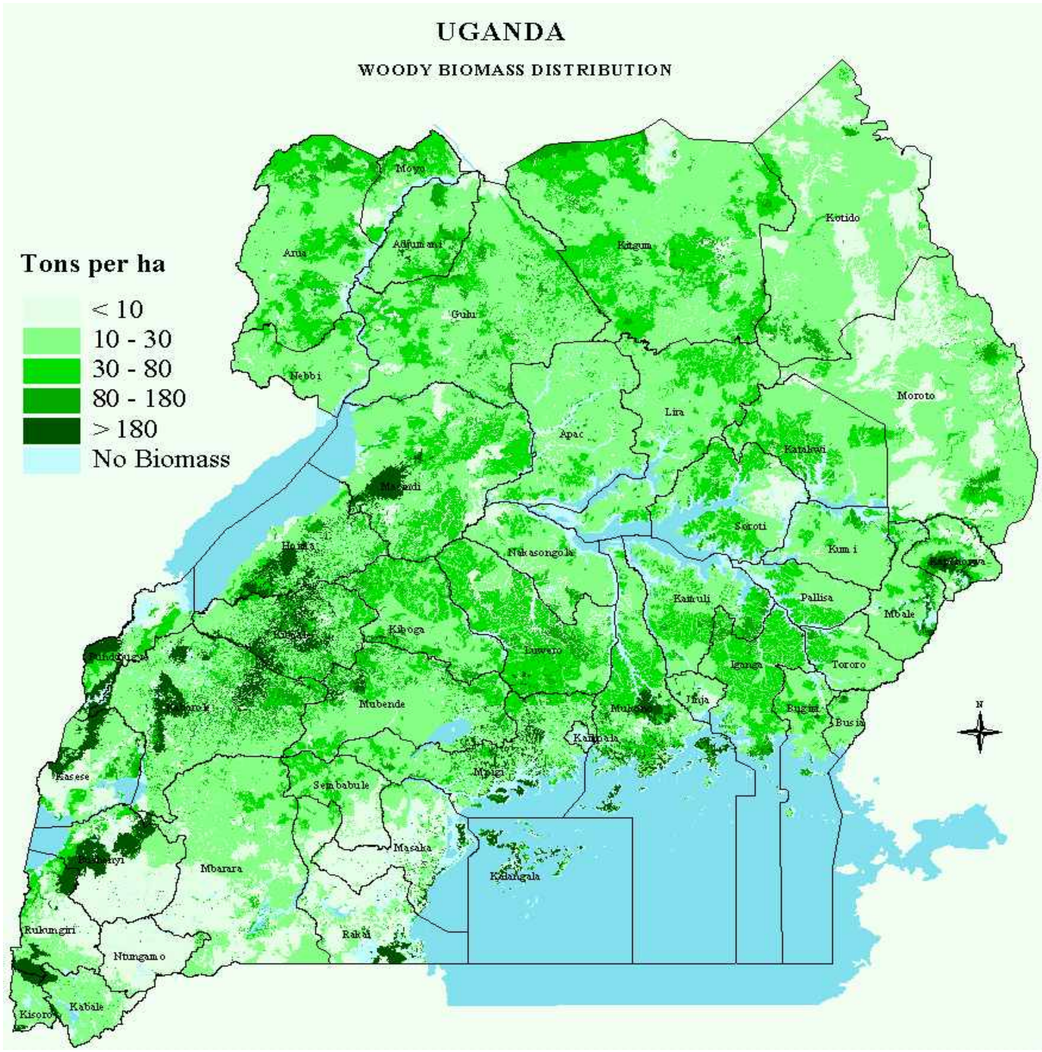
In view of the above the estimated mean standing stock in Table 5-2 were used to determine the distribution of biomass densities and standing stock per land cover and sub-strata as discussed below.

5.2.1 Distribution of Biomass Density

Biomass densities by land cover were summarised at national level as illustrated in Figure 5-7. Four main categories were identified as follows, the first category covers areas with the least biomass density of less than 10 tons per hectare such as the semi-arid regions of Northern Eastern, and Western Uganda. The second category covers biomass density class of 10-30 tons per hectare in Northern and Eastern Uganda, which corresponds with the semi-moist lowland agroecological zone. The third category covers areas with biomass density ranging between 80 and 180 tons per hectare which is mostly associated with the moist lowland agroecological zone in Central and Midwestern Uganda. Lastly, the fourth category is associated with dense biomass of over 180 tons per hectare i.e. tropical forest in lowland areas of Midwestern mostly covered by moist lowland agroecological zone and high altitude areas in Mt. Elgon (high altitude agroecological zone).

From the above it can be concluded that biomass density is dependent on agroecological zones.

Figure 5-7: National biomass density distribution (Tons/ha)



It should be noted that this is one of the key outputs of NBS.

5.2.2 Gross Biomass Standing Stock

The estimated mean biomass standing stock for each sub-stratum in Table 5-2 when multiplied by the corresponding areas of land cover and sub-strata gave gross quantities (stock) of biomass for that particular sub-stratum. Table 5-3 is an example of how the estimated mean standing stock per hectare (biomass density) was used to calculate the standing stock of biomass by land cover and sub-strata for Adjumani District in agroecological zones 3 - the semi-humid low lands.

From this basic computation, the aggregation of biomass standing stock at national, regional and district levels were obtained.

Table 5-3 : Gross biomass standing stock by substrata (Adjumani District)

District	Aezone	Strata	Substrata	Area-Ha	Mean (Kg)	SE (Kg)	Stock (Tons,000)	Lower Limit	Upper limit
ADJUMANI	3	3	ME	1,268.26	223,672.10	24,920.84	283.67	252.07	315.28
ADJUMANI	3	5	LO	84,585.55	17,181.86	1,944.30	1,453.34	1,288.88	1,617.80
ADJUMANI	3	5	ME	36,817.83	37,766.13	2,638.41	1,390.47	1,293.33	1,487.61
ADJUMANI	3	5	HI	28,446.94	57,532.21	9,776.64	1,636.62	1,358.50	1,914.73
ADJUMANI	3	6	LO	688.51	4,868.98	1,177.62	3.35	2.54	4.16
ADJUMANI	3	6	ME	767.98	14,707.13	2,395.43	11.29	9.46	13.13
ADJUMANI	3	6	HI	173.51	30,431.55	4,571.31	5.28	4.49	6.07
ADJUMANI	3	7	LO	9,880.03	2,414.33	328.75	23.85	20.61	27.10
ADJUMANI	3	7	NO	344.55	8,869.22	835.85	3.06	2.77	3.34
ADJUMANI	3	7	ME	12,782.52	10,276.52	758.17	131.36	121.67	141.05
ADJUMANI	3	7	HI	20,249.95	18,994.76	1,672.16	384.64	350.78	418.50
ADJUMANI	3	8	AV	9,428.23	767.33	769.59	7.23	-0.02	14.49
ADJUMANI	3	9	LO	47,917.17	4,966.78	292.80	237.99	223.96	252.02
ADJUMANI	3	9	ME	41,487.24	14,331.41	838.78	594.57	559.77	629.37
ADJUMANI	3	9	HI	7,301.88	29,787.18	1,676.44	217.50	205.26	229.74
ADJUMANI	3	10		604.97	11,515.33	15,890.20	6.97	-2.65	16.58
ADJUMANI	3	11	AV	319.80	22,807.60	19,450.24	7.29	1.07	13.51
ADJUMANI	3	12	NO	5,614.55					
ADJUMANI	3	13	NO	18.81					

National Biomass Standing Stock - Table 5-4 presents the total national biomass standing stock.

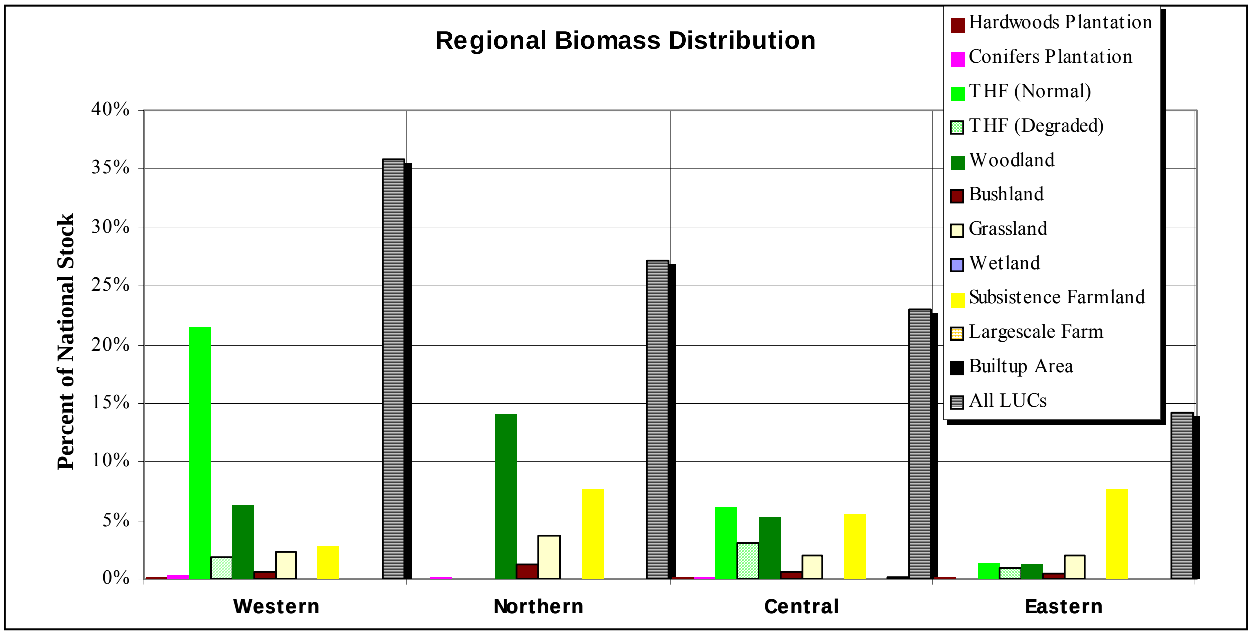
Table 5-4: Gross national biomass standing stock

Land Cover (use)	Standing Stock (000, Tons)	%
Hardwood Plantations.	1,682.7	0%
Conifers Plantations.	2,457.6	1%
Tropical Hgh Forest (Normal Stocked	136,491.2	29%
Tropical Hgh Forest (Depleted)	27,596.2	6%
Woodlands	126,014.2	27%
Bushlands	14,007.6	3%
Grasslands	46,852.4	10%
Wetlands	236.3	0%
Subsistence Farmlands	111,824.9	24%
Largescale Farmlands	154.2	0%
Builtup areas	862.8	0%
Water	0.0	0%
Impediements	0.0	0%
Totals	**468,180**	100%

Tropical high forest, subsistence farmland and woodlands alone constitute nearly 87% of the total biomass standing stock. In total, Uganda is estimated to have 468 million tons biomass standing stock. However, when considering biomass availability and accessibility for wood fuel supplies, it should be kept in mind that not all 468 million tons of biomass is available. For instance, biomass in farmland is more readily accessible and therefore available than tropical high forests, which in many cases are designated as protected or under conservation, thereby rendering them inaccessible and unavailable. The implication of this is that when assessing woodfuel requirements and its availability, accessibility and management status of the land cover needs to be taken into consideration.

Regional Biomass Standing Stock - Western Uganda has the highest biomass standing stock, followed by north, central and eastern, but the distribution varies from region to region. For instance tropical high forest take the biggest share in western and central Uganda. Similarly, woodlands and farmlands lead in the north and east respectively. Eastern Uganda has the least biomass held in the few scattered trees on farmland. For comparison of biomass in the regions see Figure 5-8.

Figure 5-8: Gross regional biomass standing stock



District Biomass Standing Stock - The leading districts are Masindi (28.5 million tons), Kibaale (23 million tons), Gulu (22 million tons), Mukono (21 million tons) and Hoima (19 million tons). Districts with the least biomass are Kampala, Ntungamo and Jinja. For details of the distribution of the biomass standing stock see appendix 13.

5.2.3 Biomass standing stock in protected and private land

Biomass in protected areas is of interest because of its unique management objectives. For instance the Forest Department manages forests for the production of various forest products (timber, fuelwood, poles and other minor products) while the Uganda Wild Life Authority manages both flora and fauna for tourism purposes. In light of the unique objectives, the gross national biomass stock was diasgregated into protected and private lands, Table 5-5 and Figure 5-9.

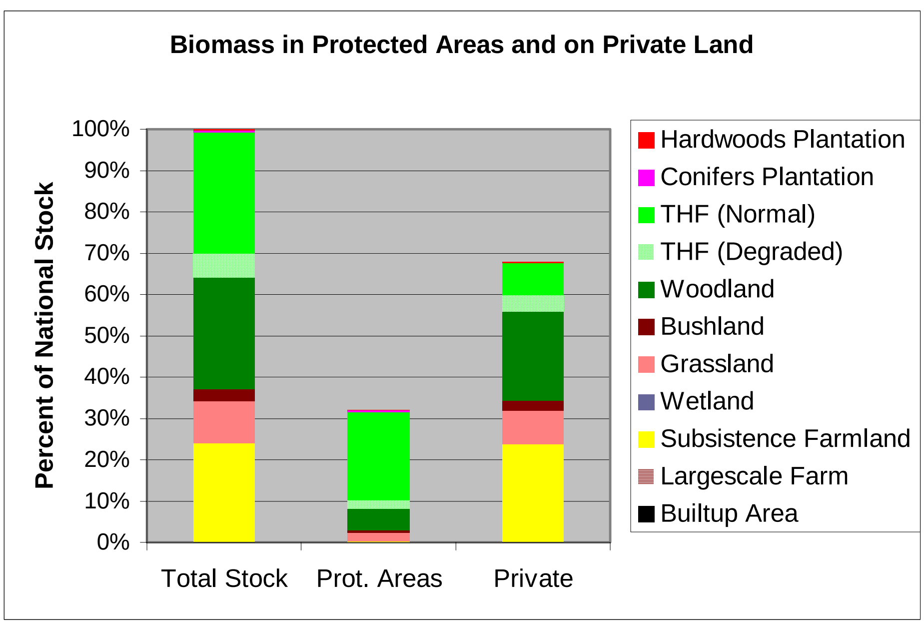
In general, out of the 468 million tons of biomass, 155 million tons (about 30%) is found in protected areas and 312 million tons in private lands. In private lands, farmlands and woodlands account for almost 70% of the biomass in private lands (Figure 5-9).

This implies that the distribution has a bearing on the accessibility and availability of biomass as a potential source of woodfuel. For instance it is known that biomass in protected areas is not readily available due to management restrictions. So, when planning for woodfuel supplies one should consider the biomass in private lands. However the distribution between the different landcovers and ownership also dictate which source is accessible or not. In this study, farmlands are assumed to be the most easily accesible because of their vicinity to the homestead.

Table 5-5 : Biomass in protected and privateland

Land Cover (use)	Standing Stock (000, Tons)	Prot. Areas (000, Tons)	Private (000, Tons)
Hardwood Plantations.	1,682.7	623	1,059.6
Conifers Plantations.	2,457.6	2,354	103.6
Tropical Hgh Forest (Normal Stocked	136,491.2	104,648	31,843.3
Tropical Hgh Forest (Depleted)	27,596.2	9,546	18,050.2
Woodlands	126,014.2	24,942	101,071.7
Bushlands	14,007.6	2,594	11,413.3
Grasslands	46,852.4	9,858	36,994.3
Wetlands	236.3	6	230.0
Subsistence Farmlands	111,824.9	1,311	110,513.6
Largescale Farmlands	154.2	4	150.5
Builtup areas	862.8	13	850.2
Water	0.0	0	0.0
Impediements	0.0	0	0.0
Totals	**468,180**	**155,900**	**312,280**

Figure 5-9: Biomass in protected areas



More details of the biomass distribution by land cover within the protected areas are given Table 5-6. The biomass distribution is organised according to ownership and management status as follows: Central and Local Forest reserves (columns 2 and 3), Departmental or Joint Management areas under Forest Department and Uganda Wildlife Authority, Game Reserves and National Parks under UWA. For details of biomass in protected areas by districts see appendix 14.

As shown, tropical high forest (normally stocked) are the most stocked, followed by woodlands, depleted tropical high forest and least stocked is grasslands (Table 5-6).

Table 5-6: Biomass in protected area by ownership

Land Cover (Use)	**Forest Department, FD**		**FD/UWA**	**Uganda Wildlife Authority**		
(Classes)	Central Forest Rserves (,000 tons)	Local Forest Reserves (,000 tons)	DepartmentalJoint Management (,000 tons)	Game Reserves (,000 tons)	National Parks (,000 tons)	Total (,000 tons)
Hardwood Plantations.	566	54		0	3	623
Conifers Plantations.	2,013	0			341	2,354
Tropical Hgh Forest (Normal Stocked)	57,118	56	4,598	621	42,255	104,648
Tropical Hgh Forest (Depleted)	5,898	29	184		3,436	9,546
Woodlands	12,924	19	295	3,963	7,741	24,942
Bushlands	940	5	61	770	818	2,594
Grasslands	2,022	5	226	3,640	3,966	9,858
Wetlands	1	0		2	4	6
Subsistence Farmlands	1,105	27	3	77	99	1,311
Largescale Farmlands	4	0			0	4
Builtup areas	8	0		1	4	13
Water						0
Impediements						0
Total	**82,597**	**196**	**5,366**	**9,073**	**58,667**	**155,900**

The results also reveal that more than half the total biomass in protected areas is held in Central Forest Reserves (82 million tonnes of biomass), followed by National Parks, Game Reserves, Departmental Joint Management and Local Forest Reserves tons in that order. More details of biomass in PAs is given in Appendix 14.

5.3 Biomass growth and yield

Growth is the rate of biomass accumulation per unit time expressed in kgs or tones per hectare per year, while yield is the expected stock at a specified point in time expressed in tonnes or cubic metres per hectare. In this study, approximately 300 plots were established for periodic re-measurements in order to determine the growth and yield of biomass in each land cover/use. In addition, 35 plots were established in some selected peri-urban plantations specifically for determining growth and yield of eucalyptus plantations. The ages of the plantations ranged from one to seven years. The results of the growth analysis without and with agroecological zones are presented below.

5.3.1 National biomass growth (without agro-ecological zones)

Table 5-7 presents results of biomass growth for selected land cover without agro-ecological zones. Note that in some cases, the number of sample plots is not representative for any reliable statistical inferences. For instance there are only two sample plots in tropical high forests; two in degraded tropical high forest and two in built up areas. The few plots are not sufficient to draw conclusions for the entire land cover strata across the country although it is better than nothing. In other land cover/use the number of sample plots are fairly representative e.g. subsistence farmland, grassland, woodland and bushlands. But then, the CVs are higher than the expected 25%.

Table 5-7: Results of biomass growth without agroecological zones

Land Cover/Use	Predicted Weight 1st Visit(Tons/Ha Airdry)	Predicted Weight 2nd Visit(Tons/Ha Airdry)	Difference between the 1st and 2nd Visit	Duration in Decimal Years	Current Annual Increment, CAI (Tons/Ha Airdry)	No. of Plots	STDev 1st Visit	CV % 1st Visit	STDev 2nd Visit	CV % 2nd Visit
Plantations (Hardwoods)	37	50	13	0.99	13	6	31	85%	40	81%
Tropical High Forest, THF	131	145	14	0.95	15	2	68	52%	70	48%
THF Degraded	121	142	21	1.83	11	2	34	28%	29	20%
Woodland	39	48	10	1.97	5	30	25	64%	31	63%
Bush	5	7	1	2.61	1	13	4	79%	6	81%
Grass Land	9	12	3	2.45	1	50	8	83%	9	76%
Subsistence Farmland	14	18	4	2.43	1	195	29	200%	33	184%
Built up Area	25	34	9	2.55	3	2	31	123%	42	124%

Nevertheless, Table 5-7 protrayed that tropical high forests have the highest rate of growth, followed by plantations (woodlots), degraded tropical high forests, woodlands, built up areas and subsistence farmlands in that order. The high rate of growth in normal tropical high forest and degraded tropical high forest is an indicator of after-effect of either disturbance caused by encroachment, logging and/or harvesting operations. As observed by Pancel (1993), tropical high forests always have seedlings or trees on ‘stand by” that avail themselves the opportunity to grow very fast whenever a gap occurs in any given space at any given time. This is why tropical high forests normally grow or re-grow very fast in the first 20 years. For example (IPCC, 1995) quoted figures of biomass growth for a moist forest in Africa at 11 tons per hectare (dry-matter) on the assumption that tropical high forests re-grow to 70% of undisturbed forest biomass in twenty years. This compares well with NBS findings of 15 tons (equivalent to 12 tons air-dry). See Table 5-7. Between 20 years to 100 years, IPPC stated that tropical high forests would grow at a rate of 1 ton (dry matter) per ha per year.

IPCC (1995) also quoted biomass growth rates of 4 tons per ha per year for dry forests (age between 0-20 years) and 0.25 tons (20-100 years). NBS findings are 5 tons (4 tons dry matter) per ha per year for woodlands which agrees quite well with the IPCC estimate for dry forest types.

5.3.2 National biomass growth by agro-ecological zones

The results of biomass growth above were further aggregated under the four agro-ecological zones for land cover/use in order to obtain a more representative growth estimate for each land cover. However, due to lack of sufficient sample plots this was not possible. For instance, in Table 5-7, there are 6 plots for plantations, whereas after splitting between agroecological zones there are only 2 plots in high altitude areas, 1 plot in semi-arid and 3 plots in moist lowland. Similarly the 30 plots in woodlands without agroecological zones were reduced to two in semi-arid low lands, twenty-two in semi-moist lowlands and six in moist lowlands.

Notwithstanding the problem of insufficient sample plots, the important point to note is how the agroecological zoning affected the variability of the estimates i.e. lower standard errors and CVs meant little variability and therefore better estimates. In Table 5-7 the CVs without agroecological zoning are generally all above 50%, whereas, with agroecological zoning CVs for some land cover such as grasslands, woodlands, plantations and degraded tropical high forests, were considerably reduced to less than 50% (Table 5-8).

On the other hand, the estimated growth rates without agroecological zoning were noted to be lower than those with agro-ecological zoning. For instance the growth rate for plantations without agroecological zones is 13 tons per ha per year, whereas under agroecological zones the growth rates rise to approx. 25 tons per ha for high altitude areas and 15.5 tons per ha for moist lowlands.

Table 5-8 Biomass growth with agroecological zoning

Agro_ecological Zone	Land Cover/Use	Predicted Weight 1st Visit(Tons/Ha Airdry)	Predicted Weight 2nd Visit(Tons/Ha Airdry)	Difference between the 1st and 2nd Visit	B: Difference between the 1st and 2nd Visit	Duration in Decimal Years	Current Annual Increment, CAI (Tons/Ha Airdry)	No. of Plots	STDev 1st Visit	CV % 1st Visit	STDev 2nd Visit	CV % 2nd Visit
Highlands (I)	Plantations (Hardwoods)	64.37	83.94	24.66	19.57	0.79	24.7	2	46.09	72%	61.72	74%
	Subsistence Farmland	7.95	10.64	1.34	2.70	2.00	1.3	30	8.79	111%	11.77	111%
Semi-Aridlands (II)	Woodland	15.56	21.42	2.01	5.87	2.92	2.0	2	3.07	20%	4.46	21%
	Bush	7.78	9.82	0.73	2.04	2.71	0.8	6	4.38	56%	5.92	60%
	Grass Land	7.90	11.09	1.18	3.19	2.72	1.2	18	4.00	51%	5.01	45%
	Subsistence Farmland	0.71	1.70	0.31	0.99	3.43	0.3	3	0.28	40%	0.84	49%
Moist Lowlands(III)	Plantations (Hardwoods)	8.50	9.85	0.66	1.36	2.06	0.7	1				
	Woodland	37.19	45.20	4.72	8.01	1.92	4.2	22	22.71	61%	26.41	58%
	Bush	2.66	3.46	0.45	0.80	2.48	0.3	6	2.76	104%	3.67	106%
	Grass Land	12.89	15.84	1.64	2.95	2.46	1.2	20	9.24	72%	10.99	69%
	Subsistence Farmland	20.06	24.12	2.43	4.06	2.40	1.7	61	32.88	164%	37.01	153%
	Built up Area	3.21	4.23	0.45	1.02	2.24	0.5	1				
Moist Lowlands (IV)	Plantations (Hardwoods)	28.21	40.17	15.39	11.96	0.77	15.5	3	10.56	37%	5.00	12%
	THF	131.22	145.43	14.91	14.21	0.95	14.9	2	68.07	52%	69.72	48%
	THF Degraded	121.10	142.11	13.75	21.01	1.83	11.5	2	33.95	28%	29.03	20%
	Woodland	52.53	68.72	8.57	16.19	1.81	8.9	6	30.77	59%	40.54	59%
	Bush	7.30	8.92	0.58	1.61	2.80	0.6	1				
	Grass Land	4.13	6.10	0.99	1.97	2.03	1.0	12	4.81	116%	6.76	111%
	Subsistence Farmland	13.49	17.07	1.83	3.59	2.55	1.4	101	30.32	225%	35.21	206%
	Built up Area	47.40	63.74	5.73		2.85	0.0	1				

The estimates for tropical high forests and degraded tropical high forests remained the same because the sample plots were more or less the same in number and thus the same agro-ecological zone. Another interesting comparison is where 5 tons per ha was estimated for woodlands without agro-ecological zoning but with agro-ecological zoning the estimates felt to 2, 0.3 and 9 tons per hectare for semi-arid lands, semi-moist lowlands, and moist lowlands respectively.

However, it should be noted that although woodlands in moist lowlands have got the highest growth rate, it has limited coverage compared with woodlands in arid lands and semi-moist lowlands.

As will be seen in 5.3.3, below, growth rates in each land cover are crucial for the quantification of biomass annual growth and yield in each land cover.

5.3.3 Biomass Yield (undisturbed situation)

The findings in the previous section showed that the growth estimates without agro-ecological zoning were reasonably good and fairly representative at national level although the CVs are higher than with agro-ecological zoning. For this reason NBS adopted the estimates without agro-ecological zoning for the quantification of biomass growth and yield. On the basis of the growth, areas of each land cover and rotation age (year at which a tree is expected to be mature depending on the management objective), it was possible to calculate the annual growth and expected yield.

Table 5-9 is a presentation of the summary of the total annual biomass growth in protected and private areas. The second column represents the gross area for each land cover, which is split between protected areas (column 3) and private lands (column 4). The product of the growth rate in tons per hectare (column 5) with land cover areas provided the gross yield for each land cover (column 6), protected (column 7) and private land (column 8).

Table 5-9 National biomass growth & sustainable yield

Land Cover/Use	Gross Area	Protected Area (excluding HA)	Private	Growth tons/ha	Gross Yield (Tons)	Protected Area (Tons)	In Private (Tons)
Plantations Hardwoods	18,682	6,658	12,024	13	242,862	86,554	156,308
Plantations Softwoods	16,384	15,693	690		0	0	0
THF- Normal	650,150	477,068	173,083	15	9,752,257	7,156,013	2,596,244
THF - Degraded	274,058	97,011	177,047	11	3,014,633	1,067,119	1,947,514
Woodlands	3,974,102	875,854	3,098,248	5	21,062,743	4,642,028	16,420,714
Bushlands	1,422,395	296,111	1,126,285	1	1,209,036	251,694	957,342
Grasslands	5,115,266	1,149,967	3,965,299	1	6,649,846	1,494,957	5,154,888
Wetlands	484,037	32,598	451,439		0	0	0
Subsistence Farmlands	8,400,999	137,931	8,263,068	1	8,400,999	137,931	8,263,068
Commercial Farmlands	68,446	1,287	67,159		0	0	0
Built up areas	36,571	1,982	34,589	3	109,714	5,947	103,766
Water					0	0	0
Impediments	3,713	745	2,968		0	0	0
Total	**20,464,804**	**3,092,905**	**17,371,899**		**50,442,088**	**14,842,244**	**35,599,844**

At national level, Uganda can ideally expect a total yield of 50 million tons of biomass per year, out of which 15 million tons is in protected areas and the balance of about 35 million tons in private lands. The highest biomass yield is from tropical high forests and woodland in protected and private land respectively.

In comparison, World Bank estimated the sustainable yield for Uganda at approximately 11 million tons (World Bank, 1987, quoted in Forest Department, 1988). NBS project Document estimated 17 million tons for areas outside National Parks. It is clear that these earlier which were not based on any empirical data are lower than the current NBS estimates.

Although the current estimates are considered more reliable, it should be kept in mind that they are based on growth plots from undisturbed plots, which represent an ideal situation. In reality, all the land cover in Uganda is subjected to human activities such as charcoal burning, land clearance for agriculture and firewood collection among others. Therefore, the actual situation may be slightly different i.e. the net biomass growth can either be negative or positive, depending on how much is added, removed and/or how many trees actually die of natural causes in any given period for various localities.

5.3.4 Net Biomass (Growth and Removals)

As mentioned above the net biomass growth on the ground is influenced by both human activities and natural factors (natural growth, in growth and death). This was assessed through re-measurements of approximately 1179 field plots 2 to 4 years after the first measurements in 1995. The findings are presented in Table 5-10.

Table 5-10 Over all biomass trends (tonnes air-dry /ha)

Land Cover/Use	Predicted Weight 1st Visit(Tons/ Ha Airdry)	Predicted Weight 2nd Visit(Tons/H a Airdry)	Difference between the 1st and 2nd Visit	Duration in Decimal Years	Rate of annual change (Tons/Ha Airdry)	Rate of annual change (%)
CLASS	VistA (TON-HA)	VistB (TON-HA)	Difference	YEARS	change	Change in %
Plantations (Hardwoods)	46	38	-7.8	2	-3.4	-7%
Tropical High Forest THF	189	110	-79.0	3	-24.3	-13%
THFDegraded	119	87	-31.2	4	-8.3	-7%
Woodland	39	33	-6.3	3	-1.9	-5%
Bushland	15	12	-2.3	4	-0.6	-4%
Grassland	8	7	-0.2	3	0.0	-1%
Wetlands	0	0	0.0	2	0.0	
Subsistence Farmland	8	8	0.2	3	0.1	1%
Commercial Farms	0	0	0.0	4	0.0	-25%
Built up Area	4	5	0.4	3	0.1	3%

Normal tropical high forests have the highest net biomass decline of 24 tonnes (air-dry biomass)/ha/year, followed by degraded tropical high forest with a net reduction of 8 tonnes/ha/yr. Biomass stock in Eucalyptus plantations declined by about 3 tonnes air-dry biomass/ha/yr. While woodlands, bush land and commercial farmlands had a net reduction of about 2 tonnes/ha/year, 0.8 tonnes/ha/year and commercial farms respectively.

These estimates when multiplied by the corresponding area of each land cover gave the net biomass growth (dynamics) which was grouped into protected and private lands. Table 5-11 presents the national summary while Appendix 15 presents the details by districts.

Table 5-11 : Biomass dynamics at national level

Land Cover/Use	Gross Area	Protected Area (excluding HA)	Private	Net Biomass Growth tons/ha	Gross Yield (Tons)	Protected Area (Tons)	In Private (Tons)
Plantations Hardwoods	18,682	6,658	12,024	-3	-64,452	-22,970	-41,482
Plantations Softwoods	16,384	15,693	690		0	0	0
THF- Normal	650,150	477,068	173,083	-24.3	-15,781,030	-11,579,807	-4,201,222
THF - Degraded	274,058	97,011	177,047	-8.3	-2,284,317	-808,602	-1,475,715
Woodlands	3,974,102	875,854	3,098,248	-1.9	-7,604,678	-1,675,999	-5,928,679
Bushlands	1,422,395	296,111	1,126,285	-1	-896,109	-186,550	-709,559
Grasslands	5,115,266	1,149,967	3,965,299	0.0	-238,623	-53,645	-184,978
Wetlands	484,037	32,598	451,439		0	0	0
Subsistence Farmlands	8,400,999	137,931	8,263,068	0.1	505,324	8,297	497,027
Commercial Farmlands	68,446	1,287	67,159	0	205	4	201
Built up areas	36,571	1,982	34,589	0.1	4,609	250	4,359
Water			0		0	0	0
Impediments	3,713	745	2,968		0	0	0
Total	**20,464,804**	**3,092,905**	**17,371,899**		**-26,359,069**	**-14,319,022**	**-12,040,047**

The national summary shows that nearly 26 million tons of biomass is lost per year with the highest being in tropical high forests. However, since protected areas are supposed to be strictly speaking under conservation and sustainable management, a minimum loss of biomass was assumed. Therefore, in this study most of the biomass loss is assumed to be from private land where nearly 12 million tons is lost per year out of which woodlands and tropical high forest together account for 10 million tons (over 80%).

At District level, Kibaale is leading with about 1.8 tons of biomass loss, followed by Hoima with 0.7 million tons. However, districts like Iganga, Mbale, Pallisa, and Tororo are associated with positive growth due mostly to farmland and built areas. Note that these districts have hardly any natural forest and experience woodfuel scarcities.

Conclusion – This chapter presented detailed empirical data on Uganda's biomass resources, including information on the biomass structure, density, standing stock, annual growth and dynamics. The results on area of each land cover combined with biomass information yielded gross biomass standing stock at national, regional and district levels. In this way it was possible to give a comprehensive assessment of the biomass resources in Uganda during the 1990s.

It is obvious that since then, a lot of changes whether negatively or positively have occurred due to human and ecological factors like, increasing population, higher demand for fuelwood and food production. The end result in most cases has been negative leading to the overall dwindling of the biomass resource. This is the topic of discussion for the next chapter under future scenarios.

6. Future Scenarios

The previous two chapters presented and examined the area, distribution, biomass density and standing stock, present status of forest reserves, biomass growth and dynamics. It was noted in the previous chapter that the status of the biomass is not static and that a lot of changes must have occurred since then and will of course continue well into the future.

Based on the above empirical data an attempt is made to look into the future by predicting what would have happened and also will happen to the resource under '*business as usual'* and *'what if scenarios'* of land cover and biomass resource in general. It is not easy to predict what will happen exactly. However through scenarios (mathematical models based on a number assumptions it is possible to predict likely trends of events into the future. Some of the areas tackled are:

- Population verses forestlands
- Population growth verses farmlands
- Biomass dynamics.
- Charcoal production and its effect on the woodlands

6.1 Population verses Forest land

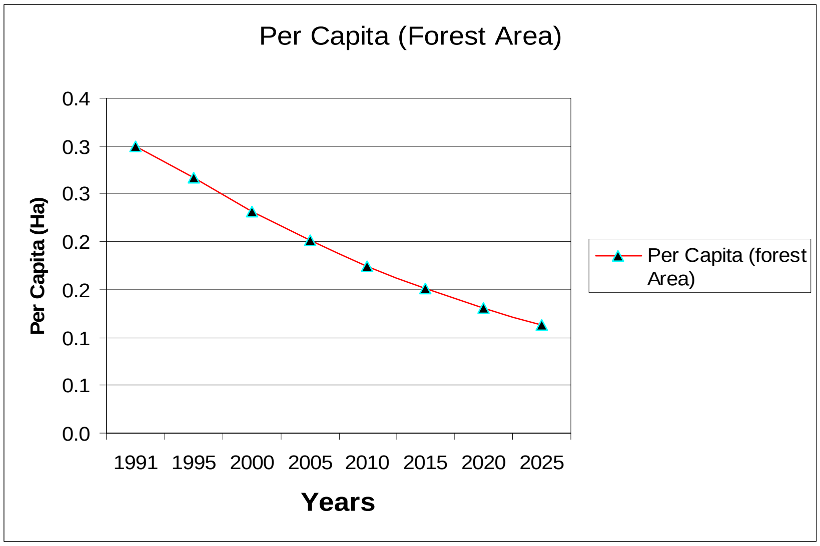
In 1991, Uganda's population was 16.7 million. At that time the forest area was nearly 5 million ha. Using this as a baseline, and a population growth rate of 2.9% future per capita forest land was projected as given below. The result show that there would be a steady decline of per capita forested area from 0.3 ha in 1991 to only about 0.1 ha per capita by the year 2025 (Table 6-1).

Table 6-1: Per Capita Gross Forest distribution and future projections

Year	1991	1995	2000	2005	2010	2015	2020	2025
Population	16.7	18.6	21.4	24.5	28.2	32.3	37.1	42.6
Total Forest (Mill. Ha)	4.9							
Per Capita (forest Area)	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1

If the gazetted areas were removed from the national gross forested area, then the per capita of forested area in 1991 would have been 0.2 ha of forested area and using the same projection, at the same rates of population growth, the per capita forest land area would drop from 0.2 to 0.1 ha by the year 2025 (Figure 6-1)

Figure 6-1: Per capita forest area (gross)

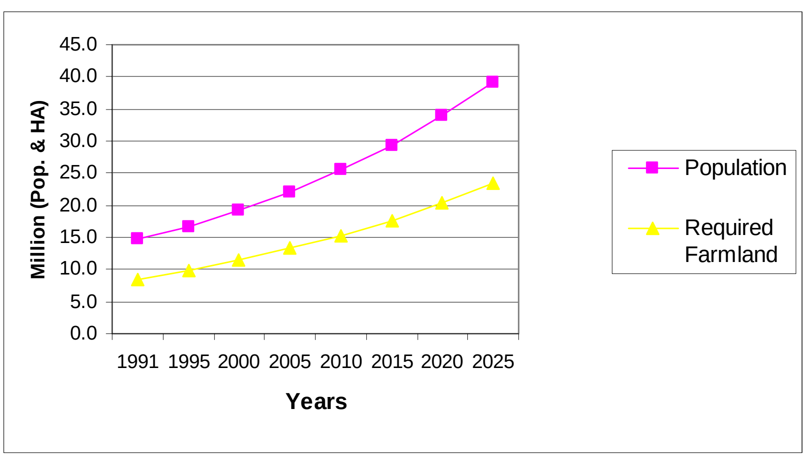


It should be noted that there are 3.5 million ha of forest under private ownership. These forests are not well managed, and, most are being cleared for agriculture.

6.2 Population growth verses farmlands

Out of the 16.7 million people in 1991, 14.8 million were rural people dwelling on approximately 8.4 million ha of subsistence farmland areas across the country. At a growth rate of 2.9% p.a., three possible scenarios emerge. In one, assuming that the per capita of 0.6 ha of farmland in 1991 is maintained, the land requirements for subsistence agriculture will expand from 8.4 million ha in 1991, to nearly 22.7 million ha. That exceeds the total land area of Uganda by an extra 1.2 million ha (Figure 6-2), which is practically impossible because the land area and the boundary of Uganda cannot be altered. Therefore the solution is to make optimal use of the available land.

Figure 6-2 : Required Farmland



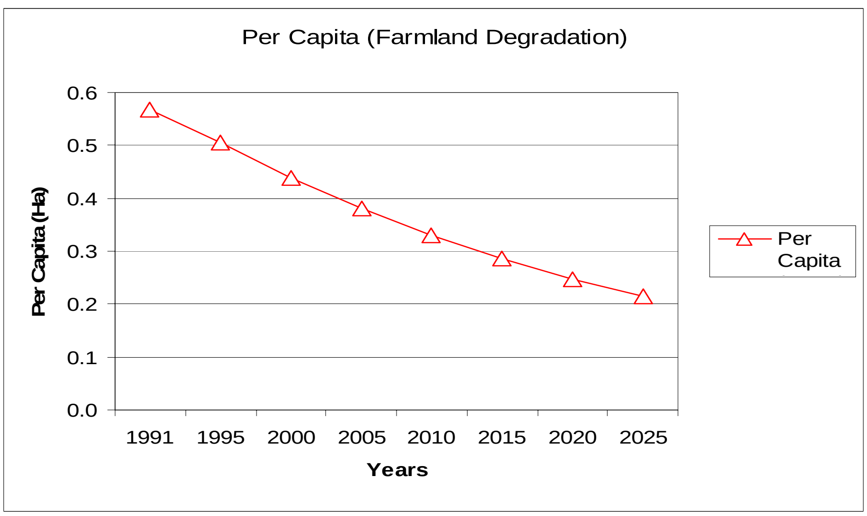
In the second scenario, the 1991 farmland area is assumed to remain entirely available for subsistence agriculture which means the subsistence farmland would end up being further sub-divided (fragmented) into smaller and smaller units, to satisfy a higher demand for food production. Under this scenario, at national level, 0.6 ha of farmland in 1991 would be fragmented to 0.2 ha per capita by the year 2025 (Table 6-2).

At local levels such as in Southwestern region – Kabale and Kisoro in particular and Eastern Uganda (Tororo), the trend could even be worse than that portrayed at national level. This is a challenge for the on going plan for modernization of agriculture, as it aims at increasing land productivity.

Table 6-2 : Projected Farmland and population

Year	1991	1995	2000	2005	2010	2015	2020	2025
Population	14.8	16.5	19.0	21.8	25.0	28.7	33.0	37.8
Total Farmland (Miill. Ha)	8.4	9.9	11.4	13.1	15.0	17.2	19.8	22.7
Per Capita (Farmlands)	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.2

Figure 6-3: Projected distribution of farmland per capita



Lastly, in the third scenario, several factors would have to be considered. For example, low agricultural productivity due to among others, low market prices resulting into decreased interest by rural population in farming as an economic activity. Land ownership, which influences the actual land available to individuals within the overall framework of private land and in some cases leading to land deprivation and rural-urban migration. The implications of all these factors imply more land becoming available for rural agriculture, although the problem would then be passed onto the rural and urban planners.

Whichever direction a given scenario takes, the country's forest and agricultural lands are facing a risk of being depleted with dire consequences. It therefore calls for sound strategic policies and management plans to be put in place for implementation right away.

6.3 Future biomass dynamics

In section 5.3.4, the net annual biomass loss or gain was presented. The estimates were used to project future scenarios of biomass dynamics under business as usual scenarios in private land cover/use. The results are presented in Table 6-3. Protected areas are assumed to be under proper management and not as vulnerable as the private areas. It is observed that the present 312 million tons of biomass held in private lands will face a deficit of 846,000 tons by the year 2025.

On land cover by land cover basis, the biomass held in tropical high forest would have been lost by the year 2010, while depleted tropical high forest would last around till 2020. Most of the land cover would have been lost by the year 2025. On the other hand, because of the positive growth in farmlands as revealed from the biomass dynamics, assuming conditions remain the same; there would be a net gain from the present 110 million tons to about 123 million tons by the year 2025.

Table 6-3 : Future scenarios of biomass dynamics

Land Cover (use)	Private	Annual Loss/Gain	2000	2005	2010	2015	2020	2025
	(000, Tons	(000, Tons)						
Hardwood Plantations	1,059.6	0						
Conifers Plantations.	103.6	0						
Tropical Hgh Forest (Normal Stocked)	31,843.3	-4,201	27,642	6,636	-14,370	-35,376	-56,382	-77,388
Tropical Hgh Forest (Depleted)	18,050.2	-1,476	16,574	9,196	1,817	-5,561	-12,940	-20,318
Woodlands	101,071.7	-5,929	95,143	65,500	35,856	6,213	-23,431	-53,074
Bushlands	11,413.3	-710	10,704	7,156	3,608	60	-3,487	-7,035
Grasslands	36,994.3	-185	36,809	35,884	34,960	34,035	33,110	32,185
Wetlands	230.0	0	230	230	230	230	230	230
Subsistence Farmland	110,513.6	497	111,011	113,496	115,981	118,466	120,951	123,436
Largescale Farmlands	150.5	0	151	152	153	154	155	156
Builtup areas	850.2	4	855	876	898	920	942	964
Water	0.0	0	0	0	0	0	0	0
Impediements	0.0	0	0	0	0	0	0	0
Totals	**312,280**	**-11,999**	**299,119**	**239,126**	**179,133**	**119,140**	**59,147**	**-846**

In protected areas, estimates of future yields were calculated using growth rates under ideal situations. The protected areas were also assumed to be under proper management. Based on these assumptions the estimated yield supply of nearly 167 million-ton in 2000 would increase to about 536 million tons by the year 2025. The negative balance from private lands would ideally be offset by the positive growth in the protected areas i.e. if the private sector participation in forest reserves takes off as envisaged in the National Forestry Plan.

Land Cover (use)	Prot. Areas	Ann. Yield	2000	2005	2010	2015	2020	2025
	(000, Tons)	(000, Tons)						
Hardwood Plantations.	623	87						
Conifers Plantations.	2,354	0						
Tropical Hgh Forest (Normal Stocked)	104,648	7,156	111,804	147,584	183,364	219,144	254,924	290,704
Th	9,546	1,067	10,613	15,949	21,284	26,620	31,956	37,291
Woodlands	24,942	4,642	29,585	52,795	76,005	99,215	122,425	145,635
Bushlands	2,594	252	2,846	4,105	5,363	6,621	7,880	9,138
Grasslands	9,858	1,495	11,353	18,828	26,303	33,777	41,252	48,727
Wetlands	6	0	6	6	6	6	6	6
Subsistence Farmlands	1,311	138	1,449	2,139	2,829	3,518	4,208	4,898
Largescale Farmlands	4	0	4	4	4	4	4	4
Builtup areas	13	6	19	48	78	108	138	167
Water	0	0	0	0	0	0	0	0
Impediements	0	0	0	0	0	0	0	0
Totals	**155,900**	**14,842**	**167,678**	**241,457**	**315,235**	**389,014**	**462,792**	**536,571**

6.4 Forest Production and Consumption

This section presents the current status of biomass supply and consumption and projections of future scenarios in light of population growth.

The estimated gross biomass supply from all the various land cover (use) is that Uganda has about 468 million tons of air-dry equivalent of wood (above ground tree biomass). Of this gross available supply, 156 million tons are held in protected areas (Forest reserves, National Parks and Game reserves) and a total of 317 million tons is held in private forests, woodlands, bushes and subsistence farmlands. Sustainable yield indicates that there would be a deficit of less than 1 million from private lands whereas a positive balance of over 536 million tons in protected areas.

The consumption of wood products (mainly sawn timber, charcoal and firewood) was estimated in 1995 to be 20 million tons (Statistical Abstract, 2000). At an estimated growth rate of 3.6% (Uganda Forestry Sector Co-ordinating Secretariat, 2001), the consumption of wood products would almost triple from 20 (the 1995 level) to about 60 million tons by the year 2025.

The analysis of the biomass dynamics in private areas indicates that by 2025, there will be a deficit of slightly less than one million tons whereas from protected areas it is projected that there will be a positive supply of 536 million. However, not this entire amount is available to meet the projected wood products demand especially woodfuel. This implies that Uganda's future biomass resources under business, as usual scenario is not sustainable.

The above projections are purely mathematical, because a number of underlying issues in the biomass, human and environmental dynamics affecting the gross supply were not taken into account. For example, under future scenarios of land for agriculture (section 6-1 above), it was revealed that if the 1991 farmland per capita was to be maintained, all the land in Uganda would have been converted to agriculture by the year 2025. This implies that the projected supply of 1.8 billion tons of biomass by the year 2025 would have been lost forever in favour of food production. Other factors to be considered are accessibility of the forest resource, management status of each land cover especially forests in gazetted and non-gazetted areas, land ownership and its direct bearing on the supply of biomass resources.

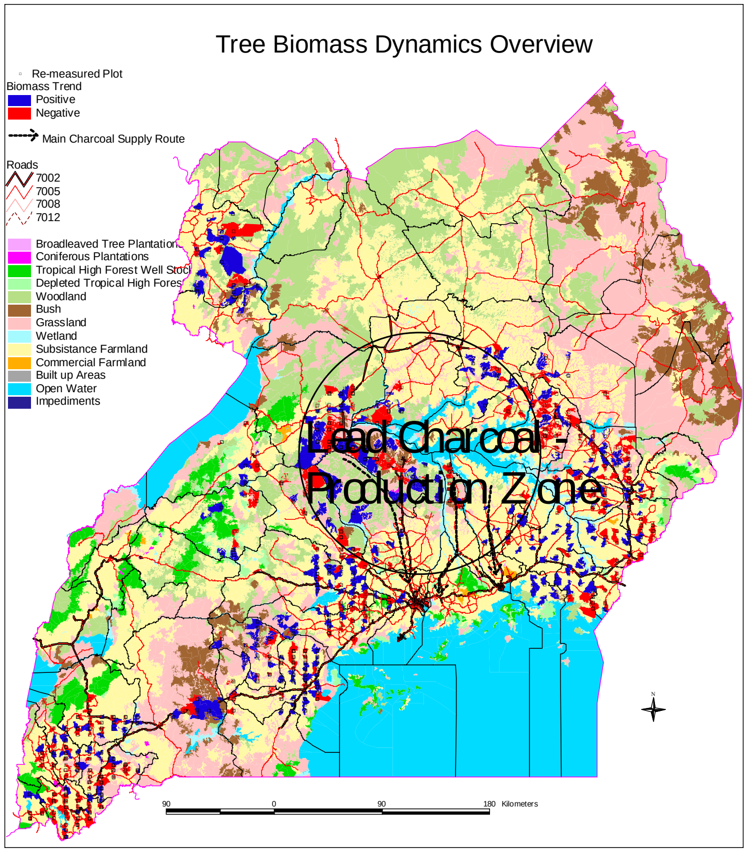
6.4.1 Charcoal production and its effect on the biomass resource

Charcoal is produced throughout Uganda to supply major towns where the majority consume charcoal as main source of energy. However, mid-western and central (Districts of Hoima, Kayunga, Kibaale, Kiboga, Masindi, Nakasongola, northern Luwero, and southern Apac) remain the main source of charcoal production in Uganda. The region extends across a radius of about 100-km at the intersection of the 32^{o} 30' longitude and the 1^{o} 30' parallel line (See Figure 6-4). It is estimated that this region supplies 250,000 tons or about 60% of total charcoal produced in Uganda to the main urban centres of Kampala, Jinja and Entebbe (ESD, 1995).

In this region, charcoal is mainly produced from woodlands which cover about 700,000 ha. Sustainable yield from this area is estimated to be around 3.5 million tons (growth rate for woodlands is 5 tons/ha/yr). At the estimated production of 250,000 tons of charcoal, which is equivalent to 3 million tons of wood, it could easily be concluded that at the present rate of extraction the region is capable of supporting Uganda's urban demand on a sustainable basis.

However, results from the dynamic assessment show that tree biomass stock in this region is declining at a rate of 1.9 tonnes per hectare annually or a total of 1.3 million tons from the 700,000 ha of woodland. Compared with the 3 million tons of wood required for the charcoal production, this leaves a balance of 1.7 million tons, which must come from other land cover/use such as trees in bushlands, grasslands and land clearance for agriculture. Either way the future of charcoal production in this area is not sustainable as the analysis has shown.

Figure 6-4: Biomass dynamics and main charcoal producing areas



In conclusion, the business as usual scenarios predicts that forestland and farmlands will generally be declining as the population increases. This will increase the rate of loss of biomass especially in private lands. On the other hand the production and consumption of forest products will be inversely affected.

It was not possible to run future scenarios on 'what if' basis i.e. the likely trends based on management options and responses if taken by planners and managers because of its complexity. However, the simple business as usual scenarios should suffice for rational decision making concerning the biomass resource.

7. References:

Aluma, John, 1987. Status of Forest Reserves in Uganda, Makerere University, Kampala.

Energy for Sustainable Development, 1985. Ministry of Natural Resources, Forest Department (unpubl), Kampala, Uganda.

Freese Frank, 1984. Statistics for Land Managers. Paenony Press, Jedburgh, Scotland.

Forest Department, 1988. National Biomass Project Document. Kampala, Uganda

Forest Department, 1992. National Biomass Study Phase I Technical Report. Kampala, Uganda.

Forest Department, 1992. National Biomass Project Review. Kampala, Uganda.

Forest Department, 1994. National Biomass Study Evaluation Mission Report. Kampala, Uganda.

Forest Department, 1995. National Biomass Review Mission Report. Kampala, Uganda.

Forest Department, 1996. National Biomass Study Phase III Project Document. Kampala, Uganda.

Government of Uganda, GoU, 1996 a, Statistical abstract. Ministry of Planning and Economic Development, (Unpubl.), Kampala.

Government of Uganda, GoU, 1996 b, Background to the Budget. Ministry of Planning and Economic Development, (Unpubl.), Kampala.

GoU, 1967 c. Atlas of Uganda. Government Printing Press, Entebbe, Uganda.

GoU d, 1963. Agricultural Census. Ministry of Agriculture and Forestry, Entebbe, Uganda.

GoU e, 1985. Budongo Forest Inventory Report. GITEC Consult, Germany.

GoU f, 1973. Forest Resources Assessment. Lockwood Consultants Canada.

GoU g, 1993. Uganda National Census of Agriculture Volumes 1I-IV. Ministry of Agriculture, Animal Industry and Fisheries, Entebbe. Uganda.

Hamilton, A.C., 1982. Deforestation in Uganda. Oxford University Press, UK.

Howard, 1986. Status of major Forest Reserves in Uganda. Oxford. U.K.

Intergovernmental Panel on Climate Change, IPCC, 1995. Greenhouse Gas Inventory Manual. London. UK.

Jacovelli, P. and Carvallo, J., 1999. The Private Forest Sector in Uganda – Opportunities for greater involvement. Uganda Forest Sector co-ordination Secretariat. Kampala, Uganda.

Knut Velle, 1997, Evaluation of Components of the National Biomass Study, Uganda: Suggestions and Recommendations for the Biomass Measurements, Statistical procedures and Strategies for Phase III of the Project. Unpubl. Forest Department and Norwegian Forestry Society. Kampala. Uganda.

Lockhood Consultants,1973. Forest Resources Development Study of Uganda. Forest Department, Entebbe, Uganda.

Michael, S. Philip, 1983. Measuring Trees and Forests. University of Dar-es-salaam, Tanzania.

Pancel L, 1983. Tropical Forestry Handbook Vol. 1. Springler-Verlang.

UNEP/GRID, 1987. Uganda Case Study : A Sample of atlas of Environmental Resource Datasets within GRID. GRID Case Study Series No. 1.

UNEP/FAO, 2000. Technical Guidelines for the Assessment and Measurement of Criteria and Indicators for for Sustainable Forest Management in Dry Zone Africa. Rome. Italy.

8. Appendices

Appendix 1:

SPATIAL CODES USED BY THE NBS

(Based on the Norwegian standard format SOSI)

All codes consist of 4 digits, and are grouped into a number of "related" groups of phenomena. Both *discrete physical* objects (e.g. a road), *continuous physical* strata (e.g land use / land cover), and *discrete virtual* objects. (e.g. administrative units) are included.

Note also the difference between LINE and CURVE is that line comprises points, which cannot be changed without changing information content (e.g. if the line points are fixed coordinate pairs with specific relevance, like an international boundary plotted from surveyed and agreed upon boundary markers), whereas the points in a curve can be changed as long as the form of the curve is kept (e.g. a contour line).

Object name	Graphical elements	Item – name	Item value
Control point:			
FIXED POINT	POINT	PSUBJ	1000
		PIDENT	N/A
		PTYPE	T (rig)
CONTOURLINE	CURVE	LSUBJ	2001
CONTOURSINK	CURVE	LSUBJ	2003
INTERMEDIATE	CURVE	LSUBJ	2004
SPOTHEIGHT	POINT	PSUBJ	2102
BATHYMETRY	CURVE	LSUBJ	2011
SPOTDEPTH	POINT	PSUBJ	2113
GRID	POINT	PSUBJ	2106
Water & waterways:			
LAKE LABEL	POINT	PSUBJ	3101
LAKESHORES	CURVE/LINE	LSUBJ	3101
POND (MAN-MADE) BND	CURVE/LINE	LSUBJ	3102
Permanent waterways:			
RIVPBIG LABEL	POINT	PSUBJ	3201
RIVPBIG-SHORE	CURVE/LINE	LSUBJ	3201
RIVBIG-CENTRE	CURVE/LINE	LSUBJ	3202
RIVPNORM-CENTRE	CURVE/LINE	LSUBJ	3211
RIVPSMALL-CENTRE	CURVE/LINE	LSUBJ	3216

Seasonal waterways:			
RIVSNORM-CENTRE	CURVE/LINE	LSUBJ	3221
RIVSSMALL-CENTRE	CURVE/LINE	LSUBJ	3226
WELL-WATERHOLE	POINT	PSUBJ	3301
BOREHOLE W/HANDPUMP	POINT	PSUBJ	3311
BOREHOLE W/MOTOR PUMP	POINT	PSUBJ	3316
Protected Areas Labels			
FOREST RESERVE LABEL	POINT	PSUBJ	4020
FOREST PARK LABEL	POINT	PSUBJ	4021
NATIONAL PARK LABEL	POINT	PSUBJ	4022
GAME RESERVE LABEL	POINT	PSUBJ	4023
HUNTING AREA LABEL	POINT	PSUBJ	4024
Administrative Boundaries	Graphical elements	Item – name	Item value
INTERNATIONAL BND	LINE/CURVE	LSUBJ	4001
DISTRICT-RC5 BND	LINE/CURVE	LSUBJ	4002
COUNTY-RC4 BND	LINE/CURVE	LSUBJ	4003
S-COUNTY-RC3 BND	LINE/CURVE	LSUBJ	4004
PARISH-RC2 BND	LINE/CURVE	LSUBJ	4005
ENUM. AREA BND	LINE/CURVE	LSUBJ	4006
VILLAGE-RC1 BND	LINE/CURVE	LSUBJ	4007
Land Cover / Use Classifications (attributes difference in parenthesis):			
LAND COVER / USE BND (CLASS)	LINE/CURVE	LSUBJ	4100
LAND COVER / USE BND (STYPE)	LINE/CURVE	LSUBJ	4101
LAND COVER / USE BND (STOCK)	LINE/CURVE	LSUBJ	4102
LAND COVER / USE BND (BTYPE)	LINE/CURVE	LSUBJ	4103
LAND COVER / USE BND (BPERC)	LINE/CURVE	LSUBJ	4104
LAND COVER / USE BND (STOCK)	LINE/CURVE	LSUBJ	4105
DESIDUOURS PLANTATION - LABEL	POINT	PSUBJ	4110
EUCALYPTUS PLANTATION - LABEL	POINT	PSUBJ	4111

ACACIA PLANTATION - LABEL	POINT	PSUBJ	4112
CASSIA PLANTATION - LABEL	POINT	PSUBJ	4113
MAHOGANY PLANTATION - LABEL	POINT	PSUBJ	4114
CONIFER PLANTATION - LABEL	POINT	PSUBJ	4120
PINE PLANTATION - LABEL	POINT	PSUBJ	4121
CYPRESS PLANTATION	POINT	PSUBJ	4122
TROPICAL HIGH FOREST - FULLY ST.	POINT	PSUBJ	4130
TROPICAL HIGH FOREST - DEPLETED	POINT	PSUBJ	4140
WOODLAND - LABEL	POINT	PSUBJ	4150
BUSHLAND - LABEL	POINT	PSUBJ	4160
GRASSLAND - LABEL	POINT	PSUBJ	4170
WETLAND - LABEL	POINT	PSUBJ	4180
SMALL-SCALE FARMLAND – LABEL	POINT	PSUBJ	4190
UNIFORM FARMLAND -LABEL	POINT	PSUBJ	4200
BUILT-UP AREAS - LABEL	POINT	PSUBJ	4300
(LUC CLASS 12: Water - use codes 3000->3316)			
IMPEDIMENTS (ROCK,SOIL) - LABELS	POINT	PSUBJ	4500

Infrastructure (all roads are centerlines in 1:50,000):			
	Graphical elements		Item value
ALL WEATHER, TARMAC W/2+ LANES	CURVE/LINE	LSUBJ	7001
ALL WEATHER, TARMAC W1-2 LANES	CURVE/LINE	LSUBJ	7002
ALL WEATHER, TARMAC - ERODED	CURVE/LINE	LSUBJ	7003
ALL WEATHER, LOOSE SURFACE	CURVE/LINE	LSUBJ	7005
ALL WEATHER, LOOSE SU - ERODED	CURVE/LINE	LSUBJ	7006
DRY WEATHER, LOOSE SURFACE	CURVE/LINE	LSUBJ	7008
DRY WEATHER, LOOSE SU-ERODED	CURVE/LINE	LSUBJ	7009
MOTORABLE TRACK	CURVE/LINE	LSUBJ	7012
BRIDGE - CARS	CURVE/LINE	LSUBJ	7041
RAILWAY	LINE	LSUBJ	7101
RAILWAY ABANDONED	LINE	LSUBJ	7102
CAR FERRY	CURVE/LINE	LSUBJ	7201
CANOE FERRY	CURVE/LINE	LSUBJ	7202
FOOTPATH	CURVE/LINE	LSUBJ	7414
BRIDGE-PEDESTRAINS	CURVE/LINE	LSUBJ	7441
AIRSTRIP – LABEL	POINT	PSUBJ	7911
AIRSTRIP BOUNDARY	LINE	LSUBJ	7911
AIRSTRIP CENTERLINE	LINE	LSUBJ	7914
AIRSTRIP, TAXING – LABEL	POINT	PSUBJ	7931
AIRSTRIP, TAXING BND	LINE	LSUBJ	7931
AIRSTRIP, TAXING CEN	LINE	LSUBJ	7934
Electricity production and distribution:			
POWER STATION	POINT	PSUBJ	8001
POWER STATION –	LINE	LSUBJ	8001

BOUNDARY			
POWER LINE, 300 KV	LINE	LSUBJ	8011
POWER LINE, 132 KV	LINE	LSUBJ	8012
POWER LINE, 33 KV	LINE	LSUBJ	8013
POWER LINE, 240 V	LINE	LSUBJ	8015
Other features:			
CULTURAL SITE	POINT	PSUBJ	6201
TOURIST SITE	POINT	PSUBJ	6202

Appendix 2: Example of Field Plot Measurements form

Field plot measurement Form

Map & cluster

Plot no: ☐☐☐☐ ☐☐☐ ☐☐ GPS file: ____________ | Controlled by: ______

Teamleader: _____ Date: ________ Antenna (h): ___m | Entry date: __________

GPS: East ___° ___' ______ North: ___° ___' ________ | Entered by: _________

GPS problem: NW☐ SE☐ NE☐ corner used! or

SW corner of plot is ___m N☐ S☐ & ____m W☐ E☐ of GPS point!

Map polygon classification: ___________ Revise?: ____________ Plot size!!

Plot size m: ☐ 20 x 20 ☐ 30 x 30 ☐ 50 x 50 ☐ 70 x 70

For strata: 1&2 5HI,6HI 3,4ME,4HI,5LO,5ME, 4LO,7LO,7ME,

6LO,6ME,7HI,9ME,9HI, 9LO,10LO

9VH,10ME,10HI,11

Plot classification: __________ Border case: SW moved ______m N☐ S☐ W☐ E☐

Relative Area Coverage in % (cross-check that rest up to 100% is trees!):

Bush, Bushfallow, Grass, Grassfallow, Coffee, Cassava, Matooke, Maize, Sweetpotato, Peas, Cotton, Sunflower, Sorghum, Sugarcane, Tea, Cocoa, Residential, Livestock pen, Indust./business, Road, Papyrus, Reeds, Water (incl floats), Miscellaneous, and others you specify.

Strip width: 5m☐ 10m☐ Time spent: ___h Complexity (LO/ME/HI): ________

Attitudes of residents (Good/Normal/Poor/Hostile): RCs: _____ People: _____

Distance to road/motorable track: ____m Accessibility (Good/Me/Poor): ___

Comments (access, location of plot/repeater, border case shifts):

Tree No	DBH	Bole Length	Tree Height	Crown Diam.	Species
	cm	m	m	m	
1					
2					
n					

Appendix 3: Program for Data Analysis – Treecal program

```
*************************************************************
******
*************************************************************
******
***
***
***                                    Programme  treecalc.prg
***
***
***
***   This programme is used for calculating the predicted
***
***   weight of the trees and plots, using both species-group
***
***   functions and size-based functions. It also roughly
***
***   estimates commercial weight (=volume) for timber
species. ***
***
***
*************************************************************
******
*************************************************************
******
*
* Revision 1.3 by Calle Hedberg 14.12.97
*
* General housekeeping commands
SET TRAP ON
SET BELL OFF
SET AUTOSAVE ON
SET EXCLUSIVE ON
```

```
SET ECHO OFF
SET STATUS OFF
SET SCOREBOARD OFF
SET TALK OFF
SET HEADINGS OFF
SET CURRENCY TO ""
SET CONFIRM OFF
_PLOFFSET = 6
CLOSE ALL
CLEAR ALL
CLEAR
*
************************************************************
******
************************************************************
******
***
***
*** Definitions of the main window types (Dialogs and Help)
***
***
***
************************************************************
******
************************************************************
******
*
DEFINE WINDOW DialogS FROM 10,25 TO 16,55 DOUBLE COLOR w+/n,
n/w
DEFINE WINDOW DialogM FROM 10,15 TO 18,65 DOUBLE COLOR w+/n,
n/w
DEFINE WINDOW DialogB FROM 6,10 TO 20,70 DOUBLE COLOR w+/n,
n/w
DEFINE WINDOW DialogF FROM 0,0 TO 24,79 DOUBLE COLOR w+/n,
n/w
DEFINE WINDOW DialogU FROM 0,0 TO 15,79 DOUBLE COLOR w+/n,
n/w
DEFINE WINDOW DialogL FROM 17,0 TO 24,79 DOUBLE COLOR w+/n,
n/w
*
************************************************************
******
************************************************************
******
***
***
```

```
***                        Definition of the area popup menu.
***
***
***
*************************************************************
******
*************************************************************
******
*
DO Sel_Area
*
IF mAreaCode = 'ALL '
     SELECT 1
     SCAN for process = 'Y'
          mAreaCode = Area_code
          mPlotFil = SPACE(7)
          mPlotFil = mAreaCode+'cov'
          mTreeFil = SPACE(7)
          mTreeFil = mAreaCode+'tre'
          USE Spec_grp IN 2 ORDER TAG Species OF Spec_grp
          USE Func_sel IN 3 ORDER TAG Group OF Func_sel
          USE &mPlotFil IN 4 ORDER TAG Plotno OF &mPlotfil
          USE &mTreeFil IN 5 ORDER TAG Plotno OF &mTreeFil
          CLEAR
          DO Calc_wt
          DO Calc_plot
          SELECT 1
     ENDSCAN
ELSE
     mPlotFil = SPACE(8)
     mPlotFil = mAreaCode+'cov'
     mTreeFil = SPACE(8)
     mTreeFil = mAreaCode+'tre'
     USE Spec_grp IN 2 ORDER TAG Species OF Spec_grp
     USE Func_sel IN 3 ORDER TAG Group OF Func_sel
     USE &mPlotFil IN 4 ORDER TAG Plotno OF &mPlotfil
     USE &mTreeFil IN 5 ORDER TAG Plotno OF &mTreeFil
     CLEAR
     DO Calc_wt
     DO Calc_plot
ENDIF
CLEAR ALL
RELEASE all
CLOSE ALL
SET STATUS ON
SET TALK ON
RETURN
```

```
*
PROCEDURE Sel_Area
     CLEAR
     USE Areacode IN 1 ORDER TAG Area_name OF Areacode
     DEFINE POPUP Selareapop FROM 8,25 TO 18,45 PROMPT FIELD
Area_Name;
          MESSAGE "Select area to edit. ESC to close the
list"
          ON SELECTION POPUP Selareapop DO Choose
          ACTIVATE POPUP Selareapop
RETURN
*
PROCEDURE Choose
     mArea_Name = SPACE(17)
     mArea_Name = PROMPT()
     SEEK mArea_Name
     PUBLIC mAreaCode
     mAreaCode = Area_code
     RELEASE mArea_Name
RETURN
*
PROCEDURE Calc_wt
     *
     @ 7,5 SAY 'Tree weights now being estimated for plot
number:'
     SELECT 5
     SCAN
          * Memory variables are initialized or reset to
zero or blank:
          mSpecies = SPACE(35)
          STORE 0 TO mGroup,mDbh
          mPred = 0.0
          mPreds = 0.0
          STORE                    0.0                    TO
mConstant,mMSE,mLND,mLNHB,mLNHT,mLNCR,mLNHCR
          STORE                    0.0                    TO
mLND2,mLNCR2,mMaxDbh,mMaxBole,mMaxHeight
          STORE                    0.0                    TO
mPred,mMaxCrown,mCrown,mBole,mHeight,mlDbh,mlDbh2
          STORE                    0.0                    TO
mlCrown,mlCrown2,mlHeight,mlBole,mAvg_adens
          mPart = Space(1)
          mComm_perc = 0.0
          mPredComm = 0.0

          * Various tree parameters are read in and their
natural log
```

```
* calculated:
mSpecies = Species
mDbh = dbh
mCrown = Crown
mHeight = Height
mBole = bole
mlDbh = Log(mdbh)
mlDbh2 = mlDbh**2
mlCrown = log(mCrown)
mlCrown2 = mlCrown**2
mlHeight = log(mHeight)
mlBole = log(mBole)
mlHt_cr = log(mHeight - mBole)
IF mAreacode <> 'TST'
     @ 9,15 SAY plotno
ENDIF
SELECT 2
SEEK(mSpecies)
mGroup = Group
mAvg_adens = Avg_adens / 1000
mComm_perc = Comm_perc

SELECT 3
SCAN for Group = mGroup
     mPart = Part
     mConstant = Constant
     mMSE = MSE
     mLND = LND
     mLNHB = LNHB
     mLNHT = LNHT
     mLNCR = LNCR
     mLNHCR = LNHCR
     mLND2 = LND2
     mLNCR2 = LNCR2
     mMaxDbh = MaxDbh
     mMaxbole = MaxBole
     mMaxHeight = MaxHeight
     mMaxCrown = MaxCrown
     SELECT 5
     mPred                                    =
EXP(mConstant+(0.5*mMSE)+(mLND*mlDbh)+(mLND2*mlDbh2);

     +(mLNHB*mlBole)+(mLNHT*mlHeight)+(mLNCR*mlCrown);
               +(mLNCR2*mlCrown2)+(mLNHCR*mlHt_cr))
     DO CASE
          CASE mPart = 'B'
               REPLACE pwt_branch WITH mPred
```

```
                    CASE mPart = 'S'
                         REPLACE        pwt_stem        WITH
mPred,pwt_tree WITH mPred+pwt_branch
                    CASE mPart = 'A'
                         REPLACE pwt_tree WITH mPred
                    OTHERWISE
                         REPLACE pwt_tree WITH -99
                         @ 11,15 SAY 'Treefile has errors!'
               ENDCASE
               SELECT 3
          ENDSCAN
          SELECT 5
          IF mDbh > mMaxDbh .OR. mBole > mMaxBole .OR. ;
          mCrown > mMaxCrown .OR. mHeight > mMaxHeight
               mPredGrp = pwt_tree
               mGroup = 99
               STORE 0.0 TO mPred99b,mPred99s,mPred99t
               SELECT 3
               SCAN for Group = mGroup
                    mPart = Part
                    mConstant = Constant
                    mMSE = MSE
                    mLND = LND
                    mLNHB = LNHB
                    mLNHT = LNHT
                    mLNCR = LNCR
                    mLNHCR = LNHCR
                    mLND2 = LND2
                    mLNCR2 = LNCR2
                    mPred                                =
EXP(mConstant+(0.5*mMSE)+(mLND*mlDbh)+(mLND2*mlDbh2);

     +(mLNHB*mlBole)+(mLNHT*mlHeight)+(mLNCR*mlCrown);

     +(mLNCR2*mlCrown2)+(mLNHCR*mlHt_cr))
                    DO CASE
                         CASE mPart = 'B'
                              mPred99b = mPred
                         CASE mPart = 'S'
                              mPred99s = mPred
                              mPred99t = mPred99b + mPred99s
                         CASE mPart = 'A'
                              mPred99t = mPred
                    ENDCASE
               ENDSCAN
               SELECT 5
```

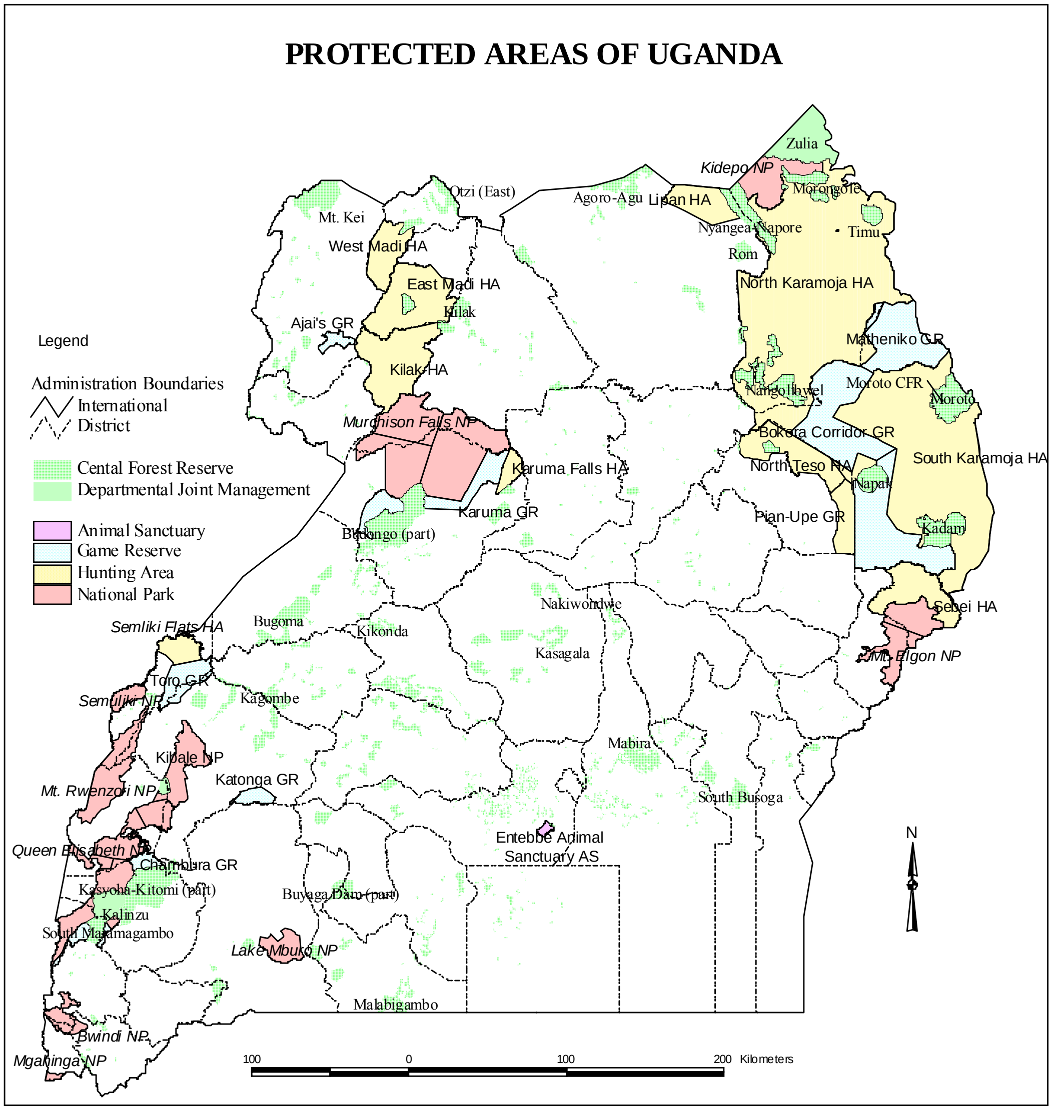
```
                IF mPred99t > mPredGrp * 1.3 .OR. mPred99t <
mPredGrp * 0.7
                     REPLACE  chk  WITH  'O',  pwt_branch  WITH
mPred99b,;
                               pwt_stem    WITH    mPred99s,
pwt_tree WITH mPred99t
                ELSE
                     REPLACE chk WITH 'E'
                ENDIF
           ELSE
                REPLACE chk WITH 'I'
           ENDIF
           REPLACE pwt_airdry with pwt_tree*mAvg_adens
           DO CASE
                CASE mDbh < 20
                     mPreds  =  EXP(0.5*0.09937  -  0.909575  +
1.544561*mlDbh + 0.50663*mlHeight + 0.333346*mlCrown)
                     REPLACE pws_tree WITH mPreds, pws_airdry
WITH pws_tree*mAvg_adens
                CASE mDbh >= 20 .AND. mDbh < 60
                     mPreds  =  EXP(0.5*0.0892  -  1.795491  +
1.943912*mlDbh + 0.473731*mlHeight + 0.245776*mlCrown)
                     REPLACE pws_tree WITH mPreds, pws_airdry
WITH pws_tree*mAvg_adens
                CASE mDbh >= 60
                     mPreds  =  EXP(0.5*0.05222  -  2.192612  +
2.032931*mlDbh + 0.31292*mlHeight + 0.436348*mlCrown)
                     REPLACE pws_tree WITH mPreds, pws_airdry
WITH pws_tree*mAvg_adens
           ENDCASE
           IF mDbh >= 30 .AND. mComm_perc > 0.0
                mPredComm          =          EXP(0.5*0.07742-
2.928985+1.594191*mlDbh+0.933774*mlHeight+0.359449*mlBole)
                REPLACE timber WITH mPredComm
           ENDIF
      ENDSCAN
RETURN
*
PROCEDURE Calc_plot
      mPlotno = SPACE(7)
      DECLARE mStrips[7]
      DECLARE mStripsAir[7]
      @ 12,5 SAY 'Total tree weight now being calculated for
plot number:'
      SELECT 4
      SCAN
```

```
          STORE                    0.0                    TO
mTotal,mTotalE,mTotalO,mTreeCov,mTotAirdry,mTotals,mTotAirdr
s
          STORE 0.0 TO mTotals,mTotAirdrs,mTotalTim
          STORE                    0.0                    TO
mStrips[1],mstrips[2],mstrips[3],mstrips[4],mstrips[5]
          STORE                    0.0                    TO
mStrips[6],mstrips[7],mStripsAir[1],mStripsAir[2]
          STORE                    0.0                    TO
mstripsAir[3],mStripsAir[4],mStripsAir[5]
          STORE 0.0 TO mStripsAir[6],mStripsAir[7]
          STORE                    0                      TO
mNo_trees,mNo_treesE,mNo_treesO,mPwtEpc,mPwtOpc,mStripNo,mPl
otsize
          mPlotNo = PlotNo
          mPlotsize = Plotsize
          mFactor = 10000 / mPlotsize ** 2
          @ 14,15 SAY mPlotno
          SELECT 5
          SET FILTER TO PlotNo = mPlotNo
          GO TOP
          SCAN
               mTotal = mTotal + pwt_tree
               mTotAirdry = mTotAirdry + pwt_airdry
               mNo_trees = mNo_trees + 1
               mTotalTim = mTotalTim + Timber
               *
               * The following IF statements calculates the
number of trees that
               * have parameters either in the Extended
range of the group
               * function used or Outside the range of the
function used (which
               * then might be either a group function OR
the generalised function
               * called '99'. Ditto for the other IF
statement below.
               *
               *IF chk = 'E'
                    *mTotalE = mTotalE + pwt_tree
                    *mNo_treesE = mNo_treesE + 1
               *ENDIF
               *IF chk = 'O'
                    *mTotalO = mTotalO + pwt_tree
                    *mNo_treesO = mNo_treesO + 1
               *ENDIF
               mTreeCov = mTreeCov + (PI()*(Crown/2)**2)
```

```
          * The next section calculates using the new size-
based functions
          * Plus it calculates weight on a strip basis
               mTotals = mTotals + pws_tree
               mTotAirdrs = mTotAirdrs + pws_airdry
               mStripno = INT(treeno/1000)
               IF mStripno > 0
                    mStrips[mStripno] = mStrips[mStripno] +
pws_tree
                    mStripsAir[mStripno]                  =
mStripsAir[mStripno] + pws_airdry
               ENDIF
          ENDSCAN
          SET FILTER TO
          SELECT 4
          mTreeCov = ROUND(mTreeCov * 100 / Plotsize ** 2,0)
          *
          * Percentage of trees outside the function ranges,
ref. comment above:
          *IF mTotal > 0.0
               *mPwtEpc = ROUND(mTotalE * 100 / mTotal,0)
               *mPwtOpc = ROUND(mTotalO * 100 / mTotal,0)
          *ENDIF

          REPLACE pwt_trees WITH mTotal, pwt_ha WITH mTotal
* mFactor,;
                    pwt_airdry  WITH  mTotAirdry,  pwt_airha
WITH mTotAirdry*mFactor,;
                    TreeCov   WITH   mTreeCov,No_trees   WITH
mNo_trees,;
                    pws_trees  WITH  mTotals,  pws_ha  WITH
mTotals*mFactor,;
                    pws_airdry  WITH  mTotAirdrs,  pws_airha
WITH mTotAirdrs*mFactor,;
                    Timbers_ha WITH mTotalTim*mFactor,;
                    strip1  WITH  mStrips[1],  strip2  WITH
mStrips[2],;
                    strip3  WITH  mStrips[3],  strip4  WITH
mStrips[4],;
                    strip5  WITH  mStrips[5],  strip6  WITH
mStrips[6],;
                    strip7 WITH mStrips[7]
                    *pwt_treesE  WITH  mTotalE,  pwt_epc  WITH
mPwtEpc,;
                    *pwt_treesO  WITH  mTotalO,  pwt_opc  WITH
mPwtOpc,;
```

```
                    *No_treesE   WITH   mNo_treesE,No_treesO
WITH mNo_treesO

          * The next if block extracts the first 'half' of
the 70x70m plots and replaces
          * values in the fields starting with 'PWS_'. Note
that the full 70x70m weight
          * for each strip are still found in strip1-7 in
the data table. The mFactor is
          * now constantly 4, since 50x50m is a quarter
hectare:

          IF mPlotsize = 70
               mTotals   =   mStrips[1]   +   mstrips[2]   +
mstrips[3] + mstrips[4]*4/7
               mTotAirdrs = mstripsAir[1] + mStripsAir[2] +
mstripsAir[3] + mstripsAir[4]*4/7
               REPLACE pws_trees WITH mTotals, pws_ha WITH
mTotals*4,;
                    pws_airdry  WITH  mTotAirdrs,  pws_airha
WITH mTotAirdrs*4
          ENDIF

          * The next if block updates the class 4 plots in
Mabira (measured in 1992).
          * An estimated annual increment of 5% has been
used, totalling 35% from 1992-98.

          IF mAreacode = 'MABU' .AND. class = 4
               REPLACE pws_ha WITH pws_ha*1.35
          ENDIF

     ENDSCAN
RETURN
```

Appendix 4: Location of Protected Areas


PROTECTED AREAS OF UGANDA
Legend
Administration Boundaries
International
District
Cental Forest Reserve
Departmental Joint Management
Animal Sanctuary
Game Reserve
Hunting Area
National Park
Zulia
Kidepo NP
Morongole
Otzi (East)
Agoro-Agu
Lipan HA
Mt. Kei
West Madi HA
Nyangea-Napore
Timu
Rom
East Madi HA
North Karamoja HA
Kilak
Ajai's GR
Matheniko GR
Kilak HA
Moroto CFR
Nangolibwel
Moroto
Murchison Falls NP
Bokora Corridor GR
South Karamoja HA
North Teso HA
Karuma Falls HA
Napak
Karuma GR
Pian-Upe GR
Budongo (part)
Kadam
Nakiwondwe
Sebei HA
Semliki Flats HA
Bugoma
Kikonda
Kasagala
Mt. Elgon NP
Toro GR
Semliki NP
Kagombe
Kibale NP
Mabira
Mt. Rwenzori NP
Katonga GR
South Busoga
Entebbe Animal Sanctuary AS
N
Queen Elisabeth NP
Chambura GR
Kasyoha-Kitomi (part)
Buyaga Dam (part)
Kalinzu
South Maramagambo
Lake Mburo NP
Malabigambo
Bwindi NP
Mgahinga NP
100
0
100
200 Kilometers

Appendix 5: Protected Areas by Ownership and type at District level

	Forest Department, FD		FD/UWA	Uganda Wildlife Authority			
District	Local Forest Reserves	Central Forest Rserves	Departmental Joint Management	Animal sanctuary	Game Reserves	National Parks	Total area-PA
	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	(Ha)	
ADJUMANI	56	6,398					6,455
APAC	105	11,373				6	11,485
ARUA	646	30,268			15,863		46,777
BUGIRI		2,421					2,421
BUNDIBUGYO	39	4,572			43,192	47,173	94,975
BUSHENYI	22	48,312	29,294		20,047	43,334	141,008
BUSIA		3,795					3,795
GULU	25	29,965			292	170,972	201,255
HOIMA	32	59,536					59,568
IGANGA	169	1,225					1,394
JINJA	150	6,131					6,280
KABALE		4,993			D	6,229	11,222
KABAROLE	23	4,390	1,181		12,340	47,435	65,370
KABERAMAIDO	11	2,569					2,580
KALANGALA		8,786					8,786
KAMPALA		7					7
KAMULI	82	692					774
KAMWENGE	5	781			10,389	42,194	53,369
KANUNGU	36	2,615			2,450	34,689	39,790
KAPCHORWA	3	6			0	60,418	60,427
KASESE	78	2,029	3,695			160,617	166,420
KATAKWI	58	5,787					5,845
KAYUNGA	57	8,220					8,277
KIBAALE	27	31,755			1		31,784
KIBOGA		38,327					38,327
KISORO		723				10,813	11,536
KITGUM	30	67,906	1				67,937
KOTIDO	40	147,807	54,575		10,070	87,984	300,476
KUMI	191	155					346
KYENJOJO	14	30,483			10,541	2,403	43,442
LIRA	298	9,649					9,946
LUWEERO	178	27,287					27,465
MASAKA	199	19,982					20,180
MASINDI	70	100,341			93,417	215,771	409,600
MAYUGE		26,025					26,025
MBALE	68	556	645			26,812	28,080
MBARARA	61	12,852			110	36,975	49,997
MOROTO		70,185			396,728		466,913
MOYO	19	28,087					28,106
MPIGI	330	30,304					30,634
MUBENDE	85	36,806					36,891
MUKONO	499	51,027					51,527
NAKAPIRIPIRIT		40,824			169,466		210,291
NAKASONGOLA		22,548					22,548
NEBBI	176	9,906					10,083
NTUNGAMO		6,020					6,020
PADER	61	10,386					10,447
PALLISA	271	320					591
RAKAI	85	38,264					38,350
RUKUNGIRI	9	15,121	909		11,396	17,360	44,794
SEMBABULE	23	12,524					12,547
SIRONKO	110		86		0	24,140	24,336
SOROTI	324	4,894					5,219
TORORO	63	700					764
WAKISO	128	6,409		6,894			13,431
YUMBE		30,706					30,706
Total	**4,957**	**1,173,753**	**90,386**				**3,107,618**

Appendix 6: Land Cover distribution in Central Forest Reserves by Districts

District	Hardwood Plantations	Softwood Plantations	Tropical High Forest (Normal)	Tropical High Forest (Depleted)	Woodlands	Bushlands	Grasslands	Wetlands	Subsistence Farmlands	Commercial Farmlands	Built up Areas	Water	Imped-iments	Sub-total
ADJUMANI			1,259		4,601		538							6,398
APAC	29				5,010	958	954	41	4,052	304	26			11,373
ARUA	337	358			21,971	963	3,844		2,766				29	30,268
BUGIRI			1,285	764	2	110	101		143				16	2,421
BUNDIBUGYO			99	49	183		2,585		1,656					4,572
BUSHENYI	16	16	39,479	2,949	844	692	2,896		1,277	112	4	27	0	48,312
BUSIA		15	419	1,631	540	468	218		500		3			3,795
GULU	208	453			17,450	352	3,784	41	7,620		8	0	50	29,965
HOIMA		380	32,102	4,625	15,159		5,137	78	1,994	46	15			59,536
IGANGA	16		552		89	132		39	397					1,225
JINJA	2,835	112		222		1,282	13	130	1,525	5	8			6,131
KABALE		1,857	1,811	156	419		269	33	394		29	23		4,993
KABAROLE	108		3,000	46	856	122	10		131	62	56			4,390
KABERAMAIDO					2,063	88	4	30	383			0		2,569
KALANGALA			5,575		555	150	1,696		583		3	225		8,786
KAMPALA								0			7			7
KAMULI	70				2	108	5		507					692
KAMWENGE			498		197		7		78					781
KANUNGU		1,485			10		422		698					2,615
KAPCHORWA		0							6					6
KASESE	0		38	52	4	40	1,547		214	133				2,029
KATAKWI	3				660		3,037		2,087					5,787
KAYUNGA	421	135		120	4,077	34	2,862	81	490			0		8,220
KIBAALE			22,548	1,165	3,176		2,158	1,594	1,115					31,755
KIBOGA	0	451	2,622	3,105	15,460	335	7,242	331	8,780		2			38,327
KISORO			542				91		90					723
KITGUM					49,051		15,651		3,141			46	17	67,906
KOTIDO					68,635	38,441	33,583		7,070				77	147,807
KUMI	54						27		74					155
KYENJOJO	55	1,835	18,071	2,325	4,080	286	2,408	319	965	102	4		34	30,483
LIRA	39	297			4,531	307	1,729		2,731		9	6		9,649
LUWEERO	18	32			18,535		8,388		313					27,287
MASAKA	113	6	3,336	4,929	319	655	4,135	343	6,098			48		19,982
MASINDI	111	78	46,248	100	46,691	201	4,395	46	2,445	13	14			100,341
MAYUGE	117	125	1,002	12,770	5,693	95	3,637	445	1,944		15	175	8	26,025
MBALE	267						234		37		18			556
MBARARA	221	1,199	3,539	102	449	482	6,261		593		6			12,852
MOROTO					19,418	36,646	10,854		3,199		3		64	70,185
MOYO	11	1			17,760	760	9,274		281					28,087
MPIGI			12,393	6,056	1,932	79	6,497	150	3,192	1	5			30,304
MUBENDE	218	117	2,368	2,022	11,028	210	9,891	269	10,667		1	12	3	36,806
MUKONO	381	200	32,126	11,853	580	836	1,645	853	1,973	254	4	316	6	51,027
NAKAPIRIPIRIT					19,786	9,834	9,532		1,673					40,824
NAKASONGOLA		1,650			10,516	5,010	4,235	82	1,011		43	1		22,548
NEBBI		2,011	187		3,423	346	2,568	54	1,313			5		9,906
NTUNGAMO	4	329			1,577	3	4,052	8	47					6,020
PADER		1			4,810		4,306		1,236		9		23	10,386
PALLISA								191	129					320
RAKAI	22		15,862	589	2,979	2,224	9,367	508	6,709		5	1		38,264
RUKUNGIRI	169		13,634		714		403		196		3			15,121
SEMBABULE	0				1,918	4,181	915		5,504		4			12,524
SOROTI	3	265			1,562	576	369	5	2,096	3	15			4,894
TORORO	80					67	63		488		2			700
WAKISO	119	10	1,332	2,253	1,031	227	171	294	792	166		14		6,409
YUMBE					23,719		6,816		120				50	30,706
Total	**6,045**	**13,418**	**261,924**	**57,886**	**414,066**	**107,298**	**200,828**	**5,965**	**103,525**	**1,202**	**321**	**899**	**377**	**1,173,753**

Appendix 7: Land cover distribution in Local Forest Reserves by Districts

LC5_NAME	Hardwood Plantations	Softwood Plantations	Tropical High Forest (Normal)	Tropical High Forest (Depleted)	Woodlands	Bushlands	Grasslands	Wetlands	Subsistence Farmlands	Commercial Farmlands	Built up Areas	Water	Imped-iments	Sub-total (Ha)
ADJUMANI									56					56
APAC	6				0		15		82		2			105
ARUA	102				2	23	57		461		0			646
BUNDIBUGYO									39					39
BUSHENYI	6						1	3	12		0		1	22
GULU									25					25
HOIMA	25				2			0	4					32
IGANGA	72					0	14		82					169
JINJA							15		133	2				150
KABAROLE	1							2	20		0			23
KABERAMAIDO					5	1			5					11
KAMULI	35						30		15	1	1			82
KAMWENGE	4				0				1					5
KANUNGU	12								24					36
KAPCHORWA	3								0					3
KASESE	17								61	0				78
KATAKWI							13		45					58
KAYUNGA	31	3					12		11					57
KIBAALE	18			0	5				4		1			27
KITGUM									28		2			30
KOTIDO						14			25		2			40
KUMI	31				33	48	43		35					191
KYENJOJO	4				6		0		4		1			14
LIRA	17				12		22		247		0			298
LUWEERO	26				84	21		6	41					178
MASAKA	24				37	86	5		46					199
MASINDI					46		15	3	6					70
MBALE	27								40					68
MBARARA	26						35		1					61
MOYO								2	17					19
MPIGI	15			85	14	47	56		112					330
MUBENDE			34				1		50					85
MUKONO			236	135	14		84	2	7			22		499
NEBBI	62				45	4		0	65					176
PADER					20				38		3			61
PALLISA					4		30	91	146					271
RAKAI	5				10	23	24		24					85
RUKUNGIRI	4						1		4					9
SEMBABULE									23					23
SIRONKO	2						20	66	22		0			110
SOROTI	0				171	81	39	1	33		0			324
TORORO						23	4		36					63
WAKISO			39	15			68		7					128
Total	**575**	**3**	**309**	**235**	**512**	**371**	**602**	**177**	**2,136**	**4**	**11**	**22**	**1**	**4,957**

Appendix 8: Land cover distribution in National Parks, NPs.

NAME of NP	Hardwood Plantations	Softwood Plantations	THF(Normal)	THF(Depleted)	Woodlands	Bushlands	Grasslands	Wetlands	Subsistence Farmlands	Commercial Farmlands	Built up Areas	Water	Imped-iments	Sub-total
Bwindi Impenetrable	0		31,046		10	0	137	5	821					32,019
Kibale	21	782	44,096	5,351	3,884	6	11,072	1,159	7,789	81	10	146		74,397
Kidepo					4,246	11,951	71,558		194		35			87,984
Lake Mburo					2,461	9,633	19,475	3,848	35			1,492	31	36,975
Mgahinga			2,221	290			1,310	32						3,853
Mt. Elgon		1,491	26,220	29,606	29,502	6,430	18,121		0					111,370
Murchison Falls					167,743	19,591	188,700	5,282	877			4,558		386,750
Queen Elizabeth	6	0	4,524	0	62,048	25,593	69,589	10,913	3,342	0	124	4,014	305	180,458
Rwenzori Mountains			59,952	45	34,426	3,002	1,296		656			95		99,472
Semuliki			19,544	1,180	7		938	17	160			204		22,050
Total (Ha)	**27**	**2,273**	**187,602**	**36,473**	**304,327**	**76,207**	**382,196**	**21,256**	**13,874**	**81**	**169**	**10,508**	**336**	**1,035,327**

Appendix 9: Land cover distribution in Game Reserves

NAME of GR	Hardwood Plantations	Tropical High Forest (Normal)	Woodlands	Bushlands	Grasslands	Wetlands	Subsistence Farmlands	Built up Areas	Water	Imped-iments	Total (Ha)
Ajai's			9,770	226	3,964	1,076	810		17		15,863
Bokora Corridor			1,311	14,492	194,861		2,380				213,044
Bugungu		363	25,713	3,510	4,383	468	1,838	3			36,275
Chambura		223	1,626	6,611	4,718	540	1,511		294		15,522
Jie			135	2,637	4,294						7,066
Karuma		611	43,855	325	11,429		660		553		57,433
Katonga			1,209		18,869	408	554				21,040
Kigezi	0	1,861	2,738	511	7,465		5,788	7			18,371
Matheniko			18,235	54,262	76,703						149,199
Pian-Upe			15,638	19,297	170,552	1,417	25	15		10	206,955
Toro			24,675	1,309	26,610	953	1,939	8	38		55,533
Total	**0**	**3,057**	**144,905**	**103,179**	**523,848**	**4,862**	**15,505**	**33**	**902**	**10**	**796,302**

Appendix 10: Land Cover distribution in DJMs

NAME of DJM	Tropical High Forest (Normal)	Tropical High Forest (Depleted)	Woodlands	Bushlands	Grasslands	Wetlands	Subsistence Farmlands	Commercial Farmlands	Water	Sub-total
Kisangi	611	1,439	1,049	102	626	43	1,005	0	1	4,877
Lomej			10		393					403
Lopeichubei			42		1,088					1,130
Morongole			1,812		5,545					7,357
Namatale		731								731
North Maramagambo	22,657	133	4,759	691	665	275	1		112	29,294
Nyangea-Napore			3,595	1,024	6		415			5,041
South Maramagambo	907				2					909
Zulia			597	7,209	32,839					40,645
Total	**24,175**	**2,304**	**11,864**	**9,026**	**41,164**	**318**	**1,421**	**0**	**113**	**90,386**

Appendix 11: Status of Forest Reserves (Deforestation and Forest Degradation) in Central Forest Reserves

Forest Name	Total Area	Degraded	Deforested	Degraded %	Deforested %
Abili	5		5		100%
Acet	262		262		100%
Aduku (South)	16		16		100%
Aloro	253		253		100%
Aminakulu	261		261		100%
Apac	5		5		100%
Apworocero	237		237		100%
Ayer (Lira Road)	11		11		100%
Bala (North)	7		7		100%
Banda Nursery	2		2		100%
Bugiri	16		16		100%
Kabale	133		133		100%
Kaniabizo	39		39		100%
Kimaka	47		47		100%
Kyantuhe	204		204		100%
Lela-Olok	219		219		100%
Mataa	107		107		100%
Matidi	237		237		100%
Nagongera (East)	20		20		100%
Nagongera (West)	139		139		100%
Nakawa Forestry Research	5		5		100%
Nakwiga	116		116		100%
Ngeta	15		15		100%
Nyaburongo	172		172		100%
Obel	234		234		100%
Ojwiting	262		262		100%
Pajimu	166		166		100%
Rushaya	29		29		100%
Tebakoli	20		20		100%
Kagwara	373		370		99%
Fort Portal	72		70		98%
Kabango-Muntandi	361		347		96%
Gung-Gung	301		289		96%
Okurango	244		232		95%
Ilera	153		145		95%
Rukungiri	24		23		94%
Opok	536		504		94%
Kapchorwa	6		6		93%
Olia	212		196		93%
Aneneng	259		240		93%
Bundikeki	401	34	367	9%	91%
Ayito	231		211		91%
Onyurut	155		142		91%
Mwiri	135		122		90%
Namalemba	51		46		90%
Opaka	208		186		89%
Kajansi	312		278		89%
Lusiba	656		583		89%
Lagute	341		302		89%
Ongom	220		193		88%
Acwao	249		212		85%
Pokoli	18		15		85%
Kijanebalola	3,019		2,575		85%
Opit (part)	5,055		4,212		83%
Epor	223		185		83%
Bugondo Hill	1,002		822		82%
Telwa	310		253		82%
Kabugeza (Kasanda)	279		218		78%
Olwal	1,390		1,081		78%
Buyaga Dam (part)	15,870		12,070		76%

Forest Name	Total Area	Degraded	Deforested	Degraded %	Deforested %
Aduku (North)	12		9		76%
Kalagala Falls	100		75		75%
Ave	783		576		74%
Atungulo	185		134		72%
Bululu Hill	426		308		72%
Kumbu (North)	15		11		72%
Kisangi (part)	481	98	344	20%	72%
Ogom	795		565		71%
Lokung	1,426		1,009		71%
Keyo	781		546		70%
Muinaina	1,041		722		69%
Ogera Hill	427		296		69%
Abera	1,186		818		69%
Kitubulu	76		52		69%
Kaliro	105		71		68%
Abuya	110		73		67%
Lokiragodo	119		79		66%
Barituku	151		100		66%
Alito	18		12		66%
Buga	268		167		62%
Mulundu	92	1	57	1%	62%
Kasolo	3,168		1,949		62%
Bobi	5		3		58%
Aram	139		81		58%
Lukodi	153		88		58%
Aboke	13		7		57%
Iziru (part)	615		346		56%
Gweri	156		86		55%
Mpinve	1,839		1,006		55%
Kabira	123	7	66	5%	54%
Paonyeme	361		195		54%
Monikakinei	159		85		54%
Luwunga	9,383	1,599	4,973	17%	53%
Onekokeo	258		134		52%
Kagoma	278		142		51%
Ogur	10		5		49%
Lobajo	112		54		48%
Wati	771		370		48%
Ngereka (part)	1,208		565		47%
Tororo	387		180		46%
Bwambara	37		17		45%
Soroti	134		61		45%
Bugana	154		69		45%
Namasiga-Kidimbuli (part)	474		213		45%
Amuka	1,100		488		44%
Walulumbu	120		52		43%
Bukakata	13	7	5	56%	42%
Wangu	31		13		42%
Kamera	124		50		41%
Sala	320		129		40%
Lubani	473		190		40%
Kasega	105		42		40%
Ayami	332		128		39%
Gulu	94		36		38%
Alungamosimosi	4,762		1,813		38%
Kitemu	65		25		38%
Walugogo	41		15		37%
Goyera	986	50	367	5%	37%
Madoci	357		130		36%
Lul Kayonga	111		38		34%
Namasagali	55		19		34%
Kulua	606		204		34%
Kyamazzi	4,828		1,569		33%
Kulo-Obia	212		68		32%

Forest Name	Total Area	Degraded	Deforested	Degraded %	Deforested %
Kasana-Kasambya	5,085		1,618		32%
Buwaiswa	34		11		31%
Lendu	2,358		730		31%
Liru	496		152		31%
Masindi	40		12		31%
Kasokwa	69	48	21	69%	31%
Namavundu	684		207		30%
Kitonya	862		259		30%
Buwa	360	215	107	60%	30%
Sitambogo	627		186		30%
Kyampisi	1,536	828	452	54%	29%
Buhungiro	1,048		305		29%
Maseege	938		264		28%
East Uru	465		130		28%
Kitasi	279	97	77	35%	28%
Buturume	189		52		28%
Ochomil	264		72		27%
Nyabyeya	355		96		27%
Kagadi	12		3		27%
Jumbi	356		94		26%
Kandanda-Ngobya	2,563	10	678	0%	26%
Nakaga	268	199	69	74%	26%
Nakaziba	99		25		26%
Budunda	105		27		25%
Namanve (part)	2,230	208	557	9%	25%
Odudui	192		48		25%
Guramwa	1,526		378		25%
Abunga	233		55		24%
Nadagi	457	73	108	16%	24%
Namazingiri	214		50		24%
Otrevu	562		129		23%
Bikira	28		6		23%
Kafu	2,635		590		22%
Mutai	262		58		22%
Mbarara	193		42		22%
Kasongoire (part)	3,080	251	664	8%	22%
Busembatya	15		3		21%
Nsowe	5,051		1,083		21%
Achuna	164		35		21%
Akileng	605		129		21%
Bugaali	116		24		21%
Buyenvu	632		128		20%
Makoko	35		7		20%
Mukambwe	195	126	39	65%	20%
Muko	167		33		20%
Ibamba	311		61		20%
Butamira	1,248		241		19%
Walugondo	153	3	30	2%	19%
Namwasa	8,146	1	1,568	0%	19%
Kanangalo	2,652		510		19%
Kajonde	345	101	66	29%	19%
Awer	220		42		19%
North Rwenzori (part)	3,532	15	664	0%	19%
Lukalu	225		42		19%
Nyabigoye	478	354	89	74%	19%
Pigire	693		128		19%
Kyewaga	229		42		18%
Kachung	3,635		667		18%
Zimwa	846		153		18%
Kateta	159		28		18%
Kisombwa	2,903		517		18%
Kabukira	460		81		18%
Nfuka-Magobwa	1,639		289		18%
Nyamakere	3,934		690		18%

Forest Name	Total Area	Degraded	Deforested	Degraded %	Deforested %
Lodonga	106		19		17%
Kasenyi	199		34		17%
Mako	298	66	51	22%	17%
Taala	8,784	1,456	1,500	17%	17%
Nabukonge	185	2	31	1%	17%
Bumude-Nchwanga	316	10	53	3%	17%
Aminkec	246		41		17%
Kyirira	94		15		17%
Musamya	739	596	122	81%	16%
Rwengiri	155		25		16%
Kigulya Hill	412		66		16%
Lufuka	269	93	42	35%	16%
Akur	6,279		982		16%
Kasa	1,164	57	179	5%	15%
Kazooba	7,325		1,120		15%
Kumbu (South)	47		7		15%
Kadre	776		117		15%
Kijwiga	260		39		15%
Kagogo	1,393		209		15%
Musoma	271		41		15%
Ogata-Akimenga	522		78		15%
Oruha	344		51		15%
West Uru	288		42		15%
Mburamaizi	505		73		14%
Kampala	132		19		14%
Lira	142		20		14%
Ajuka	256		35		14%
Kyahaiguru	427		59		14%
Bukaleba	9,536	231	1,293	2%	14%
Lutoboka	380		51		14%
Ating	1,254		169		13%
Bwezigolo-Gunga	5,138		691		13%
Bugonzi	385		51		13%
Nyakunyu	461		60		13%
Wadelai	578		75		13%
Eria	533		69		13%
Kyamugongo	119	56	15	48%	13%
Bulondo	466	391	57	84%	12%
Enyau	380		46		12%
Nambale (Kasa South)	230		28		12%
Kinyo	260		31		12%
Mbale	1,768		207		12%
Mafuga (part)	3,697		433		12%
Wantagalala	230	203	27	88%	12%
Nakalere	687		79		12%
Kalandazi	591	274	68	46%	11%
Kyalubanga	4,505		513		11%
Bugamba	1,209		137		11%
Kafumbi	335	68	38	20%	11%
Nawandigi	3,952	1,451	443	37%	11%
Ogili	5,275		589		11%
Alui	574		64		11%
Kasala	289	154	32	53%	11%
Katabalalu (part)	1,324	152	146	11%	11%
Enjeva	729		80		11%
Mulega	93		10		11%
Sambwa	282		30		11%
Naludugavu	174	55	19	31%	11%
Yubwe	188	6	20	3%	11%
Okavu-Reru	416		44		11%
Abuje	250		26		10%
Kyehara	481		50		10%
Degeya	252	22	26	9%	10%
Nyangea-Napore (part)	37,146		3,854		10%

Forest Name	Total Area	Degraded	Deforested	Degraded %	Deforested %
Abiba	2,008		205		10%
Rwensama	122		12		10%
Kalangalo	333	65	34	19%	10%
Bulogo	8		1		10%
Kabindo	1,415		142		10%
Kakasi	781		78		10%
Kyabona	122		12		10%
Nakitondo	172	103	17	60%	10%
Buziga	90		9		10%
Navugulu	2,590	132	238	5%	9%
Rukara	449		41		9%
Suru	369		33		9%
Wiceri	6,508		577		9%
Nakwaya	480		42		9%
Wamasega	196	163	17	83%	9%
Gangu	1,081	283	95	26%	9%
Lwala	5,876		505		9%
Namawanyi & Namananga	457		39		9%
Nangolibwel	19,795		1,688		9%
Nakuyazo	348	1	30	0%	8%
Bala (South)	9		1		8%
Nonve	724	659	61	91%	8%
Echuya (part)	3,586	156	298	4%	8%
Kikonda	12,042		996		8%
Arua	237		19		8%
Makokolero	100		8		8%
Wabinyomo	243	223	20	92%	8%
Zirimiti	912	306	74	34%	8%
Walumwanyi	301	239	24	79%	8%
Atiya	199		16		8%
West Bugwe	3,011	1,631	234	54%	8%
Ayer (1959 eucalyptus)	3		0		8%
Namyoya	399	121	30	30%	8%
Fumbya	423		31		7%
Kano	8,241		607		7%
Ajupane	471		35		7%
Wamale	1,925		140		7%
Bulijjo	114		8		7%
Arweny	323		22		7%
Nyabiku	374	5	25	1%	7%
Tumbi	518	207	35	40%	7%
Kasozi	41		3		7%
Kifu	1,411	533	94	38%	7%
Moroto	48,261		3,202		7%
Awang	164		11		7%
Laura	2,744		179		7%
Kiula	2,180		139		6%
Kagongo	123		8		6%
Alit	193		12		6%
Wambabya	3,422	1,311	211	38%	6%
Bukone	139		9		6%
Wantayi	241	143	15	59%	6%
Aminteng	228		14		6%
Namakupa	285	9	17	3%	6%
Kavunda	140	72	8	51%	6%
Mugomba	698	210	41	30%	6%
Banga	176		10		6%
Semunya	717	189	42	26%	6%
Mubuku	1,689		98		6%
Nile Bank	553	222	32	40%	6%
Kikumiro	721		41		6%
Luvunya	884	146	50	16%	6%
Buvuma	1,092	266	62	24%	6%
Kasonke	131		7		5%

Forest Name	Total Area	Degraded	Deforested	Degraded %	Deforested %
Rwensambya	672		37		5%
Kisisita	831	132	45	16%	5%
Kabulego	168	159	9	95%	5%
Achwali	369		20		5%
Dakabela	205		11		5%
Lwamunda	4,455	1,597	230	36%	5%
Maruzi	6,101		309		5%
Nakindiba	140	132	7	94%	5%
Ruzaire	1,195		60		5%
Nanfuka	296		15		5%
Kanjaza	319	247	15	78%	5%
Igwe	1,108	533	52	48%	5%
Mujuzi	5,723	342	254	6%	4%
Mpanga	1,012	14	43	1%	4%
Lemutome	120		5		4%
Mabira	29,566	7,099	1,215	24%	4%
Atigo	962		39		4%
Kadam	40,824		1,673		4%
Nakalanga	1,632	114	67	7%	4%
Angutewere	281		11		4%
Kyalwamuka	6,525		262		4%
Ozubu	700		28		4%
Kasagala	10,105		397		4%
Katabalalu (part)(Wegami)	20		1		4%
Kyansonzi	692	269	27	39%	4%
Kigona River (part)	903	448	35	50%	4%
Ihimbo	477		18		4%
Bira	309	139	12	45%	4%
Namafuma	104		4		4%
Kibego	1,275	77	47	6%	4%
Usi	433		16		4%
Irimbi	288	86	10	30%	4%
Kalinzu	13,984	1,120	496	8%	4%
Morongole	8,127		277		3%
Sirisiri	474		16		3%
Kyamurangi	423		14		3%
Kisakombe	213	85	7	40%	3%
Kizinkuba	636	99	21	16%	3%
Kitonya Hill	299		10		3%
Ayipe	891		29		3%
Otukei (part)	2,024		63		3%
Kasyoha-Kitomi (part)	38,467	1,930	1,186	5%	3%
Ibambaro	3,701		114		3%
South Busoga	16,107	12,539	493	78%	3%
Kisasa	318	227	10	71%	3%
Matiri	5,472		166		3%
Kalombi	3,803		114		3%
Bajo	3,313		92		3%
Katakwi	32		1		3%
Bujawe	4,965	450	133	9%	3%
Towa	1,486		39		3%
Nabanga	463	27	12	6%	3%
Bukaibale	1,164	333	28	29%	2%
Kaweri	1,231	54	30	4%	2%
Mwola	621	97	15	16%	2%
Kagombe	17,751	339	419	2%	2%
Koko	234		5		2%
Wabisi-Wajala	4,457		104		2%
Muhangi	1,881	19	44	1%	2%
Achwa River	8,546		198		2%
Natyonko	1,233	303	29	25%	2%
Luwafu	397	13	9	3%	2%
Ayer (Bala Road)	9		0		2%
Kagorra	4,302	2,223	95	52%	2%

Forest Name	Total Area	Degraded	Deforested	Degraded %	Deforested %
Namatiwa	1,616	569	35	35%	2%
Anyara	123		3		2%
Rwengeye	324		7		2%
Itwara	8,680	6	186	0%	2%
Alerek	7,410		155		2%
Iyi	2,402		50		2%
Wabitembe	284	74	6	26%	2%
Nakiza	665	205	13	31%	2%
Kanaga	661		12		2%
Kifunvwe	189		3		2%
Rwoho	9,054		163		2%
Buloba	272	169	5	62%	2%
Kabuye	147	54	2	37%	1%
Parabongo	2,805		41		1%
Mukihani	3,672	107	53	3%	1%
Jubiya	4,766	3,796	69	80%	1%
Bugoma	39,949	2,433	561	6%	1%
Otzi (West)	422		6		1%
Lukuga	108		1		1%
Busowe	1,758		23		1%
Kapimpini	6,068		71		1%
Katuugo	3,481		40		1%
Nkera	750		8		1%
Ochomai	233		2		1%
Kilak	10,298		104		1%
Got-Gweno	2,251		22		1%
Luwawa	363	55	3	15%	1%
Budongo (part)	81,660	40	757	0%	1%
Napono (part)	3,762		32		1%
Wakayembe	172	60	1	35%	1%
Gwengdiya	170		1		1%
Oliduro	210		2		1%
Nyakarongo	3,490	14	23	0%	1%
South Maramagambo	14,398		87		1%
Kachogogweno	407		2		1%
Lul Oming	366		2		1%
Kumi	29		0		1%
Otzi (East)	18,527		91		0%
Sozi	232	40	1	17%	0%
Nsekuro Hill	131		1		0%
Kubanda	213		1		0%
Kahurukobwire	1,047	5	4	0%	0%
Along-Kongo	154		1		0%
Kasato	2,600		9		0%
Kyahi	4,259		14		0%
Kijuna	1,159		4		0%
Mugoye	949		3		0%
Rom	10,863		26		0%
Era	7,404		17		0%
Nsube	853		2		0%
Kitechura	5,332		11		0%
Buuka	320		1		0%
Lamwo	2,407		2		0%
Kaduku	557		0		0%
Agoro-Agu	26,266		23		0%
Mt. Kei	41,532		35		0%
Nalubaga	249	141	0	57%	0%
Wankweyo	4,938		3		0%
Luleka	405	58	0	14%	0%
Omier	2,314		0		0%
Labala	1,673		0		0%
Malabigambo	11,078	1	0	0%	0%
Adero	251		0		0%
Aringa River	38		0		0%

Forest Name	Total Area	Degraded	Deforested	Degraded %	Deforested %
Bufumira	340		0		0%
Bugomba	270		0		0%
Bugusa	259		0		0%
Bukedea	16		0		0%
Buluku	295		0		0%
Bunjazi	80		0		0%
Buwanzi	472	84	0	18%	0%
Funve	165		0		0%
Gala	870		0		0%
Izinga Island	107	30	0	28%	0%
Kabwika-Mujwalanganda	8,277		0		0%
Kaiso	1,892		0		0%
Kakonwa	756	87	0	11%	0%
Kamukulu	5		0		0%
Kamusenene	6,121		0		0%
Kande	238	111	0	47%	0%
Kibeka	9,628		0		0%
Kigona (part)	351	305	0	87%	0%
Kihaimira	551	451	0	82%	0%
Kijogolo	282		0		0%
Koja	246	92	0	37%	0%
Kuzito	153	55	0	36%	0%
Lajabwa	45		0		0%
Lalak	2,198		0		0%
Linga	38		0		0%
Lomej	360		0		0%
Lotim-Puta	1,894		0		0%
Lukale	383		0		0%
Lukolo	168		0		0%
Luku	3,989		0		0%
Lul Opio	247		0		0%
Luwungulu	26		0		0%
Mala Island	1		0		0%
Manwa (South East)	176	109	0	62%	0%
Muhunga	412		0		0%
Nakunyi	121	40	0	33%	0%
Namabowe	129	103	0	80%	0%
Namalala	2,397		0		0%
Namatembe	248		0		0%
Napak	21,924		0		0%
Ngogwe (Bwema Island)	63	30	0	47%	0%
Nimu	330	13	0	4%	0%
Nkese	7		0		0%
Nkogwe	296	57	0	19%	0%
Nkose	128		0		0%
Ntungamo	13		0		0%
Ocamo-Lum	239		0		0%
Olamusa	400	183	0	46%	0%
Rugongi	5		0		0%
Sekazinga	0		0		0%
Tero (East)	1,070		0		0%
Tero (West)	2,683		0		0%
Timu	12,179		0		0%
Tonde	74		0		0%
Zoka	6,148		0		0%
Zulia	51,635		0		0%
	1,173,753	**57,886**	**105,048**	**5%**	**9%**

Appendix 12: Status of Forest reserves: Local Forest Reserves

FD_NAME	Total	Degraded	Deforested	Degraded %	Deforested %
Abako	4		4		100%
Achaba	1		1		100%
Achilet	17		17		100%
Acholi-Bur	3		3		100%
Adekokwok	8		8		100%
Adilang	3		3		100%
Adjumani	48		48		100%
Adwari	13		13		100%
Agwata	12		12		100%
Alido	5		5		100%
Alik	8		8		100%
Amaich (Ginnery)	13		13		100%
Amaich (H/Q)	15		15		100%
Amugo	8		8		100%
Anaka	3		3		100%
Anyeke	5		5		100%
Apala	10		10		100%
Atan	11		11		100%
Atanga	2		2		100%
Atura	10		10		100%
Awere	6		6		100%
Bata (North)	5		5		100%
Bata (South)	5		5		100%
Busegula	48		48		100%
Busumbu	8		8		100%
Butiti	2		2		100%
Chegere	7		7		100%
Cwero	8		8		100%
Dokolo	9		9		100%
Ekwera	8		8		100%
Erusi	21		21		100%
Giligili	28		28		100%
Icheme	16		16		100%
Kamigo	37		37		100%
Kamuli	5		5		100%
Kangai	15		15		100%
Kitgum	5		5		100%
Koboko	19		19		100%
Koch-Goma	5		5		100%
Labongo	5		5		100%
Logiri	16		16		100%
Ludara	34		34		100%
Manibe	56		56		100%
Mateme	45		45		100%
Mbaraka	8		8		100%
Mutufu	16		16		100%
Naam-Okora	4		4		100%
Namukonge	5		5		100%
Nsinze (North & South)	13		13		100%
Ntusi	23		23		100%
Nyakikindo	39		39		100%
Nyakinoni	5		5		100%
Omoro	9		9		100%
Orom	5		5		100%
Orumo	5		5		100%
Otwal	6		6		100%
Pabbo	7		7		100%
Pader-Palwo	3		3		100%
Padibe	6		6		100%

FD_NAME	Total	Degraded	Deforested	Degraded %	Deforested %
Paicho	2		2		100%
Pakelle	8		8		100%
Palabek	5		5		100%
Teiponga	56		56		100%
Aloro (Ngonyeboke)	7		7		100%
Oluvu	79		78		99%
Alebtong	12		12		99%
Maracha	22		21		98%
Pakwach	13		12		97%
Eruba	8		8		96%
Oduarata	90		86		96%
Ovuju (West)	48		45		94%
Kanyampara	62		58		94%
Aputi	13		12		92%
Nyakigumba	11		10		91%
Laropi	19		17		91%
Kolonyi	20		17		85%
Ovuju (East)	87		73		84%
Ozu	9		7		82%
Ngai	1		1		81%
Ezuku (North & South)	18		14		79%
Kibale	1	0	1	22%	78%
Kango	18		14		78%
Asuret	58		45		77%
Wabirago	65	17	49	25%	75%
Kagogo	3		2		74%
Butebe	7		5		74%
Nakiwondwe	8		6		72%
Kalungu	18		13		72%
Wakatanga	50		36		72%
Bukigai	19		13		71%
Kaswera	58	18	39	31%	69%
Kyakumpi	11		7		68%
Kihihi	36		24		67%
Kaabong	40		27		66%
Kooga	11		7		65%
Nawaikona	12		8		63%
Mubende	85		50		59%
Jami	13		7		58%
Nyapea	8		5		58%
Bunafu	30		17		57%
Matale	32		18		57%
Yivu	50		28		57%
Jaka	44		24		54%
Kyamuhunga	8		4		53%
Awelo	13		7		52%
Goligoli	45		23		51%
Bulyabwita	5		3		49%
Mudakoli	31		15		49%
Kidiki	11		5		48%
Aloi	22		10		48%
Rakai	12		6		47%
Amanamana	11		5		45%
Kyere	13		6		44%
Hoima	5		2		41%
Manwa (South West)	13		5		40%
Aber	10		4		40%
Molitar	27		10		37%
Ongwara	10		4		37%
Achwera	21		8		37%

FD_NAME	Total	Degraded	Deforested	Degraded %	Deforested %
Kebisoni	6		2		35%
Nakasenyi	20		7		35%
Bombo	65		22		34%
Lumoto	93		30		32%
Koreng	70		21		31%
Kanginima	16		4		28%
Bugembe	20		6		28%
Katenta	5		1		28%
Utumbari	80		21		26%
Nabieso	8		2		25%
Lwengo	21		5		25%
Aburiburi	40		9		22%
Nabika	86		17		20%
Kabwohe	3		1		20%
Nazigo	57		11		19%
Nebbi	10		2		19%
Sembula	45		8		18%
Obule	39		7		17%
Nabijoka	45		8		17%
Budugade	61	51	10	83%	17%
Kachumbala	22		4		17%
Nyabirongo	16		3		17%
Odruwa	18		3		16%
Binyin	3		0		15%
Palango	11		2		15%
Nabukolyo	31		4		13%
Kirebe	51		6		13%
Kakumiro	26		3		12%
Omodoi	55		6		12%
Jerere	80		9		12%
Kahunge	5		1		10%
Nyantungo	6		1		9%
Kuluva	10		1		9%
Bowa	10		1		9%
Bubolo	21		2		9%
Kijubya	27		2		8%
Gunda	60	3	5	4%	8%
Manwa (North)	90		7		8%
Kalo	77		6		7%
Makoka	19		1		7%
Nyagak	39		3		7%
Mpara	1		0		6%
Buwola	27		1		5%
Ibanda	14		1		4%
Mafudu	11		0		4%
Ongino	36		1		4%
Nambuga	68	12	2	18%	3%
Kabola	34		1		3%
Namasale	10		0		1%
Mbulamuti	32		0		1%
Bwizibwera	28		0		0%
Amorokin	85		0		0%
Buzimba	24		0		0%
Kabula	41		0		0%
Kabuna	30		0		0%
Kalagala (Busakwa)	16		0		0%
Kamachya	24		0		0%
Kaptokoi	86		0		0%
Kidetok	9		0		0%
Kinoni	18		0		0%

FD_NAME	Total	Degraded	Deforested	Degraded %	Deforested %
Masindi Port	19		0		0%
Mawanga	10		0		0%
Nsese	38		0		0%
Nyio-Bamboo	57		0		0%
Olilim	5		0		0%
Ragem	45		0		0%
Kirigye	54	47	0	88%	0%
Nawaitale	87	39	0	45%	0%
Namunyoro	93	24	0	26%	0%
Buduli	65	11	0	18%	0%
Kerenge	74	10	0	13%	0%
Kasulo	58	4	0	6%	0%
	4,957	235	2,151	5%	43%

Appendix 13: Biomass by District

District	Hardwood Plantations	Softwood Plantations	Tropical High Forest (Normal)	Tropical High Forest (Depleted)	Woodlands	Bushlands	Grasslands	Wetlands	Subsistence Farmlands	Commercial Farmlands	Built up Areas	Sub-total
ADJUMANI			284		4,480	20	543	7	1,050	7	7	6,398
APAC	17				1,988	211	922	9	5,591	14	10	8,761
ARUA	176	59			6,549	598	448	6	2,664	1	13	10,516
BUGIRI	0		323	150	709	59	75	5	1,910	14	7	3,251
BUNDIBUGYO			10,320	239	1,196	48	729	8	702		1	13,243
BUSHENYI	112	2	12,979	341	423	141	257		449	0	12	14,717
BUSIA	1	2	96	174	194	44	19	2	644	2	7	1,188
GULU	26	73			14,363	420	1,801	5	5,456	4	18	22,166
HOIMA	4	65	11,451	2,929	3,047	68	802	1	1,302	0	8	19,677
IGANGA	15		129		118	62	37	10	5,993	0	13	6,378
JINJA	311	28	5	10	14	30	1		606	0	44	1,050
KABALE	99	280	1,820	32	8	9	85		551		14	2,899
KABAROLE	83	117	6,516	562	548	3	206		481	0	15	8,531
KABERAMAIDO					703	27	186	5	1,908		1	2,830
KALANGALA			4,170	5	334	10	71		415		0	5,006
KAMPALA	3			40	1	11	1		90	0	195	340
KAMULI	30	3			993	167	508	30	6,081	2	14	7,826
KAMWENGE	3		4,770	90	1,420	46	701	1	641	0	2	7,674
KANUNGU	18	223	4,235	31	562	39	106		391	0	2	5,606
KAPCHORWA	1	224	4,333	1,311	493	106	409		221		3	7,099
KASESE	15	0	8,620	198	1,495	191	311		191	0	29	11,051
KATAKWI	1				527	2	3,440	5	5,088		11	9,073
KAYUNGA	56	21	16	43	259	211	345	9	1,834	3	7	2,802
KIBAALE	3		13,327	3,258	3,960	53	592	0	2,337		7	23,537
KIBOGA	0	74	515	180	6,241	172	1,223	7	2,332	1	3	10,748
KISORO	11	0	2,301	27		2	17		221		5	2,585
KITGUM					13,736	141	2,101		3,486		8	19,472
KOTIDO	1				4,757	1,947	5,426		647		3	12,781
KUMI	12				266	181	991	8	2,855	4	9	4,325
KYENJOJO	22	299	7,735	799	4,721	47	836	2	3,232	1	4	17,700
LIRA	7	45			1,715	162	1,278	8	7,565	7	24	10,811
LUWEERO	7	5	21	694	7,959	87	1,103	14	6,140	0	12	16,042
MASAKA	115	1	1,115	1,063	214	109	552		501	0	23	3,692
MASINDI	27	17	12,722	184	11,772	351	2,317	10	1,111	33	22	28,565
MAYUGE	12	21	199	1,226	341	53	110		1,377	0	4	3,343
MBALE	37		1,064	988	178	16	48	0	1,018		29	3,378
MBARARA	84	185	721	20	370	1,477	3,358	0	894	0	26	7,135
MOROTO					1,213	1,773	2,631		263		6	5,886
MOYO	2	0		0	2,580	47	413	8	881		5	3,937
MPIGI	10		4,337	2,391	1,386	120	1,072	2	2,198	0	9	11,525
MUBENDE	69	21	870	2,902	3,918	561	1,508	3	6,157	9	11	16,028
MUKONO	50	32	12,830	4,703	224	178	260	0	3,476	0	34	21,788
NAKAPIRIPIRIT					815	1,537	2,100	0	105		3	4,560
NAKASONGOLA	0	256			2,694	842	783	12	527	1	18	5,134
NEBBI	14	309	43		880	502	1,055	2	1,576	1	2	4,384
NTUNGAMO	32	50			53	3	272		192		3	605
PADER	0	0			8,732	18	557		6,379		7	15,694
PALLISA	4				36	3	119	24	2,646	2	6	2,841
RAKAI	68		3,379	248	378	322	1,215		252	0	8	5,870
RUKUNGIRI	55		3,292		293	60	179		174		4	4,056
SEMBABULE	7				285	518	1,033	1	117		1	1,962
SIRONKO	3		470	571	330	60	315	0	411		4	2,165
SOROTI	1	43			231	34	775	17	3,294	5	31	4,431
TORORO	20		0	4	93	40	32	14	2,254	43	23	2,523
WAKISO	33	2	1,484	2,184	369	66	161		2,100	0	74	6,472
YUMBE	6				4,845	2	418	1	849		0	6,122
Total (,000 tons)	**1,683**	**2,458**	**136,491**	**27,596**	**126,014**	**14,008**	**46,852**	**236**	**111,825**	**154**	**863**	**468,180**

Appendix 14: Biomass in Protected Areas by District

District	Local Forest Reserves	Central Forest Rserves	Departmental Joint Management	Animal sanctuary	Game Reserves	National Parks		Country Stock	Balance in private
	(000,Tons)	(000,Tons)	(000,Tons)	(000,Tons)	(000,Tons)	(000,Tons)	Total ,000 tons	Total ,000 tons	
ADJUMANI	0	388					388	6,398	6,010
APAC	2	238				0	240	8,761	8,521
ARUA	13	961			405		1,379	10,516	9,136
BUGIRI		365					365	3,251	2,887
BUNDIBUGYO	1	79			1,086	10,168	11,334	13,243	1,909
BUSHENYI	1	7,987	4,428		207	1,166	13,788	14,717	929
BUSIA		281					281	1,188	907
GULU	0	927			0	3,179	4,106	22,166	18,059
HOIMA	2	9,453					9,455	19,677	10,221
IGANGA	9	136					145	6,378	6,233
JINJA	2	330					332	1,050	718
KABALE		710				1,340	2,049	2,899	850
KABAROLE	0	617	60		229	6,255	7,160	8,531	1,371
KABERAMAIDO	0	100					100	2,830	2,729
KALANGALA		1,144					1,144	5,006	3,861
KAMPALA		0					0	340	340
KAMULI	5	15					21	7,826	7,806
KAMWENGE	0	112			198	4,736	5,046	7,674	2,628
KANUNGU	1	229			82	4,479	4,791	5,606	816
KAPCHORWA	0	0			0	6,161	6,161	7,099	938
KASESE	1	30	254			9,623	9,908	11,051	1,143
KATAKWI	1	95					95	9,073	8,978
KAYUNGA	4	192					196	2,802	2,607
KIBAALE	2	4,093			0		4,095	23,537	19,442
KIBOGA		1,633					1,633	10,748	9,114
KISORO		122				2,061	2,183	2,585	402
KITGUM	0	1,535	0				1,536	19,472	17,937
KOTIDO	0	2,313	379		70	732	3,494	12,781	9,287
KUMI	7	6					13	4,325	4,312
KYENJOJO	1	4,075			183	437	4,696	17,700	13,004
LIRA	7	286					293	10,811	10,518
LUWEERO	7	709					716	16,042	15,327
MASAKA	6	1,390					1,396	3,692	2,296
MASINDI	2	13,117			2,257	4,222	19,598	28,565	8,968
MAYUGE		1,643					1,643	3,343	1,700
MBALE	3	17	60			2,186	2,266	3,378	1,112
MBARARA	3	946			1	272	1,221	7,135	5,914
MOROTO		735			2,825		3,560	5,886	2,325
MOYO	0	756					756	3,937	3,180
MPIGI	15	3,610					3,625	11,525	7,899
MUBENDE	10	1,510					1,520	16,028	14,508
MUKONO	54	9,917					9,971	21,788	11,818
NAKAPIRIPIRIT		534			1,052		1,585	4,560	2,974
NAKASONGOLA		587					587	5,134	4,547
NEBBI	9	516					525	4,384	3,859
NTUNGAMO		132					132	605	474
PADER	1	318					319	15,694	15,374
PALLISA	3	3					6	2,841	2,835
RAKAI	1	3,165					3,166	5,870	2,704
RUKUNGIRI	0	2,699	177		477	387	3,740	4,056	316
SEMBABULE	0	89					89	1,962	1,872
SIRONKO	1		8		0	1,264	1,273	2,165	892
SOROTI	6	167					173	4,431	4,258
TORORO	0	12					12	2,523	2,510
WAKISO	16	606		94			716	6,472	5,756
YUMBE		969					969	6,122	5,153
Total	**196**	**82,597**	**5,366**		**9,073**	**58,667**	155,900	**468,180**	**312,280**

Appendix 15. Biomass Dynamics by Districts

District	Hardwood Plantations	Tropical High Forest (Normal)	Tropical High Forest (Depleted)	Woodlands	Bushlands	Grasslands	Wetlands	Subsistence Farmlands	Commercial Farmlands	Built up Areas	**Sub-Total**
ADJUMANI		-232		-277,945	-1,030	-1,993	0	5,814	-2	40	**-275,349**
APAC	-486			-122,279	-5,748	-4,282	0	25,816	-3	54	**-106,928**
ARUA	-4,816			-277,210	-15,997	-1,217	0	17,546	0	72	**-281,622**
BUGIRI	-17	-3,647	-6,979	-44,180	-3,149	-247	0	6,499	-4	40	**-51,683**
BUNDIBUGYO		-55,438	-5,704	-11,155	-105	-2,869	0	2,007		6	**-73,257**
BUSHENYI	-3,586	-28,681	-1,470	-1,432	-415	-1,693	0	12,322	-3	60	**-24,898**
BUSIA	-28	-285	-1,917	-13,520	-2,538	-104	0	3,148	-1	41	**-15,204**
GULU	-219			-737,495	-13,574	-3,351	0	28,711	-1	99	**-725,829**
HOIMA	-74	-396,561	-184,023	-133,429	-5,408	-3,099	0	6,997	-4	42	**-715,559**
IGANGA	-234	-548		-9,086	-2,869	-172	0	13,129	0	69	**289**
JINJA	-1,452	-816	-279	-505	-771	-19	0	2,855	-27	229	**-785**
KABALE	-6,230	-8,325	-1,530	-90	-352	-753	0	8,155	0	69	**-9,056**
KABAROLE	-2,328	-45,291	-10,373	-11,241	-79	-425	0	5,408	-17	72	**-64,273**
KABERAMAIDO				-29,617	-1,369	-913	0	5,382		7	**-26,510**
KALANGALA		-397,998	-460	-8,039	-453	-456	0	426		1	**-406,979**
KAMPALA	-107		-4,089	-58	-465	-4	0	415	0	1,026	**-3,282**
KAMULI	-625			-52,813	-6,530	-1,574	0	15,156	-1	74	**-46,314**
KAMWENGE	-115	-31,781	-1,740	-45,353	-1,449	-1,686	0	7,091	0	9	**-75,024**
KANUNGU	-701	-18,781	-2,716	-8,064	-417	-244	0	4,549	-1	12	**-26,363**
KAPCHORWA	-41	-256	-2,254	-30,925	-2,520	-2,172	0	2,648	-2	17	**-35,504**
KASESE	-606	-83,141	-11,422	-5,849	-2,215	-692	0	6,038	-14	145	**-97,755**
KATAKWI	-9			-32,647	-179	-11,100	0	13,430		59	**-30,446**
KAYUNGA	-485	-1,473	-2,614	-18,827	-8,559	-1,179	0	4,956	-1	35	**-28,146**
KIBAALE	-46	-1,386,547	-277,269	-133,433	-1,538	-2,330	0	10,271		34	**-1,790,857**
KIBOGA	-6	-12,767	-6,007	-278,907	-6,623	-3,893	0	6,800	0	15	**-301,389**
KISORO	-697	-16,765			-55	-66	0	3,311		27	**-14,246**
KITGUM				-815,666	-18,216	-7,555		16,713		42	**-824,682**
KOTIDO	-58			-292,588	-140,703	-24,930		6,841		11	**-451,427**
KUMI	-124			-15,352	-6,082	-3,596	0	10,027	-1	48	**-15,080**
KYENJOJO	-580	-536,600	-79,292	-155,305	-1,712	-2,538	0	10,807	-9	19	**-765,210**
LIRA	-76			-122,211	-4,894	-4,161	0	27,554	-2	131	**-103,658**
LUWEERO	-111	-3,329	-46,387	-407,625	-4,198	-5,350	0	10,636	-1	64	**-456,303**
MASAKA	-3,840	-64,983	-38,924	-9,117	-5,254	-3,998	0	13,205	-1	119	**-112,792**
MASINDI	-588	-90,878	-15,666	-334,459	-11,073	-3,699	0	9,598	-36	117	**-446,685**
MAYUGE	-43	-6,792	-14,297	-2,423	-2,377	-158	0	3,963	-2	20	**-22,110**
MBALE	-908		-20	-407	-626	-249	0	6,055		152	**3,996**
MBARARA	-2,751	-3,916	-576	-28,515	-101,339	-21,799	0	17,078	-1	138	**-141,681**
MOROTO				-53,840	-82,771	-7,252		4,211		33	**-139,618**
MOYO	-25		-42	-101,292	-2,496	-2,210	0	2,241		26	**-103,798**
MPIGI	-267	-205,020	-111,018	-56,661	-6,724	-3,588	0	8,876	-3	48	**-374,359**
MUBENDE	-1,684	-61,043	-182,768	-159,627	-16,327	-4,162	0	19,544	-10	59	**-406,017**
MUKONO	-402	-541,576	-283,102	-11,571	-7,636	-1,418	0	8,885	-49	181	**-836,688**
NAKAPIRIPIRIT				-22,663	-115,005	-7,025	0	1,704	0	12	**-142,977**
NAKASONGOLA	-5			-222,997	-27,713	-3,445	0	3,231	0	95	**-250,834**
NEBBI	-349	-82		-39,975	-14,248	-2,808	0	10,004	0	10	**-47,447**
NTUNGAMO	-1,001			-669	-196	-4,341	0	5,894		16	**-297**
PADER	-12			-474,315	-870	-2,941		22,197		40	**-455,902**
PALLISA	-135			-1,767	-271	-626	0	8,764	-1	33	**5,997**
RAKAI	-2,332	-58,995	-21,814	-21,268	-17,886	-8,558	0	8,387	-1	41	**-122,424**
RUKUNGIRI	-1,364	-6,317		-989	-18	-914	0	4,727		17	**-4,857**
SEMBABULE	-311			-26,466	-31,885	-3,932	0	4,027	0	7	**-58,560**
SIRONKO	-201		-83	-17,256		-956	0	3,135	-1	22	**-15,339**
SOROTI	-20			-9,076	-1,496	-3,358	0	10,755	-1	168	**-3,029**
TORORO	-438	-29	-371	-5,460	-2,321	-257	0	8,985	-12	127	**225**
WAKISO	-667	-132,335	-160,502	-15,341	-2,757	-902	0	6,786	-7	206	**-305,519**
YUMBE	-224			-219,656	-214	-1,721	0	3,319		1	**-218,495**
Total	**-41,426**	**-4,201,228**	**-1,475,709**	**-5,928,654**	**-711,713**	**-184,978**	**0**	**497,028**	**-222**	**4,359**	-12,042,543

.

9. Annexes of National and District land cover Maps

Annex 1: National land cover Map

Annex 2: Adjumani District land cover Map

[Insert map)

Annex 3: Apac District land cover Map

[Insert map)

Annex 4: Arua District land cover Map

[Insert map)

Annex 5: Bugiri District land cover Map

[Insert map)

Annex 6: Bundibugyo District land cover Map

[Insert map)

Annex 7: Bushenyi District land cover Map

[Insert map)

Annex 8: Busia District land cover Map

[Insert map)

Annex 9: Gulu District land cover Map

[Insert map)

Annex 10: Hoima District land cover Map

[Insert map)

Annex 11: Iganga District land cover Map

[Insert map)

Annex 12: Jinja District land cover Map

[Insert map)

Annex 13: Kabale District land cover Map

[Insert map)

Annex 14: Kabarole District land cover Map

[Insert map)

Annex 15: Kaberamaido District land cover Map

[Insert map)

Annex 16: Kalangala District land cover Map

[Insert map)

Annex 17: Kampala District land cover Map

[Insert map)

Annex 18: Kamuli District land cover Map

[Insert map)

Annex 19: Kamwenge District land cover Map

[Insert map)

Annex 20: Kanungu District land cover Map

[Insert map)

Annex 21: Kapchorwa District land cover Map

[Insert map)

Annex 22: Kasese District land cover Map

[Insert map)

Annex 23: Katakwi District land cover Map

[Insert map)

Annex 24: Kayunga District land cover Map

[Insert map)

Annex 25: Kibaale District land cover Map

[Insert map)

Annex 26: Kiboga District land cover Map

[Insert map)

Annex 27: Kisoro District land cover Map

[Insert map)

Annex 28: Kitgum District land cover Map

[Insert map)

Annex 29: Kotido District land cover Map

[Insert map)

Annex 30: Kumi District land cover Map

[Insert map)

Annex 31: Kyenjojo District land cover Map

[Insert map)

Annex 32: Lira District land cover Map

[Insert map)

Annex 33: Luweero District land cover Map

[Insert map)

Annex 34: Masaka District land cover Map

[Insert map)

Annex 35: Masindi District land cover Map

[Insert map)

Annex 36: Mayuge District land cover Map

[Insert map)

Annex 37: Mbale District land cover Map

[Insert map)

Annex 38: Mbarara 38: District land cover Map

[Insert map)

Annex 39: Moroto 39: District land cover Map

[Insert map)

Annex 40: Moyo District land cover Map

[Insert map)

Annex 41: Mpigi District land cover Map

[Insert map)

Annex 42: Mubende District land cover Map

[Insert map)

Annex 43: Mukono District land cover Map

[Insert map)

Annex 44: Nakapiripirit District land cover Map

[Insert map)

Annex 45: Nakasongola District land cover Map

[Insert map)

Annex 46: Nebbi District land cover Map

[Insert map)

Annex 47: Ntungamo District land cover Map

[Insert map)

Annex 48: Pader District land cover Map

[Insert map)

Annex 49: Pallisa District land cover Map

[Insert map)

Annex 50: Rakai District land cover Map

[Insert map)

Annex 51: Rukungiri District land cover Map

[Insert map)

Annex 52: Sembabule District land cover Map

[Insert map)

Annex 53: Sironko District land cover Map

[Insert map)

Annex 54: Soroti District land cover Map

[Insert map)

Annex 55: Tororo District land cover Map

[Insert map)

Annex 56: Wakiso District land cover Map

[Insert map)

Annex 57: Yumbe District land cover Map

[Insert map)