The National Biomass Study,

Forest Department, Uganda.

# TECHNICAL REPORT

# National Biomass Study, Phase I

November 1989 - December 1991

Kampala, 01.09.92

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- All The **National Biomass Study** staff for their dedicated hard work and perseverance throughout the project period.

The above list is not by any means exhaustive. Once again all those who have assisted in this study are gratefully acknowledged.

Knut Velle
Biomass Inventory Specialist

Paul Drichi
Counterpart

# 1 Introduction1 Introduction

In the past all woodfuel came from the forest. It was abundant and no other form of household energy was needed. Forest utilization was sustainable, and the annual cut for woodfuel and other purposes exceeded neither the annual growth of the forests in a particular area nor in Uganda as a whole.

This changed in the 20th century, and deforestation has in the last three to four decades reached alarming levels. The major part is a result of clearing virgin land for agricultural expansion, a consequence of population growth and increased food demand. Commercial timber, charcoal and firewood production, supplying the larger wood consumption centres, have also led to uncontrolled depletion of woodland and forested areas.

Woodfuel is the most significant source of energy in Uganda, and an overwhelming proportion of the population depends on it. Thus the apparent woodfuel scarcity crises in many regions of the country has become a major concern of almost everyone. One of the main objectives of this study is to provide information about the gravity of this concern.

In addition, the resulting environmental/ecological disturbances have led to negative impacts and imbalances in natural water catchment systems, increased soil erosion hazards and possibly more erratic rainfall patterns.

Furthermore, women and children spend more time and effort travelling longer distances to collect firewood. This in turn leads to less time spent on for instance food production or education, thus contributing to an on-going vicious circle.

Serious planning and strong measures are therefore becoming more and more necessary on all levels of Ugandan society: Both the local (community), district, and national levels must act together to change the present trend of increasing woodfuel deficits. This planning should aim at abating the situation in the short term and solving the problem in the long term. For instance, whereas trees are preferable as a woodfuel source, the increasing deficit will necessitate use of bush, grass and agricultural residues until sufficient afforestation combined with shifts to other potential energy sources (e.g. hydro-electric power) have taken place.

Unfortunately, no up-to-date reliable data exist on the current growing stock of woody resources. The currently available data are based on forest inventories of some **Forest Reserves.** However, the major sources of woodfuel are not Forest Reserves, but areas with trees and bushes on public and private land. To date, no assessment of woody resources has been carried out in these areas. The situation is the same in almost all other developing countries.

The **Government of Uganda (GoU)** has recently launched a very ambitious **National Tree Planting Programme (NTPP),** which aims at establishing 3,950 tree nurseries at parish (Resistance Council II)[1] level in all 38 districts of the country. GoU has also announced new environmental legislation where both individual land owners and communities will be forced to plant trees in specific locations (e.g. steep slopes, riverbanks or as border-fences) and in specific volumes (e.g. a minimum of 10% of any private land). The cost of this will be high, though, and funds are scarce. The implementation of NTPP will therefore require both priority decisions and proper planning at all stages. Up-to-date information on the present situation and trends is a necessary prerequisite for this.

The National Biomass Study will provide unique information on the distribution - and indirectly on consumption - of woody biomass in the country. This report from Phase I covers around 13,500 km² around nine urban centres. Phase II, which has just started, will provide similar information for the whole country. The project's computerized **Environment Information System (EIS)** also enables a wide range of environmental analysis, modelling and predictions on the future situation given various types of intervention (or non-intervention) at the relevant political/administrative levels.

The project will therefore provide important inputs to the planning and decision-making process. In addition, the data and information produced can be used as inputs to a number of other potential users working on environment, conservation or natural resource management issues.

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1 For any reader not familiar with the current political/administrative structure in Uganda: These Resistance Councils are established in around 30,000 villages (RC I), 4,000 parishes (RC II), 734 sub-counties (RC III), 149 counties (RC IV), and 38 districts (RC V). In addition there is the national assembly, the National Resistance Council (NRC).

**A more detailed description of Phase II can be found in the "Report from the Review Mission, January/February 1992". This report is available from the National Biomass Study, Forest Department, Nakawa, Kampala.**

# 2 Project Background2 Project Background

The National Biomass Study (NBS) was originally a part of the **Second Power Project** within **The Ministry of Energy**, which included a number of woodfuel-related studies. The project was to be funded through loans from the **International Development Association (IDA)**, which is part of the **World Bank** group.

Under this project, provision was made for charcoal marketing and household energy surveys and a biomass inventory of public and private land. The biomass inventory, which was to deal with the country's woody biomass resources, was found to be closely related to the **Forest Inventory** of the main industrial and wood productive areas in the country, a project to be carried out under the IDA-supported **Uganda Forest Rehabilitation Project (UFRP)**. It was therefore decided that the National Biomass Study should be carried out in close cooperation with this forest inventory project.

Thus, in 1987, the Government of Uganda, the World Bank and the **Norwegian Ministry of Development Cooperation** agreed that the latter should take over the responsibility for the financial and technical assistance in preparing the detailed Terms of Reference, work plan and cost estimates for the National Biomass Study. **The Norwegian Forestry Society (NFS)** was selected as the implementing agency in cooperation with the **Biometrics Section** of The Forest Department, within the then **Ministry of Environment Protection (MEP)**. MEP has later been merged with other ministries to form the **Ministry of Water, Energy, Minerals and Environment Protection (MWEMEP).**

A planning team comprising Mr. **Andreas Fitje,** Senior Lecturer in forest mensuration (The Agricultural University of Norway), Mr. **Trygve Refsdal,** Forest Management Specialist (Orgut A/S Oslo) and Mr. **Arnulf Ødegaard,** Head of Department/International Forestry Development (NFS), travelled to Uganda in November 1987. After meetings and discussions with Forest Department Staff plus field visits, the planning team submitted a final report in January 1988 called "*National Biomass Study - Uganda - Project Description*". It included a work plan for the implementation of the study, covering Uganda's main woodfuel, pole and fodder supply areas.

The study, expected to last 4 years, was planned in two phases:

(I) **Phase I** (2 years) was initially targeted at ten wood deficit urban areas and larger wood consumption areas. Its aim was to provide detailed and cost specific data on the biomass energy resources in these areas. The number of areas was later reduced to nine, since Kitgum had to be left out. The prevailing insecurity did not allow the Biomass Unit to carry out aerial photography and ground sampling in this area.

(II) **Phase II** (2 years), commencing immediately after Phase I, was designed to provide more general information with regard to the biomass energy resources and the land use in Uganda as a whole. It should serve as a basis for natural resource policy decisions, land use planning and energy planning on global, national and district levels.

The project description also included detailed cost estimates for both phases. A total sum of 14.3 million Norwegian Kroner, equivalent to USD 2.2 mill, was eventually granted by the **Norwegian Agency for Development Cooperation (NORAD)**. The grant was to be disbursed during the four year period of the project, covering investment and recurrent costs.

Finally, detailed Terms of Reference for the **Biomass Inventory Specialist, Remote Sensing Specialist, Computer Programming Specialist** and other short term consultancies were drawn up.

Due to a number of unforeseen circumstances, the project implementation did not strictly follow the prescribed time schedule. Phase I commenced in May 1989 with the arrival of the Biomass Inventory Specialist, Mr. **Knut Velle.** Mr. **Paul Drichi,** Forest Officer in the Biometrics Section of the Forest Department was appointed counterpart to Mr. Velle in August 1989. The project work was pending up to November 1989 due to delayed signing of the agreement between the Government of Uganda and The Norwegian Forestry Society.

After the agreement finally was signed, though, the specialist and his counterpart immediately embarked upon implementing the project. The field work began slowly, but picked up momentum after vehicles and equipment had been acquired. More staff members, mainly Forest Officers and Foresters, were attached to the project and trained on-the-job for the special assignments. The project areas were completed one after another in the following order; **Jinja, Mbarara, Kampala/Entebbe, Kamuli, Mbale, Kabale, Moroto, Arua** and **Kumi.**

The main interested party at the time of project preparation was the Ministry of

Energy. Since the actual implementation started this interest seems to have declined. Attempts to establish a **Joint Committee,** comprising representatives from several ministries, aborted since most representatives repeatedly did not turn up. One main reason for this lack of interest might be the rather long period (2 years) necessary to produce the information wanted. This was due to the method applied involving **regression analysis,** thus basic data from all the areas had to be collected before starting the computations. Calculating the areas one by one would have resulted in too small samples for some of the analyses. It would also have increased the amount of work considerably.

Questions have frequently been raised about the selection of the ten project areas. The main criteria used were the following:

- The areas should represent a broad geographical dissemination of urban centres in the country, so as to obtain a wide range of reference areas in terms of natural vegetation.

- The areas should have a perceived pronounced woodfuel deficiency.

Obviously some other areas also meet these criteria and could as well have been selected.

According to the Project Description, Forest Reserves should not be included into the Biomass Study area. However, discussions about this subject led to the conclusion that a better depiction of the total situation would be obtained if Forest Reserves were included. Even though felling of trees from these areas is restricted and people are basically prohibited from fetching wood here, the wood products still contribute in meeting the general demand.

Another intricate problem is that the project areas do not represent closed communities. Large quantities are transferred in and out. Some represent supply areas where woodfuel is transported out of the community. Other areas cover their demand by receiving from outside. This trading between areas complicates the assessment of the wood balance situation. *As this issue is not taken into account in this study, the actual situation for each area may differ from our calculations.*

A biomass study is a rather new and unconventional wood inventory where new parameters, variables and measurement designs are introduced. As no standard strategies/methods exist - at least for tropical conditions - an appropriate method was designed. This method has been carefully described in the following chapters.

# 3 Description of the Project Areas3 Description of the Project Areas

A presentation and overview map of each area are included as Appendix A, but brief introductions are given below. *Note that the project areas are named after the main urban centre, and they are not the same as the district.*

(1) The **Arua** project area, with a size of about 1,050 square km and a population of about 210,000 (i.e. a population density of 200 persons per square km) is located in the north-western corner of the country. It is heavily cultivated.

(2) The **Jinja** project area is located in the central southern part, close to Lake Victoria. Rainfall is normally sufficient for this extensively cultivated area. The population of about 390,000 is concentrated around the urban centre. The project area is about 1,590 square km, i.e. it has a population density of about 250 persons per square km.

(3) The **Kabale** project area is located in the extreme south-western part of the country. About 240,000 people are living in this 950 square km area (i.e. around 250 persons per square km). Although hilly and at a high altitude, the area is heavily cultivated.

(4) The **Kampala** project area of about 3,000 square km, surrounding the capital, has a population of about 1.43 mill (i.e. around 475 persons per square km). The bi-modal rainfall regime provides a good basis for the extensive cultivation in this area.

(5) The **Kamuli** project area is located in the central part of the country. It is about 1,260 square km and has a scattered population of about 100,000 (i.e. around 80 persons per square km).

(6) The **Kumi** project area is about 1,540 square km and has a population of about 150,000 (i.e. around 100 persons per square km). The location is in the central eastern part of the country.

(7) The **Mbale** project area covers a heavily populated region in the

extreme east with an area of about 1,950 square km and a population of 640.000 (i.e. around 330 persons per square km). Most of the area is extensively cultivated.

(8) The **Mbarara** project area is the smallest of the project areas with about 920 square km and a population of about 140,000 (i.e. around 150 persons per square km). It is located in the western part of Uganda. Rather dry, the area is dominated by pasture land.

(9) The **Moroto** project area is the most scattered populated area, with a population of only about 30,000. It covers an area of about 1,310 square km in the north eastern part of Uganda, so the population density is only around 23 persons per square km. The climate is semi-arid.

*Figure 1: Map of Uganda Showing the Nine Phase I Project Areas.*

# 4 Objective and Strategy4 Objective and Strategy

## 4.1 Objective of Phase I4.1 Objective of Phase I

The primary objective of Phase I is to:

> "*Estimate the growing stock and annual increment of woody biomass and agricultural residues fit for woodfuel for the nine project areas.*"

The results show a static picture of the situation at the time of the inventory. Thus extensive measurements of the annual increment of trees were impossible within the Phase I time constraints. However, rough estimates, based upon simple assumption modelling and repeated measurement of a limited number of tree plots are included.

Systematic dynamic monitoring of the nine areas (i.e. re-measurements of a large number of plots measured during Phase I) is incorporated as an important element in Phase II (ref. the Report from the Review Mission). The results will most likely be published in the middle of 1993.

## 4.2 Strategy for Phase I4.2 Strategy for Phase I

The strategy/approach used during Phase I was based upon nine main elements, which altogether represent a complete process of a biomass survey. These are briefly outlined below, and will be explained in detail later in this report.

(1) **Mapping Process:** The areas were delineated in accordance with a land use / land cover classification system, purposely to stratify the areas into homogeneous biomass units. The resulting maps give information about both the location and area cover of each vegetation

type.

(2) **Photo Interpretation:** A sampling system was designed using **Double Sampling,** which involved a comprehensive use of aerial photos. The photos were subject to an interpretation technique comprising assessment of certain features for a great number of sample plots.

(3) **Field Checking:** A sub-sample of the photo-interpreted plots were sought out in the field for accurate measurements of the actual standing stock of different categories of biomass.

(4) **Biomass Weighing/Measurements:** A great number of trees were measured, subsequently felled and weighed in order to establish single tree weight tables through a statistical regression process. Similarly, on bushland and farmland the occurring biomass was cut and weighed to establish amounts of standing stock of such biomass categories.

(5) **Wood Specimen Measurements:** Conversion between volume and weight and between fresh and air dry weight requires suitable conversion factors. As these were available only for a few of the relevant species, an additional sub-project had to be carried out. A large number of wood specimens were cut and measured before and after air drying, thus establishing the desired wood property factors.

(6) **Repeated Plot Measurements:** A sub-sample of about 4% of the plots of the main study was randomly selected for re-measurement as a basis for increment estimation. The second measurement was carried out about 1.5 years after the first field checking.

(7) **Woodfuel Consumption Assessment:** Annual per capita woodfuel consumption figures were investigated using relevant literature and project reports. By means of sub-county areas and population figures, the number of inhabitants of each project area was calculated. These two factors enabled estimation of the total woodfuel consumption in each area.

(8) **Woodfuel Transport Study:** A woodfuel transport study was implemented to acquire information about means of transport applied, distances moved, quantities transported and species used, in order to reveal the infrastructure of the woodfuel transport.

(9) **Processing:** Inputs from the eight elements above were needed to produce the final results. The single tree tables enabled the calculation of the biomass of all the trees in the selected field plots, and the measurements of bush and agricultural residues formed the basis for the weight processing of these categories. The photo interpretation

applied to Double Sampling ensured a broad representation and adequate sampling intensity. The maps and area distribution enabled the calculation of the total biomass for each area and land use / land cover class. The re-measurements have given indications of annual increment, and these figures related to the consumption given the basis for a woodfuel balance accounts. Lastly, the transport study has revealed the transport infrastructure.

# 5 Stratification and Mapping5 Stratification and Mapping

**Sub-objectives:** *Stratify the area utilizing a classification system designed specifically in accordance with the forest conditions and the main objectives of the project.*

## 5.1 The Mapping Process5.1 The Mapping Process

The **panchromatic** (black & white) aerial photos covering the project areas are at a scale of approximately 1:25.000 - exceptionally 1:30.000. Overlaps are standard; about 60% in the run/flight direction and about 30% between the runs.

Using traditional map making equipment, autograph WILD A8 **stereoplotter,** and the diapositives of the aerial photos, the maps were constructed via a 100*100 cm **coordinatograph** on to semi-matt overlay foils/drafting film fixed to the corresponding topographical maps of East Africa, series Y 732 in scale 1:50,000. Base maps of each project area, where the areas were classified into land cover / land use classes (normally denoted as "land use/cover classes" in this report), were produced. Two stereoplotters were in continuous use for one year to complete the 50 (partial) map sheets covering the nine areas.

To facilitate the search for different vegetational features, paper prints and a 3x table mirror **stereoscope** were simultaneously used during the process. This stereoscope provided a wider view of the area than the small scene seen in the stereoplotter. *Distinct features to a minimum of approximately 0.5 hectare were delineated.* Such small units were in particular important when dealing with planted woodlots. Units smaller than 0.5 ha were generalized into the surrounding land use/cover class. The area stratification was not demarcated on the prints ahead of this process, but drawn out directly from the visual image in the stereoplotter - simultaneous interpretation/plotting as opposed to field interpretation. Possible errors here are discussed in chapter 14. The following list gives the relevant covering map sheets.

*Table 1: Map Sheets (1:50,000) used in the Stratification Process.*

| | | |
|---|---|---|
| JINJA: | KABALE: | ARUA: |
| Jinja...... - 72/1 | Kabale..... - 93/4 | |
| Arua....... - 11/4 | | |
| Iganga..... - 62/4 | Rubanda.... - 93/2 | |
| Vurra...... - 19/2 | | |
| Kagoma..... - 62/3 | Mparo...... - 94/1 | |
| Uleppi..... - 20/1 | | |
| Ikulwe..... - 72/2 | Maziba..... - 94/3 | |
| Rutir...... - 12/3 | | |
| Bwema...... - 72/3 | | |
| Lugazi..... - 71/2 | | |
| KAMULI: | MBARARA: | MOROTO: |
| Kamuli..... - 62/1 | Mbarara.... - 86/1 | |
| Moroto..... - 27/3 | | |
| Kayonza.... - 61/2 | Rubindi.... - 77/3 | |
| Lotome..... - 36/1 | | |
| Namwedwa... - 62/2 | Sanga...... - 77/4 | |
| Katikekile. - 36/2 | | |
| Nawaikoke.. - 52/4 | Lake Mburo. - 86/2 | |
| Lopei...... - 26/4 | | |
| Balawoli... - 52/3 | Kabwohe.... - 85/2 | |
| Kangole.... - 35/2 | | |
| Bale....... - 51/4 | | |
| Loolimo.... - 27/4 | | |
| KAMPALA: | MBALE: | KUMI: |
| Kampala.... - 71/1 | Mbale...... - 54/3 | |
| Kumi....... - 53/2 | | |
| Entebbe.... - 70/4 | Nagongera.. - 64/1 | |
| Bukedea.... - 54/1 | | |
| Kajansi.... - 71/3 | Bubulo..... - 64/2 | |
| Kapiri..... - 43/4 | | |
| Kibanga.... - 71/4 | Budadiri... - 54/4 | |
| Magoro..... - 44/3 | | |
| Kakiri..... - 70/2 | Kapchorwa.. - 54/2 | |
| Bombo...... - 61/3 | Kamuge..... - 53/4 | |
| Kayonga.... - 61/4 | Busolwe.... - 63/2 | |
| Lugazi..... - 71/2 | Bukedea.... - 54/1 | |
| Bowa....... - 60/4 | Kumi....... - 53/2 | |

## 5.2 Geographical Information System5.2 Geographical Information System

The 50 (partial) map sheets resulting from the process above were then digitally captured using a **Geographical Information System (GIS)** called **PC-ARC/INFO,** version 3.4D. A GIS is a powerful computer-based programme developed specifically for the capturing, processing, analyzing and outputting of spatial (geographical) data. A GIS normally comprises two different elements which are linked together: One part handles the spatial features (lines, polygons or map-units, points), the other handles the properties of these spatial features (normally called **attributes**).

Typically attributes in our context are land use/cover class (polygon attribute) or road type (line attribute). PC-ARC/INFO uses **dBase** for attribute handling.

The data capture was done using a **digitizer,** an electronic device where all relevant lines and points on the map sheets are traced with a cursor and the coordinates transferred to the GIS programme. This work was done using the GIS at the **National Environment Information Centre (NEIC)** in Kampala.

PC-ARC/INFO automatically calculates the area of all closed polygons (i.e. delineated land use/cover classes in this case), and the results are part of the attribute tables stored in dBase format. Adding up the area of all polygons belonging to the different land use/cover classes is done by using the ARC/INFO command "FREQUENCY". Exporting the results to for instance a word processor is also easily done.

PC-ARC/INFO also has powerful map composition capabilities. The partial 1:50,000 sheets were merged during digitizing. During map composition, colours, legends and other map features were designed and combined with the spatial data. The resulting map composites were plotted out using a Calcomp 2036M A0 8-pen plotter.

## 5.3 The Classification System5.3 The Classification System

No existing classification system was found to cover the necessary strata requirements. *Most of the existing systems are designed for botanical or environmental thematic purposes.* As diversion of biomass is our perspective, the mentioned systems were not adequate. A classification system fitting the project purpose was therefore designed. The classification system is a combined land cover / land use system, and the classification score was determined in accordance with the overall dominating class.

A major goal was the formulation of one classification system applicable to all the project areas. It was therefore made flexible and general to suit the different conditions encountered throughout the country. One class may vary within certain limits from area to area due to all inherent factors affecting the growth of vegetation; e.g. typical farmland in Jinja is not the same as in Moroto. The system was designed in order to determine differences - both amount/concentration and type of biomass. Although rather wide and general, using a single classification system for the entire country facilitates easy data processing and enables comparative analyses of vastly differing regions.

Twelve vegetation land cover / land use classes were defined for the stratification of the project areas. These are summarized in the box below, and some additional explanations and comments follow.

*Table 2: Land Use / Land Cover Classes.*

| | |
|---|---|
| (1) | Plantations and woodlots - deciduous trees/broadleaves ("hardwood"). |
| (2) | Plantations and woodlots - coniferous trees ("softwood"). |
| (3) | Tropical high forest - normally stocked. |
| (4) | Tropical high forest - depleted/encroached. |
| (5) | Woodland - trees and shrubs (average height > 4 m). |
| (6) | Bushland - bush, thickets, scrubs (average height < 4 m). (Some shrubs and scattered trees may occur.) |
| (7) | Grassland, rangelands, pasture land, open savannah. (Some scattered trees, shrubs, scrubs and thickets may occur.) |
| (8) | Wetland vegetation, swamp areas, papyrus. |
| (9) | Subsistent, mixed farmland recently used or in use - with/without scattered trees, agricultural fallow areas. |
| (10) | Uniform, mono-cropped, non-seasonal farmland without any trees and shrubs - e.g. tea and sugar estates. |
| (11) | Urban or rural built up area, bare rock, miscellaneous impediment. |
| (12) | Water - larger rivers, ponds and lakes. |

Some types of vegetation mentioned in this chapter need further explanation. There appears to be a lot of confusion and disagreement in general regarding the understanding and definition of bush, shrub, scrub and thicket. In this study, the following definitions were used:

- *Shrub:* branchy "tree" without a clear/straight bole/stem, mainly 4-10 m.
- *Scrub:* without a defined bole/stem, less than 4 m, mainly one species isolated in a cluster.
- *Thicket:* many non-defined stem growths of a number of species growing in clusters, mainly less than 7 m.
- *Bush:* continuous wide spread growing scrub and thicket.

Comments and explanations of the classification system are found below.

### 5.3.1 Plantations5.3.1 Plantations

These are the man-made tree plantations. Young generation woodlots are dominant in this class in the project areas.

Class 1 consists of deciduous, broad-leaved trees mainly of *Eucalyptus spp., Maesopsis eminii, Acacia mearnsii* (Black Wattle) and some *Markhamia platycalyx.*

Class 2 includes the *Conifers*; *Pine spp.* and *Cypress spp.*

### 5.3.2 Tropical High Forest5.3.2 Tropical High Forest

These natural forests with a high variety of species were divided into two classes:

Class 3 is normally stocked **Tropical High Forest (THF).** This was found both in the form of large forests (e.g. Mabira Forest in the Jinja project area) and in smaller patches.

Class 4 is depleted/degraded/encroached and has a reduced richness of species composition. The understorey is dominated by secondary bush and shrubs, in particular *Solanum spp.*

### 5.3.3 Woodland, Bushland and Grassland5.3.3 Woodland, Bushland and Grassland

This group covers all intermediate land use/cover classes from bare grassland to densely stocked woodland.

Class 5 represents the most woody areas where trees and shrubs are the predominant cover. There is both a wet type occurring as a zone along wetlands (riverine forest) and a dry type appearing on dry, grass-covered areas. *To qualify as woodland the average height of the trees must exceed 4 m.*

Class 6 refers to vegetation dominated by bush, scrubs and thickets growing together as an entity, but not exceeding an average height of 4 m.

This class may have different origins. In dry, grass-covered areas it appears to be permanent, including for example normally taller growing species which have been arrested from their potential by persistent fires and/or other biotic factors; (for example *Acacia hockii* in Mbarara and *Commiphora africana* in Moroto).

This class also occurs on abandoned farmland in the form of a late fallow with rapid impetus of mainly *Lantana camara*. On clear cut abandoned forest land the vegetation is rapidly progressing to bush comprising many different pioneer species as the first phase of succession.

The following are some of the most common species in bushland: *Securinega virosa, Acanthus pubescens, Lantana camara, Rhus natalensis, Rhus vulgaris, Harizonia spp., Acacia gourmensii, Solanum spp., Ziziphus africana, Xymenia americana, Securidaca longipendiculata, Dovylis macrocalyx* (Wild Kei apple), *Maytenus senegalensis, Maesa lanceolata* and *Alchomea cordifolia.* Together with these woody shrubs/scrubs, there is often heavy progress of grass species like *Pennisetum spp.* (Elephant-grass), *Imperata cylindricum* (Spear grass) and *Hypherenia ruffa* occur.

Class 7: Grazing grounds, whether rangelands, improved pastures or natural savannah grassland are all grouped together in this class. Various trees - bush/woody vegetation frequently occur on this land, but grass cover dominates the scene.

### 5.3.4 Wetlands5.3.4 Wetlands

Class 8 comprises both permanent wetland - usually with papyrus and reeds - and some seasonally flooded areas. These are found along lake shores and in valleys with impeded drainage, where the vegetation shows clear symptoms of frequent high water table. Various vegetation may occur, but the most dominant is wet grass. Among the indicator trees are *Acacia siberiana* and palms such as *Phoenix reclinata.*

### 5.3.5 Farmland Area5.3.5 Farmland Area

This accounts for 50-90% of most project areas.

Class 9: Included in this class are all the small-holder subsistence farm units. All kinds of cropping systems are found: mixed cropping, multiple cropping and shifting cultivation combined within small areas. Scattered trees/tree clusters are also frequently found, especially in the near vicinity of the homesteads. These are mostly fruit trees and various multipurpose trees as support to and integrated in the farming system (agroforestry). *The biomass coverage displays a wide range from bare ground to almost closed forest.*

Class 10: These are large scale commercial farms such as tea and sugar estates, especially found in Jinja project area.

### 5.3.6 Impediment Area5.3.6 Impediment Area

Areas grouped here were for various reasons thought to be mainly non-productive.

Class 11 includes towns, village trading centres, quarries, homesteads, school compounds, roads, bare rock and recreational grounds. However, most of the class 11 areas encountered were built-up areas, and here considerable biomass was recorded; in particular as various compound trees and multiple use trees growing close to the homesteads. As can be easily seen in chapter 11.10, the total amount of biomass per ha exceeded the amount per ha in class 9 for most project areas.

Phase II will obviously cover far more genuine non-productive areas like mountain ranges/rocks and occasionally land so eroded that it will be non-productive in the coming years. Using baseline data of biomass per ha from phase I, class 11 would in such cases lead to gross over-estimation of biomass. To classify such areas, i.e. areas with no or insignificant woody biomass, a separate class 13 will be defined - for use in phase II.

Note also that roads, just like smaller rivers, always are generalized into the surrounding land use/cover class. Infrastructure and rivers are, though, stored separately in the Geographical Information System as line features.

Class 12 comprises open water, like large rivers, ponds and lakes. The boundary between open water and surrounding wetland with a permanent high water table is sometimes difficult to draw. In particular, aggressive floats like the water hyacinth might "blur" these boundaries. This was not considered a main problem in the nine project areas, though.

# 6 Systematic Sample Plot Survey - Double Sampling6Systematic Sample Plot Survey - Double Sampling

**Sub-objective:** *To estimate the standing stock of woody biomass through representative sample plots.* As indicated, this sampling method is based upon a selection of plots in two phases.

In the first phase a large number of plots were selected for aerial photo interpretation, which implied assessing certain attributes/-features which were assumed to correlate with the actual standing stock. *In this case crown cover of trees and bushes, assessed in percent, was assumed to correlate with the actual field biomass.*

In the second phase sub-samples of the first phase plots were selected for field checking. This implied a thorough mensuration of all the biomass in the plot, involving tree measurements, species identification, bush assessment and agricultural cover, for the determination of true field biomass.

The sampling method **"Double Sampling"** was selected due to its efficiency when dealing with large areas and the availability of aerial photos.

The aim was to determine potential relationships between the photo assessments and the field measurements of the selected sub-samples using regression equations. Furthermore, following the Double Sampling procedure correction factors attained from the sub-samples were applied, together with the corresponding level calculated from the first phase sample. This will be explained further in chapter 10.5.

## 6.1 First Stage: Photo Plot Interpretation6.1 First Stage: Photo Plot Interpretation

In this stage a large number of sample plots - about 20,000 - were interpreted/assessed to obtain significant representation. Every photo model/stereo pair (described below) contained 25 photo plots. All plots on all the relevant models within the boundaries of the project areas were assessed, with the exception of those which were shaded/clouded/blurred. Tabulated below are the relevant photo/model data.

*Table 3: Photo Interpretation Review.*

| Proj. area | Total No.of photos | No.of(1) stereo pairs | No. of overlaps phot. | No. of overlaps ster. pairs | No. of Effi-cient pairs | No. of Inter-preted plots(2) | Samp-ling inten-sity % |
|---|---|---|---|---|---|---|---|
| Arua | 124 | 62 | 1 | 1 | 61 | 1,699 | 0.40 |
| Jinja | 163 | 80 | 0 | 0 | 80 | 2,018 | 0.32 |
| Kabale | 112 | 55 | 5 | 3 | 52 | 1,673 | 0.44 |
| Kampala | 267 | 133 | 35 | 18 | 115 | 3,424 | 0.29 |
| Kamuli | 171 | 86 | 6 | 2 | 84 | 2,374 | 0.47 |
| Kumi | 190 | 95 | 0 | 0 | 95 | 2,476 | 0.40 |
| Mbale | 168 | 84 | 28 | 14 | 70 | 2,313 | 0.30 |
| Mbarara | 116 | 59 | 5 | 2 | 57 | 1,725 | 0.47 |
| Moroto | 153 | 77 | 0 | 0 | 77 | 2,164 | 0.41 |
| Total | 1,464 | 731 | 80 | 40 | 691 | 19,866 | 0.37 |

(1) Number of stereo pairs applied in our system.
(2) These are the interpreted plots used in the computation. The plots were interpreted by three interpreters independently and for each area the series with the best correlation was selected.

### 6.1.1 Design of a Key Overlay6.1.1 Design of a Key Overlay

A systematic sampling grid system was designed to designate the sample plots. The photos used in the stratification process (see chapter 5.1) were also used for this task. The sample plots were allocated by means of a fixed, nearly size-proof, transparent key overlay, containing 25 plots designed in a systematic grid in the shape of a cross, numbered from 1 to 25, see Appendix B. When mounting like this the cross centre coincided approximately with the photograph centre so as to avoid plots located near to the edges. This minimized the effects of photo deformations, distortions, displacements, cover effects and scale variations due to relief and tip/tilt exposures. The fiducial frame marks on the photos were transferred to the overlay.

In mounting the overlay the top heading of the photo faces the left hand side when the overlay is in correct readable position (see Appendix C, illustration of the stereo pair setting). The overlay was only mounted on photos with an even number, hence every other photo model was relevant. However, all the photos were needed to get stereo cover on both sides of the photo centre. The overlay was then fixed on top of the photo so that the fiducial marks on photo and overlay fit exactly. The method described is called the **Fixed Overlay Method.** There should be only one way of mounting/fixing the overlay.

The overlay size of a plot was 2 mm by 2 mm - 1 cm apart from centre to centre. Assuming a scale of 1:25.000, the actual field size of a plot was 50 m by 50 m with a spacing distance of 250 m from one plot centre to the next. As the scale on a photo varies depending on the extent of the relief, the field size of the 2 mm by 2 mm plot varies accordingly. This was assumed *not* to seriously affect the result as long as the assessments were expressed relatively (e.g. crown cover in percent). All 25 plots were interpreted in this phase by means of 8x table mirror stereoscopes or APT-2 zoom mirror stereoscope with an adjustable magnification within the interval 3x - 15.5x. For every photo model a form was filled in containing all the 25 plots for the following assessments and recordings:

- Interpreter;
- Photo number and plot number;
- Land use / Land cover class;
- Crown cover percent of trees;

- Crown cover percent of bush;
- Number of upper-storey trees;
- Plot tree height.

### 6.1.2 The Interpreters6.1.2 The Interpreters

Keeping the connection between the measurements and the interpreters is important. Every person may have his/her way of assessing the scores differently or have a systematic tendency in one direction or another. As long as the interpreter is consistent, the Double Sampling processing technique will correct for this potential bias. Hence, the processing was run separately for each interpreter. *Three independent sets of interpretation data were acquired for every project area.*

### 6.1.3 Photo Number and Plot Number6.1.3 Photo Number and Plot Number

It is equally important to have a firm geographical location for every plot measured. By means of the fixed overlay, photo number and plot number, every plot has only one possible location. One can always go back, fit the overlay and pinpoint the same square. In some of the project areas there were duplicate photo numbers. In these cases a "new photono." was created by concatenating run number and photo number.

### 6.1.4 Land Use/Cover Class6.1.4Land Use/Cover Class

The classification system used in the mapping process - described in chapter 5.3 - was applied, whereby the dominating land use/cover class was assessed and recorded.

### 6.1.5 Crown Cover Percent of Trees6.1.5 Crown Cover Percent of Trees

The aim here was to assess the relative area within the plot covered by tree canopies. All identifiable trees observed should be included in the score, not only predominant/upper storey trees, assuming that the total canopy cover is significantly correlated to the biomass. The cover percentage was determined in intervals of 5 % (i.e. rounded to the nearest 5%).

Different methods have been tried in order to reduce estimation error (for example using a crown cover scale), however with little success. The problem stems from the wide range of canopy sizes and densities within and between plots. One would need a great number of keys to cover such wide diversity. After practising for some time it appeared that experience and the naked eye were the best guides. To gain this experience, training on two different levels was required. When scrutinizing the plot under the stereoscope, your imagination must be used to visually move the canopies to one corner or side of the plot to facilitate ease in the estimation of the cover score. Secondly one must go out into the field checking/ground truthing to ascertain what is actually there. This feedback will guide you closer to the "correct" assessment. This is further commented in chapter 14, "Sources of Error".

### 6.1.6 Crown Cover Percent of Bush6.1.6Crown Cover Percent of Bush

It was assumed that bush contributes considerably to the pertinent biomass. As the concentration and structure of bush biomass differ from trees, it was necessary to have a separate score for this category. There were difficulties in the differentiation between both this category and agricultural crops and smaller trees. The cover was scored in intervals of 5 %.

### 6.1.7 Number of Upper-Storey Trees6.1.7 Number of Upper-Storey Trees

Initially, assessing the total number of trees, including all storeys, turned out to be too intricate and was thus temporarily discontinued. Estimating the number of trees in the upper canopy alone is problematic when they are clustered. Counting smaller trees/ narrow canopy trees from 1:25,000 photographs proved almost impossible. Adjustments in the absolute count, necessary to correct for scale variation simply serve to exacerbate the problem of inaccuracy. Such scoring contained too high a potential of error and it was thus considered not to contribute significantly in terms of regression analysis.

The scoring was taken up again later as the interpreters gained more experience. The crown cover gives a good indication of the horizontal tree dissemination. In order to provide a more comprehensive depiction, it was assumed that an indicator of the vertical variation factor could be useful. The abundance of big trees was used as such an indicator. However, although aerial photo interpretation is extensively useful for relative analysis, absolute measurements proved complicated. Therefore, the identification of upper storey trees by means of a mirror stereoscope brought a big quandary. A relative appraisal is not appropriate as a relatively big tree in a small tree stand may not qualify as an upper storey tree. To suit our purposes, we defined a big tree as having a height of at least 10 meters. In addition, only trees with a crown width of at least 10 meters were considered to contribute significantly to the biomass. To overcome the mentioned problems, the enumerator used discernable features (e.g. houses, roads) as a basis for size comparison.

This score was included as the second independent variable in the multiple regression processing in three of the project areas. *However, the analysis showed that this variable gave very little significant contribution to the correlation.* Hence, it was left out of the final analysis.

### 6.1.8 Plot Tree Height6.1.8 Plot Tree Height

Tree height is commonly a significant variable in forest volume photo interpretation equations expressing the vertical forest scene, most often reflecting the average height of size-dominating/upper-storey trees. However, similar to the previous chapter, we found the assignment of an appropriate definition for a "large tree" very difficult, due to the great variability encountered within the plots and between the land use/cover classes. In addition the use of tall trees as an indicator of average tree height, do not adequately account for areas with an abundance of smaller trees. When trying to score an average height for the plot, a major problem was to weight between the occurring clusters, single large trees and small tree groups. This problem was particularly pronounced when dealing with the commonest land use/cover class, subsistent farmland, where the number and size of trees show great variation and where much of the biomass is found in lower storey clusters. This dilemma produced results indicating almost the same average height for every plot, which induced us to conclude that *this assessment did not improve the correlation and it was thus abandoned.*

## 6.2 Second Stage: Field Plot Measurements6.2 Second Stage: Field Plot Measurements

*The aim is to formulate an expression of the total amount of the different types of biomass in the selected plots.* This was carried out by thoroughly measuring/assessing all the biomass within the plots. The following list reviews the data collection from the field plots. The percentages give relation to the total numbers.

*Table 4: Field Plot Measurement Review.*

| Project area | Number of stereo pairs No. | % | Number of plots No. | % | Number of trees | Sampling intensity % |
|---|---|---|---|---|---|---|
| Arua | 59 | 97 | 369 | 24 | 18,413 | 0.09 |
| Jinja | 61 | 76 | 373 | 19 | 21,329 | 0.06 |
| Kabale | 51 | 98 | 297 | 23 | 18,121 | 0.08 |
| Kamp./Enteb. | 97 | 84 | 405 | 14 | 14,640 | 0.03 |
| Kamuli | 78 | 93 | 404 | 19 | 21,491 | 0.08 |
| Kumi | 81 | 85 | 444 | 19 | 15,567 | 0.07 |
| Mbale | 55 | 79 | 423 | 24 | 9,999 | 0.05 |
| Mbarara | 62(108) | | 325 | 23 | 13,092 | 0.09 |
| Moroto | 58 | 75 | 377 | 20 | 16,456 | 0.07 |
| Total | 602 | 87 | 3,417 | 17 | 149,108 | 0.06 |

() Overlapping models + two models slightly outside the project area measured in the field.

As supplementary information about the plot measurements refer to the following appendices: Appendix D, "List of Common Species and their Relative Occurrence" and Appendix E, "List of Species from the Plot Measurements". *Frequency distributions on size and species of the measured trees, not included in this report, were also computed.*

### 6.2.1 Allocation of Field Plots6.2.1 Allocation of Field Plots

Normally, design of a system for allocation of field plots to each stratum is affected by the following factors:

- Variation within each stratum;
- Importance of each stratum;
- Costs involved for each stratum.

With regard to our case the different land use/cover classes and the nine project areas both represent the strata. All the factors mentioned obviously vary for all the strata. Due to other reasons beyond our control, we were not in a position to distinguish between the relative importance or cost effectiveness of the project areas, but *considered them all as equal.*

In estimating the standing stock it is apparently most efficient to allocate relatively more plots where the greatest quantities are located. In order to achieve this, a method of weighting the plots should be introduced. However, the above factors are also intervening and interacting with each other in such a way that in combination they partly repeal the effect of weighting on the efficiency. For instance, the high forest is more important than the grassland savanna, but the latter is much cheaper to measure. Furthermore, one objective was to get a good estimate for each land use/cover class. In considering the needs and distribution of the population, it is more important to obtain reliable information where the wood is scarce than where it is abundant. Therefore, regardless of the interference of these factors, *they were presumed to be equal for all strata.* Realizing this situation the most efficient allocation of sample plots is obtained when the number of plots for each stratum is picked in proportion to the relative occurrence of the strata. In such cases, the normal procedure is to apply one or another random sampling system.

Initially, the five plots located in the centre of each photo model were surveyed, resulting in a systematic, cluster sample. However, we soon realized this method was almost impossible to implement due to four main reasons related to the plots:

- Inaccessibility; e.g. high water table, safety/security;
- Impossibility in locating the plot e.g. lack of nearby discernible features;
- Un-obtainability of permission to start the measurements;
- Abandonment due to extensive changes having taken place since the time of photography; e.g. many trees having been felled (photo and field do not correspond).

Gaining this experience, we were obliged to select plots which were accessible, locatable, unchanged and where we did not meet resistance from the land owner or the local Resistance Councils (RC's). However, the demand of representative distribution, selecting various types of plots according to the relative occurrence, was subject to special concern. Although unfortunate in terms of achieving an appropriate random sample, this method was the only practical one which suited the circumstances. The potential bias here must be considered when utilizing the data for specific purposes. The number of field plots is important in the determination of whether or not a potential bias can be overlooked.

It must be emphasized that the distribution of plots does not necessarily reflect the relative area cover of each land use/cover class. Adequate biomass data from all classes were needed to obtain the correction factors to enable Double Sampling processing.

### 6.2.2 Field Plot Size and Shape6.2.2 Field Plot Size and Shape

The selection of the sample plot size is also important for the efficiency of the inventory. There were several factors affecting the choice of the sample plot size.

- **Variation within the plot:** The more homogeneous the vegetation strata are, the smaller the sample plots need to be. In our case there is no doubt that the growth of biomass shows a great variation even within small areas. To detect these continuous fluctuations, the plot size should be relatively large.

- **Variation within the stratum:** If the fluctuations within a stratum are not reflected within a single plot, a greater number of smaller plots will be more representative.

- **Allowance of error in locating the plot:** The plots can seldom be precisely located, thus an error of ± 5 m was tolerated. Using a larger plot size reduces the relative importance of such locational errors. (5 m is a smaller fraction of a large plot than a small one.)

- **Relation to phase II:** The plot size was also considered in relation to the spatial resolution, pixel size and accuracy of **Landsat/SPOT** satellite imagery, i.e. the needs of phase II of the project were considered. In this context larger plots are advantageous.

- **Time saving:** Moving to a new plot and locating it is time consuming. From a cost efficiency perspective it is better to have fewer larger plots, within reasons.

- **Photo interpretation:** The plots are to be interpreted in the office under a mirror stereoscope, a difficult task if the plots are too small.

Based upon an evaluation of the above factors, *a plot size of 50 m by 50 m (2,500 m²) was chosen.* Square plots, as opposed to circular or rectangular were preferred for practical reasons.

### 6.2.3 Number of Field Plots - Sample Size6.2.3 Number of Field Plots - Sample Size

The number of field plots is obviously affected by the plot size. Once the plot size is determined, the sample size is consequently restricted according to the level of accuracy specified. Normally one is in possession of some knowledge about the variation in the forest in terms of standing stock per hectare, based upon experience from former similar inventories. If this is not the case, an initial inventory should be carried out. Thereby the sample size can be estimated for specified requirements regarding the sampling error.

The number of sample plots in each stratum can be calculated from the following formula:

$$s_m = \frac{s}{\sqrt{n}}$$

where $s_m$ = standard error of the mean (sampling error)
s = standard deviation of single observations
n = number of observations

The variation within a certain forest is often given as **CV = Coefficient of Variation (s %),** which is standard deviation in percent of the mean.

$$CV = s\,\% = \frac{100\%*s}{\bar{x}}$$

Similarly, the $s_m$% is the standard error of the mean in percent of the mean:

$$s_m\,\% = \frac{100\%*s_m}{\bar{x}}$$

Merging the two first formulas into the last (first replacing $s_m$ and then s%), we get:

$$s_m\% = \frac{s\%}{\sqrt{n}}$$

Squaring and swapping then give us the required number of observations (i.e. required number of field plot samples) as a function of the sampling error and the CV:

$$n = \frac{(s\%)^2}{(s_m\%)^2}$$

As we were not carrying out a traditional forest inventory, no empirical data on the CV were available. However, *we made a rough estimate of the CV being 100%.* It was also decided that the sampling error should not exceed 5%, which then produced the following:

$$n = \frac{100^2}{5^2} = 400$$

Under the mentioned presumptions, 400 should be an adequate number of plots for each project area.

### 6.2.4 Work Description6.2.4 Work Description

Each inventory team consisted of 3 - 4 people. A Forest Officer or a Forester was the team leader accompanied by either a Forester or a Forest Ranger and 1 - 2 casual staff. The individual skills were considered when the teams were established, so that all knowledge required was covered. Each team had a vehicle and was equipped as follows: calliper, diameter tape, hypsometer, measuring tape, relevant air photos, 3x mirror stereoscope, photo plot overlay, photo carrier, compass, clipboard, pen, appropriate form, an equipment bag and panga.

As previously mentioned there was no fixed system for selecting the plots to be measured, and it was up to the team leader and/or the Biomass Inventory Specialist to choose the plots, always considering representativeness. Upon arrival at the plot the team would assess further the suitability (i.e. considering the factors mentioned above).

It is of paramount importance to accurately locate the plot. What is measured in the field must coincide with the office photo interpretation. This is a basic condition of the Double Sampling technique. Location of the plot was carried out using the stereoscope mounted on the current photo model, i.e. examining the plot stereoscopically. Considering the photo scale of 1:25.000, the plot should be located accurately within an interval of ± 5 m. The corner with the most identifiable landmarks was determined. From this point the other corners were determined by taking compass bearings adjusted according to the flight direction indicated on the photo index plan. Simultaneously the photos were scrutinized for the presence of distinct objects. After demarcating the corners, the measurements followed.

#### 6.2.4.1 Tree Measurements6.2.4.1 Tree Measurements

All trees within the plot were measured for the following variables:

- **dbh** (diameter breast height), rounded to the nearest cm. This was either measured 130 cm above the ground or just above any buttress present.

- **height** - rounded to the nearest decimeter (total height from the ground up to the crown point).

- **bole length** - rounded to the nearest decimeter. The bole is the height from the ground up to the first main branch. Measurements should be considered to be accurate.

- **crown width** - rounded to the nearest dm. (The diameter of the vertical projection of the crown, taking the average of two crosswise measurements.)

- **species** - the species of each tree was recorded on the tally form in botanical full names or other names in which the species is commonly known. Each species was given a code number, which was assigned to each tree during data entry into the computer. The list of the species, with codes, can be found in Appendix E.

As well as in the conventional sense of the word, "tree" was also applied to certain shrubs. (The biomass was the major subject as opposed to lumber considerations for sawmilling or other purposes.) *Thus all trees with a dbh greater than 3 cm and a height greater than 1.3 m were measured and recorded.*

#### 6.2.4.2 Biomass Cover Assessment6.2.4.2 Biomass Cover Assessment

The relative area cover in 5% intervals of all categories of biomass encountered in the plot (i.e. trees, bush, coffee, cassava, sugar-cane, papyrus, grass, potatoes, matooke/bananas, maize, cotton, tobacco and miscellaneous vegetables/crops) was assessed. The aim was to attain a total picture of the biomass in the plot. To convert these figures into weights a special study of each of these growths/crops was required. (In the processing phase these figures were converted into either woody biomass or agricultural residues, contributing to the availability of woodfuel/firewood.)

#### 6.2.4.3 Land Use/Cover Class Determination6.2.4.3 Land Use/Cover Class Determination

The land use/cover class was determined in accordance with the classification system outlined in chapter 5.3. It was important for the subsequent processing to have a record of species composition and biomass category for each land use/cover class. It is worth mentioning that a number of questions arose under the determination of the land use/cover class. *When different classes were represented in the plot, the predominant class was recorded as prevailing for the whole plot.*

### 6.2.5 Formalities6.2.5 Formalities

The **District Forest Officers (DFO's)** have authority mainly within the Forest Reserves. However, some reserved tree species outside Forest Reserves are accorded special legislative protection, also under the DFO's jurisdiction. As the work took place mainly on public land and often close to people's homesteads, it was necessary to obtain permission beyond the DFO's jurisdiction in order to carry out the field work. The normal procedure was to take an introductory letter from the Forest Department to the relevant **District Administrator (DA).** The DA's office issued a letter to all relevant Sub County Chiefs which in turn were requested to inform all relevant Resistance Committees (RC's). The inventory teams carried with them the letter from the DA, stamped and approved by the Sub County Administration. Even so, in some areas there were frequent resistance and obstacles which resulted in some arguing and consequently delays.

Appendix F, "Field Instructions for the Plot Measurements", gives a more detailed description on the topics covered in this chapter.

# 7 Single Tree Biomass Tables7 Single Tree Biomass Tables

**Sub-objective:** *Determining the dependent variable and potential independent variables as the basis for constructing volume/weight regression equations.*

In order to develop single tree biomass tables, a total of 2,721 trees were cut down for accurate measurements of tree variables which were assumed to be correlated to the tree biomass. Tree felling took place in five of the nine project areas. The table below shows the trees cut and measured in each of these areas:

*Table 5: Number of Trees felled per Area.*

| Project Area | Number of Trees cut |
|---|---|
| Jinja | 693 |
| Kamp./Enteb. | 54 |
| Kamuli | 705 |
| Mbale | 867 |
| Mbarara | 402 |
| Total | 2,721 |

Refer to Appendix G for frequency distribution on size of the test-trees.

Experience has shown that the sizes and species of test trees should ideally be allocated so that each tree represents the same fraction of the total basal area measured. In normally stocked forests this is achieved by using a relascope. Using a fixed test tree quotient, every n-th tree filling the relascope is picked out as a test tree. The basal area of the tree is weighted in such a way that a large tree has a greater probability of being picked than a small one. (Every test tree represents the same basal area depending on the relascope factor.) As the basal area is significantly correlated to the volume of the tree, we can conclude that the relascope selects the test trees which represent the same weight as well as the volume. If the distribution of sizes in the relevant universe of trees is known, test tree tables can be derived by assigning a test tree quotient for each size class.

Our purpose was to use the test trees as a basis for computing weight tables. The above described method is also appropriate for this process. The greater the contribution of a particular size category to the total weight, the greater its test tree representation should be.

Due to the fact that as many as 360 different species, with a wide range of sizes had been recorded, it was easy to realize the impossibility of covering all of them sufficiently with test trees. Therefore the field crew was instructed to try and disperse the test trees as randomly as possible over the whole range of species and sizes. In addition, many other practical problems were encountered in connection with the felling process, resulting in considerable deviations from the instructed method. These problems were most frequently associated with obtaining permission for felling. It was not acceptable to start felling everywhere, and the owner did not always approve even though compensation was paid. It is difficult to evaluate the degree of success in achieving a representative sample. Refer to Appendix H, "Field Instructions for the Felling of Trees for Volume/Weight Determination", for a detailed description of the tree felling measurement process.

Furthermore, it is important to point out that the trees were not necessarily picked out from within the sample plots, but rather strictly *within the relevant project area.* This was assumed not to affect the results as long as the intention was to generate general weight equations.

The same standing parameters as with the plot measurements were measured as independent variables; dbh, height, bole, crown width and species. After felling, the height and bole of the tree were tape measured. The tree was then de-branched, cut into manageable pieces and weighed. The stem part and the branch-wood were weighed and recorded separately. In the case of big trees, for practical reasons, volume was measured instead of the weight, which involved measuring mid diameter and length of each log and branch, converting to volume by means of the mid area formula. The volume was then converted to weight using the corresponding **Wood Density.**

# 8 Bush and Agricultural Residues8 Bush and Agricultural Residues

*A special study was undertaken for different categories of bush and agricultural residues of interest, in order to get an estimate of the potential woodfuel contribution/annual increment for felling/pruning/uprooting.* This was carried out by measuring square plots of 10 by 10 meters. In addition, information from **Ministry of Agriculture, Animal Industry and Fisheries** and from a number of peasants formed part of the basis for the assessments.

Plots of bush/scrubs measuring 10 by 10 m were randomly selected for weight measurement. All biomass of this land use/cover class (6) within the plot was cut and the fresh weight recorded. Special field studies on agricultural residues were carried out in Kampala and Jinja. Listed below are the number of plots measured for bush and agricultural residues, respectively.

*Table 6: Plots Measured for Bush.*

| Area | No. of plots |
|---|---|
| Jinja | 7 |
| Kamuli | 5 |
| Moroto | 22 |
| Mbarara | 4 |
| Total | 38 |

*Table 7: Plots measured for Agric. Residues.*

| Crop type | No.of plots 10m by 10m |
|---|---|
| Cassava | 30 |
| Coffee | 15 |
| Maize | 8 |
| Sorghum | 3 |
| Sugarcane | 7 |
| Total | 63 |

In addition, sugar cane at estates plus husks from coffee production were looked into separately. The data used was partly derived from some measurements, partly from interviews with estate managers and others involved in the utilization of bagasse and coffee husks.

Phase II will follow up this part through further measurements of both bush and agricultural residues.

# 9 Wood Moisture Content and Density Measurements

9 Wood Moisture Content and Density Measurements

*Objective:* The amount of energy in a load of firewood is strongly dependent upon its water content. The **Basic Density** of the wood is thus important. As the main aim of the project is to acquire knowledge about the supply of energy, these two parameters had to be looked into. In order to do realistic analyses of the actual situation, i.e. imitate the situation at the homesteads, the measurements were directed at obtaining information about wood under air dry as opposed to oven dry condition.

Available handbooks/research papers do not contain figures for all species. Only the most common and commercial species, which account for only a small fraction of those occurring, were previously examined. Thus all the non-commercial and uncommon ones have been ignored. The Biomass Study, however, deals with all species suitable for woodfuel which are actually collected and used for this purpose. In practice, almost all occurring species fall into this category.

## 9.1 Backing Theory Moisture Content (MC)

9.1 Backing Theory Moisture Content (MC)

A living tree, or timber which is freshly felled, contains water. The water content varies between:

- Parts of one and the same tree;
- Heartwood and sapwood;
- Trees/sizes of the same species;

- Position or location of the tree;
- Growing site;
- Time of the year.

Wood is hygroscopic, i.e. it absorbs and desorbs moisture from and to the environment. Since the properties of timber depend greatly on the amount of moisture it contains, it is frequently necessary to know the exact moisture content of a piece of wood that one intends to use.

Moisture content is the weight of water in wood. What is often confusing (when not specified) is that this can be expressed both as a percentage of the dry weight of the wood itself *or* as a percentage of fresh weight. The most common one is to express MC as a percentage of the oven dry weight:

$$MC\,(\%) = \frac{(Wet\ weight\ \text{-}\ Dry\ weight)*100}{Dry\,Weight}\%$$

An example: The wet weight of a wood specimen is 335 grams. After air drying the weight is 200 grams, and after oven drying the weight is 170 grams. From the formula above we find the moisture content of fresh and air dry wood, respectively:

$$MC\ fresh\,(\%) = \frac{(335 - 170)*100}{170}\% = 97\,\%$$

$$MC\ airdry\,(\%) = \frac{(200 - 170)*100}{170}\% = 18\%$$

The same examples calculated as a percentage of fresh weight give MCs of 49% and 9% respectively.

## 9.2 Backing Theory Density9.2 Backing Theory Density

Wood is an anisotropic porous material. This is due to the differences in the molecular configuration in the three directions i.e. longitudinal, radial and tangential. Hence it affects the properties of wood, e.g. strength and density. Since wood is a porous material, there is a constant interchange of water between it and the air (environment) depending on which is wetter. An external manifestation of this is the observable shrinkage and swelling. It is therefore essential that we define at which particular mass and volume the moisture content is being measured, if Density is being determined.

Wood Density is defined as mass divided by volume, both measured at the same moisture content. The resulting units are gram/cm$^3$ or kg/m$^3$.

$$Wood\ Density = \frac{Mass\,(g)}{Volume\,(cc)}$$

This concept is useful because it allows us to calculate how heavy a given volume of a material will be or conversely what volume a given weight will be.

At the special conditions fresh volume (volume measured at moisture content > 30%) and oven dry weight, we get the conventional density or **Basic Density,** which is the most commonly used value for wood density.

An example: The wood specimen above has a fresh volume of 325 cm$^3$ before drying. After oven drying the weight is 170 grams. Using the formula, we get:

$$Basic\ Density = \frac{170\ g}{325\ cm^3} = 0.52\ g/\ cm^3$$

## 9.3 Work Objectives9.3 Work Objectives

Information about moisture content and density of woody material are important elements in the final processing steps. Data for only a few species were found in available books and research notes/files of the Forest Department. Information on almost all of the traditional non-commercial species were not available. Hence the project had to undertake this research as an additional task, in order to acquire this baseline information.

### 9.3.1 Density9.3.1 Density

As outlined in chapter 7, trees were felled and weighed/measured for the purpose of establishing biomass functions, thus the records from this process were given partly in wet weight, partly in volume. Instructions were given that weighing was to be preferred. However, for practical reasons, the big logs and branches had to be measured for volume. As weight was introduced as the most appropriate unit for the dependent variable, all volume results had to be converted to weight. For this calculation density was needed. The rationality behind the acquisition of density data was therefore to enable the conversion from volume to weight.

### 9.3.2 Moisture Content9.3.2 Moisture Content

The weight obtained from the field was the fresh weight, which is not specifically interesting for woodfuel purposes. For conversion into units of energy, either oven dry weight or air dry weight was required. Air dry weight was preferred as it is more comparable with ordinary cooking practises. Thus wood moisture content data were necessary to enable the conversion from wet weight to air dry weight.

## 9.4 Specimen Measurements
9.4 Specimen Measurements

The work was aimed at collecting representative specimens of both stem and branch wood from as many occurring species as possible. It was carried out in connection with the tree felling process. After felling, one or two specimens from the stem and branches were randomly cut and fresh weight and volume measurements immediately taken. The specimens were kept in an open, roofed shed until reaching a stable air dry weight, after 6 to 12 weeks. During that time the specimens were repeatedly weighed and actual moisture content recorded by means of an electric moisture meter. In addition the air dry volume was found by submerging the specimens into water, weighing and calculating the weight of the water displacement (which is equal to the volume). The size of the specimens varied from 50 grams to a maximum of 2 kg. (The scales had an upper limit of 2 kg with an accuracy of 1 gram.) Refer to Appendix J: "Instructions for Moisture Content/ Density Measurements." for detailed instructions in this process.

For the purpose of determining Density and Moisture Content, a total of 4,556 specimens were collected and measured from three of the project areas as shown in the table 8 below. Technical parameters for a total of 112 different species were determined.

The calculated results are presented in Appendix K, "List of Basic Density and Moisture Content at Air dry Condition of Species measured under The National Biomass Study".

*Table 8: Sample Specimens.*

| Project Area | Number of specimens collected |
|---|---|
| Jinja | 931 |
| Kamuli | 1,897 |
| Mbale | 1,728 |
| Total | 4,556 |

The overall averages for these measurements were as follows:

- Moisture content: **14.7%** (air dry)

- "Basic" density: **0.61** (The term "Basic" is actually not quite correct as air dry wood was applied. "Basic" presumes oven dry wood.)

- Air dry weight/wet weight: **0.56**

In addition a sub-sample of 325 specimens (out of the 4,556) of 72 different species were oven dried in order to check the readings of the electric moisture meter.

In addition to the measurements under the project, available second hand data were collected from various sources. These are listed in Appendix L, "List of Species and their Densities at various Moisture Contents".

If the purpose was to obtain scientific, high accuracy data, both trees and specimens must be selected more specifically due to the fact that MC and Density vary for reasons stated in 9.1. However, attaining such data would constitute a substantial project in itself, and was regarded as outside the limits of the Biomass Study project. Our aim was to obtain approximate figures for each species. However, there is no reason to suspect that our method of random sampling should contain any significant bias.

## 9.5 Energy / Calorific Values for Different Species9.5 Energy / Calorific Values for Different Species

**Amounts of energy** are most commonly given in **Joule (J)** or **kilowatt hours (kwh).** The unit **calories** is an old term, but also used. The conversion between the units are as follows:

- 1 kJ = 0.24 kCal = 0.28 * $10^{-3}$ kWh

- 1 kWh = 5600 kJ = 860 kCal

- 1 kCal = 4.19 kJ = 1.16 * $10^{-3}$ kWh

For **effect** (energy per unit of time), the following units are used:

- 1 kW = 1 kJ/s = 3600 kJ/h = 860 kCal/h = 1.36 Hp

- 1 kCal/h = 1.163 W

- 1 mCal/h = 1.163 kW
- 1 Hp = 0.736 kW

**Efficiency of combustion**, **energy contents** or **calorific value**, expressing amount of energy per unit of weight for a certain fuel, is commonly given as kJ/kg, mJ/ton, kCal/kg or kWh/kg.

Calorific value of wood does not vary much between species. A number of examples collected from different sources are shown below.

*Table 9: Calorific Values for some Species from different Sources.*

| | | |
|---|---|---|
| *Turyareeba, P.J. (1990):* | | |
| Albizia coriaria (w) | 4,362 kcal/kg | 18,258 mJ/ton |
| - " - (b) | 4,485 - " - | 18,773 - " - |
| Mitragyna stipulosa (w) | 4,496 - " - | 18,822 - " - |
| - " - (b) | 4,200 - " - | 17,580 - " - |
| Acacia seyal (w) | 4,259 - " - | 17,830 - " - |
| - " - (b) | 4,188 - " - | 17,530 - " - |
| Combretum binderanum (w) | 4,254 - " - | 17,809 - " - |
| - " - (b) | 3,860 - " - | 16,159 - " - |
| Eucalyptus grandis (w) | 4,571 - " - | 19,135 - " - |
| - " - (b) | 3,534 - " - | 14,792 - " - |
| *National Academy of Science (1980):* | | |
| Acacia senegal | 3,200 kcal/kg | 13,395 mJ/ton |
| Balanites aegyptiaca | 4,600 - " - | 19,256 - " - |
| Dalbergia nitidula | 4,000 - " - | 16,744 - " - |
| Acacia tortilis | 4,400 - " - | 18,418 - " - |
| Ziziphus mauritiana | 4,900 - " - | 20,511 - " - |
| *Doat, J. (198?):* | | |
| Chlorophora excelsa | 5,040 kcal/kg | 21,097 mJ/ton |
| - " - | 5,075 - " - | 21,244 - " - |
| *Beijbom (1958):* | | |
| Pinus sylvestris (wt) | 4,777 kcal/kg | 20,000 mJ/ton |
| Norway spruce (wt) | 4,634 - " - | 19,600 - " - |
| Betula spp. | 4,623 - " - | 19,350 - " - |
| Average | 4,373 kcal/kg | 18,305 mJ/ton |

w = wood b = bark wt = whole tree

The average of the above listed species should give a calorific value applicable for our calculations. Taking into account that these values are prevailing for oven dry wood, a certain reduction must be realised as 14.7% (in relation to dry weight) was the actual average moisture content. From the graph displayed below, it is seen that this moisture content gives an insignificant reduction in calorific value, thus a rounding down to 18,000 mJ/ton should be sufficient.

The graph below - used in relevant literature - displays the connection between moisture content and combustion efficiency;

- the lower graph (1) when the total weight is 1 kg;
- the upper graph (2) when the total weight is 1 kg dry wood + water.

Regarding a MC of 100% as an example, the wood in the upper graph contains 1 kg wood + 1 kg water. In the lower graph the wood contains 0.5 kg wood + 0.5 kg water.

```
             ¦                                                  ¦
    kwh/kg 5-+-                                      MJ/kg 18.0-+-
             ¦                                                  ¦
Combustion   ¦                                                  ¦
efficiency 4-+-                (2)                         14.4-+-
             ¦                                                  ¦
             ¦                                                  ¦
           3-+-                                            10.8-+-
             ¦                                                  ¦
             ¦                 (1)                              ¦
           2-+-                                             7.2-+-
             ¦                                                  ¦
             ¦                                                  ¦
           1-+-                                             3.6-+-
             ¦                                                  ¦
             ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦
           0-+----+----+----+----+----+----+----+----+----+----+
             ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦
                      25        67        150       400
              Moisture Content, % of Dry Weight

             ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦
             +----+----+----+----+----+----+----+----+----+--
                  ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦    ¦
                      20        40        60        80
              Moisture Content, % of Total Weight
```

When dealing with large amounts of energy, these units are too small. In such cases one uses the standard scientific units outlined in the table below.

*Table 10: Units above 1 million.*

| Term | Symbol | Power | Factor |
| --- | --- | --- | --- |
| Kilo | K | $10^{3}$ | Thousand |
| Mega | M | $10^{6}$ | Million |
| Giga | G | $10^{9}$ | Billion |
| Tera | T | $10^{12}$ | Trillion |
| Peta | P | $10^{15}$ | Quadrillion |

# 10 Processing10 Processing

## 10.1 Establishing Single Tree Biomass Equations10.1 Establishing Single Tree Biomass Equations

At the plot measurements all the trees were measured for the independent variables dbh, bole length, total height and crown width. In order to obtain the woody biomass of the trees, single tree tables must be calculated. As outlined and tabulated in chapter 7, a total of 2,721 trees of 123 different species had been felled for this purpose.

### 10.1.1 Grouping of Species10.1.1 Grouping of Species

It was not possible within the range of this project to create biomass functions for all of the 360 relevant species individually. Attaching the function to the species may not even be the best method as the shape and size of trees vary also within the same species. Some way of grouping the trees had to be found. *In our case the species and the shape of the trees were used as criteria, the former being most important.* The grouping of species was a difficult task even though a specialist was consulted. Another way of approaching the grouping problem may have been to consider the shape and size, using a tree shape model system and arrive at a shape-size score for each tree. Applying this method, though, we would have encountered a number of difficulties, e.g. lack of account of different wood properties. Time was a major limiting factor with regard to experiments on this subject.

The approach selected comprised the following steps:

(1) Group the species based on similarities of morphological features and wood property characteristics *through scrutinizing the data from both the tree felling and the field plot measurement records.*

(2) Run regression analysis for each group of species to establish biomass equations, using the data from the tree felling process. As independent variables: dbh, tree height, bole length, crown height and crown

width. As the dependent variable: fresh weight.

The test-trees cut and measured for biomass regression equation establishment were grouped into 38 different categories. The group name indicates the main species within the group. Each group should contain at least 25 test-trees - the total number being 2,721 test-trees. All the trees were joined into one file independently of the area in which they had been felled. Table 11 gives a summary overview of the grouping. A more detailed specification of all species and their grouping can be found in Appendix M.

*Table 11: Grouping of Test-trees / Species.*

| Group | | No of test-trees | No of tree species | No of non-test tree species | |
|---|---|---|---|---|---|
| 1: | Acacia | 239 | 8 | 1 | |
| 2: | Albizia | 204 | 12 | 21 | |
| 3: | Bridelia | 72 | 2 | 5 | |
| 4: | Cassia | 62 | 3 | 6 | |
| 5: | Celtis | 33 | 4 | 21 | |
| 6: | Chlorophora | 70 | 10 | 23 | |
| 7: | Combretum | 171 | 6 | 2 | |
| 8: | Cypress/Pine | 10 | 2 | 5 | * |
| 9: | Erythrina | 111 | 2 | 2 | |
| 10: | Eucalyptus | 85 | 1 | 0 | * |
| 11: | Euphorbia | 21 | 2 | 2 | |
| 12: | Ficus natalensis | 64 | 1 | 0 | |
| 13: | Ficus spp. | 99 | 6 | 5 | |
| 14: | Funtumia | 39 | 1 | 2 | |
| 15: | Grewia | 96 | 2 | 1 | |
| 16: | Lannea | 66 | 1 | 3 | |
| 17: | Maesopsis | 62 | 4 | 8 | |
| 18: | Mangifera/Artocarpus | 96 | 3 | 4 | |
| 19: | Markhamia | 121 | 1 | 0 | |
| 20: | Maytenus | 38 | 1 | 2 | |
| 21: | Persea | 55 | 3 | 3 | |
| 22: | Piliostigma | 71 | 1 | 5 | |
| 23: | Rhus | 100 | 3 | 1 | |
| 24: | Sapium | 54 | 2 | 1 | |
| 25: | Securidaca/Securinega | 43 | 3 | 0 | |
| 26: | Spathodea | 94 | 5 | 8 | |
| 27: | Stereospermum | 58 | 2 | 0 | |
| 28: | Strychnos | 25 | 2 | 6 | |
| 29: | Syzygium | 21 | 2 | 3 | |
| 30: | Terminalia | 73 | 3 | 2 | |
| 31: | Vernonia | 78 | 2 | 10 | |
| 32: | Vitex | 27 | 2 | 10 | |
| 33: | Cussonia | 49 | 1 | 0 | |
| 34: | Antiaris | 59 | 3 | 2 | |
| 35: | Annona | 34 | 2 | 0 | |
| 36: | Gardenia | 30 | 2 | 3 | |
| 37: | Ornamentals/shrubs | 60 | 10 | 78 | |
| 38: | Steganotaenia | 31 | 3 | 0 | |
| | Total | 2721 | 123 | 245 | |

*Groups 8 and 10 were combined for the biomass calculations, due to the number of trees in 8 being too low.

### 10.1.2 Unit of the Dependent Variable10.1.2 Unit of the Dependent Variable

Volume units are traditionally used to measure amounts of wood. As the primary objective of the Biomass Study is to express amounts of wood for woodfuel purposes, units of energy or dry weight (air dry weight) were more appropriate. Using volume as the unit would mean that differences in wood properties, for example basic density and moisture content between species would be ignored. This may have had a considerable effect on the results.

*It was thus clear that the final results should be expressed using either energy units or air dry weight.*

Whether units of energy or weight of air dry wood are used is not important, as the calorific value between species varies little per weight unit of dry material. An energy value is achieved by multiplying the weight with the calorific value. *Air dry weight was selected as the unit to be used when presenting final results.*

In order to make single tree biomass equations one is faced with three options for selecting the dependent variable; *volume, wet weight* and *dry weight*. Because the independent variables in question; dbh, tree height, bole length, crown width and crown length (tree height minus bole length) are directly volume related, *volume probably stands as the best statistical dependent variable.*

However, weighing is a much easier process for the big majority of (smaller) trees. In addition, there exists sources of error when converting from volume to weight. Therefore, it was decided to use weight as the result unit (dependent variable) in the single tree biomass equations.

Wet weight (also called fresh or green weight) was chosen for the following reasons: Firstly, the correlation of the independent variables is more unpredictable when dealing with dry weight. Secondly, *wet weight was assumed to be more significantly correlated to volume than dry weight.* This decision was based on the assumption that between species; basic density (dry weight divided by wet volume) varies more than wet density (wet weight divided by wet volume). The wood sap partly compensates the differences in density, i.e. light and "porous" wood will normally contain more water than dense, heavy wood types.

### 10.1.3 Regression Analysis10.1.3 Regression Analysis

The process of felling trees for the purpose of constructing single tree weight tables is outlined in chapter 7. In accordance with the discussion above (chapter 10.1.2), the fresh wood weight was selected as the dependent variable *y*. Two sets of equations were designed independently; one for the stem and one for the branch-wood. *y* was obtained directly by using wet weight, or in the case of volume, via wet density. The independent variables (dbh, bole length, tree height, crown width and crown height) are corresponding to $x_1$, $x_2$, $x_3$, $x_4$ and $x_5$. Multiple regression calculations were run for each of the 37 groups (groups 8 and 10 were joined under the processing) listed in 10.1.1, using a software package called **Statistical Analysis System (SAS).**

In order to obtain maximum R square[2], the multiple regression model selected works stepwise as follows:

(1) The highest correlating independent variable was selected.

(2) All combinations of two independent variables were tested, and the one with the highest correlation was selected.

(3) All combinations of three independent variables were tested, and the one with the highest correlation was selected.

(4) Same procedure for four variables as for three.

(5) Same procedure for five variables.

The following table displays the selected regression equations including the significant variables with the corresponding coefficients (b, c, d, e and f) for both bole and branches for each group (in values of natural logarithm). y gives the wet weight.

General model:

$$\ln(y) = a + b*\ln(x_1) + c*\ln(x_2) + d*\ln(x_3) + e*\ln(x_4) + f*\ln(x_5)$$

where

$x_1$ = dbh — st. = stem

$x_2$ = bole length — br. = branches

$x_3$ = tree height

$x_4$ = crown width

$x_5$ = crown height

[2] A simple explanation of regression analysis and R square can be found in App. P.

*Table 12: Selected Regression Equations, including Significant Variables with the Corresponding Coefficients.*

| VAR Group | a INTERCEPT | b | c | d | e | f | R square | MEAN | CV |
|---|---|---|---|---|---|---|---|---|---|
| 1 st. | -2.082 | 1.677 | 0.369 | 0.631 | *** | *** | 0.87 | 0.168 | 14.3 |
| br. | -1.793 | 1.843 | *** | *** | 0.490 | 0.330 | 0.88 | 0.218 | 13.8 |
| 2 st. | -2.134 | 1.696 | 0.349 | 0.596 | *** | *** | 0.94 | 0.121 | 10.2 |
| br. | -1.173 | 1.759 | *** | -0.846 | 0.547 | 0.897 | 0.92 | 0.189 | 12.3 |
| 3 st. | -1.947 | 1.623 | 0.330 | 0.530 | *** | *** | 0.85 | 0.103 | 13.6 |
| br. | -1.375 | 1.197 | *** | *** | 0.621 | 0.798 | 0.87 | 0.137 | 13.7 |
| 4 st. | -3.047 | 1.846 | 0.381 | 0.772 | *** | *** | 0.93 | 0.072 | 9.3 |
| br. | -1.412 | 1.427 | *** | *** | 0.736 | 0.246 | 0.90 | 0.112 | 11.2 |
| 5 st. | -1.908 | 2.111 | 0.450 | *** | *** | *** | 0.98 | 0.117 | 9.2 |
| br. | -0.413 | 2.601 | *** | -1.082 | *** | *** | 0.93 | 0.229 | 13.9 |
| 6 st. | -2.280 | 1.170 | 0.306 | 0.987 | 0.429 | *** | 0.94 | 0.119 | 9.3 |
| br. | -0.507 | 1.279 | *** | -0.838 | 0.833 | 0.936 | 0.84 | 0.262 | 14.8 |
| 7 st. | -2.654 | 1.609 | 0.194 | 1.069 | *** | *** | 0.90 | 0.134 | 12.7 |
| br. | -1.604 | 1.349 | *** | *** | 0.643 | 0.684 | 0.87 | 0.207 | 14.4 |
| 8 st. | -2.947 | 1.552 | *** | 1.294 | *** | *** | 0.87 | 0.205 | 12.2 |
| br. | -1.079 | 1.776 | *** | -0.530 | 0.304 | 0.565 | 0.92 | 0.115 | 10.9 |
| 9 st. | -2.093 | 1.726 | 0.198 | 0.482 | *** | *** | 0.84 | 0.197 | 14.9 |
| br. | -0.880 | 0.851 | *** | 0.661 | 0.926 | *** | 0.80 | 0.255 | 15.5 |
| 10 st. | -2.947 | 1.552 | *** | 1.294 | *** | *** | 0.87 | 0.205 | 12.2 |
| br. | -1.079 | 1.776 | *** | -0.530 | 0.304 | 0.565 | 0.92 | 0.115 | 10.9 |
| 11 st. | -2.911 | 2.155 | 0.835 | *** | *** | *** | 0.94 | 0.087 | 9.0 |
| br. | -1.860 | 2.345 | *** | *** | *** | *** | 0.88 | 0.148 | 8.5 |
| 12 st. | -2.371 | 1.577 | 0.215 | 0.878 | *** | *** | 0.94 | 0.136 | 10.3 |
| br. | -2.363 | 1.944 | *** | *** | *** | 0.816 | 0.94 | 0.181 | 10.9 |
| 13 st. | -2.184 | 1.638 | 0.373 | 0.663 | *** | *** | 0.92 | 0.095 | 8.7 |
| br. | -1.290 | 1.605 | *** | -0.566 | 0.706 | 0.724 | 0.88 | 0.225 | 12.5 |
| 14 st. | -2.216 | 1.723 | 0.322 | 0.557 | *** | *** | 0.97 | 0.041 | 6.5 |
| br. | -1.507 | 1.249 | *** | *** | 0.621 | 0.526 | 0.86 | 0.165 | 15.8 |

*Table 12: Continued...*

| VAR Group | a INTERCEPT | b | c | d | e | f | R square | MEAN | CV |
|---|---|---|---|---|---|---|---|---|---|
| 27 st. | -1.390 | 1.561 | 0.358 | *** | 0.432 | *** | 0.84 | 0.190 | 17.5 |
| br. | -1.970 | 1.854 | *** | *** | 0.791 | *** | 0.92 | 0.146 | 13.6 |
| 28 st. | -2.245 | 2.471 | 0.735 | *** | -0.672 | *** | 0.85 | 0.165 | 18.7 |
| br. | -2.302 | 2.464 | *** | *** | *** | *** | 0.79 | 0.314 | 19.3 |
| 29 st. | -2.249 | 1.393 | *** | 1.071 | *** | *** | 0.77 | 0.225 | 13.5 |
| br. | -2.334 | 1.587 | *** | *** | 0.465 | 0.825 | 0.93 | 0.115 | 9.2 |
| 30 st. | -2.177 | 2.122 | 0.383 | *** | *** | *** | 0.86 | 0.182 | 15.8 |
| br. | -1.591 | 1.608 | *** | *** | 0.940 | *** | 0.86 | 0.198 | 13.9 |
| 31 st. | -1.812 | 1.599 | 0.276 | 0.511 | *** | *** | 0.68 | 0.205 | 19.6 |
| br. | -0.996 | 1.537 | *** | *** | 0.325 | 0.404 | 0.78 | 0.176 | 14.5 |
| 32 st. | -1.897 | 1.265 | *** | 1.099 | *** | *** | 0.87 | 0.114 | 11.2 |
| br. | -2.772 | 1.396 | *** | 0.770 | 0.894 | *** | 0.94 | 0.129 | 12.3 |
| 33 st. | -2.779 | 1.617 | 0.592 | 0.936 | *** | *** | 0.88 | 0.111 | 10.5 |
| br. | -3.815 | 2.382 | *** | *** | 0.888 | *** | 0.89 | 0.232 | 14.8 |
| 34 st. | -1.724 | 2.135 | 0.307 | *** | *** | *** | 0.99 | 0.121 | 6.8 |
| br. | -1.074 | 2.394 | *** | -1.579 | *** | 1.418 | 0.96 | 0.329 | 13.1 |
| 35 st. | -2.915 | 1.194 | *** | 1.858 | *** | *** | 0.84 | 0.142 | 15.5 |
| br. | -1.146 | 1.337 | *** | *** | 1.028 | *** | 0.88 | 0.135 | 12.3 |
| 36 st. | -2.179 | 1.333 | *** | 1.029 | *** | *** | 0.73 | 0.303 | 29.3 |
| br. | -0.510 | 0.863 | *** | 0.580 | 1.116 | *** | 0.86 | 0.212 | 14.6 |
| 37 st. | -1.073 | 1.621 | 0.476 | *** | *** | *** | 0.80 | 0.160 | 14.7 |
| br. | -0.556 | 1.327 | *** | -0.436 | 0.721 | 0.537 | 0.74 | 0.242 | 15.8 |
| 38 st. | -2.778 | 1.508 | *** | 1.292 | *** | *** | 0.77 | 0.128 | 13.5 |
| br. | -1.782 | 1.520 | *** | *** | *** | 1.123 | 0.77 | 0.163 | 13.1 |

Columns b–f: SIGNIFICANT INDEPENDENT VARIABLES

*** = Not significant

*Dbh was always the selected variable in step 1.* Therefore, as well as being the independent variable that is easiest to measure, it also provides the most reliable information about both stem-wood and branch-wood. Thus, dbh was the most important variable.

Furthermore as independent variables of the stem weight, bole length and tree height were mostly significant. For the branch-wood, crown width and crown height were important additional independent variables.

## 10.2 Plot Weight Calculation10.2 Plot Weight Calculation

Using the equations listed in 10.1.3, the total biomass of all the trees recorded for each field plot was calculated. This was done through exporting the relevant dBase-files as ASCII-files and then importing them into SAS.

Furthermore, *mean, max, min, N, CV (Coefficient of Variation)* and *Standard Error of the Mean* were computed for each land use/cover class within each project area in terms of fresh weight in kg per hectare. A number of frequency lists were also produced: Species frequency, frequency distribution of number of trees in each land use/cover class and frequency distribution of wet weight of trees per 10 cm dbh classes. These lists are not included in this report, but are available for interested users.

The resulting tables are presented in chapter 11.

## 10.3 Establishing the Plot Biomass Equations10.3 Establishing the Plot Biomass Equations

The photo-interpreted data (the methodology is explained in chapter 6.1) could now be correlated with the actual biomass data for each plot. A number of regression models were tested - both logarithmic and non-logarithmic - to establish the best possible relationship between these two data sets.

## 10.4 Regression Analysis10.4 Regression Analysis

Plot fresh weight was used as the dependent variable. Crown cover of trees (CRCOV) was applied as the only independent variable. After testing a number of different combinations of the independent variable, we ended up with the following model giving the best function with regard to R square:

$$y = a + b * CRCOV + c * CRCOV^2 + d * \sqrt{CRCOV} + e * CRCOV * \sqrt{CRCOV}$$

The same model of natural logarithm in some cases gave a slightly better R square. However, the selected model appeared to work adequately as a whole for all the areas and all the interpreters.

As mentioned in chapter 6.1.7, the number of upper storey trees was also tested as an additional independent variable. However, *the results were confusing and offered little additional correlation.*

The regression analysis gave the following coefficients for the stem-wood and branch-wood separately:

*Table 13: Coefficients for the Stem-wood (st.) and Branch-wood (br.).*

| PROJECT AREA | | a INTER-CEPT | b | c | d | e | R square |
|---|---|---|---|---|---|---|---|
| | | | SIGNIFICANT INDEPENDENT VARIABLES | | | | |
| ARUA | st. | 1616.07 | *** | 5.02 | 883.83 | *** | 0.42 |
| | br. | 3535.92 | *** | 5.17 | 1212.52 | *** | 0.23 |
| JINJA | st. | 9634.22 | 38831.55 | 555.25 | -51400.04 | -8339.23 | 0.40 |
| | br. | 10460.26 | 15391.15 | 175.80 | -17728.18 | -2979.32 | 0.25 |
| KABALE | st. | 1933.89 | 571.57 | *** | *** | *** | 0.25 |
| | br. | 2439.01 | 324.70 | *** | *** | *** | 0.23 |
| KAMPALA | st. | 3692.20 | 678.16 | *** | *** | *** | 0.21 |
| | br. | 6215.09 | 869.23 | *** | *** | *** | 0.20 |
| KAMULI | st. | 4915.67 | 10815.45 | 157.82 | -15110.85 | -2274.19 | 0.37 |
| | br. | 12342.52 | 30926.80 | 452.34 | -45335.02 | -6522.19 | 0.32 |
| KUMI | st. | 2912.89 | 326.88 | *** | *** | *** | 0.22 |
| | br. | 7437.81 | 689.29 | *** | *** | *** | 0.17 |
| MBALE | st. | 1583.07 | 674.67 | *** | *** | *** | 0.19 |
| | br. | 3251.54 | 935.57 | *** | *** | *** | 0.29 |
| MBARARA | st. | 1198.89 | *** | 3.36 | 677.27 | *** | 0.18 |
| | br. | 1360.62 | *** | 2.67 | 994.77 | *** | 0.29 |
| CRCOV < 30: | | | | | | | |
| MOROTO | st. | 524.75 | *** | 9.37 | 461.98 | *** | 0.35 |

These were the equations finally selected. Significant values of higher regression steps, resulting in considerably better R square, were obtained. There were, however, many other considerations involved during the process of scrutiny and model selection. The main problem was due to the dependent variable containing few sample units from the upper half of the crown cover range. Most of the scores were concentrated at lower and middle levels. In these intervals the functions were well justified. However, beyond the middle scores the curves occasionally behaved out of control. For instance, some of the "better" models had one or more negative coefficients and were flexible and well fitted up to a certain level. But at higher crown cover scores, the curve tended to culminate and even reach negative y-values. Alternatively if the function started exponentially, it might shoot up at higher x-levels. Such functions must not be handled uncritically. If a high x'-score occur, the function may give a completely absurd y-value, either extremely low or high. Hence, some of the apparently good equations had to be rejected.

On the other hand, simpler functions such as linear functions also cause problems, mainly because they are inflexible and do not fit so well in the relevant area. However, they do represent a "safe" compromise.

As was necessary for Moroto, slashing the scope into two intervals was tried, but only partly successful. The problems with such an approach are obvious. If the scatter diagram shows a cluster of points, prolonging the x-axis scope as much as possible is important in order to get a firm status of the function. Both the number and the spreading of the scatter points will affect the success of sub-dividing the x-values.

Another relevant issue to discuss is the applicability of the method itself. When the R square shows low values, the method is questionable. On the other hand, a number of error factors might have contributed to the low correlation: The complexity of many tropical vegetation patterns (e.g. dense canopies), seasonal changes, difficulties with our classification system, lack of experience with this type of photo interpretation among the interpreters and not enough time for a "pilot" approach. All these issues have been discussed repeatedly within the project and there are different views on how these error factors should be weighted (see chapter 14, "Sources of Error" for further details on possible error factors). There is still faith in the methodology, but further research into these topics are obviously necessary. The Biomass Study intends for instance to suggest such topics for further research done by outside persons/groups (e.g., M.Sc. or Ph.D. students).

# 10.5 Double Sampling Processing10.5 Double Sampling Processing

As mentioned in chapter 6, the processing was based upon the application of Double Sampling, which involves sampling in two phases or stages. The principle of Double Sampling, related to this study, is as follows:

*Stage 1:* A random sample of photo-plots is taken - a great number of the variable $x'_i$ (i = 1,2,3, ..., n') which is "easily" attained (little work per plot). In our case $x'_i$ was represented by crown cover scores of a large number of photo-interpreted plots.

*Stage 2:* A random sub-sample from the stage 1 sample is taken - small number of the "true" variable $y_i$ (i = 1,2,3, ..., n) which is "difficult" to attain (much work per plot). In this case $y_i$ represented the field measured crown cover score and $x_i$ the values from stage 1 respectively.

The variables of the method are illustrated in the frame below. The first column ($x'_i$) contains a larger number (9 plots in this case) of crown cover estimates based on photo interpretation (stage 1). The third column ($y_i$) contains the crown cover scores of a sub-sample of these plots, measured in the field. The second column ($x_i$) contains the photo-estimated crown cover scores for the same sub-sample plots as in the third column.

| | Photo-interpreted | | Field measured | |
|---|---|---|---|---|
| | $x'_i$ | $x_i$ | $y_i$ | |
| | 20 | | | |
| | 10 | 10 | 10 | |
| | 15 | | | |
| n'=9 | 35 | 35 | 30 | n=3 |
| | 5 | | | |
| | 10 | | | |
| | 20 | | | |
| | 15 | | | |
| | 5 | 5 | 15 | |
| | $\bar{x}'$ = 15 | $\bar{x}$ = 16.7 | $\bar{y}$ = 18.3 | |

After the recording and entering were completed, the correction can be calculated by **Ratio Estimation** in the form

$$y = R*x$$

where R is the correction factor, or by **Regression Estimation** in the form

$$y = a + b*x$$

Variance of mean by ratio estimation (Cochran, 1967) is:

$$Var(\overline{Y_R}) = \frac{S_y^2 - 2RS_{yx} + R^2 S_x^2}{n} + \frac{2RS_{yx} - R^2 S_x^2}{n'}$$

After correction by double sampling, we obtain the final estimate:

$$\overline{y_R} = \frac{\overline{y}}{x} * \overline{x'} = R * \overline{x'}$$

where R gives the estimated correction factor and x' the level.

Implementation of Double Sampling in this study by Regression Estimation comprised the following steps:

(1) Establish the x' plots (approx. 20,000) and provide adequate measurements of photo-interpreted crown cover scores.

(2) Establish y; i.e. from a sub-sample (3,417) of (1), obtain the total biomass fresh weight of the plots.

(3) Establish relationships between the results from (1) and (2) for the sub-sample plots by regression equations for each land use/cover class.

(4) Assign biomass weights to all x' plots by means of the equations obtained in (3), and calculate the average x'.

(5) From (4) extract the weights for the sub-sample plots and calculate x. R is found as the weight ratio y/x for each land use/cover class.

(6) The final estimate is then found by multiplying the correction factor R with the level x'.

This method was applied for the tree biomass estimation. For the bush biomass estimation, Ratio Estimation was used according to the following steps:

(1) Same as above.

(2) Establish y; i.e. from a sub-sample of (1), obtain the field bush cover score - the "true" value.

(3) Calculate the correction factor R, based on the sample units occurring in both (1) x and (2) y.

(4) For each land use/cover class multiply the obtained correction factor with the average level x', from (1).

(5) From (4) the final, estimated bush cover score is obtained which subsequently is multiplied with the fixed mass per ha of bush.

## 10.6 Area Calculations Using a GIS10.6 Area Calculations Using a GIS

The size of closed polygons are automatically calculated in PC-ARC/INFO. Adding up all polygons for each land use/cover class and project area yielded the following figures:

*Table 14: Area on Land Use/Cover Class for each Project Area in km².*

| Class | Arua | Jinja | Kabale | Kampala | Kamuli | Kumi | Mbale | Mbarara | Moroto |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 10.69 | 8.21 | 49.55 | 10.30 | 0.48 | 1.61 | 2.31 | 5.62 | 0.07 |
| 2 | 0.00 | 3.22 | 13.35 | 0.55 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| 3 | 0.00 | 93.99 | 0.00 | 33.60 | 0.00 | 0.00 | 7.91 | 0.00 | 0.35 |
| 4 | 0.00 | 8.33 | 0.00 | 17.10 | 0.00 | 0.00 | 7.43 | 0.00 | 0.00 |
| 5 | 62.06 | 58.99 | 0.13 | 272.42 | 19.29 | 14.43 | 11.04 | 3.09 | 19.31 |
| 6 | 134.93 | 120.38 | 118.53 | 247.94 | 357.91 | 101.92 | 84.71 | 24.10 | 766.41 |
| 7 | 0.00 | 56.17 | 33.63 | 26.94 | 2.80 | 0.38 | 0.00 | 613.38 | 207.70 |
| 8 | 1.22 | 32.02 | 10.58 | 296.36 | 28.61 | 135.23 | 75.38 | 38.72 | 0.00 |
| 9 | 830.41 | 820.30 | 713.31 | 1,754.32 | 830.86 | 1,203.78 | 1,723.96 | 222.15 | 312.80 |
| 10 | 2.60 | 70.95 | 14.18 | 78.90 | 16.01 | 9.47 | 24.99 | 2.16 | 0.24 |
| 11 | 8.10 | 23.37 | 1.72 | 107.70 | 1.59 | 8.84 | 13.60 | 8.19 | 6.31 |
| 12 | 0.00 | 290.92 | 0.62 | 148.25 | 4.73 | 60.97 | 0.19 | 0.49 | 0.00 |
| All | 1,050.01 | 1,586.85 | 955.60 | 2,994.38 | 1,262.28 | 1,536.63 | 1,951.53 | 917.90 | 1,313.19 |

## 10.7 Bush Biomass10.7 Bush Biomass

When estimating the biomass of the bush vegetation, the Ratio Estimation technique of Double Sampling was used. The cover of bush was assessed for all plots both from the field measurements (y) and the photo interpretation (x).

*Table 15: Summary of Data Collected on Bush - Fresh Weight in kg of 10 m by 10 m Plots.*

| AREA | NO OF PLOTS | MEAN | MIN | MAX | STD |
|---|---|---|---|---|---|
| JINJA | 7 | 269.8 | 116.5 | 409.0 | 100.1 |
| KAMULI | 5 | 460.8 | 319.0 | 606.0 | 96.2 |
| MBARARA | 4 | 220.0 | 51.0 | 368.0 | 137.4 |
| MOROTO | 22 | 406.3 | 107.0 | 900.0 | 229.9 |
| Total | 38 | 339.2 | 51.0 | 900.0 | 53.8 |

The plots were considered to have a bush cover of 100%.

Due to the small number of plots in some of the land use/cover classes, it was found appropriate to combine the types into two groups, assuming that the potential bias of the crown cover assessment did not vary between classes. Thus class 9 was calculated separately, whereas the remaining classes were joined into one group. The computation of the combined group was carried out as follows: The correction factor y/x was found as the average of all participating plots for each of the two groups. This common factor was then used to the level x' corresponding to each land use/cover class.

## 10.8 Agricultural Residues10.8 Agricultural Residues

The results of our special studies on each of the agricultural crops encountered are listed in table 16. 50% was regarded as moisture content for coffee, 60% for cassava and 67% for sugar, maize and sorghum. These estimates were based on staff experience as well as literature and interviews with estate managers.

Table 16 was the basis for the computation of agricultural residues. Multiplied with the area cover within each land use/cover class, the amount of each crop type was derived.

*Table 16: Agricultural Residues - Average Weights Acquired from 10 m by 10 m Plots.*

| Crop type | No. of plants 0.01ha | Pruning freq. pr.year | Harvest times pr.year | Fresh Weight pr.plant in kg | No. of stems pr.plant | Air dry Harvest pr/ha/y in tons | |
|---|---|---|---|---|---|---|---|
| Cassava | 35.9 | - | 1.0 | 3.7-7.2 | 3.7 | 5.3-10.3 | *1 |
| Coffee | 12.9 | 1.0 | - | 10.-23.6 | 4.2 | 1.5 -3.6 | *2 |
| Maize | 74.1 | - | 1.1 | 1.5 | 2.5 | 3.7 | *1 |
| Sorghum | 72.0 | - | 1.0-2.0 | 1.3 | 8.0 | 3.1-6.2 | *1 |
| Sugar cane | 29.1 | 2.4 | - | 10.0 | 7.3 | 6.3 | *2 |
| Sugar cane | 71.5 | - | 0.7 | 30.0 | 24.0 | 47.2 | *3 |
| Papyrus | - | - | 1.0 | - | - | 25.0 | *4 |

*1 - Assumed continuous growth.
*2 - Assumed pruning of 1 stem pr. plant pr. pruning.
*3 - Sugar cane from estates.
*4 - Collected data from IUCN Wetland Project 1991.

## 10.9 Population Figures Extracted from the 1991 Census10.9 Population Figures Extracted from the 1991 Census

The main objective of the Biomass Study is, as previously stated, to assess the supply of miscellaneous woodfuel *in order to identify areas with a prevailing deficiency.* In order to do this, information about consumption is vital. Consumption of woodfuel in the project areas was assumed to be roughly proportional to the population density.

From the Population Census of January 1991 the relevant figures were extracted as follows:

- The project areas were transferred to the census maps.
- From these maps the area of all relevant sub-counties (185) were measured using a planimeter, both for the total area and that within the project boundaries. The ratio; area inside to total area was then derived for each sub-county, refer to Appendix N.
- Population figures for the same sub-counties were then found.
- The area ratios were applied to the census figures for each sub-county to approximate the population within the project areas and the population density, refer to Appendix O. The occurrence of uninhabitable regions such as lakes and papyrus swamps were considered.
- Finally, the population figures were rectified after obtaining the "correct" areas from the GIS-based information system.

The method presumes that the population is evenly distributed, which of course is not quite correct. However, the method gives figures which were considered to be sufficiently accurate. The results are given in the following table:

*Table 17: Population Figures for the Relevant Project Areas.*

| Project Area | Area $km^2$ | Population | Population Density |
|---|---|---|---|
| Arua | 1050.0 | 210,100 | 200 |
| Jinja | 1586.9 | 392,300 | 247 |
| Kabale | 955.6 | 243,600 | 255 |
| Kampala | 2994.4 | 1,433,000 | 479 |
| Kamuli | 1262.3 | 97,300 | 77 |
| Kumi | 1536.6 | 148,900 | 97 |
| Mbale | 1951.5 | 644,300 | 330 |
| Mbarara | 917.9 | 137,700 | 150 |
| Moroto | 1313.2 | 33,800 | 26 |
| Total | 13420.1 | 3,341,000 | 249 |

## 10.10 Woodfuel Consumption10.10 Woodfuel Consumption

Data on energy consumption in Uganda exist, but the most important surveys done are either disputed (e.g. the CODA survey, see below) or it is difficult to extract accurate and widely applicable figures. It was not possible within our framework to conduct any large scale surveys in the project areas, and an estimated average was selected after looking into all relevant sources at our disposal. The following sections give the background for this estimate.

Considering that the biomass project is dealing with urban areas, the relevant consumption contains a relatively high proportion of charcoal which requires a higher amount of wood inputs due to losses in the conversion process. In addition considerable amounts of woodfuel are used for industrial purposes and in public establishments (brick and tile burning, tobacco curing, bakeries, hospitals, schools plus poles for local building purposes). Information on the conversion efficiency of the charcoal kilns used in Uganda is thus essential in order to arrive at consumption figures in the form of air dry woody biomass.

### 10.10.1 Charcoal Kiln Efficiency in Uganda10.10.1 Charcoal Kiln Efficiency in Uganda

Traditional earth kilns, like the **Long Kinyankole Kiln** and the **Pit Kiln,** are totally dominant among charcoal burners in Uganda. Improved kilns were introduced in the 60's and the early 70's with some success, but this development retarded during the dark years.

We have found no large scale survey on the efficiency of these earth kilns, but some limited surveys and various estimates give a coherent picture:

- A survey of the earth kiln efficiency in Nebbi district in 1985/86 (Collins, 1986) yielded average conversion efficiency (by weight) of around 10%.

- Dr. Aluma at the Department of Forestry, Makerere University, estimates the conversion efficiency by weight to 15% (Aluma, 1989). The estimate is based on visiting a large number of charcoal kiln sites (personal communication).

- Utilization Officer Carvalho, Forest Department, states a conversion efficiency *by dry weight* of 10-15% (Carvalho, 1986).

- The HEPP report asserts that earth kilns has a low conversion efficiency ranging between 7% and 15%, and the report uses 10% in its calculations. The sources are not clearly stated, but seem to be international (e.g., other sub-Saharan countries and FAO).

Both Collins and others emphasize that Ugandan charcoal burners normally use almost fresh wood as raw material (air dried from 1-15 days). The reasons for this might be several: Impatience, no real knowledge of the positive relationship between dryness and conversion efficiency, no strong motive for increasing the conversion efficiency since the raw material normally is free, or that they find the kiln easier to control, which again might reflect poor techniques and/or lack of proper attention. Our small size wood specimens (see chapter 9.4) reached an average stable moisture content of 14.7% after 6-12 weeks. The larger logs used in kilns would require far more, especially if they are left in the open. Even if most sources above do not specify the moisture content, one can therefore assume that it often will be in the 40-80% range. A conversion factor from *air dry wood (MC around 15%)* to charcoal of 15% might thus seem a bit low.

Another negative factor is the lack of proper tools for tree felling - most charcoal burners use axes or pangas for both felling and chopping up the trees, normally leaving high stumps and other waste. Since most conversion studies have been comparing the weight of stacked wood with the weight of the resulting charcoal, such waste are not really considered. From this point of view, using the conversion efficiency estimates alone give a too low figure for the amount of air dry biomass actually used to produce charcoal.

Finally, the official Government of Uganda estimate is found in **Background to the Budget 1992-93,** published in June 1992. Here it is estimated that 1.596 mill tons of wood (round wood equivalents) were used to produce 200,000 tons of charcoal in 1991. This indicates a conversion efficiency by weight of approximately 12.5% - but it must be noted the document does not define "round wood" with regard to moisture content.

As a result of the factors mentioned above, *an average conversion factor from charcoal to air dry biomass of 6.6 has been adopted.* It should be noted here that improved kilns have a conversion efficiency of 20-35%, depending on the wood species used. Successful introduction of improved kilns might therefore radically increase the output from charcoal production.

### 10.10.2 International Studies of Woodfuel Consumption10.10.2International Studies of Woodfuel Consumption

A constant of *1.04 m³* is widely used for the annual per capita consumption of woody biomass for fuel purposes in the Third World. After the appropriate calculations, one obtain *600 kg of air dry weight per capita per annum,* assuming an average density of fresh wood of 1.03 g/cm³ and an average ratio air dry weight divided by fresh weight of 0.56 (own results). In addition other sources of energy are being used (paraffin, LP Gas and electricity).

Some energy consumption studies have been carried out in Kenya, published in "Energy Environment and Development in Africa." Volume 6; "Wood, Energy and Households. Perspectives on Rural Kenya", and Volume 7; "Energy Use in Rural Kenya - Household Demand and Rural Transformation". Annual consumption of about *800 kg per capita* was here obtained as the average total energy consumption converted into dry round wood equivalents. The results from these studies were assumed relevant for Ugandan conditions.

Several studies of charcoal consumption in larger cities have been done in different sub-Saharan countries:

- Charcoal consumption in *Mogadishu* has been estimated to *117 kg per capita per year* (ESMAP Report No 5796-SO, 1985);
- Consumption in *Lusaka* has been estimated to *191 kg per capita per year* (ESMAP Report No 4110-ZA);
- Consumption in *Ghana* has been estimated to *176 kg per capita per year* (ESMAP Report No 623-GH); and
- Consumption in *Addis Ababa* for the charcoal equivalent of *all* biomass fuels has been estimated to *106 kg per capita per year* (ILO, CEPPE, 1987).

As could be expected, these figures vary considerably. It is reasonable to assume that this is partly due to sampling methods used, partly due to factual differences in consumption patterns. Assuming that charcoal constitutes about 70% of the consumption in Addis Ababa (i.e. 76 kg), we get an average of *140 kg per capita per year* for these cities.

Finally, it is worth mentioning that the **World Commission on Environment and Development (WCED, 1987)** observed that 70% of the population in developing countries use mainly woodfuel and - depending on availability and other factors - burn between 350 kg and 2,900 kg per capita per year.

### 10.10.3 Ugandan Studies of Woodfuel Consumption10.10.3 Ugandan Studies of Woodfuel Consumption

We have found two recent Ugandan studies which directly or indirectly dealt with woodfuel consumption: The **Uganda Household Budget Survey (1989-90)** done by the **Department of Statistics** (World Bank/UNDP Project UGA/88/R01) and the **Household Energy Planning Program (HEPP)** done by **CODA and partners,** as Kenyan consultant company (CODA, 1990).

#### 10.10.3.1 The Uganda Household Budget Survey10.10.3.1 The Uganda Household Budget Survey

The Uganda Household Budget Survey was conducted from April 1989 to March 1990. This survey was oriented towards expenditure in monetary terms, i.e. it is neither giving figures for quantities of goods consumed nor for goods obtained without payment (e.g. direct collection of woodfuel by the household or woodfuel obtained via "barter deals"). It should also be mentioned that the overall figures might be low, since respondents might be lying either because they suspect the figures will be used for taxation purposes or if part of their expenditure is due to income from the "black" part of the economy.

Furthermore, the price data for charcoal published in the **Consumer Price Index (CPI)** are based on the prices per kg of charcoal purchased in tins (20 litre or 4-5 litre sizes) at the charcoal markets, and these prices are 100-150% higher than the prices of charcoal bought in bags. Such aspects are obviously of less interest for the CPI as such, since it is primarily used for measuring relative price changes, i.e. monitoring inflation. Using these prices for converting monetary expenditure into actual per capita charcoal consumption thus yield an impossibly low figure (50-60 kg per capita per year).

The data on consumption patterns among different expenditure groups might be useful when combined with other data sources, though:

- About 45% of the households purchase charcoal from markets, 35% from small stalls and 20% from other sources, including along the roadside.

- Using Kampala as an example, the *household* expenditure pattern in the survey period was as follows: The low expenditure group (54.7%) spent Ush 1,176 on charcoal and Ush 74 on firewood, the middle expenditure group (32%) spent Ush 1,996 on charcoal and Ush 44 on firewood, and the high expenditure group (13.3%) spent Ush 2,213 on charcoal and Ush 106 on firewood. All groups combined spent Ush 1,578 on charcoal and Ush 69 on firewood.

A quick and informal check on consumption among some staff in Forest Department and the Makerere University found that most of these consumed around 2 bags of charcoal per month. Since these household consisted of 4-6 members in line with the average Kampala household (Census-91), and the average weight of charcoal bags in Kampala is 45 kg (see chapter 13), this indicate a consumption of around 200 kg per capita per year. Assuming that these Civil Servants belong to the middle expenditure group, and that they to a greater extent than average buy charcoal in bags, one can deduct that average consumption among all households in Kampala would be *120-150 kg per capita per year.*

It must be emphasized that the above conclusion is a very rough estimate, but it corresponds well with the experience among people who have been involved in the discussions. Several participants in this discussion also pointed out certain cultural patterns resulting in high charcoal consumption: The common opinion that the staple food matooke gets better when it is steamed for hours instead of boiled; the tendency to keep the cooking fire going all day long due to tea making, brewing, etc; the tendency to move the stove outside due to lack of space (there is a severe house shortage in Uganda) or in order to avoid smoke etc; and finally the many ceremonies (weddings, burials) demanding woodfuel use above the normal.

In-depth analysis of raw data collected by the Household Budget Survey in order to extract information tailored for our purposes will, if possible, be done in cooperation with the Statistics Department and Department of Energy during Phase II.

#### 10.10.3.2 The Household Energy Planning Program (HEPP)10.10.3.2 The Household Energy Planning Program (HEPP)

The Household Energy Planning Program (HEPP) was initially expected to come up with highly reliable and detailed information on for instance woodfuel consumption in various parts of Uganda. The consultant CODA and Partners delivered their report, but both methodologies and results have been heavily criticised. The net result was that the report in practice has been discarded as a basis for governmental policy in the area.

Parts of the HEPP study *do* seem rather weak: For instance, Coda interviewed only 29 transporters of woodfuel. In comparison, the Biomass Study interviewed almost 2,000 woodfuel transporters in our limited Woodfuel Transport Study (see chapter 13). On the other hand: Coda's household energy surveys covered 450 urban and 158 rural households, and their household stove performance tests covered 186 urban and 64 rural households. The number of rural households are again very low (considering that 88% of all Ugandans live in rural areas!), but the 450 and 186 urban households should be high enough to give valid - if not high accuracy - data both on actual consumption and on energy type preferences. It should be noted that the sampling method used also is disputed, but even if the sampling might have been sub-optimal its effect on average consumption figures should not be exaggerated. As shown in the Household Budget Survey, overall consumption has a coefficient of variation of about 50%.

According to HEPP's kitchen tests, average consumption of charcoal in urban areas was *156.7 kg per capita per annum* (Coda, 1990). *Average per capita firewood consumption in rural areas was estimated to 218.7 kg per annum.* These measurements were based on traditional stoves, and various types of improved stoves showed significant gains (up to 40%).

### 10.10.3.3 Sources of Institutional Consumption Data10.10.3.3 Sources of Institutional Consumption Data

A substantial part of the population in urban areas belongs to institutions, educational, health and military institutions in particular. Dr. Aluma (Aluma, 1989) gives some figures (in volume solid wood) for a number of such institutions, all based on recorded purchases:

- 16 schools used an average of 1.5 $m^3$ per student per annum. (This figure is suspiciously high.)
- Mulago Hospital (Kampala) used an average of 0.6 $m^3$ per patient-year.
- Makerere University used an average of 0.3 $m^3$ per student per annum.

As could be expected, the per capita consumption of people in institutions are clearly lower than per capita household consumption (economies of scale).

The same study also gives figures for some hotels and restaurants, some brick making sites, jaggeries and so forth. Another similar estimate for tobacco curing has come from the Publicity Secretary for the West Nile (Arua) Tobacco Growers Union (New Vision, 02.09.92):

> "*An individual farmer uses up to 15 cubic metres of firewood in a season. Firewood supply is quite insufficient.*"

Again, this estimate is not properly defined, and can only be taken as a rough indication of how much firewood is used for tobacco curing. *The total consumption in the commercial sector cannot be accurately calculated without further studies, but it should be regarded as substantial.*

### 10.10.4 Other Sources of Consumption Data10.10.4 Other Sources of Consumption Data

Woodfuel consumption in Uganda has over the years been estimated by a number of national and international bodies. Regrettably, these are basically estimates based on various internationally available figures and not based on large scale, highly reliable studies within Uganda itself.

The official Government of Uganda estimate is found in Background to the Budget 1992-93. Here the total firewood and charcoal production in 1991 for household, commerce and industry - both monetary and non-monetary - is estimated to 16.6 mill tons (round wood). Most of this is firewood used in rural households. Assumed this quantity is green weight, it should be equivalent to around 9.3 mill ton air dry wood (15% MC), or around 600 kg per capita per year.

Finally, a number of projects and studies give estimates for overall national woodfuel consumption. For instance, a joint UNDP/World Bank study estimated the total Ugandan woodfuel requirement in 1990 to be roughly 1.4 $m^3$ per capita (UNDP/World Bank, 1986), i.e. around 830 kg of air dry biomass per capita per year as an average for both urban and rural consumption.

### 10.10.5 Conclusion10.10.5 Conclusion

Based upon the above factors, *a rough estimate of one ton of air dry wood was determined as the total per capita annual energy consumption in the project areas, and this formed the basis for our calculations.*

We are then assuming that average per capita charcoal consumption in urban areas is around 150 kg per year, roughly equivalent to 1 ton air dry wood using the adopted average conversion factor of 6.6. In addition we have consumption related to all kinds of industrial production, ref. various examples above and some consumption of firewood.

Firewood consumption in rural areas, including all consumption related to extensive brick-making in our peri-urban project areas, tobacco production, brewing, jaggeries, etc, are roughly estimated to 600-900 kg air dry biomass per capita per year.

The project areas are peri-urban, and we ended therefore with an estimate of one ton air dry biomass per capita per year. It should be noted though, that this estimate possibly is a bit too high. In our opinion, a slight over-estimation is a safer option than under-estimation in this case. Accurate data are unavailable, and nobody will be hurt if the efforts to reduce woodfuel consumption (e.g., improved stoves, electrification) and increase supply (e.g., afforestation, better kilns) are too strong. Under-estimation, on the other hand, might lead to weak counter-measures and subsequently an ever widening gap between consumption and supply.

Using the population figures from the table in chapter 10.9, the following basic demand of energy converted into air dry wood was thus obtained:

*Table 18: Estimated Annual Need of Woodfuel Converted into Air Dry Wood*

| Project Area | Tons | $M^3$ | Energy TJ |
|---|---|---|---|
| Arua | 210,100 | 364,300 | 3,782 |
| Jinja | 392,300 | 680,100 | 7,061 |
| Kabale | 243,600 | 422,300 | 4,385 |
| Kampala | 1,433,000 | 2,484,400 | 25,794 |
| Kamuli | 97,300 | 168,700 | 1,751 |
| Kumi | 148,900 | 258,100 | 2,680 |
| Mbale | 644,300 | 1,117,000 | 11,597 |
| Mbarara | 137,700 | 238,700 | 2,479 |
| Moroto | 33,800 | 58,600 | 608 |
| Total | 3,341,000 | 5,792,200 | 60,137 |

- Average volume of 1 ton air dry weight is 1.73 $m^3$
- 1 ton = 0.018 TeraJoule (TJ) = $0.018 \times 10^{12}$ Joule

# 11 Standing Stock of Biomass (Results)11 Standing Stock of Biomass (Results)

The following tables display the calculations and resulting standing stock of tree and bush biomass as well as agricultural residues.

The tree and bush biomass figures in this chapter also contain a proportion of leaves and small twigs, estimated to three percent. This amount was deducted under the calculation of harvestable biomass, chapter 12. The incorporation of twigs and leafage was due to the method applied when felling trees, where the trees were partly weighed and partly measured for volume. In cases of weighing, the whole tree was included.

The low values of biomass in class 1 (deciduous plantations) is due to the fact that all age classes were included in this land use/cover class and a large proportion was young stands. Values for class 2 (Conifer plantations) were taken from Forest Department inventory records, which give standing stock per hectare of commercial stem volumes. Branch-wood was added according to the developed biomass functions.

Apart from the Arua project area, where there is no papyrus, 80% of the wetland was regarded as permanent papyrus with an annual production of 25 tons/ha dry matter (IUCN Wetland Project, 1991). This was considered when calculating the total standing stock and average per hectare of trees and bush on wetland areas (land use/cover class 8).

For bush the overall average fresh weight of 339,2 kg was used as the basic weight of the standing stock on a 10 m by 10 m plot having a cover of 100%. By using an air dry weight over fresh weight factor of 0.5 (estimated from our measurements), the basic weight was converted to 169,6 kg air dry weight.

With regard to agricultural residues only crop categories found to be *commonly* used as fuel were included. For instance, grass was left out for this reason (even if the project was aware of it being actually used in some areas). However, in cases of extreme deficiency, such "secondary" sources can be used. In the tables of agricultural residues the column "Miscellaneous" include vegetables and sweet potatoes, which was regarded as not contributing to usable woodfuel biomass. "Impediment" also includes water.

The produced quantity of coffee husks is included under coffee in the tables of agricultural residues. From the ongoing project **Farming Systems Programme,** under the Ministry of Agriculture, Animal Industry and Fisheries, the following information about yield of coffee was acquired: Coffee is harvested twice a year producing an average of 0.8 tons of air dry berries per harvest, comprising 50% pure beans and 50% husks, i.e. 0.8 tons of husks per hectare per year. This amount is prevailing for Robusta Coffee. For Arabica Coffee the corresponding yield is 0.35. Robusta husks are removed at local hulleries and piled up there for potential use. A lot of it is used at miscellaneous clay burning factories. As opposed to Robusta, Arabica husks are removed through a wet process and given time to rot away. Hence, the husks from Mbale, where Arabica is grown, were not considered as applicable for fuelwood.

## 11.1 Arua - Biomass Tables11.1 Arua - Biomass Tables

*Table 19: Arua: Standing Stock of Tree Biomass*

| Land Use/ Cover Class | Part | Tons per hectare Fresh Weight | Air Dry weight/ Fresh Weight | Tons per hectare Air Dry Weight | Area ha | Total Air Dry Weight Tons |
|---|---|---|---|---|---|---|
| 1 | stem | 35.25 | 0.49 | 17.27 | 1,069 | 18,460 |
| | branch | 40.70 | 0.46 | 18.72 | 1,069 | 20,020 |
| 5 | stem | 28.44 | 0.57 | 16.21 | 6,206 | 100,590 |
| | branch | 33.52 | 0.53 | 17.76 | 6,206 | 110,240 |
| 6 | stem | 6.02 | 0.56 | 3.37 | 13,493 | 45,470 |
| | branch | 9.04 | 0.53 | 4.79 | 13,493 | 64,620 |
| 7 | stem * | 6.87 | 0.58 | 3.99 | 0 | 0 |
| | branch * | 9.98 | 0.54 | 5.39 | 0 | 0 |
| 8 | stem | 3.35 | 0.53 | 1.78 | 122 | 220 |
| | branch | 5.78 | 0.51 | 2.95 | 122 | 360 |
| 9 | stem | 3.02 | 0.53 | 1.60 | 83,041 | 133,030 |
| | branch | 5.72 | 0.52 | 2.97 | 83,041 | 246,960 |
| 11 | stem | 3.77 | 0.52 | 1.96 | 810 | 1,590 |
| | branch | 6.29 | 0.55 | 3.46 | 810 | 2,800 |

*) Under the mapping process occurring patches of grassland (type 7) were combined with mixed farmland (type 9).

*Table 20: Arua: Double Sampling Estimates for Air Dry Bush Biomass*

| Land Use/Cover Class | Cover scores, bush | | | Air dry weight | |
| --- | --- | --- | --- | --- | --- |
| | $\bar{x}'$ | $R=\bar{y}/\bar{x}$ | $R*\bar{x}'$ | per ha tons | total tons |
| 1 | 3 | 1.05 | 3.1 | 0.53 | 570 |
| 5 | 15 | 1.05 | 15.7 | 2.67 | 16,540 |
| 6 | 56 | 1.05 | 58.7 | 9.95 | 134,250 |
| 7 | 12 | 1.05 | 12.6 | 2.13 | - |
| 8 | 1 | 1.05 | 1.0 | 0.18 | 20 |
| 9 | 2 | 1.67 | 3.3 | 0.57 | 46,950 |

Table 21 displays the percentage area cover of the surveyed crops and the corresponding total air dry weights in tons per year for the contributing woodfuel crop categories.

*Table 21: Arua: Agricultural Crops; Percentage Area Cover and Total Weights in Ton/Year*

| Land Use/Cover Class | | Cassava | Grass | Matooke | Maize | Built area | Miscell. |
|---|---|---|---|---|---|---|---|
| 1 | % cover | 10% | 31% | | | | 1% |
| | weight | 570 | | | | | |
| 5 | % cover | | 25% | | | 3% | 2% |
| | weight | | | | | | |
| 6 | % cover | | 33% | | | 4% | |
| | weight | | | | | | |
| 7 | % cover | | 72% | | | 2% | 2% |
| | weight | | | | | | |
| 8 | % cover | | 86% | 1% | 1% | | 3% |
| | weight | | | | 10 | | |
| 9 | % cover | 17% | 47% | 1% | 5% | 5% | 16% |
| | weight | 74,820 | | | 15,360 | | |
| 11 | % cover | | 26% | | 1% | 61% | 2% |
| | weight | | | | 30 | | |
| Total | tons | 75,390 | | | 15,400 | | |

*Table 22: Arua: Total Standing Stock of Air Dry Woody Biomass and Agricultural Residues in Tons*

| Land U/C Class | Tree biomass | Bush biomass | Crop residues | Total |
|---|---|---|---|---|
| 1 | 38,480 | 570 | 570 | 39,620 |
| 5 | 210,830 | 16,540 | 0 | 227,370 |
| 6 | 110,090 | 134,250 | 0 | 244,340 |
| 8 | 580 | 20 | 10 | 610 |
| 9 | 379,990 | 46,950 | 90,180 | 517,120 |
| 11 | 4,390 | 0 | 30 | 4,420 |
| Total | 744,360 | 198,330 | 90,790 | 1,033,480 |

# 11.2 Jinja - Biomass Tables11.2 Jinja - Biomass Tables

*Table 23: Jinja: Standing Stock of Tree Biomass*

| Land Use/ Cover Class | Part | Tons per hectare Fresh Weight | Air Dry weight/ Fresh Weight | Tons per hectare Air Dry Weight | Area ha | Total Air Dry Weight Tons |
|---|---|---|---|---|---|---|
| 1 | stem | 154.44 | 0.52 | 80.31 | 821 | 65,930 |
| | branch | 59.36 | 0.53 | 31.46 | 821 | 25,830 |
| 2 | stem | 315.00** | 0.50* | 157.50 | 322 | 50,720 |
| | branch | 180.00** | 0.50* | 90.00 | 322 | 28,980 |
| 3 | stem | 112.29 | 0.51 | 57.27 | 9,399 | 538,260 |
| | branch | 53.69 | 0.50 | 26.84 | 9,399 | 252,300 |
| 4 | stem | 79.31 | 0.51 | 40.45 | 833 | 33,690 |
| | branch | 41.95 | 0.51 | 21.40 | 833 | 17,820 |
| 5 | stem | 39.11 | 0.56 | 21.90 | 5,899 | 129,210 |
| | branch | 35.86 | 0.54 | 19.36 | 5,899 | 114,220 |
| 6 | stem | 9.87 | 0.54 | 5.33 | 12,038 | 64,130 |
| | branch | 11.32 | 0.53 | 6.00 | 12,038 | 72,200 |
| 7 | stem | 10.90 | 0.56 | 6.10 | 5,617 | 34,270 |
| | branch | 13.47 | 0.53 | 7.14 | 5,617 | 40,090 |
| 8 | stem | 9.63 | 0.52 | 5.01 | 3,202 | 16,040 |
| | branch | 10.46 | 0.51 | 5.34 | 3,202 | 17,080 |
| 9 | stem | 9.40 | 0.51 | 4.79 | 82,030 | 393,170 |
| | branch | 14.40 | 0.48 | 6.91 | 82,030 | 567,160 |
| 11 | stem | 11.73 | 0.52 | 6.10 | 2,337 | 14,250 |
| | branch | 17.55 | 0.52 | 9.12 | 2,337 | 21,320 |

* = estimated value
** = derived from forest inventory of Namafuma.

*Table 24: Jinja: Double Sampling Estimates for Air Dry Bush Biomass*

| Land Use/Cover Class | Cover scores, bush x' | R=y/x | R*x' | Air dry weight per ha tons | total tons |
|---|---|---|---|---|---|
| 1 | 23 | 1.06 | 24.4 | 4.14 | 3,400 |
| 2 | 10 | 1.06 | 10.6 | 1.80 | 580 |
| 3 | 22 | 1.06 | 23.4 | 3.96 | 37,260 |
| 4 | 26 | 1.06 | 27.6 | 4.69 | 3,900 |
| 5 | 29 | 1.06 | 30.8 | 5.23 | 30,830 |
| 6 | 24 | 1.06 | 25.5 | 4.32 | 52,060 |
| 7 | 22 | 1.06 | 23.4 | 3.96 | 22,270 |
| 8 | 21 | 1.06 | 22.3 | 3.78 | 76,150 |
| * | | | | | |
| 9 | 6 | 2.25 | 13.5 | 2.29 | 187,820 |
| 10 | 12 | 1.06 | 12.8 | 2.16 | 15,340 |
| 11 | 1 | 1.06 | 1.1 | 0.18 | 420 |

* Papyrus is included with 64.040 tons.

Table 25 displays the percentage area cover of the surveyed crops and the corresponding total air dry weights in tons per year for the contributing woodfuel crop categories.

*Table 25: Jinja: Agricultural Crops; Percentage Area Cover and Total Weights in Ton/Year*

| Land Use/Cover Class | | Coffee | Cassava | Grass | Matooke | Maize | Sugar Cane | Impediment | Misc. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | % cover | | 2% | 3% | 7% | | | 7% | 2% |
| | weight | | 170 | | | | | | |
| 4 | % cover | 3% | 2% | 2% | 2% | | | | |
| | weight | 110 | 170 | | | | | | |
| 5 | % cover | 2% | | 7% | 2% | 1% | | | |
| | weight | 520 | | | | 220 | | | |
| 6 | % cover | 2% | | 26% | 2% | | | 3% | 2% |
| | weight | 1060 | | | | | | | |
| 7 | % cover | | 1% | 76% | | | | 2% | 2% |
| | weight | | 580 | | | | | | |
| 8 | % cover | | | 54% | | 1% | 1% | 5% | 4% |
| | weight | | | | | 120 | 200 | | |
| 9 | % cover | 15% | 7% | 23% | 15% | 5% | 1% | 12% | 6% |
| | weight | 54140 | 59140 | | | 15180 | 5170 | | |
| 11 | % cover | 4% | 1% | 8% | 7% | 1% | 1% | 2% | 67% |
| | weight | 410 | 240 | | | 90 | 150 | | |
| Total | tons | 56240 | 60300 | | | 15610 | 5520 | | |

*Table 26: Jinja: Total Standing Stock of Air Dry Woody Biomass and Agricultural Residues in Tons*

| Land U/C Class | Tree biomass | Bush biomass | Crop residues | Total |
|---|---|---|---|---|
| 1 | 91,760 | 3,400 | 170 | 95,330 |
| 2 | 79,700 | 580 | 0 | 80,280 |
| 3 | 790,560 | 37,260 | 0 | 827,820 |
| 4 | 51,510 | 3,900 | 280 | 55,690 |
| 5 | 243,430 | 30,830 | 740 | 275,000 |
| 6 | 136,330 | 52,060 | 1,060 | 189,450 |
| 7 | 74,360 | 22,270 | 580 | 97,210 |
| 8 | 33,120 | 76,150 | 320 | 109,590 |
| 9 | 960,330 | 187,820 | 133,630 | 1,281,780 |
| 10 | 0 | 15,340 | 234,420 | *249,760 |
| 11 | 35,570 | 420 | 890 | 36,880 |
| Total | 2,496,670 | 430,030 | 372,090 | 3,298,790 |

*)30% of the sugar plantation area was considered under fallow resulting in 234,420 tons of bagasse coming from estates.

## 11.3 Kabale - Biomass Tables11.3 Kabale - Biomass Tables

*Table 27: Kabale: Standing Stock of Tree Biomass*

| Land Use/ Cover Class | Part | Tons per hectare Fresh Weight | Air Dry weight/ Fresh Weight | Tons per hectare Air Dry Weight | Area ha | Total Air Dry Weight Tons |
|---|---|---|---|---|---|---|
| 1 | stem | 32.15 | 0.51 | 16.40 | 4,955 | 81,250 |
| | branch | 19.61 | 0.51 | 10.00 | 4,955 | 49,550 |
| 2 | stem | 360.00* | 0.50 | 180.00 | 1,335 | 240,300 |
| | branch | 200.00* | 0.50 | 100.00 | 1,335 | 133,500 |
| 5 | stem | 21.10 | 0.54 | 11.39 | 13 | 150 |
| | branch | 13.33 | 0.52 | 6.93 | 13 | 90 |
| 6 | stem | 7.73 | 0.51 | 3.94 | 11,853 | 46,720 |
| | branch | 5.73 | 0.50 | 2.87 | 11,853 | 33,970 |
| 7 | stem | 4.81 | 0.54 | 2.60 | 3,363 | 8,730 |
| | branch | 4.07 | 0.52 | 2.12 | 3,363 | 7,120 |
| 8 | stem | 3.36 | 0.50 | 1.68 | 1,058 | 1,780 |
| | branch | 3.25 | 0.49 | 1.59 | 1,058 | 1,690 |
| 9 | stem | 4.67 | 0.51 | 2.38 | 71,331 | 169,700 |
| | branch | 3.88 | 0.49 | 1.90 | 71,331 | 135,670 |
| 11 | stem | 7.24 | 0.50 | 3.62 | 172 | 620 |
| | branch | 5.45 | 0.50 | 2.73 | 172 | 470 |

* derived from forest inventory data of Mafuga/Kiriima.

*Table 28: Kabale: Double Sampling Estimates for Air Dry Bush Biomass*

| Land Use/Cover Class | Cover scores, bush x' | R=y/x | R*x' | Air dry weight per ha tons | total tons |
|---|---|---|---|---|---|
| 1 | 3 | 1.30 | 3.9 | 0.66 | 3,270 |
| 5 | 10 | 1.30 | 13.0 | 2.20 | 30 |
| 6 | 36 | 1.30 | 46.8 | 7.94 | 94,110 |
| 7 | 8 | 1.30 | 10.4 | 1.76 | 5,920 |
| 8 * | 1 | 1.30 | 1.3 | 0.22 | 21,390 |
| 9 | 2 | 2.50 | 5.0 | 0.85 | 60,630 |
| 11 | 1 | 1.30 | 1.3 | 0.22 | 40 |

* Papyrus included with 21,160 tons.

Table 29 displays the percentage area cover of the surveyed crops and the corresponding total air dry weights in tons per year for the contributing woodfuel crop categories.

*Table 29: Kabale: Agricultural Crops; Percentage Area Cover and Total Weights in Ton/Year*

| Land Use/Cover Class | | Grass | Matooke | Maize | Sugar Cane | Misc. | Impediment |
|---|---|---|---|---|---|---|---|
| 1 | % cover | 19% | 1% | | | 2% | 7% |
| | weight | | | | | | |
| 5 | % cover | 28% | 2% | | | | |
| | weight | | | | | | |
| 6 | % cover | 21% | | | | 7% | 3% |
| | weight | | | | | | |
| 7 | % cover | 72% | 1% | | | 2% | 3% |
| | weight | | | | | | |
| 8 | % cover | 55% | | | | 7% | 2% |
| | weight | | | | | | |
| 9 | % cover | 30% | 15% | 2% | | 37% | 6% |
| | weight | | | 5,280 | | | |
| 11 | % cover | 7% | 4% | 1% | | 2% | 66% |
| | weight | | | 10 | | | |
| Total | tons | | | 5,290 | | | |

*Table 30: Kabale: Total Standing Stock of Air Dry Woody Biomass and Agricultural Residues in Tons*

| Land U/C Class | Tree biomass | Bush biomass | Crop residues | Total |
|---|---|---|---|---|
| 1 | 130,800 | 3,270 | 0 | 134,070 |
| 2 | 373,800 | 0 | 0 | 373,800 |
| 5 | 240 | 30 | 0 | 270 |
| 6 | 80,690 | 94,110 | 0 | 174,800 |
| 7 | 15,850 | 5,920 | 0 | 21,770 |
| 8 | 3,470 | 21,390 | 0 | 24,860 |
| 9 | 305,370 | 60,630 | 5,280 | 371,280 |
| 11 | 1,090 | 40 | 10 | 1,140 |
| Total | 911,310 | 185,390 | 5,290 | 1,101,990 |

## 11.4 Kampala - Biomass Tables11.4 Kampala - Biomass Tables

*Table 31: Kampala: Standing Stock of Tree Biomass*

| Land Use/ Cover Class | Part | Tons per hectare Fresh Weight | Air Dry weight/ Fresh Weight | Tons per hectare Air Dry Weight | Area ha | Total Air Dry Weight Tons |
|---|---|---|---|---|---|---|
| 1 | stem | 53.59 | 0.50* | 26.79 | 1,030 | 27,600 |
| | branch | 70.17 | 0.50* | 35.08 | 1,030 | 36,130 |
| 2 | stem | 44.38 | 0.50* | 22.19 | 55 | 1,220 |
| | branch | 58.37 | 0.50* | 29.19 | 55 | 1,610 |
| 3 | stem | 53.20 | 0.53 | 28.20 | 3,360 | 94,740 |
| | branch | 69.67 | 0.51 | 35.53 | 3,360 | 119,380 |
| 4 | stem | 35.44 | 0.51 | 18.07 | 1,710 | 30,900 |
| | branch | 46.91 | 0.51 | 23.92 | 1,710 | 40,910 |
| 5 | stem | 27.48 | 0.53 | 14.56 | 27,242 | 396,750 |
| | branch | 36.70 | 0.50 | 18.35 | 27,242 | 499,950 |
| 6 | stem | 10.44 | 0.54 | 5.64 | 24,794 | 139,810 |
| | branch | 14.87 | 0.51 | 7.58 | 24,794 | 188,010 |
| 7 | stem | 5.89 | 0.53 | 3.12 | 2,694 | 8,410 |
| | branch | 9.03 | 0.51 | 4.61 | 2,694 | 12,410 |
| 8 | stem | 3.93 | 0.54 | 2.12 | 29,636 | 62,920 |
| | branch | 6.52 | 0.53 | 3.46 | 29,636 | 102,420 |
| 9 | stem | 7.24 | 0.52 | 3.77 | 175,432 | 660,500 |
| | branch | 11.34 | 0.49 | 5.56 | 175,432 | 975,050 |
| 11 | stem | 8.06 | 0.54 | 4.35 | 10,770 | 46,860 |
| | branch | 11.81 | 0.53 | 6.26 | 10,770 | 67,410 |

*) estimated value

*Table 32: Kampala: Double Sampling Estimates for Air Dry Bush Biomass*

| Land Use/Cover Class | Cover scores, bush | | | Air dry weight | |
|---|---|---|---|---|---|
| | x' | R=y/x | R*x' | per ha tons | total tons |
| 1 | 1 | 1.13 | 1.1 | 0.19 | 200 |
| 3 | 16 | 1.13 | 18.0 | 3.05 | 10,260 |
| 4 | 25 | 1.13 | 28.1 | 4.77 | 8,160 |
| 5 | 25 | 1.13 | 28.1 | 4.77 | 129,940 |
| 6 | 21 | 1.13 | 23.6 | 4.01 | 99,350 |
| 7 | 6 | 1.13 | 6.8 | 1.14 | 3,080 |
| 8* | 5** | 1.13 | 5.7 | 0.96 | 621,120 |
| 9 | 5 | 0.67 | 3.3 | 0.57 | 99,180 |
| 11 | 5 | 1.13 | 5.6 | 0.95 | 10,270 |

*) Papyrus is included with 592,720 tons.
**) Estimated value

Table 33 displays the percentage area cover of the surveyed crops and the corresponding total air dry weights in tons per year for the contributing woodfuel crop categories.

*Table 33: Kampala: Agricultural Crops; Percentage Area Cover and Total Weights in Ton/Year*

| Land Use/Cover Class | | Coffee | Cassava | Grass | Matooke | Maize | Sugar Cane | Impediment | Misc. |
|---|---|---|---|---|---|---|---|---|---|
| 3 | % cover | | | 12% | | | | 2% | |
| | weight | | | | | | | | |
| 4 | % cover | 6% | 3% | 4% | | | | | |
| | weight | 450 | 530 | | | | | | |
| 5 | % cover | 9% | 4% | 6% | 3% | | | 1% | 2% |
| | weight | 10790 | 11220 | | | | | | |
| 6 | % cover | 2% | 1% | 10% | 2% | | | 3% | 1% |
| | weight | 2180 | 2550 | | | | | | |
| 7 | % cover | 1% | 2% | 79% | 2% | | | 1% | 2% |
| | weight | 120 | 550 | | | | | | |
| 8 | % cover | | | 24% | | | | 1% | |
| | weight | | | | | | | | |
| 9 | % cover | 13% | 12% | 22% | 22% | 1% | 1% | 9% | 6% |
| | weight | 100350 | 216830 | | | 6490 | 11050 | | |
| 11 | % cover | 2% | 1% | 5% | 3% | | | 70% | |
| | weight | 950 | 1110 | | | | | | |
| Total tons | | 114840 | 232790 | | | 6490 | 11050 | | |

*Table 34: Kampala: Total Standing Stock of Air Dry Woody Biomass and Agricultural Residues in Tons*

| Land U/C Class | Tree biomass | Bush biomass | Crop residues | Total |
|---|---|---|---|---|
| 1 | 63,730 | 200 | 0 | 63,930 |
| 2 | 2,830 | 0 | 0 | 2,830 |
| 3 | 214,120 | 10,260 | 0 | 224,380 |
| 4 | 71,810 | 8,160 | 980 | 80,950 |
| 5 | 896,700 | 129,940 | 22,010 | 1,048,650 |
| 6 | 327,820 | 99,350 | 4,730 | 431,900 |
| 7 | 20,810 | 3,080 | 670 | 24,560 |
| 8 | 165,340 | 621,120 | 0 | 786,460 |
| 9 | 1635,550 | 99,180 | 334,720 | 2,069,450 |
| 11 | 114,270 | 10,270 | 2,060 | 126,600 |
| Total | 3512,980 | 981,560 | 365,170 | 4,859,710 |

## 11.5 Kamuli - Biomass Tables11.5 Kamuli - Biomass Tables

*Table 35: Kamuli: Standing Stock of Tree Biomass*

| Land Use/ Cover Class | Part | Tons per hectare Fresh Weight | Air Dry weight/ Fresh Weight | Tons per hectare Air Dry Weight | Area ha | Total Air Dry Weight Tons |
|---|---|---|---|---|---|---|
| 5 | stem | 29.67 | 0.54 | 16.02 | 1,929 | 30,900 |
| | branch | 64.99 | 0.50 | 32.49 | 1,929 | 62,680 |
| 6 | stem | 10.35 | 0.54 | 5.59 | 35,791 | 200,070 |
| | branch | 18.93 | 0.51 | 9.66 | 35,791 | 345,560 |
| 7 | stem | 9.88 | 0.56 | 5.53 | 280 | 1,550 |
| | branch | 18.47 | 0.52 | 9.61 | 280 | 2,690 |
| 8 | stem | 6.06 | 0.60 | 3.63 | 2,861 | 10,400 |
| | branch | 12.21 | 0.53 | 6.47 | 2,861 | 18,520 |
| 9 | stem | 9.50 | 0.52 | 4.94 | 83,086 | 410,610 |
| | branch | 19.03 | 0.49 | 9.32 | 83,086 | 774,530 |
| 11 | stem | 6.27 | 0.55 | 3.45 | 159 | 550 |
| | branch | 12.41 | 0.54 | 6.70 | 159 | 1,070 |

Note that areas classified as deciduous plantations and uniform farmland under the stratification process turned out to be abandoned land (reverted to bush), subsistence farmland, or were used for grazing (e.g., dairy farms). These areas were thus grouped under other classes when calculating the biomass.

*Table 36: Kamuli: Double Sampling Estimates for Air Dry Bush Biomass*

| Land Use/Cover Class | Cover scores, bush | | | Air dry weight |
|---|---|---|---|---|
| | x' | R=y/x | R*x' | per ha tons total tons |
| 5 | 22 | 1.22 | 26.8 | 4.54 8,760 |
| 6 | 46 | 1.22 | 56.0 | 9.50 340,010 |
| 7 | 14 | 1.22 | 17.0 | 2.89 810 |
| 8 | 5 | 1.22 | 6.1 | 1.03 60,170 |
| * | | | | |
| 9 | 6 | 1.00 | 7.3 | 1.24 103,030 |
| 11 | 4 | 1.22 | 4.9 | 0.83 130 |

*) Papyrus is included with 57,220 tons.

Table 37 displays the percentage area cover of the surveyed crops and the corresponding total air dry weights in tons per year for the contributing woodfuel crop categories.

*Table 37: Kamuli: Agricultural Crops; Percentage Area Cover and Total Weights in Ton/Year*

| Land Use/Cover Class | | Coffee | Cassava | Grass | Matooke | Maize | Sugar Cane | Impediment | Misc. |
|---|---|---|---|---|---|---|---|---|---|
| 5 | % cover | 1% | | 22% | 2% | 1% | | 1% | 1% |
| | weight | 60 | | | | 70 | | | |
| 6 | % cover | 1% | 1% | 12% | 1% | | | 1% | 3% |
| | weight | 1180 | 2790 | | | | | | |
| 7 | % cover | | | 71% | | 1% | | 1% | 2% |
| | weight | | | | | 10 | | | |
| 8 | % cover | | | 71% | | 4% | | 3% | |
| | weight | | | | | 420 | | | |
| 9 | % cover | 12% | 5% | 23% | 8% | 17% | 1% | 11% | 4% |
| | weight | 32900 | 32400 | | | 52260 | 5230 | | |
| 11 | % cover | 2% | | 5% | | | | 70% | |
| | weight | 10 | | | | | | | |
| Total tons | | 34150 | 35190 | | | 52760 | 5230 | | |

*Table 38: Kamuli: Total Standing Stock of Air Dry Woody Biomass and Agricultural Residues in Tons*

| Land U/C Class | Tree biomass | Bush biomass | Crop residues | Total |
|---|---|---|---|---|
| 5 | 93,580 | 8,760 | 130 | 102,470 |
| 6 | 545,630 | 340,010 | 3,970 | 889,610 |
| 7 | 4,240 | 810 | 10 | 5,060 |
| 8 | 28,920 | 60,170 | 420 | 89,510 |
| 9 | 1185,140 | 103,030 | 122,790 | 1,410,960 |
| 11 | 1,620 | 130 | 10 | 1,760 |
| Total | 1859,130 | 512,910 | 127,330 | 2,499,370 |

## 11.6 Kumi - Biomass Tables11.6 Kumi - Biomass Tables

*Table 39: Kumi: Standing Stock of Tree Biomass*

| Land Use/ Cover Class | Part | Tons per hectare Fresh Weight | Air Dry weight/ Fresh Weight | Tons per hectare Air Dry Weight | Area ha | Total Air Dry Weight Tons |
|---|---|---|---|---|---|---|
| 1 | stem | 30.00* | 0.50* | 15.00 | 161 | 2,420 |
| | branch | 30.00* | 0.50* | 15.00 | 161 | 2,410 |
| 5 | stem | 20.38 | 0.58 | 11.82 | 1,443 | 17,060 |
| | branch | 44.27 | 0.52 | 23.02 | 1,443 | 33,220 |
| 6 | stem | 10.17 | 0.58 | 5.90 | 10,192 | 60,130 |
| | branch | 22.74 | 0.54 | 12.28 | 10,192 | 125,180 |
| 7 | stem | 6.81 | 0.52 | 3.54 | 38 | 130 |
| | branch | 15.64 | 0.49 | 7.67 | 38 | 290 |
| 8 | stem | 3.70 | 0.57 | 2.11 | 13,523 | 28,490 |
| | branch | 9.09 | 0.52 | 4.73 | 13,523 | 63,920 |
| 9 | stem | 5.11 | 0.54 | 2.76 | 120,378 | 332,240 |
| | branch | 12.58 | 0.53 | 6.67 | 120,378 | 802,680 |
| 11 | stem | 7.82 | 0.59 | 4.61 | 884 | 4,080 |
| | branch | 17.78 | 0.58 | 10.31 | 884 | 9,120 |

*) estimated value

*Table 40: Kumi: Double Sampling Estimates for Air Dry Bush Biomass*

| Land Use/Cover Class | Cover scores, bush | | | Air dry weight | |
|---|---|---|---|---|---|
| | x' | R=y/x | R*x' | per ha tons | total tons |
| 5 | 21 | 1.64 | 34.5 | 5.85 | 8,440 |
| 6 | 50 | 1.64 | 82.1 | 13.93 | 141,990 |
| 7 | 8 | 1.64 | 13.1 | 2.23 | 80 |
| 8 * | 1 | 1.64 | 1.6 | 0.28 | 274,250 |
| 9 | 2 | 3.00 | 6.0 | 1.02 | 122,500 |
| 11 | 2 | 1.64 | 3.3 | 0.56 | 490 |

*) Papyrus is included with 270.460 tons.

Table 41 displays the percentage area cover of the surveyed crops and the corresponding total air dry weights in tons per year for the contributing woodfuel crop categories.

*Table 41: Kumi: Agricultural Crops; Percentage Area Cover and Total Weights in Ton/Year*

| Land Use/Cover Class | | Cassava | Grass | Matooke | Maize | Impediment | Misc. |
|---|---|---|---|---|---|---|---|
| 5 | % cover | | 13% | | | 2% | |
| | weight | | | | | | |
| 6 | % cover | 1% | 24% | | | 2% | |
| | weight | 540 | | | | | |
| 7 | % cover | | 74% | | 1% | 3% | |
| | weight | | | | 0 | | |
| 8 | % cover | | 81% | | 1% | 1% | |
| | weight | | | | 500 | | |
| 9 | % cover | 14% | 56% | | 4% | 3% | 10% |
| | weight | 89320 | | | 17820 | | |
| 11 | % cover | 6% | 9% | 1% | 1% | 65% | |
| | weight | 280 | | | 30 | | |
| Total tons | | 90140 | | | 18350 | | |

*Table 42: Kumi: Total Standing Stock of Air Dry Woody Biomass and Agricultural Residues in Tons*

| Land U/C Class | Tree biomass | Bush biomass | Crop residues | Total |
|---|---|---|---|---|
| 1 | 4,830 | 0 | 0 | 4,830 |
| 5 | 50,280 | 8,440 | 0 | 58,720 |
| 6 | 185,310 | 141,990 | 540 | 327,840 |
| 7 | 420 | 80 | 0 | 500 |
| 8 | 92,420 | 274,250 | 500 | 367,170 |
| 9 | 1134,920 | 122,500 | 107,140 | 1,364,560 |
| 11 | 13,190 | 490 | 310 | 13,990 |
| Total | 1481,370 | 547,750 | 108,490 | 2,137,610 |

## 11.7 Mbale - Biomass Tables11.7 Mbale - Biomass Tables

*Table 43: Mbale: Standing Stock of Tree Biomass*

| Land Use/ Cover Class | Part | Tons per hectare Fresh Weight | Air Dry weight/ Fresh Weight | Tons per hectare Air Dry Weight | Area ha | Total Air Dry Weight Tons |
|---|---|---|---|---|---|---|
| 1 | stem | 29.69 | 0.51 | 15.14 | 231 | 3,500 |
| | branch | 42.23 | 0.51 | 21.54 | 231 | 4,980 |
| 2 | stem | 40.00* | 0.50* | 20.00 | 1 | 20 |
| | branch | 40.00* | 0.50* | 20.00 | 1 | 20 |
| 3 | stem | 40.38 | 0.50* | 20.19 | 791 | 15,970 |
| | branch | 57.05 | 0.50* | 28.52 | 791 | 22,560 |
| 4 | stem | 24.40 | 0.50 | 12.20 | 743 | 9,070 |
| | branch | 34.90 | 0.49 | 17.10 | 743 | 12,700 |
| 5 | stem | 29.05 | 0.50 | 14.53 | 1,104 | 16,040 |
| | branch | 41.34 | 0.48 | 19.85 | 1,104 | 21,910 |
| 6 | stem | 9.61 | 0.55 | 5.29 | 8,471 | 44,770 |
| | branch | 14.83 | 0.55 | 8.16 | 8,471 | 69,110 |
| 7 | stem | 6.04 | 0.53 | 3.20 | ** | 0 |
| | branch | 9.43 | 0.49 | 4.62 | ** | 0 |
| 8 | stem | 3.89 | 0.55 | 2.14 | 7,538 | 16,150 |
| | branch | 6.46 | 0.53 | 3.42 | 7,538 | 25,790 |
| 9 | stem | 6.28 | 0.51 | 3.20 | 172,396 | 552,010 |
| | branch | 9.84 | 0.49 | 4.82 | 172,396 | 831,120 |
| 11 | stem | 7.54 | 0.51 | 3.84 | 1,360 | 5,230 |
| | branch | 11.51 | 0.49 | 5.64 | 1,360 | 7,670 |

*) estimated value. **) combined with farmland (type 9).

*Table 44: Mbale: Double Sampling Estimates for Air Dry Bush Biomass*

| Land Use/Cover Class | Cover scores, bush $\bar{x}'$ | $\bar{R}=\bar{y}/\bar{x}$ | $\bar{R}*\bar{x}'$ | Air dry weight per ha tons | Air dry weight total tons |
|---|---|---|---|---|---|
| 1 | 17 | 1.07 | 18.2 | 3.09 | 710 |
| 3 | 12 | 1.07 | 12.9 | 2.18 | 1,730 |
| 4 | 13 | 1.07 | 13.9 | 2.36 | 1,750 |
| 5 | 14 | 1.07 | 15.0 | 2.54 | 2,810 |
| 6 | 49 | 1.07 | 52.5 | 8.90 | 75,430 |
| 8* | 2 | 1.07 | 2.1 | 0.36 | 153,500 |
| 9 | 3 | 1.50 | 4.5 | 0.76 | 131,570 |
| 11 | 1 | 1.07 | 1.1 | 0.18 | 250 |

*) Papyrus is included with 150,760 tons.

Table 45 displays the percentage area cover of the surveyed crops and the corresponding total air dry weights in tons per year for the contributing woodfuel crop categories.

*Table 45: Mbale: Agricultural Crops; Percentage Area Cover and Total Weights in Ton/Year*

| Land Use/Cover Class | | Coffee | Cassava | Grass | Matooke | Miscell. | Impediment |
|---|---|---|---|---|---|---|---|
| 1 | % cover | | 2% | 23% | 7% | | 2% |
| | weight | | 40 | | | | |
| 4 | % cover | 18% | | 3% | 3% | | |
| | weight | 200 | | | | | |
| 5 | % cover | | 35% | | | | |
| | weight | | 3010 | | | | |
| 6 | % cover | | | 20% | 2% | 2% | 3% |
| | weight | | | | | | |
| 7 | % cover | | 3% | 75% | 2% | 2% | 3% |
| | weight | | 2020* | | | | |
| 8 | % cover | | | 57% | | | 1% |
| | weight | | | | | | |
| 9 | % cover | 6% | 12% | 33% | 24% | 9% | 5% |
| | weight | 15520 | 153290 | | | | |
| 11 | % cover | 3% | 2% | 10% | 8% | 1% | 64% |
| | weight | 60 | 210 | | | | |
| Total | tons | 15780 | 158570 | | | | |

*) 5% of the area of vegetation type 9 was regarded as type 7 due to overgeneralization of type 9 during the mapping process.

*Table 46: Mbale: Total Standing Stock of Air Dry Woody Biomass and Agricultural Residues in Tons*

| Land U/C Class | Tree biomass | Bush biomass | Crop residues | Total |
|---|---|---|---|---|
| 1 | 8,480 | 710 | 40 | 9,230 |
| 2 | 40 | 0 | 0 | 40 |
| 3 | 38,530 | 1,730 | 0 | 40,260 |
| 4 | 21,770 | 1,750 | 200 | 23,720 |
| 5 | 37,950 | 2,810 | 3,010 | 43,770 |
| 6 | 113,880 | 75,430 | 0 | 189,310 |
| 7 | 0 | 0 | 2,020 | 2,020 |
| 8 | 41,940 | 153,500 | 0 | 195,440 |
| 9 | 1383,130 | 131,570 | 168,810 | 1,683,510 |
| 11 | 12,900 | 250 | 270 | 13,420 |
| Total | 1658,620 | 367,750 | 174,350 | 2,200,720 |

# 11.8 Mbarara - Biomass Tables11.8 Mbarara - Biomass Tables

*Table 47: Mbarara: Standing Stock of Tree Biomass*

| Land Use/ Cover Class | Part | Tons per hectare Fresh Weight | Air Dry weight/ Fresh Weight | Tons per hectare Air Dry Weight | Area ha | Total Air Dry Weight Tons |
|---|---|---|---|---|---|---|
| 1 | stem | 21.21 | 0.50 | 10.60 | 562 | 5,960 |
| | branch | 20.84 | 0.47 | 9.79 | 562 | 5,500 |
| 5 | stem | 9.25 | 0.53 | 4.90 | 309 | 1,520 |
| | branch | 10.04 | 0.51 | 5.12 | 309 | 1,580 |
| 6 | stem | 3.82 | 0.58 | 2.21 | 2,410 | 5,340 |
| | branch | 4.56 | 0.52 | 2.37 | 2,410 | 5,710 |
| 7 | stem | 2.18 | 0.54 | 1.18 | 61,338 | 72,070 |
| | branch | 2.63 | 0.48 | 1.26 | 61,338 | 77,350 |
| 8 | stem | 1.97 | 0.50 | 0.98 | 3,872 | 3,810 |
| | branch | 2.33 | 0.50 | 1.17 | 3,872 | 4,520 |
| 9 | stem | 2.73 | 0.51 | 1.39 | 22,215 | 30,920 |
| | branch | 2.87 | 0.50 | 1.44 | 22,215 | 31,900 |
| 11 | stem | 4.06 | 0.50 | 2.03 | 819 | 1,660 |
| | branch | 4.97 | 0.48 | 2.38 | 819 | 1,950 |

*Table 48: Mbarara: Double Sampling Estimates for Air Dry Bush Biomass*

| Land Use/Cover Class | Cover scores, bush $\bar{x}'$ | $R=\bar{y}/\bar{x}$ | $R*\bar{x}'$ | Air dry weight per ha tons | total tons |
|---|---|---|---|---|---|
| 1 | 8 | 1.29 | 10.3 | 1.74 | 980 |
| 5 | 9 | 1.29 | 11.6 | 1.96 | 610 |
| 6 | 39 | 1.29 | 50.1 | 8.50 | 20,490 |
| 7 | 5 | 1.29 | 6.4 | 1.09 | 66,880 |
| 8 | 2 | 1.29 | 2.6 | 0.44 | 79,130 |
| * 9 | 2 | 2.50 | 5.0 | 0.85 | 18,840 |
| 11 | 2 | 1.29 | 2.6 | 0.44 | 360 |

*) Papyrus is included with 77,440 tons.

Table 49 displays the percentage area cover of the surveyed crops and the corresponding total air dry weights in tons per year for the contributing woodfuel crop categories.

*Table 49: Mbarara: Agricultural Crops; Percentage Area Cover and Total Weights in Ton/Year*

| Land Use/Cover Class | | Cassava | Grass | Matooke | Maize | Miscell. | Impediment |
|---|---|---|---|---|---|---|---|
| 1 | % cover | 1% | 23% | | | | 1% |
| | weight | 30 | | | | | |
| 5 | % cover | | 23% | | | | 8% |
| | weight | | | | | | |
| 6 | % cover | | 30% | | 1% | | 2% |
| | weight | | | | 90 | | |
| 7 | % cover | | 84% | | | | 3% |
| | weight | | | | | | |
| 8 | % cover | | 41% | | | | 23% |
| | weight | | | | | | |
| 9 | % cover | 1% | 25% | 45% | 2% | 12% | 6% |
| | weight | 1180 | | | 1640 | | |
| 11 | % cover | | 11% | 3% | 1% | 2% | 70% |
| | weight | | | | 30 | | |
| Total tons | | 1210 | | | 1760 | | |

*Table 50: Mbarara: Total Standing Stock of Air Dry Woody Biomass and Agricultural Residues in Tons*

| Land U/C Class | Tree biomass | Bush biomass | Crop residues | Total |
|---|---|---|---|---|
| 1 | 11,460 | 980 | 30 | 12,470 |
| 5 | 3,100 | 610 | 0 | 3,710 |
| 6 | 11,050 | 20,490 | 90 | 31,630 |
| 7 | 149,420 | 66,880 | 0 | 216,300 |
| 8 | 8,330 | 79,130 | 0 | 87,460 |
| 9 | 62,820 | 18,840 | 2,820 | 84,480 |
| 11 | 3,610 | 360 | 30 | 4,000 |
| Total | 249,790 | 187,290 | 2,970 | 440,050 |

## 11.9 Moroto - Biomass Tables11.9 Moroto - Biomass Tables

*Table 51: Moroto: Standing Stock of Tree Biomass*

| Land Use/ Cover Class | Part | Tons per hectare Fresh Weight | Air Dry weight/ Fresh Weight | Tons per hectare Air Dry Weight | Area ha | Total Air Dry Weight Tons |
|---|---|---|---|---|---|---|
| 1 | stem | 30.00* | 0.50* | 15.00 | 7 | 100 |
| | branch | 30.00* | 0.50* | 15.00 | 7 | 110 |
| 3 | stem | 38.00 | 0.50* | 19.00 | 35 | 670 |
| | branch | 51.24 | 0.50* | 25.62 | 35 | 900 |
| 5 | stem | 15.42 | 0.59 | 9.10 | 1,931 | 17,560 |
| | branch | 30.53 | 0.52 | 15.87 | 1,931 | 30,650 |
| 6 | stem | 3.70 | 0.57 | 2.11 | 76,641 | 161,410 |
| | branch | 7.21 | 0.50 | 3.60 | 76,641 | 276,210 |
| 7 | stem | 3.51 | 0.58 | 2.03 | 20,770 | 42,230 |
| | branch | 6.73 | 0.50 | 3.36 | 20,770 | 69,870 |
| 9 | stem | 1.07 | 0.56 | 0.60 | 31,280 | 18,800 |
| | branch | 2.12 | 0.49 | 1.04 | 31,280 | 32,560 |
| 11 | stem | 1.49 | 0.56 | 0.84 | 631 | 530 |
| | branch | 2.62 | 0.50 | 1.31 | 631 | 830 |

*) estimated value

*Table 52: Moroto: Double Sampling Estimates for Air Dry Bush Biomass*

| Land Use/Cover Class | Cover scores, bush: x' | Cover scores, bush: R=y/x | Cover scores, bush: R*x' | Air dry weight: per ha tons | Air dry weight: total tons |
|---|---|---|---|---|---|
| 3 | 8 | 1.00 | 8.0 | 1.36 | 50 |
| 5 | 12 | 1.00 | 12.0 | 2.04 | 3,930 |
| 6 | 54 | 1.00 | 54.0 | 9.16 | 701,910 |
| 7 | 6 | 1.00 | 6.0 | 1.02 | 21,140 |
| 9 | 1 | 2.50 | 2.5 | 0.42 | 13,260 |
| 11 | 4 | 1.00 | 4.0 | 0.68 | 430 |

Table 53 displays the percentage area cover of the surveyed crops and the corresponding total air dry weights in tons per year for the contributing woodfuel crop categories.

*Table 53: Moroto: Agricultural Crops; Percentage Area Cover and Total Weights in Ton/Year*

| Land Use/Cover Class | | Grass | Maize/Sorghum | Miscellaneous | Impediment |
|---|---|---|---|---|---|
| 5 | % cover | 31% | | | 3% |
| | weight | | | | |
| 6 | % cover | 24% | 1% | | 2% |
| | weight | | 2,380 | | |
| 7 | % cover | 78% | | 2% | 1% |
| | weight | | | | |
| 8 | % cover | 10% | | | 70% |
| | weight | | | | |
| 9 | % cover | 68% | 10% | 15% | 1% |
| | weight | | 9,700 | | |
| 11 | % cover | 38% | | 10% | 26% |
| | weight | | | | |
| Total | tons | | 12,080 | | |

*Table 54: Moroto: Total Standing Stock of Air Dry Woody Biomass and Agricultural Residues in Tons*

| Land U/C Class | Tree biomass | Bush biomass | Crop residues | Total |
|---|---|---|---|---|
| 1 | 210 | 0 | 0 | 210 |
| 3 | 1,570 | 50 | 0 | 1,620 |
| 5 | 48,210 | 3,930 | 0 | 52,140 |
| 6 | 437,620 | 701,910 | 2,380 | 1,141,910 |
| 7 | 112,100 | 21,140 | 0 | 133,240 |
| 9 | 51,360 | 13,260 | 9,700 | 74,320 |
| 11 | 1,360 | 430 | 0 | 1,790 |
| Total | 652,430 | 740,720 | 12,080 | 1,405,230 |

## 11.10 Land Use/Cover & Project Area Matrix11.10 Land Use/Cover & Project Area Matrix

Table 55 shows the total air dry biomass in tons per hectare for each land use/cover class in each area. The figures are extracted from the tables in the previous sub-chapters.

*Table 55: Total Standing Stock of Air Dry Biomass in Tons/ha for each Land Use/Cover Class and Project Area*

| Class / Area | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ARU | 37.1 | * | * | * | 36.6 | 18.1 | * | 5.0 | 6.2 | * | 5.5 |
| JIN | 116.1 | 249.3 | 88.1 | 66.9 | 46.6 | 15.7 | 17.3 | 34.2 | 15.6 | 35.2 | 15.8 |
| KBL | 27.1 | 280.0 | * | * | 20.8 | 14.7 | 6.5 | 23.5 | 5.2 | * | 6.6 |
| KLA | 62.1 | 51.5 | 66.8 | 47.3 | 38.5 | 17.4 | 9.1 | 26.5 | 11.8 | * | 11.8 |
| KLI | * | * | * | * | 53.1 | 24.9 | 18.1 | 31.3 | 17.0 | * | 11.1 |
| KUM | 30.0 | * | * | * | 40.7 | 32.2 | 13.2 | 27.2 | 11.3 | * | 15.8 |
| MBL | 40.0 | 40.0 | 50.9 | 31.9 | 39.6 | 22.3 | * | 25.9 | 9.8 | * | 9.9 |
| MBR | 22.2 | * | * | * | 12.0 | 13.1 | 3.5 | 22.6 | 3.8 | * | 4.9 |
| MOR | 30.0 | * | 46.3 | * | 27.0 | 14.9 | 6.4 | * | 2.4 | * | 2.8 |
| Avg | 40.7 | 266.8 | 80.5 | 48.8 | 39.3 | 18.5 | 5.3 | 26.9 | 10.5 | 35.2 | 11.4 |

Table 55 has been included here partly to show the variation between similar land use/cover classes in different project areas, partly because the matrix forms the core of the baseline data for the biomass calculations in phase II. Each cell in the table will be a potential *reference class* - with a specific value for air dry woody biomass per ha - which might be selected through SPOT image interpretation and ground truthing (a form of "extrapolation"). A few comments to some land use/cover classes:

- The high values for plantations in Jinja reflect that plantations there are partly older and partly better stocked.

- There are marked differences in Tropical High Forest biomass per ha. The Jinja project area is dominated by the Mabira Forest, whereas for instance THF areas in the Kampala project area comprises remnants of THF mostly in valleys and along the fringes of papyrus swamps and Lake Victoria. The other areas have less dense THF's.

- For classes 5, 6, 7, 9 and 11, note the general trend that surplus areas (Jinja, Kamuli, Kumi) have high values in almost all classes whereas deficit areas (e.g., Mbarara, Kabale) have low values in most classes.

## 11.11 Assembled Results for All Project Areas11.11 Assembled Results for All Project Areas

Table 56 displays the total averages in tons of air dry weight per hectare for the three categories of biomass. The averages do not include papyrus areas (80% of land use/cover class 8), uniform farmland (class 10), built-up area (class 11) and water (class 12).

*Table 56: Standing Stock of Biomass in Tons per Hectare Air Dry Weight*

| Project Area | Tree Biomass | Bush Biomass | Agric. Residues | Total | Trees % | Bush % | Agric % |
|---|---|---|---|---|---|---|---|
| Arua | 7.12 | 1.91 | 0.87 | 9.90 | 71.9 | 19.3 | 8.8 |
| Jinja | 20.93 | 2.98 | 3.16 | 27.07 | 77.3 | 11.0 | 11.7 |
| Kabale | 9.78 | 1.76 | 0.06 | 11.60 | 84.3 | 15.2 | 0.5 |
| Kampala | 14.03 | 1.56 | 1.51 | 17.10 | 82.1 | 9.1 | 8.8 |
| Kamuli | 15.26 | 3.74 | 1.05 | 20.05 | 76.1 | 18.7 | 5.2 |
| Kumi | 10.88 | 2.05 | 0.80 | 13.74 | 79.2 | 14.9 | 5.9 |
| Mbale | 8.88 | 1.17 | 0.94 | 11.00 | 80.8 | 10.6 | 8.6 |
| Mbarara | 2.81 | 1.25 | 0.03 | 4.09 | 68.7 | 30.5 | 0.8 |
| Moroto | 4.98 | 5.67 | 0.09 | 10.74 | 46.4 | 52.7 | 0.9 |
| Average | 10.99 | 2.37 | 1.03 | 14.40 | 76.3 | 16.5 | 7.2 |

Figure 2 displays the total standing stock of biomass in tons per capita air dry weight for the three categories of biomass for each project area, as well as the average for all project areas.

ContainsDatafor

PostscriptOnly.

*Figure 2: Standing Stock per Capita in the Nine Project Areas*

# 12 Harvestable Biomass12 Harvestable Biomass

In chapter 11, the total standing stock of occurring relevant biomass is outlined. Only a proportion of this amount can be harvested annually without depleting the mass. To sustain the biomass, the long term annual increment can be taken out. Usually this is predicted in increment prognoses tables. Establishment of such tables involves a substantial amount of work in mensuration and calculation of actual yields over a long period of time. Unfortunately, there were no tables available of this kind fit for our purposes. Thus, simple models had to be designed in order to predict biomass increment.

Initially, Forest Reserves were meant to be left out from the study. However, the project concluded that the results give a better picture of the total supply source situation if these areas were included. Even if felling in Forest Reserves is restricted, the wood products taken out will rotate within the trading system and benefit the people. It should be emphasized that the degree of extraction in Forest Reserves varies considerably. For instance, if the Mabira Forest Reserve - where all encroachers were evicted three years ago and all extraction banned - is excluded from the biomass calculation for the Jinja project area, the total biomass is reduced by approximately 25%.

The project areas are not closed communities, hence wood of all categories are brought in and out. *This factor was not considered in the accounts of woodfuel balance - each area was examined as a separate, closed unit.* A key aspect for decision-makers and planners would be to assess this woodfuel exchange not only from a *market* point of view, but also from an *energy budget* point of view. In other words, in order to reduce transport costs, supplies of woodfuel must be located close to the consumers.

Our basic assumption has been that transporting woodfuel normally should be avoided since it will increase the total energy consumption through for instance petrol/diesel consumption. Analyzing each area separately, aiming at a tree biomass surplus in all areas is therefore a correct approach.

## 12.1 Estimating Tree Biomass Increment12.1 Estimating Tree Biomass Increment

There is no doubt that tree biomass is the main element in the woodfuel supply. Estimating the quantity which can be harvested without depleting the base resource is thus of paramount importance. *Finding this amount does not necessarily lead to the conclusion that such quantity should be harvested.* Most of the areas, i.e. Arua, Jinja, Kabale, Kampala, Mbale and Mbarara have already cut too much and the growing stock is not sufficient to yield the needed demand.

As mentioned above, adequate information about increment e.g. increment/ forecast functions were not available. The Review Mission (February 1992) recommended that repeated measurements/ dynamic monitoring should be included in Phase II of the Biomass Study. This has been accepted and will commence towards the end of 1992. It is assumed that about 30% of all the 3,417 field plots from Phase I will be re-measured.

The mission also suggested a preliminary survey of a number of plots as an input to the final report from Phase I. This was immediately followed up, and a sub-sample of about 120 field plots were re-measured about 1.5 years after the first visit. These were selected randomly from four of the project areas; Jinja, Kamuli, Mbale and Mbarara, but with an emphasis on covering all land use/cover classes. The re-measured plots fell into two categories;

(1) those which had been "tampered" with (trees cut etc), and

(2) those untouched since the first visit.

Untouched plots - about 1/3 of the total - should give an indication of natural increments, whereas all plots together should give an indication of actual biomass development (i.e. natural increment minus harvested biomass). All the plots were computed for standing stock, similar to the first time.

It must be emphasized that the *sample size is too small* and the *period of time too short* to draw any *firm* conclusions on the biomass increments in different land use/cover classes and different areas. However, the results gave some rough indications about growth capacities and biomass trends as outlined below. The figures were rounded off.

From category (1) and (2) all the plots were computed, giving the general change in growing stock:

*Table 57: Annual Change in Growing Stock*

| | |
|---|---|
| Jinja | - 10% |
| Kamuli | + 5% |
| Mbale | + 5% |
| Mbarara | - 10% |
| Average (weighted) | - 3% |

Undisturbed plots - category (2) - were then computed separately, yielding the following rounded figures for the annual increment:

*Table 58: Natural Annual Increment*

| | |
|---|---|
| Deciduous plantations | 15% |
| Conifer plantations | 7% |
| Tropical high forest | 5% |
| Savannah woodlands | 5% |
| Bush- and grassland | 10% |
| Subsistence farmland | 15% |
| Built-up area | 10% |

The high increment rate on farmland is most likely due to the short rotation period of the trees. The plot measurements revealed that an overwhelming proportion of the trees are small, i.e. trees are cut before reaching an age of biological maturity. Calculated in percent, the increment will obviously be higher with small trees than with big trees. Using the above listed rates as a basis, the tree biomass increment was calculated, weighted for the proportional occurrence of different land use/cover classes as shown in table 59.

*Table 59: Estimated Annual Increment in Percent*

| Project Area | Average (%) |
|---|---|
| Arua | 11.1 |
| Jinja | 9.6 |
| Kabale | 10.8 |
| Kampala | 10.6 |
| Kamuli | 12.6 |
| Kumi | 13.6* |
| Mbale | 13.6* |
| Mbarara | 11.2 |
| Moroto | 5.0** |
| Total (weighted) | 11.2 |

*) The increment seems high most likely due to over-generalization of area to vegetation type 9 (farmland).
**) Estimated value.

## 12.2 Harvestable Bush12.2 Harvestable Bush

Bush occurs in different categories depending on the land use/cover class and land use practices. On savannah areas it appears as the natural vegetation in the form of scrubs and thickets. Similarly, in forests not completely closed it appears as an understorey layer. On farmland, bush is primarily an undesired growth in fast progress after land abandonment/ neglect or fallow. In wood scarcity areas, bush stems and twigs are commonly used as firewood and must thus be regarded as an actual woodfuel resource. The rotation time of bush was - based on general knowledge - estimated to two years, hence 50% of standing stock can theoretically be harvested every year. Considering the leafage, smallest twigs and normal waste, 30% is regarded as a realistic estimate, amounting to 5.09 tons air dry harvestable wood per hectare at 100% cover. This average was used for all the project areas.

## 12.3 Potential from Agricultural Residues12.3 Potential from Agricultural Residues

Agricultural residues are not preferred as firewood. Residue collection is time consuming, and it burns fast. In addition, removing too much of the residues will deplete the soil and might thus contribute to land degradation.

Extensive use of this fuel source should be seen as a symptom of shortage of other and more proper types of woodfuel sources. In the following woodfuel balance tables, 50% of the agricultural residues are regarded as harvestable.

Fuel potentials from grass were not quoted. According to our observations, grass is not used with the exception of a few areas. However, under extreme woodfuel deficit situations, this source can certainly be used as a "last resort".

## 12.4 Woodfuel Balance - All Project Areas12.4 Woodfuel Balance - All Project Areas

The final results of tree increment / harvestable biomass potentials, total for all land use/cover classes, are given in the following tables.

*Table 60: Annual Tree Increment / Harvestable Biomass Potentials in Tons Air Dry Weight*

| | Tree biomass increment | Bush biomass 30% | Agricult. residues 50% | Total | Surplus or Deficiency |
|---|---|---|---|---|---|
| Arua | 82,300 | 57,710 | 45,400 | 185,410 | – 24,690 |
| Jinja | 239,840 | 125,140 | 186,050 | 551,030 | + 158,730 |
| Kabale | 98,830 | 53,950 | 2,650 | 155,420 | – 88,180 |
| Kampala | 373,750 | 285,630 | 182,590 | 841,970 | – 591,030 |
| Kamuli | 234,680 | 149,260 | 63,670 | 447,600 | + 350,300 |
| Kumi | 201,010 | 159,400 | 54,250 | 414,650 | + 265,750 |
| Mbale | 225,650 | 107,020 | 87,180 | 419,840 | – 224,460 |
| Mbarara | 28,090 | 54,500 | 1,490 | 84,070 | – 53,630 |
| Moroto | 32,620 | 215,550 | 6,040 | 254,210 | + 220,410 |
| Total | 1516,780 | 1208,150 | 629,280 | 3354,210 | + 13,210 |

In tons per hectare, the results are as follows:

*Table 61: Annual Tree Increment / Harvestable Biomass Potentials in Tons per Hectare Air Dry Weight*

| | Tree biomass | Bush biomass | Agricultural residues | Total |
|---|---|---|---|---|
| Arua | 0.78 | 0.55 | 0.43 | 1.77 |
| Jinja | 1.51 | 0.79 | 1.17 | 3.47 |
| Kabale | 1.03 | 0.56 | 0.03 | 1.63 |
| Kampala | 1.25 | 0.95 | 0.61 | 2.81 |
| Kamuli | 1.86 | 1.18 | 0.50 | 3.55 |
| Kumi | 1.31 | 1.04 | 0.35 | 2.70 |
| Mbale | 1.16 | 0.55 | 0.45 | 2.15 |
| Mbarara | 0.31 | 0.59 | 0.02 | 0.92 |
| Moroto | 0.25 | 1.64 | 0.05 | 1.94 |
| Total | 1.12 | 0.89 | 0.46 | 2.47 |

Figure 3 shows the distribution in percent of the total potential harvestable biomass.

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*Figure 3: Distribution in percent of Tree Increment / Harvestable Biomass Potentials*

The annual tree increment is calculated on the basis of the prevailing standing stock and rough estimates of the increment rates. It is emphasized that *these quantities are not identical with the amounts recommendable for harvesting.* Apart the needed demand and should thus be handled with care until a sufficient growing stock is reached.

The next table shows the results in tons per capita.

*Table 62: Annual Tree Increment/ Harvestable Biomass Potentials in Tons per Capita Air Dry Weight*

| | Tree biomass | Bush biomass | Agricultural residues | Total |
|---|---|---|---|---|
| Arua | 0.39 | 0.27 | 0.22 | 0.88 |
| Jinja | 0.61 | 0.32 | 0.47 | 1.40 |
| Kabale | 0.41 | 0.22 | 0.01 | 0.64 |
| Kampala | 0.26 | 0.20 | 0.13 | 0.59 |
| Kamuli | 2.41 | 1.53 | 0.65 | 4.60 |
| Kumi | 1.35 | 1.07 | 0.36 | 2.78 |
| Mbale | 0.35 | 0.17 | 0.14 | 0.65 |
| Mbarara | 0.20 | 0.40 | 0.01 | 0.61 |
| Moroto | 0.97 | 6.38 | 0.18 | 7.52 |
| Total | 0.45 | 0.36 | 0.19 | 1.00 |

As outlined earlier, one ton per capita is considered as an adequate biomass quantity. Our calculations gave - incidentally - exactly the same figure for the potential harvestable biomass in all the project areas. This is also shown in figure 4 on the next page.

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*Figure 4: Harvestable Biomass Potentials in Tons per Capita Air Dry Weight*

# 13 Woodfuel Transport Study13 Woodfuel Transport Study

The objectives of this sub-project are the following:

(a) To establish transport distances for various means of transport.

(b) To establish relative quantities transported by various means of transport.

(c) To establish the cost of woodfuel in each project area.

(d) To locate the major areas supplying woodfuel to the urban centre in each project area.

(e) To establish the common tree species used for woodfuel purposes.

Urban as well as rural woodfuel scarcity often origins from improper, expensive and insufficient transport practices. Obvious symptoms of this are the appearance of overcut land surrounding highly populated centres, villages and towns. Information about prevailing transport habits are therefore crucial in coming up with adequate recommendations. Answers to the above mentioned sub-objective issues will thus act as good guidelines.

## 13.1 Methodology13.1 Methodology

This survey was carried out in all the project areas between August and October 1991. The data were collected using a simple questionnaire (see Appendix I), which was filled in by a number of woodfuel transporters and dealers in each project area. These "interviews" were conducted along major roads leading to urban centres, market places and large consumption points (bakeries, brick burning sites and local breweries), in addition to landing sites in areas where boats/canoes are used for woodfuel transportation.

### 13.1.1 Sampling Design13.1.1 Sampling Design

In principle, the sampling area was determined by measuring a maximum distance of 21 km along each main road leading to the urban centre. Any transporter or dealer of woodfuel encountered within this area was interviewed. For Kampala this distance was increased to 30-35 km, whereas Jinja, Mbale and Mbarara had their distances increased by 25-30 km, since these areas have large urban centres requiring large supply areas.

Each respondent was asked to give complete information as demanded by the questionnaire. If a respondent dealt both in charcoal and fuel-wood, or used more than one means of transport, several questionnaires were used.

### 13.1.2 Commonly Used Tree Species13.1.2 Commonly Used Tree Species

The study employed a simple ranking system to find out which tree species were widely used for woodfuel purposes. Each respondent was asked to name at least three common tree species used for firewood or charcoal. The frequency of individuals using a particular tree species was then calculated on percentage response. Numerous tree species are not presented due to being irregularly or rarely used.

### 13.1.3 Estimation of Weights13.1.3 Estimation of Weights

In each project area, several bags of charcoal were weighed and the average weight determined. This weight was used as a standard for calculating load of charcoal transported, both total and by each respondent in a month. For firewood, several stacks were weighed in each project area and the average determined. Estimation of total load transported by each individual was based on the average weight and number of stacks.

### 13.1.4 Constraints13.1.4 Constraints

A number of constraints were encountered:

(a) It was impossible to get a sufficient number of respondents on some roads, as they were scarce and scattered (a minimum of 25 respondents were considered sufficient).

(b) A few respondents were suspicious of the exercise, hence not willing to disclose true information.

(c) Some respondents were uncertain of the distance travelled during the collection and distribution process - in particular when it was transported by canoe.

(d) Many vehicles and canoes move long distances in search for woodfuel. They reach their destinations either late in the evening or very early in the morning, and were thus not available for our daytime interviews.

(e) Other means of transport include trains, which presumably transport large quantities of woodfuel from rural to some urban areas. However, railway lines were not considered in this study due to its spatial inflexibility.

(f) The distance between the source of woodfuel and the market was considered. In most cases transporters obtain their woodfuel directly from the primary sources. However, some transporters obtain their woodfuel from secondary sources in areas where woodfuel from primary sources are bulked for further trading.

# 13.2 Woodfuel Transport in Arua13.2 Woodfuel Transport in Arua

## 13.2.1 Relative Frequency of Transporters13.2.1 Relative Frequency of Transporters

A total of 312 transporters were interviewed, 85 transporting charcoal and 227 firewood. The table below shows the frequency of woodfuel transporters and the various means of transport used in collection and distribution of woodfuel. Woodfuel is mostly transported on foot, whereas vehicle transport is uncommon.

*Table 63: Frequency of Woodfuel Transporters in Arua*

| | Frequency of Respondents | | | |
|---|---|---|---|---|
| | Charcoal | | Firewood | |
| Means of Transport | No | % | No | % |
| Vehicle *) | 5 | 6 | - | - |
| Bicycle | 27 | 32 | 15 | 7 |
| Foot **) | 53 | 62 | 212 | 93 |
| Total | 85 | 100 | 227 | 100 |

*) refers to any transport on road using four or more wheels.
**) refers to the carriage of goods on head, carts or animals.

## 13.2.2 Average Distance Travelled13.2.2 Average Distance Travelled

The average distances travelled by each means of transport were between 11 and 17 km for bicycles, while footers walked between 10 and 11 km for both firewood and charcoal.

### 13.2.3 Quantity Transported13.2.3 Quantity Transported

A random survey carried out in this project area reveals that 85 transporters supply about 76 tons of charcoal to the markets every month, while 227 firewood transporters deliver about 38 tons. The figure for firewood seems low, indicating low demand. This is because firewood is mainly used for domestic purposes as there are few large scale firewood consuming activities in Arua township. Firewood for tobacco curing is mostly collected/bought locally and transported directly to the consumer.

The average load per trip and number of trips for each means of transport are shown in the next table.

*Table 64: Average Load per Trip by various Means of Transport (Arua)*

| | Average Load (tons/trip) | | Average no of trips/month | |
|---|---|---|---|---|
| Means of Transport | Charcoal | Firewood | Charcoal | Firewood |
| Vehicle | 4.70 | - | 2 | - |
| Bicycle | 0.04 | 0.02 | 21 | 7 |
| Foot | 0.03 | 0.02 | 10 | 8 |

The following two figures present the relative load transported by various means and for various distances. Although vehicles are not commonly used, they cover about 50% of the total charcoal transportation, while foot and bicycle transport about 20 and 30% respectively. Most firewood is transported on foot and very little on bicycle.

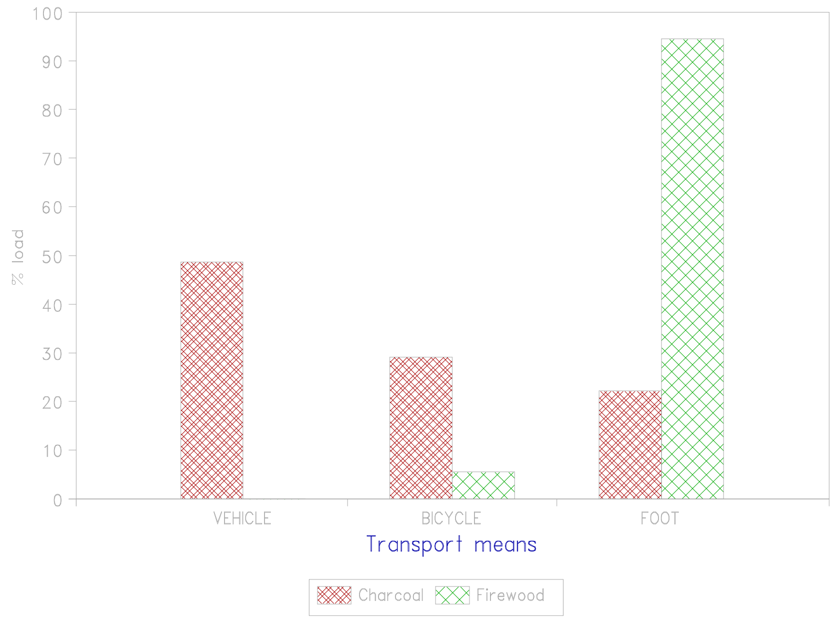


*Figure 5: Percentage load transported by various means in Arua*

Woodfuel supplies are concentrated within a distance of 10 to 30 km. Although no firewood is obtained beyond 20 km, charcoal can be hauled up to 40 km.


*Figure 6: Percentage load transported for various distances in Arua*

### 13.2.4 Tree Species Commonly Used13.2.4 Tree Species Commonly Used

i. Charcoal species: Response (%).

| | |
|---|---|
| Combretum spp. | 75 |
| Butyrospermum paradoxum | 55 |
| Terminalia spp. | 42 |
| Acacia spp. | 26 |
| Pseudospondius microcarpa | 19 |
| Grewia mollis | 18 |
| and many others. | |

ii. Firewood species:

| | |
|---|---|
| Combretum spp. | 52 |
| Acacia spp. | 37 |
| Grewia mollis | 26 |
| Terminalia spp. | 21 |
| Butyrospermum paradoxum | 15 |
| Vernonia amygdalena | 15 |

# 13.3 Woodfuel Transport in Jinja13.3Woodfuel Transport in Jinja

## 13.3.1 Relative Frequency of Transporters13.3.1 Relative Frequency of Transporters

A total of 221 transporters were interviewed in this area. 209 of these were transporters of charcoal and 12 of firewood. The frequency of transporters and the various means of transport used in collection and distribution of woodfuel is given in table 65.

*Table 65: Frequency of Woodfuel Transporters in Jinja*

| | Frequency of Respondents | | | |
|---|---|---|---|---|
| | Charcoal | | Firewood | |
| Means of Transport | No | % | No | % |
| Vehicle | 5 | 2 | - | - |
| Bicycle | 159 | 76 | 10 | 83 |
| Foot | 2 | 1 | 2 | 17 |
| Canoe *) | 43 | 21 | - | - |
| Total | 209 | 100 | 12 | 100 |

*) refers to any transport on water.

## 13.3.2 Average Distance Travelled13.3.2 Average Distance Travelled

Woodfuel is transported on road by vehicle, bicycle or foot, and on water by various water vessels. Vehicles move an average distance of about 80 km in collecting charcoal, while bicycles and canoes move an average distance of about 18 and 59 km respectively. The few footers interviewed were those unloading charcoal from canoes at the landing sites, thus average distance figures for footers were too low to be included. For firewood, the average distances of foot and bicycle transport were 7 and 10 km respectively.

### 13.3.3 Quantity Transported13.3.3 Quantity Transported

This survey reveals that 209 transporters of charcoal bring about 375 tons to the markets every month, while 12 transporters of firewood deliver about 20 tons. The average load per trip and number of trips per month for each transport means were also calculated and are presented in the next table.

*Table 66: Average Load per Trip by Various Means of Transport (Jinja)*

| | Average Load (tons/trip) | | Average no of trips/month | |
|---|---|---|---|---|
| Means of Transport | Charcoal | Firewood | Charcoal | Firewood |
| Vehicle | 0.40 | - | 6 | - |
| Bicycle | 0.05 | 0.06 | 29 | 23 |
| Foot | 0.05 | 0.04 | 15 | 15 |
| Canoe | 0.93 | - | 4 | - |

Apart from transporting charcoal from primary sources, bicycles also take part in the distribution of charcoal delivered by canoes from the landing sites. Thus, bicycle transporters make more trips per month than any other means of transport in this area. Bicycles form a major component of the internal transport network providing a market to door service. The next two figures show the percentage load transported by various means and percentage load at various distances. Apart from the charcoal transported by vehicles and canoes, most woodfuel is obtained from the surrounding areas where bicycle transport is dominant.

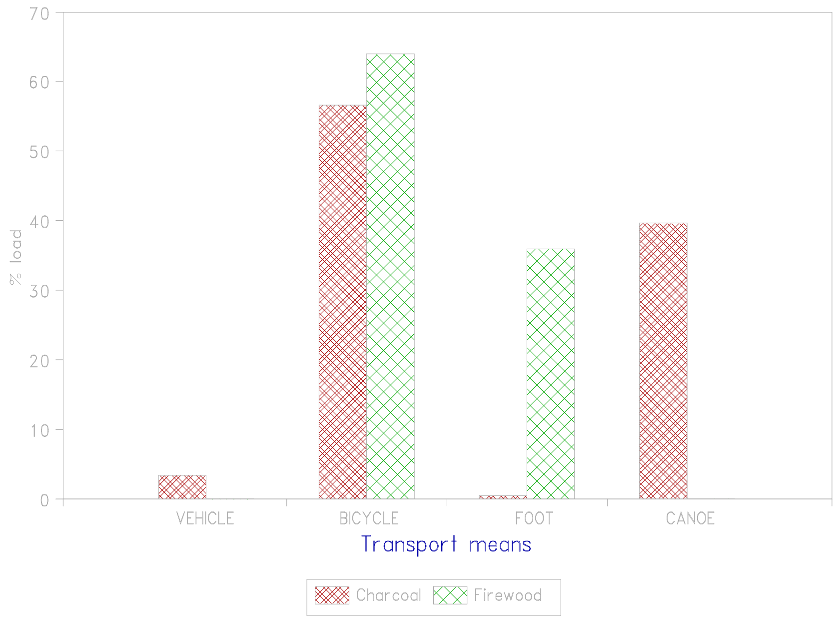


*Figure 7: Percentage load transported by various means in Jinja*

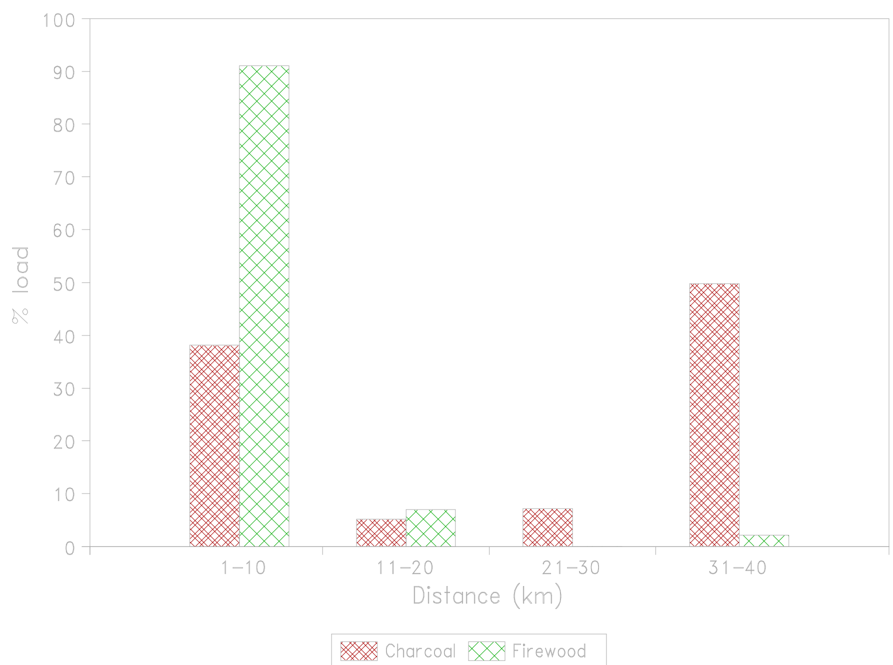


*Figure 8: Percentage load transported for various distances in Jinja*

### 13.3.4 Tree Species Commonly Used13.3.4 Tree Species Commonly Used

i. Charcoal species: Response (%).

| | |
|---|---|
| Teclea nobilis | 53 |
| Acacia polyacantha | 32 |
| Markhamia platycalyx | 30 |
| Ficus natalensis | 30 |
| Albizia spp. | 29 |
| Maena duchenei | 11 |
| Phyllanthus discoideus | 11 |
| Mangifera indica | 7 |
| Sapium ellipticum | 7 |
| Pseudospondius microcarpa | 6 |

ii. Firewood species:

| | |
|---|---|
| Sapium ellipticum | 50 |
| Ficus natalensis | 33 |
| Acacia polyacantha | 16 |
| Vernonia amygdalina. | 16 |
| Solanum spp. | 9 |

## 13.4 Woodfuel Transport in Kabale13.4 Woodfuel Transport in Kabale

### 13.4.1 Relative Frequency of Transporters13.4.1 Relative Frequency of Transporters

A total of 200 transporters were interviewed in this area, 138 transporting charcoal and 62 firewood. The table below shows the frequency of woodfuel transporters and the various means of transport used in collection and distribution of woodfuel.

*Table 67: Frequency of Woodfuel Transporters in Kabale*

| Means of Transport | Frequency of Respondents Charcoal No | Charcoal % | Firewood No | Firewood % |
|---|---|---|---|---|
| Vehicle | 3 | 2 | 18 | 29 |
| Bicycle | 78 | 57 | 17 | 27 |
| Foot | 57 | 41 | 27 | 44 |
| Total | 138 | 100 | 62 | 100 |

## 13.4.2 Average Distances Travelled13.4.2 Average Distances Travelled

Charcoal transport is mainly by bicycle and foot and rarely by vehicle, but the few vehicles travel long distances. A significant number of vehicles is involved in firewood transport. Charcoal is mainly converted from *Acacia mearnsii* (Black wattle), which is often found growing on hilly terrain where vehicle transport is difficult. Transport of firewood are equally distributed among the various means of transport. Average distances travelled are for vehichles 38 km (charcoal) and 12 km (firewood), for bicycles 12 km and 6 km, and for footers 8 km and 6-7 km, respectively.

The differences in transport distance between bicycle and foot are not so big, since most of the firewood is collected from woodlots near the town.

## 13.4.3 Quantity Transported13.4.3 Quantity Transported

In Kabale, 138 transporters bring about 137 tons of charcoal to the markets every month, while 62 transporters bring about 246 tons of firewood. This implies that more firewood is consumed than charcoal.

*Table 68: Average Load per Trip by Various Means of Transport (Kabale)*

| Means of Transport | Average Load (tons/trip) Charcoal | Average Load (tons/trip) Firewood | Average no of trips/month Charcoal | Average no of trips/month Firewood |
|---|---|---|---|---|
| Vehicle | 1.20 | 4.00 | 1 | 2 |
| Bicycle | 0.04 | 0.04 | 26 | 59 |
| Foot | 0.04 | 0.03 | 28 | 39 |

The next two figures show the percentage load transported by various means and the percentage load at various distances.

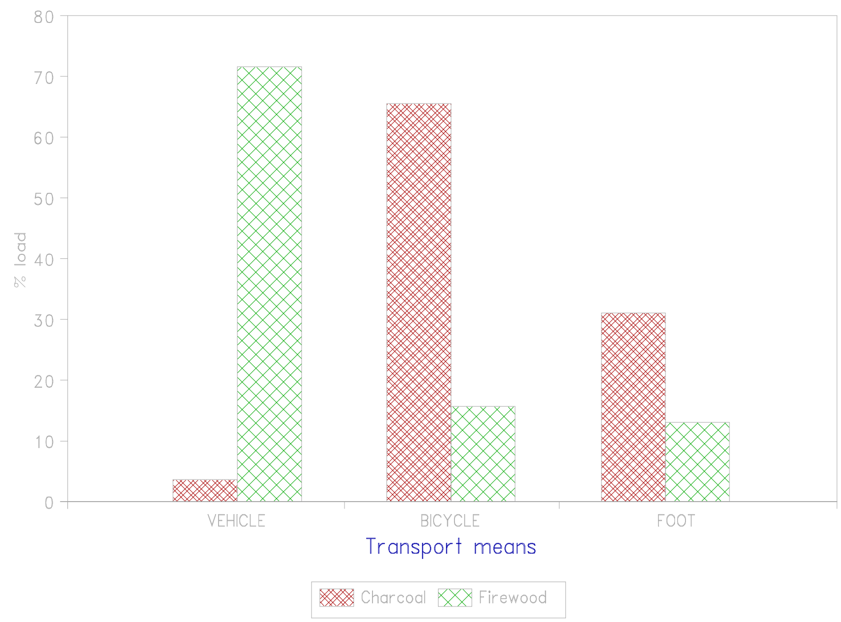


*Figure 9: Percentage load transported by various means in Kabale*

Most of the firewood is transported by vehicle, whereas bicycles dominate the charcoal transport. Firewood is mainly used for domestic heating, in educational institutions and for local brewing of the famous "muramba and bushera". Unreliable and/or non-existent electricity supply have increased the consumption of firewood in this area. Woodfuel is mostly hauled from a distance of 1 to 20 km, although some minor quantities of charcoal are obtained beyond 20 km.

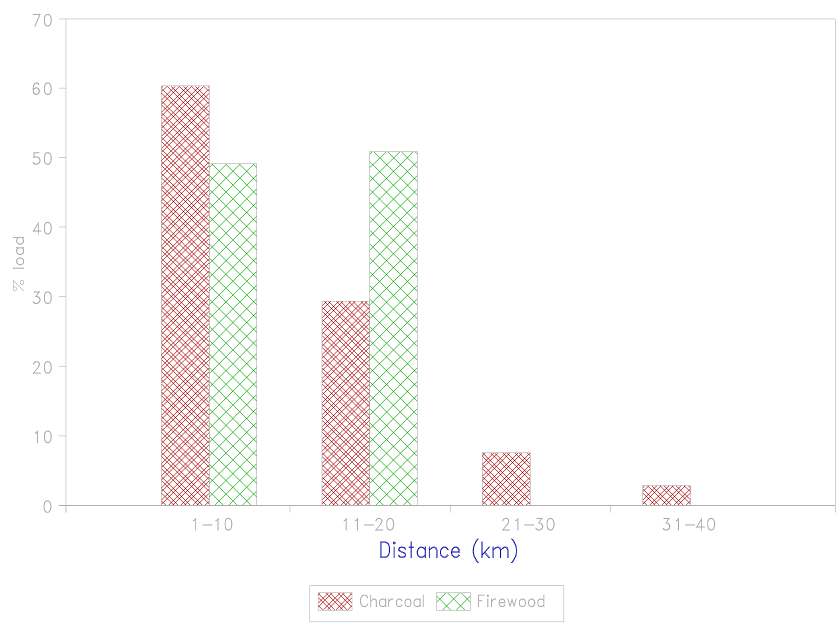


*Figure 10: Percentage load transported for various distances in*

### 13.4.4 Tree Species Commonly Used13.4.4 Tree Species Commonly Used

i. Charcoal species: Response (%).

| Species | Response (%) |
|---|---|
| Acacia mearnsii | 96 |
| Eucalyptus grandis | 19 |

ii. Firewood species:

| Species | Response (%) |
|---|---|
| Eucalyptus grandis | 94 |
| Acacia mearnsii | 16 |
| Ficus natalensis | 3 |
| Mitrigyna stripulosa | 3 |

## 13.5 Woodfuel Transport in Kampala13.5 Woodfuel Transport in Kampala

### 13.5.1 Relative Frequency of Transporters13.5.1 Relative Frequency of Transporters

A total of 274 respondents were interviewed in this area. 207 of these were transporters of charcoal and 67 of firewood. The table below shows the frequency of woodfuel transporters and the various means of transport used in collection and distribution of woodfuel.

*Table 69: Frequency of Woodfuel Transporters in Kampala*

| | Frequency of Respondents | | | |
|---|---|---|---|---|
| | Charcoal | | Firewood | |
| Means of Transport | No | % | No | % |
| Vehicle | 12 | 6 | 6 | 9 |
| Bicycle | 187 | 90 | 52 | 78 |
| Foot | 3 | 1 | 5 | 7 |
| Canoe | 5 | 3 | 4 | 6 |
| Total | 207 | 100 | 67 | 100 |

The woodfuel transport is dominated by bicycles. Transport by foot is rather uncommon.

### 13.5.2 Average Distance Travelled13.5.2 Average Distance Travelled

With regard to charcoal the following transport pattern was observed: vehicles can be categorized as long distance movers travelling an average distance of about 90 km (charcoal) and 28 km (firewood), bicycles and canoes as medium distance movers with average distances of 22/17 km and 25/55 km respectively, while footers travel a short distance of about 2-4 km. Canoes tend to move a longer distance with firewood than with charcoal. In general terms, longer distances are travelled in collection of charcoal than of firewood.

## 13.5.3 Quantity Transported13.5.3 Quantity Transported

About 500 tons of charcoal and 155 tons of firewood are supplied to the markets every month. The average load per trip and number of trips per month were also calculated and are presented in the table below.

*Table 70: Average Load per Trip by Various Means of Transport (Kampala)*

| Means of Transport | Average Load (tons/trip) Charcoal | Firewood | Average no of trips/month Charcoal | Firewood |
|---|---|---|---|---|
| Vehicle | 3.67 | 4.11 | 4 | 3 |
| Bicycle | 0.08 | 0.03 | 17 | 20 |
| Foot | 0.05 | 0.02 | 8 | 14 |
| Canoe | 1.30 | 1.08 | 9 | 10 |

Many vehicles and canoes transport both woodfuel and other goods, which explains the relative small loads recorded for the two types of transport. The percentage load transported by various means and the percentage load at various distances are presented in the next two figures.


*Figure 11: Percentage load transported by various means in Kampala*

About 45 % of the total woodfuel is transported more than 31 km. This is a substantial proportion of long distance transport which indicates that the city surroundings cannot meet the demand sufficiently. However, the suburb areas can afford to supply minor quantities of different categories of wood and miscellaneous residues.

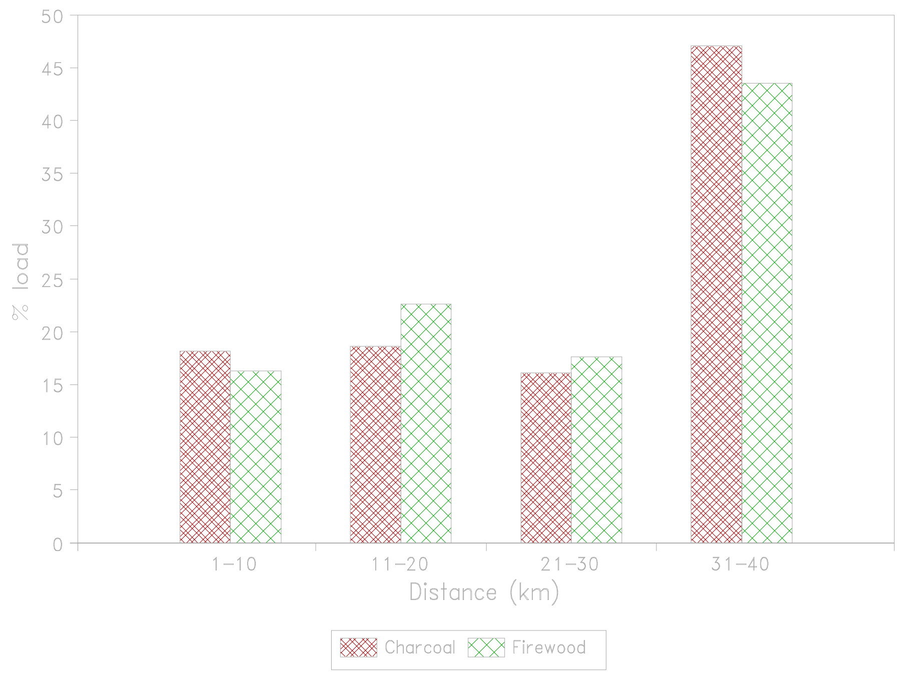


*Figure 12: Percentage load transported for various distances in Kampala*

## 13.5.4 Tree Species Commonly Used13.5.4 Tree Species Commonly Used

i. Charcoal species:

| Charcoal species | Response (%). |
|---|---|
| Sapium ellipticum | 33 |
| Albizia spp. | 31 |
| Pseudospondius microcarpa | 24 |
| Ficus natalensis | 19 |
| Coffea excelsa | 14 |
| Mangifera indica | 11 |
| Acacia polycantha | 9 |
| Phoenix reclinata | 8 |
| Cassia spp. | 8 |

| | |
|---|---|
| Polyscias fulva | 6 |

ii. Firewood species:

| | |
|---|---|
| Sapium ellipticum | 30 |
| Ficus natalensis | 21 |
| Coffea excelsa | 21 |
| Albizia spp. | 12 |
| Eucalyptus saligna | 12 |
| Harungana madagascariensis | 12 |
| Cassia spp. | 11 |
| Acacia polycantha | 9 |
| Maesopsis eminii | 9 |
| Ficus exasperata | 7 |

## 13.6 Woodfuel Transport in Kamuli13.6 Woodfuel Transport in Kamuli

### 13.6.1 Relative Frequency of Transporters13.6.1 Relative Frequency of Transporters

A total number of 105 respondents were interviewed in this area. 86 of these were transporters of charcoal and 19 of firewood. Table 71 shows the frequency of transporters and the various means of transport used in collection and distribution of woodfuel.

*Table 71: Frequency of Woodfuel Transporters in Kamuli*

| | Frequency of Respondents | | | |
|---|---|---|---|---|
| | Charcoal | | Firewood | |
| Means of Transport | No | % | No | % |
| Vehicle | 2 | 2 | 2 | 11 |
| Bicycle | 83 | 97 | 17 | 89 |
| Foot | 1 | 1 | - | - |
| Total | 86 | 100 | 19 | 100 |

Kamuli project area has no waterway, thus canoe transport is not relevant. There was also a very low response from both vehicle and foot transporters, thus bicycle transport dominates the entire exercise.

### 13.6.2 Average Distance Travelled13.6.2 Average Distance Travelled

Vehicles travel around 52 km (charcoal) and 28 km (firewood), bicycles 9 km and 5 km, and footers 2 km (charcoal). Most vehicles go to Jinja town.

### 13.6.3 Quantity Transported13.6.3 Quantity Transported

This survey shows that 86 transporters of charcoal bring about 162 tons to the markets every month, while 19 transporters of firewood deliver about 74 tons.

The average load per trip and number of trips per month were also calculated and are presented below.

*Table 72: Average Load per Trip by Various Means of Transport (Kamuli)*

| | Average Load (tons/trip) | | Average no of trips/month | |
|---|---|---|---|---|
| Means of Transport | Charcoal | Firewood | Charcoal | Firewood |
| Vehicle | 0.16 | 7.00 | 19 | 4 |
| Bicycle | 0.12 | 0.05 | 16 | 23 |
| Foot | 0.04 | - | 20 | - |

From table 72 it is clear that vehicles transport larger quantities of firewood per trip than charcoal. This is due to a high demand for firewood in Kamuli especially in schools and bakeries as a result of unreliable supply of electricity. The following two figures show the percentage load transported by various means of transport and the percentage load at various distances. Most charcoal is transported less than 20 km. This is mainly due to the following factors:

(a) Location of resources near the town

(b) Scarcity of vehicles for long distance travelling

(c) Low urban population hence low demand since it is not as widely used in schools and bakeries as firewood.

About 75 % of the total firewood load is transported by vehicles, which accounts for the long distance moved.

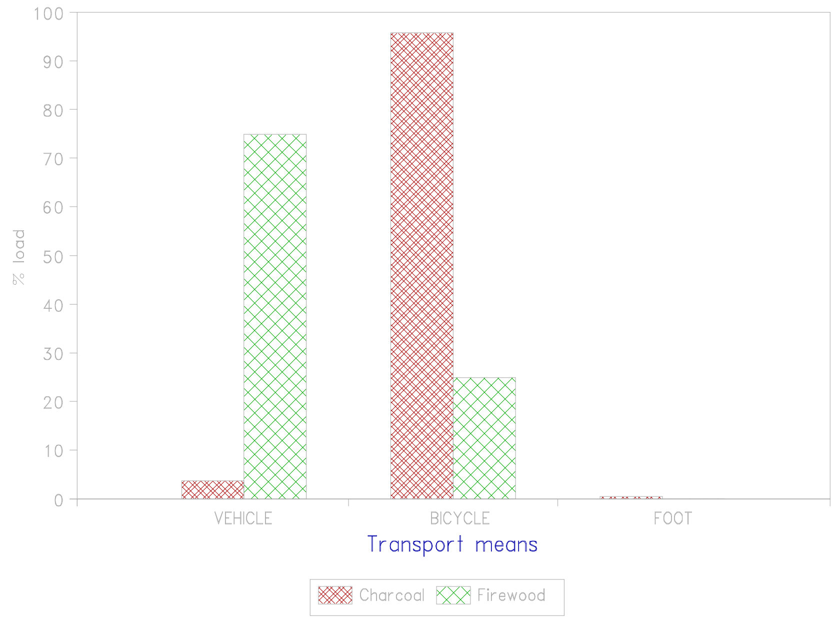


*Figure 13:* *Percentage load transported by various means of transport in Kamuli*

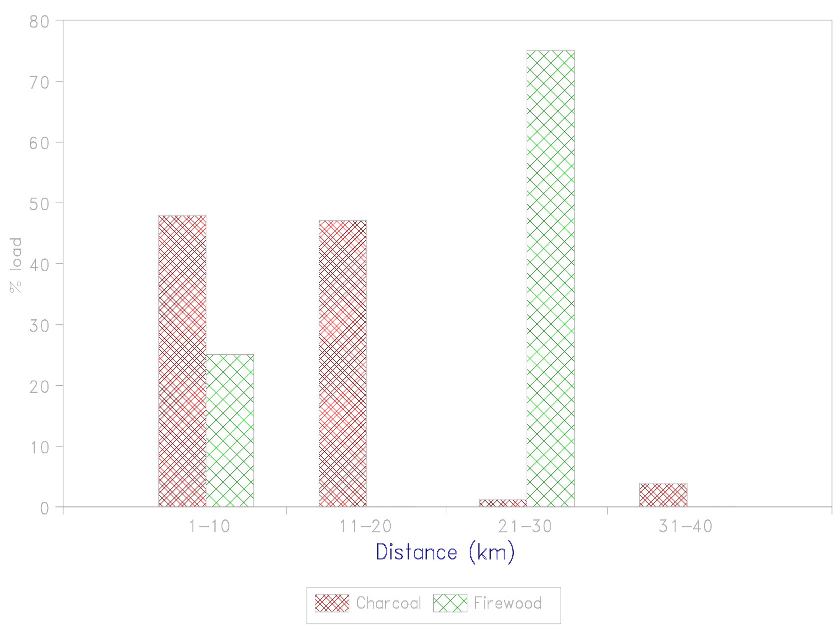


*Figure 14: Percentage load transported for various distances in Kamuli*

### 13.6.4 Tree Species Commonly Used13.6.4 Tree Species Commonly Used

| | | |
|---|---|---|
| i. | Charcoal species: | Response (%). |
| | Combretum spp. | 62 |
| | Acacia polyacantha | 38 |
| | Sapium ellipticum | 24 |
| | Cassia spp. | 20 |
| | Phyllanthus discoideus | 13 |
| | Albizia spp. | 12 |
| ii. | Firewood species: | |
| | Acacia polyacantha | 58 |
| | Cassia spp. | 37 |
| | Dicrostachys glomerata | 16 |
| | Ficus natalensis | 16 |
| | Sapium ellipticum | 11 |
| | Advised micrantha | 11 |

# 13.7 Woodfuel Transport in Kumi13.7 Woodfuel Transport in Kumi

## 13.7.1 Relative Frequency of Transporters13.7.1 Relative Frequency of Transporters

A total of 197 transporters were interviewed, 109 transporting charcoal and 88 firewood. The frequency of woodfuel transporters and the various means of transport used in collection and distribution of woodfuel is shown in table 73.

*Table 73: Frequency of Woodfuel Transporters in Kumi*

| | Frequency of Respondents | | | |
|---|---|---|---|---|
| | Charcoal | | Firewood | |
| Means of Transport | No | % | No | % |
| Vehicle | 14 | 13 | - | - |
| Bicycle | 20 | 18 | 5 | 6 |
| Foot | 75 | 69 | 83 | 94 |
| Total | 109 | 100 | 88 | 100 |

## 13.7.2 Average Distance Travelled13.7.2 Average Distance Travelled

Foot transport is the most common means of transport. All the vehicles encountered were those transporting charcoal to Mbale. This implies that no woodfuel is transported by vehicle into Kumi town. For charcoal, the average distance varies from 7 to 10 km for foot and bicycle while for firewood between 5 and 7 km respectively.

## 13.7.3 Quantity Transported13.7.3 Quantity Transported

From the results, 109 transporters supply about 102 tons of charcoal to the markets every month, while 88 transporters deliver about 18 tons of firewood. The average load per trip and number of trips per month are shown in table 74.

*Table 74: Average Load per Trip by Various Means of Transport (Kumi)*

| Means of Transport | Average Load (tons/trip) Charcoal | Firewood | Average no of trips/month Charcoal | Firewood |
|---|---|---|---|---|
| Vehicle | 0.25 | - | 6 | - |
| Bicycle | 0.06 | 0.026 | 11 | 5 |
| Foot | 0.10 | 0.04 | 9 | 5 |

It can be seen that more charcoal load is transported on foot than on bicycle. This is because footers transport charcoal using wheelbarrows and not by carrying it on their heads, while firewood is transported on both wheelbarrows and heads. The next two figures show the percentage load transported by various means and the percentage load at various distances.

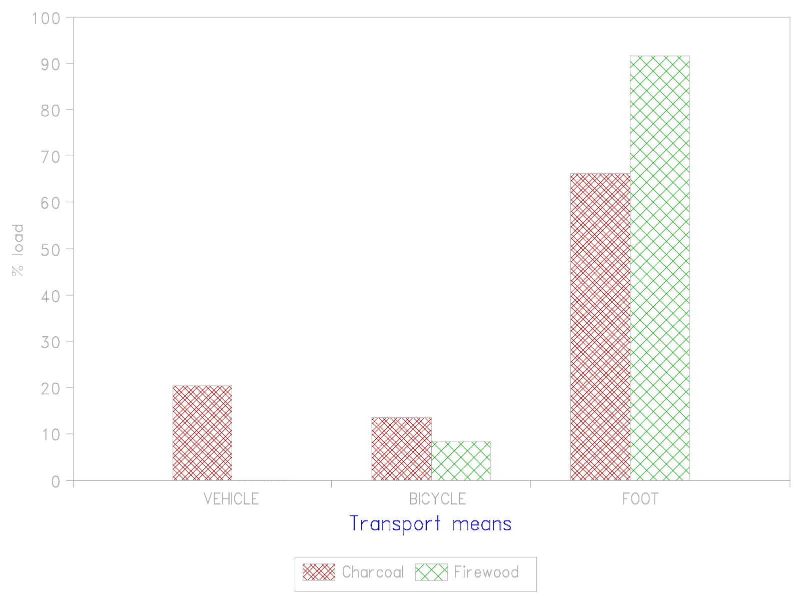


*Figure 15: Percentage load transported by various means of transport in Kumi*

In this area, woodfuel is mostly traded on specific market days. There are five major markets situated along Mbale-Soroti road that fall within this project area namely; Kachumbala, Bukedea, Atutur, Kumi Central Market and Mukura each market operates once a week. Most woodfuel is obtained from a distance of 1 to 10 km. This is due to the fact that all markets mentioned, are located within areas of reasonable supply. A lot of firewood is used in making the local brew "Ajono" and preparation of food consumed within the market.

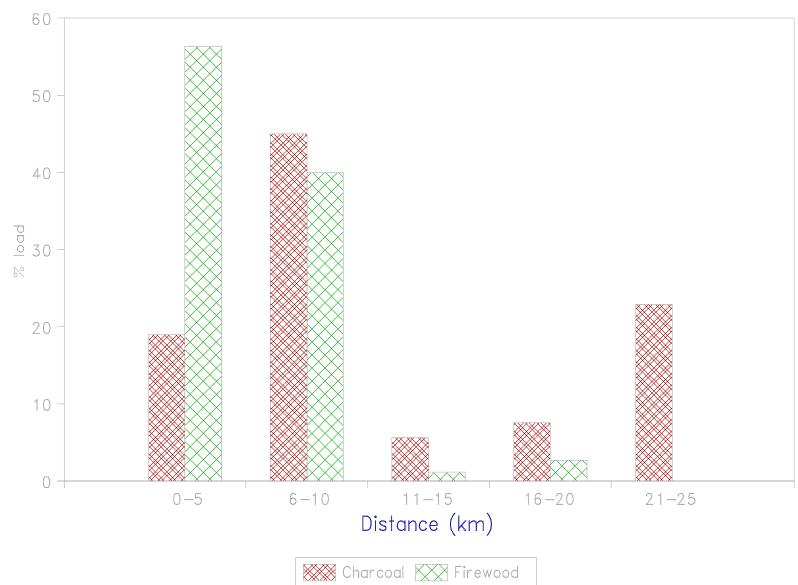


*Figure 16: Percentage load transported for various distances in Kumi*

### 13.7.4 Tree Species Commonly Used13.7.4 Tree Species Commonly Used

i. Charcoal species: Response (%).

| Charcoal species | Response (%) |
|---|---|
| Albizia spp. | 49 |
| Terminalia spp. | 37 |
| Butyrospermum paradoxum | 18 |
| Acacia spp. | 18 |
| Tamarindus indica | 13 |
| Mangifera indica | 12 |
| Grewia mollis | 7 |
| Ficus mucuso | 6 |
| Combretum spp. | 5 |

ii. Firewood species:

| Firewood species | Response (%) |
|---|---|
| Acacia spp. | 31 |
| Ficus natalensis | 23 |
| Cassia spp. | 19 |
| Albizia spp. | 19 |
| Combretum spp. | 17 |
| Terminalia spp. | 14 |
| Grewia mollis | 10 |
| Ficus mucuso | 10 |
| Tamarindus indica | 6 |

## 13.8 Woodfuel Transport in Mbale13.8 Woodfuel Transport in Mbale

### 13.8.1 Relative Frequency of Transporters13.8.1 Relative Frequency of Transporters

A total of 240 transporters were interviewed, 199 transporting charcoal and 41 firewood. Table 75 shows the frequency of woodfuel transporters and the various means of transport used in collection and distribution of woodfuel.

*Table 75: Frequency of Woodfuel Transporters in Mbale*

| | Frequency of Respondents | | | |
|---|---|---|---|---|
| | Charcoal | | Firewood | |
| Means of Transport | No | % | No | % |
| Vehicle | 16 | 8 | 1 | 3 |
| Bicycle | 173 | 87 | 19 | 46 |
| Foot | 10 | 5 | 21 | 51 |
| Total | 199 | 100 | 41 | 100 |

### 13.8.2 Average Distance Travelled13.8.2 Average Distance Travelled

Charcoal transport is dominated by bicycle, firewood is transported on both bicycle and foot, while vehicles are rarely used. Vehicles travel longer distances in search for charcoal than any other means of transport. Most charcoal used in Mbale town is transported from the neighbouring districts Kumi and Pallisa. The distance travelled for firewood collection varies between 5 and 11 km.

### 13.8.3 Quantity Transported13.8.3 Quantity Transported

199 transporters supply about 302 tons of charcoal to the markets every month, while 41 transporters deliver about 22 tons of firewood. The figure for firewood indicates low demand. This can be attributed to a constant supply of electricity and few institutions. The average load per trip and number of trips per month are shown in the next table. For charcoal, the frequency of collection is almost the same for all the three means of transport.

*Table 76: Average Load per Trip by Various Means of Transport (Mbale)*

| Means of Transport | Average Load (tons/trip) | | Average no of trips/month | |
|---|---|---|---|---|
| | Charcoal | Firewood | Charcoal | Firewood |
| Vehicle | 0.98 | 0.16 | 10 | 4 |
| Bicycle | 0.06 | 0.04 | 13 | 19 |
| Foot | 0.03 | 0.03 | 10 | 10 |

The following two figures show the percentage load transported by various means and the percentage load at various distances.

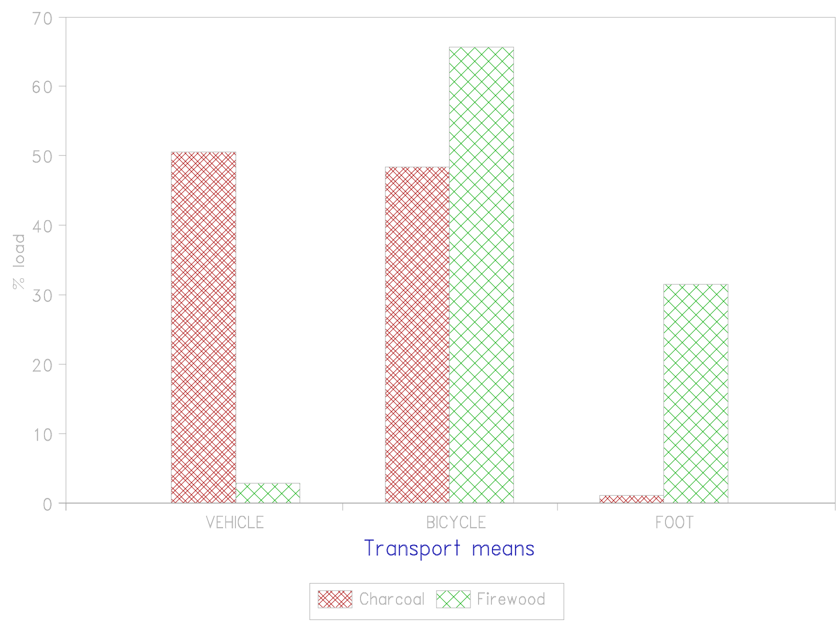


*Figure 17: Percentage load transported by various means of transport in Mbale*

About 50 and 49 % of total charcoal load is transported by vehicle and bicycle respectively, while only 1 % is transported on foot. Most firewood is transported by bicycle while vehicles transport a very small quantity of about 3 %. Firewood is mainly collected between 1 and 20 km, while most charcoal is collected between 21 and 50 km.

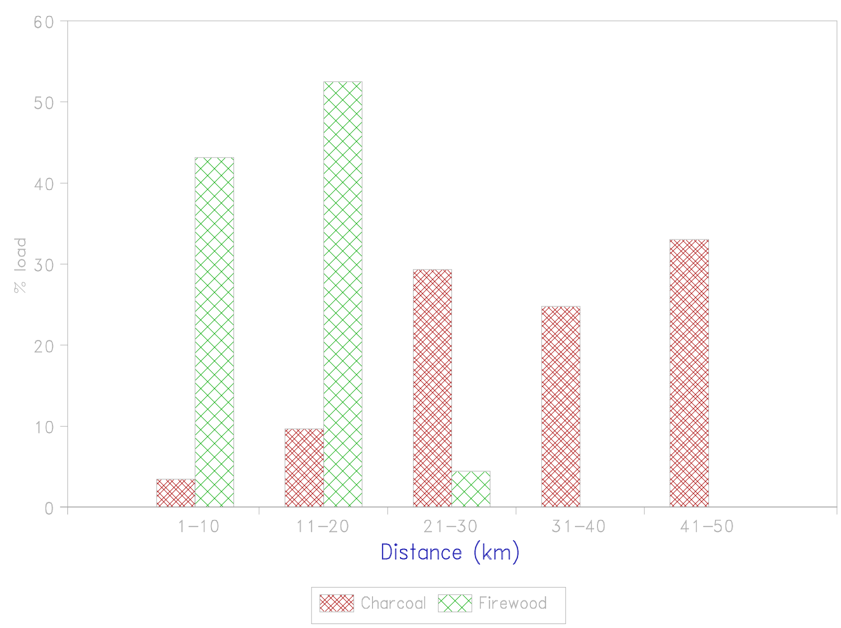


*Figure 18:* *Percentage load transported for various distances in Mbale*

### 13.8.4 Tree Species Commonly Used13.8.4 Tree Species Commonly Used

i. Charcoal species:

| Charcoal species | Response (%). |
|---|---|
| Albizia spp. | 49 |
| Ficus natalensis | 28 |
| Acacia spp. | 27 |
| Ficus mucuso | 26 |
| Combretum spp. | 22 |
| Chlorophora excelsa | 13 |
| Tamarindus indica | 10 |
| Butyrospermum paradoxum | 6 |
| Grewia mollis | 6 |
| Markhamia platycalyx | 5 |

ii. Firewood species:

| | |
|---|---|
| Acacia spp. | 37 |
| Ficus natalensis | 32 |
| Ficus mucuso | 27 |
| Markhamia platycalyx | 20 |

| | |
|---|---|
| Grewia mollis | 15 |
| Mangifera indica | 15 |
| Albizia spp. | 12 |
| Combretum spp. | 10 |
| Ficus exasperata | 10 |
| Lantana camara10 | |

## 13.9 Woodfuel Transport in Mbarara13.9 Woodfuel Transport in Mbarara

### 13.9.1 Relative Frequency of Transporters13.9.1 Relative Frequency of Transporters

A total of 232 respondents were interviewed, 183 transporting charcoal and 49 firewood. Table 77 shows the frequency of transporters and the various means of transport used in the collection and distribution of woodfuel.

*Table 77: Frequency of Woodfuel Transporters in Mbarara*

| | Frequency of Respondents | | | |
|---|---|---|---|---|
| | Charcoal | | Firewood | |
| Means of Transport | No | % | No | % |
| Vehicle | 7 | 4 | 39 | 80 |
| Bicycle | 174 | 95 | 10 | 20 |
| Foot | 2 | 1 | - | - |
| Total | 183 | 100 | 49 | 100 |

Most charcoal transporters in Mbarara use bicycles, whereas firewood transport is mainly by vehicles. Transport on foot is rare here. The demand for firewood in Mbarara is very high, as there are a lot of educational institutions, commercial activities such as brick-burning, hotels etc.

### 13.9.2 Average Distance Travelled13.9.2 Average Distance Travelled

Vehicles travel 32 km (charcoal) and 27 km (firewood), bicycles 17 km and 7 km, and footers 8 km (charcoal).

### 13.9.3 Quantity Transported13.9.3 Quantity Transported

The results show that 183 transporters of charcoal bring about 348 tons to the markets every month, while 49 firewood transporters bring about 732 tons. The average load per trip and average number of trips by each means of transport are shown below.

*Table 78: Average Load per Trip by Various Means of Transport (Mbarara)*

| Means of Transport | Average Load (tons/trip) Charcoal | Average Load (tons/trip) Firewood | Average no of trips/month Charcoal | Average no of trips/month Firewood |
|---|---|---|---|---|
| Vehicle | 1.84 | 3.55 | 2 | 5 |
| Bicycle | 0.09 | 0.04 | 20 | 8 |
| Foot | 0.05 | - | 22 | - |

It was found that vehicles transport larger quantities of firewood than of charcoal per trip.

The following two figures present the percentage load transported by various means and the percentage load at various distances. It is seen that most of the woodfuel is collected within 30 km, although smaller quantities are collected beyond 30 km.

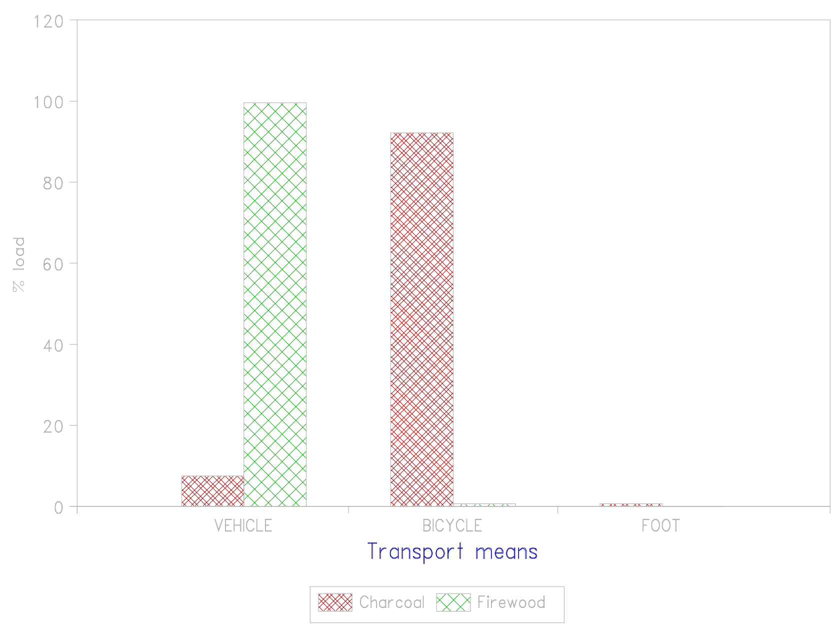


*Figure 19: Percentage load transported by various means of transport in Mbarara*

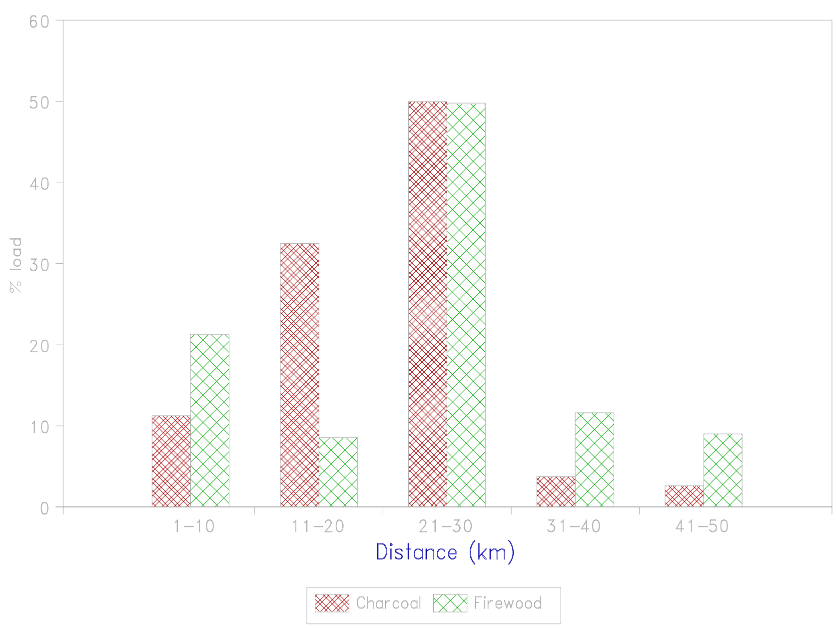


*Figure 20:* *Percentage load transported for various distances in Mbarara*

### 13.9.4 Tree Species Commonly Used13.9.4 Tree Species Commonly Used

| | | |
|---|---|---|
| i. | Charcoal species: | Response (%). |
| | Acacia spp. | 100 |
| ii. | Firewood species: | |
| | Eucalyptus spp. | 55 |
| | Acacia spp. | 45 |
| | Sapium ellipticum | 4 |
| | Ficus natalensis | 4 |

## 13.10 Woodfuel Transport in Moroto13.10 Woodfuel Transport in Moroto

### 13.10.1 Relative Frequency of Transporters13.10.1 Relative Frequency of Transporters

A total of 170 respondents were interviewed, 52 transporting charcoal and 118 firewood. The frequency of transporters and the various means of transport used in collection and distribution of woodfuel are shown in table 79.

*Table 79: Frequency of Woodfuel Transporters in Moroto*

| | Frequency of Respondents | | | |
|---|---|---|---|---|
| | Charcoal | | Firewood | |
| Means of Transport | No | % | No | % |
| Bicycle | - | - | 1 | 1 |
| Foot | 52 | 100 | 117 | 99 |
| Total | 52 | 100 | 118 | 100 |

### 13.10.2 Means of Transport13.10.2 Means of Transport

Transport on foot is totally dominant in Moroto. This is mainly due to:

(a) Poor accessibility to the primary source of woodfuel;

(b) Low population density;

(c) Abundant woodfuel located relatively near the urban centre;

(d) There are relatively few vehicles and bicycles in the area.

### 13.10.3 Average Distance Travelled13.10.3 Average Distance Travelled

Charcoal is on average carried 11 km and firewood 9 km. The only bicycle transporter encountered had bought charcoal from a secondary source located within the town.

### 13.10.4 Quantity Transported13.10.4 Quantity Transported

From the results, 52 transporters bring about 29 tons of charcoal to the markets every month, while 118 transporters deliver about 106 tons of firewood. The average load transported per trip and average number of trips for each means of transport are shown in table 80.

*Table 80: Average Load per Trip by Various Means of Transport (Moroto)*

| Means of Transport | Average Load (tons/trip) | | Average no of trips/month | |
|---|---|---|---|---|
| | Charcoal | Firewood | Charcoal | Firewood |
| Bicycle | - | 0.04 | - | 12 |
| Foot | 0.03 | 0.04 | 14 | 20 |

In this area, woodfuel gathering is traditionally women's activity carrying heavy loads on the head, and the average bicycle and head loads are equal. The next two figures show the percentage load transported by various means and the percentage load at various distances.

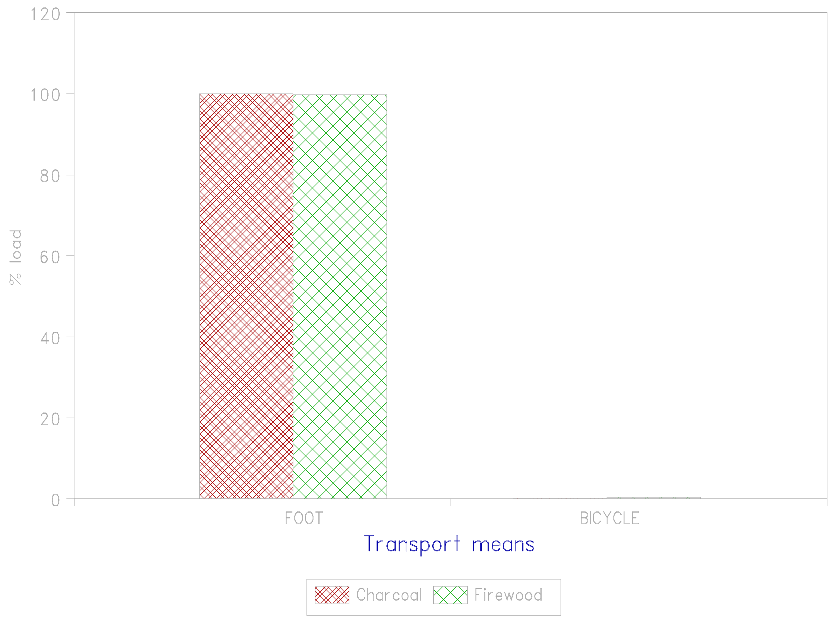


*Figure 21:* *Percentage load transported by various means of transport in Moroto*

About 50 and 90 % load of firewood and charcoal respectively are transported from 6 to 15 km. The maximum distance travelled in this area is about 20 km.

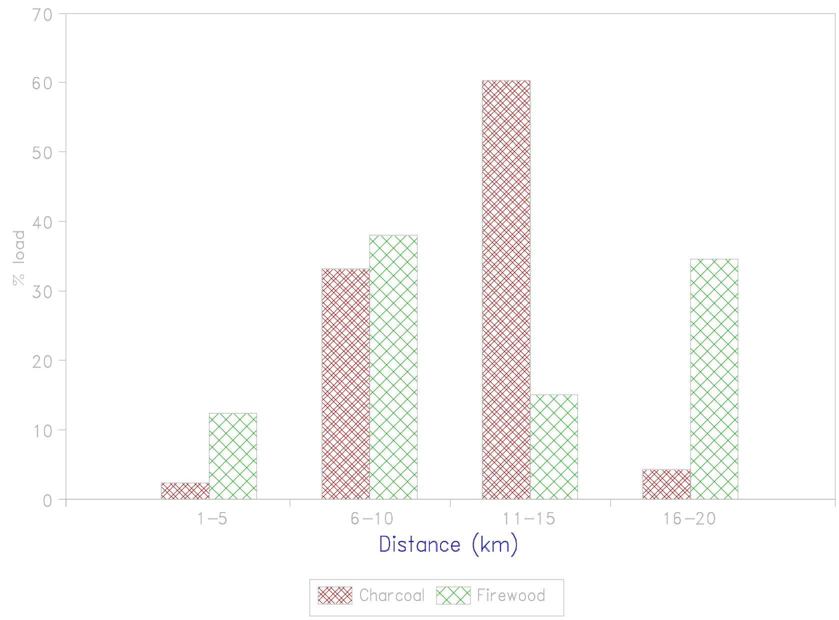


*Figure 22: Percentage load transported for various distances in Moroto*

### 13.10.5 Tree Species Commonly Used13.10.5 Tree Species Commonly Used

i. Charcoal species:

| Charcoal species | Response (%). |
|---|---|
| Balanites aegyptiaca | 94 |
| Acacia spp. | 87 |
| Terminalia brownii | 25 |
| Combretum spp. | 19 |
| Ozoroa reticulata | 6 |
| Nuxia opositifolia | 4 |

ii. Firewood species:

| Firewood species | Response (%). |
|---|---|
| Acacia spp. | 91 |
| Balanites aegyptiaca | 34 |
| Combretum spp. | 9 |
| Rhus natalensis | 8 |
| Terminalia brownii | 6 |
| Ozoroa reticulata | 3 |

## 13.11 Summary of Results13.11 Summary of Results

A total of 1,951 transporters were interviewed in all the project areas, 65 % of them transporting charcoal and 35 % firewood. Due to lack of information on the actual total number of transporters in each project area, it was not possible to determine the total quantity transported to each urban centre per month. The figures presented in this study are based on the total response. The average distance travelled during charcoal collection varies between 10 and 30 km, whereas that of firewood ranges between 5 and 25 km. The means of transport used vary from area to area depending on the transport infrastructure, demand and supply and the major economic activities of the area.

Transport and distribution of woodfuel is mainly affected by the following factors:

(a) Means of transport

(b) Distance

(c) Weight of load

(d) Price/cost structure

(e) Charcoal/firewood

Other factors affecting the transportation are:

(a) Availability of the woodfuel

(b) Mechanical condition of the transport means

(c) Health condition of the transporter

(d) Road conditions

(e) The prevailing weather situation.

### 13.11.1 Transport Distance13.11.1 Transport Distance

In all the project areas woodfuel is mainly transported by vehicle, bicycle, foot and canoe. The average transport distance varies from area to area. The next figure shows the average distance for all types of transport means in the nine project areas. Charcoal transport can be divided into three categories:

(1) *Long supply distance:* In this category the average distance varies between 26 and 29 km (extreme end of the sampling areas) and includes Mbale, Jinja and Kampala. These are large urban centres with a well developed infrastructure and high population density. The high demand of charcoal in these areas have resulted in tree degradation near the centre surroundings and thus forced supplies from more remote areas.

(2) *Medium supply distance:* This category varies between 15 and 18 km including Mbarara and Arua. These are towns in a transition stage of developing into large urban centres.

(3) *Short supply distance:* This category varies between 10 and 11 km and include Kamuli, Moroto, Kabale and Kumi. With the exception of Kabale, these are small towns with less developed infrastructure and low population density and woodfuel resources are located near the urban centres.


*Figure 23: Average distance travelled during collection of woodfuel in all project areas*

Firewood transport distance patterns differ from charcoal; two categories can easily be distinguished. The first category contains areas with a transport distance ranging between 18 and 23 km, including Mbarara and Kampala. The second category encompasses the rest with a distance of 5 to 10 km. Generally, shorter distance is travelled for firewood than charcoal.

### 13.11.2 Price/cost Structure13.11.2 Price/cost Structure

The average price of woodfuel in each project area was calculated (the exchange rate used was USD 1.00 = Ush 970.00). The next two figures present the current price trends.

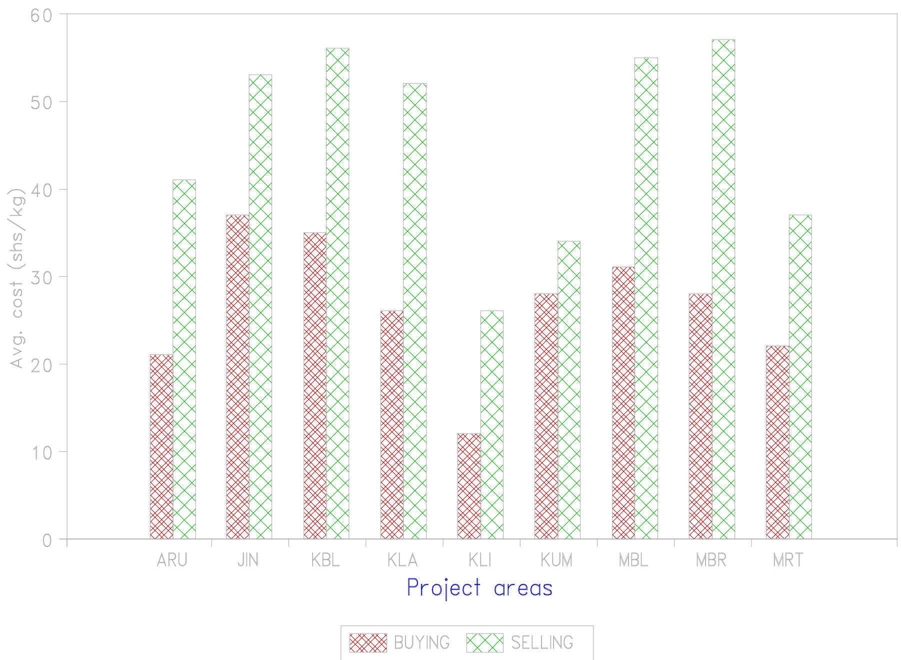


*Figure 24: Price structure of charcoal in all project areas*

These figures refer to the transporter's cost of buying a given load of firewood or charcoal and the amount of money earned from sales of the same load. In Kumi and Moroto nothing is paid for firewood collection. Resources are abundant in form of bushes and shrubs (see list of common species used), which are mainly collected from public land. In other areas, firewood prices show two major trends: Jinja, Kabale, Kamuli and Mbarara fall within a range of 4 to 8 Ush/kg, while Kampala, Arua and Mbale fall between 12 and 13 Ush/kg.

Charcoal prices show two distinct levels of variation; for both buying and selling. The average buying price of charcoal ranges between 26 and 37 Ush/kg in Jinja, Mbale, Kampala, Kumi, Kabale and Mbarara, while in the rest of the areas it varies from 12 to 22 Ush/kg. With the exception of Kumi, a similar trend can be observed in the selling prices which vary from 53 to 57 Ush/kg for the first category and from 26 to 41 Ush/kg for the second category of areas. Considering the selling prices, a kilogram of charcoal is about three times of a kilogram of firewood.

The consumer prices of charcoal in all the areas range between 25 and 60 shillings per kilogram, while those of firewood vary from 10 to 25 shillings per kilogram. The apparent relationship between consumer price/selling rate and transport distance is more due to the distinct dependence between transport distance and deficiency/demand; explained under category (1) *Long supply distance.*

Firewood prices show similar trends; the cost of a kilogram of firewood in Kampala, Mbale, Mbarara, Kabale and Arua is about 19 to 26 shillings, while in Kumi, Moroto, Jinja and Kamuli, the average price lies between 10 and 13 Ush/kg.


*Figure 25: Price structure of firewood in all project areas*

The average weight per bag of charcoal, the average distance travelled during collection of fuelwood by the various means of transport and the percentage of the total load transported in all the project areas are summarized in tables 81, 82, and 83.

*Table 81: Average Weight per Bag of Charcoal*

| Project area | Average weight (kg) |
|---|---|
| Arua | 40 |
| Jinja | 45 |
| Kabale | 40 |
| Kampala | 45 |
| Kamuli | 45 |
| Kumi | 40 |
| Mbale | 45 |
| Mbarara | 30 |
| Moroto | 65 |

*Table 82: Total Load Transported in each Project Area.*

| Project area | No of respondents Charcoal | Firewood | Load(ton/month) Charcoal | Firewood |
|---|---|---|---|---|
| Arua | 85 | 227 | 76 | 38 |
| Jinja | 209 | 12 | 375 | 20 |
| Kabale | 138 | 62 | 29 | 106 |
| Kampala | 207 | 67 | 498 | 155 |
| Kamuli | 86 | 19 | 162 | 74 |
| Kumi | 109 | 88 | 102 | 18 |
| Mbale | 199 | 41 | 302 | 22 |
| Mbarara | 183 | 49 | 348 | 732 |
| Moroto | 52 | 118 | 137 | 246 |
| Total | 1268 | 683 | 2029 | 1411 |

*Table 83: Average Distance and Percentage Load by various Transport Type in all Project Areas.*

| Transport means | Average distance (km) | % load Charcoal | Firewood |
|---|---|---|---|
| Vehicle | 20-90 | 20 | 33 |
| Bicycle | 10-30 | 51 | 23 |
| Foot | 1-10 | 24 | 40 |
| Canoe | 10-60 | 5 | 4 |

In most areas, bicycle transport is predominant. However, in Kumi, Moroto and Arua most of the woodfuel is transported on foot. In Kabale, transport of charcoal is dominated by bicycle, while firewood is mostly by foot.

### 13.11.3 Tree Species Commonly Used13.11.3 Tree Species Commonly Used

It has been found that mainly savannah tree species are used as woodfuel sources. Apart from Kabale and Mbarara, the widely planted Eucalyptus is not commonly used for this purpose, but instead preferred as fencing posts and building poles. The common tree species used for woodfuel purposes can be categorized on a regional basis as shown below;

| Region: | Species: |
|---|---|
| Central and Eastern | Sapium ellipticum<br>Albizia spp.<br>Ficus spp. |
| North and North Eastern | Combretum spp.<br>Terminalia spp.<br>Acacia spp. |
| South Western | Acacia spp.<br>Eucalyptus grandis. |

In all the project areas, the major areas supplying woodfuel to the urban centre were located on maps of scale 1:250,000 and 1:350,000 for Kampala and Jinja as shown in Appendix A (shown as shaded areas).

# 14 Sources of Error14 Sources of Error

The National Biomass Study encompasses a considerable number of elements. Some of these elements form a basis for other elements, others are interlinked in various ways. *All elements containing measurements and/or assessments have sources of error.* Errors, both systematic and random, are normal for such studies and cannot be avoided. Systematic errors have all through consciously been subjected to special concern, thus brought to a minimum. Random errors are therefore believed to predominate the total "error picture".

The various sources of error are described and assessed separately in the following sub-chapters. The reader should, though, have three key aspects of this study in mind when assessing these error sources:

(1) The Biomass Study could not benefit upon experiences from similar studies, neither in Uganda nor in other sub-Saharan countries. Most biomass inventory projects in sub-Saharan Africa are heavily geared towards very limited areas or towards use of low-resolution satellite imagery with (at best) rudimentary ground truthing. In addition, the project discovered that baseline data assumed to be available were non-existent (e.g. wood density for various species) or contradictory / unreliable (e.g. data on woodfuel consumption). The study comprises thus some "pioneer" elements.

(2) The project initially expected to "inherit" staff experienced in inventory work from the "Forest Inventory" project, but this was impossible due to reasons beyond project control. Most of the people recruited had considerable experience as Forest Department staff, but only one had extensive experience with traditional inventories (including some use of aerial photos). None of them had experience from *biomass* inventories, and none had experience with computerized data processing. Training had to be done on-the-job, often under a lot of work pressure, and mistakes were obviously done.

(3) The workload has been intense most of the time. Considerations related to time and work input took precedence when deciding on some issues. For instance, completing one "pilot" area first would have been preferable - but this was regarded as impossible given the time frame and the analytical method selected. This should be expected:

The ideal and optimum approach is seldom possible within the framework of a real world project.

## 14.1 The Mapping Process14.1 The Mapping Process

The stratification was, as outlined earlier, done by two photogrammetrists at the Department of Surveying and Mapping in Entebbe. The job took about one year. They had a lot of experience with photo interpretation and mapping in general, but were only to a certain extent acquainted with our stratification units (classification system). Biomass staff was present during the first weeks and later visited the photogrammetrists regularly. However, sources of error might be related to that there was no time / resources available for combining the stratification with ground truthing. The field experience had to come from Biomass Staff - which themselves were in a learning process - and such verbal communication will always be somewhat error-prone.

The first area interpreted, Jinja, was found to contain a number of errors and was redone. As with Biomass staff, the photogrammetrists were learning to interpret according to our land use/cover classification system "on-the-job".

Possible stratification errors affect the area distribution between the land use/cover classes, and subsequently the calculated biomass. In cases where biomass per hectare for the two conflicting types is close, the error can be ignored. Systematic misinterpretation has not been discovered, and one should therefore expect that over- and under-estimation connected to random errors counterbalance each other.

These maps were digitized. Manual digitizing is error-prone no matter how experienced the operator is - line tracing will normally have an error-margin of 0.5 - 1.0 mm (individually dependent). In this case, the operator (a Forest Officer) had no previous training and got only limited training and backstopping, though caught up reasonably fast. Visual comparison of source maps/photos and draft plottings has not revealed large errors, and minor random digitizing errors are therefore regarded as insignificant. A few label errors (i.e., polygons which has been given a wrong land use/cover class code) were found after the area calculations had been done, but these polygons were small and the impact on the results thus negligible.

## 14.2 Photo Interpretation14.2 Photo Interpretation

The low correlation between photo interpreted crown cover and calculated biomass is naturally of primary concern when discussing sources of errors. There are different views on how the various factors presumably have contributed to the overall low correlation. Since the study is the first of its kind in Uganda, the "weighing" of the following factors would necessarily depend on experience and perspectives:

- *The presence of significant correlation* is a basis for the application of Double Sampling, thus the *applicability of the methodology* must also be considered. Assessing the crown cover is difficult when the vegetation patterns are complex e.g. crown sizes and shapes are different and partly obscured from above. In a several storey stand, crown cover alone is not a good measure for the biomass. Crown cover as a scoring key works better the more homogeneous the trees are both in size and shape. Hence, a very good correlation is not expected for some of the relevant forest situations.

- The *fitness of our classification system,* especially when dealing with "border cases" and with areas comprising a mosaic of different classes is questionable. The classification system was discussed in depth many times, but it always retained with the initial 12 classes. Considering the great variation and versatility within Ugandan vegetation, the design of a "linear" class system reflecting all this complexity is an impossibility. Any classification system dealing with land use / land cover will be a compromise: Too few classes may hide important shades, too many classes create "pizza" maps. A complex system will furthermore be difficult to use for non-experts. *A moderate number of classes leads to higher variation within each stratum,* though, and the differences between the project areas exemplify this (see chapter 11.10).

- *Only one of the interpreters had experience with interpretation of aerial photos.* This lack of experience is mainly due to the difficulties in higher education (e.g., Makerere University) during the years of civil strife. Scarce resources and lack of equipment inhibited practical training in photo interpretation. The negative developments within Forest Department in the same period should also be mentioned, since there was no money for aerial photographing and thus no fresh photos available for interpretation. Photo interpretation requires special capabilities connected to sight and imagination from the operator. Considering the fact that high quality interpretation normally requires many years of experience, this must be considered as a likely source of errors.

- For various reasons, *only one of the interpreters alternated regularly between photo and field interpretation.* The same interpreter had also the highest correlation scores, and these data sets were used in the regression analysis. Considering the fact that alternating between field assessments and photo interpretation normally is regarded as important, lack of such was a mistake.

It should also be noted that the significant differences normally found between different interpreters make a period of training, testing and then selection of the best interpreters advantageous. Again, this was not possible due to the heavy workload.

Incorrect interpretation might have resulted in the deterioration of the data substructure as well as escalating the error estimate. Photo interpretation represents a qualitative assessment, very difficult to check as there can be no objectively true and correct scores. As mentioned earlier, a systematic diverging score of crown cover will not have a negative effect since such bias is corrected through the Double Sampling technique. However, random errors must be within reasonable limits to get reliable results.

Scoring a wrong land use/cover class causes results which are out of control, depending on which classes are mixed up. The problem appears in particular when dealing with "mosaic areas", but such errors can be regarded as occasional and are assumed to have contributed less to the low correlation than incorrect crown cover scores.

## 14.3 Field Plot Measurements14.3 Field Plot Measurements

Field plot measurements were the most difficult element due to complex land use/cover patterns, a wide distribution of species, a great number of measurements, difficulties in accurately locating plots, inaccessibility of plots and occasionally problematic interactions with the local people and/or RC's. Plot measurements are thus more error-prone than other elements, and *strong emphasis was put on stressing work accuracy and on checking and re-checking results.*

Furthermore, certain mistakes here will have significant consequences. A key condition for the Double Sampling procedure is that the plots checked/ measured in the field must coincide with the corresponding plots interpreted. Correct location is thus of major importance. Even though the field team leaders gained impressive skills in ground orientation, some few plots may have been dislocated. Again the consequences are unpredictable depending on the differences between the correct and the wrong plot. Assuming that the interpreted scores for the two plots are equal, the erroneous location will have no effect at all. However, *this source of errors contributes to a general reduced confidence in the data integrity.*

The description of the field plot measurements in chapter 6 gave a detailed overview of a number of factors inhibiting the use of a systematic or random sampling system when selecting field plots (e.g., inaccessibility of plots or un-obtainability of permission to start the measurements). The potential bias might be a source of errors, and must be considered when utilizing the data for specific purposes. The impact of this potential bias on our biomass results is related to the number of plots in the various classes, effecting the efficiency of the inventory. Too few plots allocated to a class will result in less accuracy on the estimated values.

Errors in tree measurements and/or cover assessments must also be expected, but *such random errors can be regarded as insignificant due to their minor effect on the final results.*

## 14.4 Biomass Weighing/Measurements14.4 Biomass Weighing/Measurements

The felling process for establishment of biomass equations was outlined in chapter 7. This assignment emerged as an additional sub-project due to a complete lack of suitable biomass functions. Even if it took a lot of time and efforts, the work itself was rather uncomplicated and straightforward apart from some technical problems with the power saws. Field instructions were worked out, included as Appendix H. The process involved a lot of tree variable measurements where the normal sources of reading errors were present, both from the measuring tape, calliper and weighing scales. Also here general work accuracy was utterly pronounced. Cross checking caused some corrections, some forms were not properly filled in and were therefore discarded. Otherwise, this element is assumed to contain a minimum of errors. The problems were more related to the selection of trees, which is commented under Processing.

## 14.5 Wood Specimen Measurements14.5 Wood Specimen Measurements

This "extra" task also consumed significant resources over a long period of time. The work required attention to details and high accuracy in both species determination and reading the instruments used, especially the volume measurements involving weighing the displacement of water. In cases were numbers or codes were mixed up, portions fallen off and got lost or in other ways giving a wrong result, the record was discarded.

## 14.6 Processing14.6 Processing

The calculations were carried out using PC-based software. Most of the special programmes and routines used were programmed by an expert consultant from the Agricultural University of Norway and checked thoroughly. We have thus no reason to believe there are any systematic errors originating from erroneous processing / programming.

Grouping of trees, based on species and morphology was an intricate assignment and hence should be subjected to further research. However, we have no reason to believe that another or "improved" grouping would have a significant impact upon the overall results (the regression analyses gave throughout an R square of about 0.9).

A more significant source of error is related to the distribution of test-trees as the basis for the single tree biomass equations. All functions are unreliable when used outside the size ranges of the test-trees, giving a result which is more or less out of control, depending on which variable is extrapolated and how much. The test-trees do not cover the relevant intervals of all independent variables for all groups. Collecting such a complete sample would have been a substantial project in itself, thus some of the functions have been "stretched". Since time constraints did not allow a thorough examination of this matter, we are not in a position to give any estimate of this error. Potential users of these functions, including the Biomass Study in Phase II, will have to be careful when using them, especially in new areas and for large trees.

All data entered were also checked thoroughly, both through proof-reading and logical tests, but the amount of data were so large that some errors most likely slipped through. Such errors should have no significant effects on the overall results.

Finally, we have here deliberately avoided investigating error propagation and/or estimating the total error margins. As should be obvious from the previous sub-chapters, reasonably accurate error estimates (quantified) for the single elements are presently impossible or at least very difficult to obtain. A total error margin estimate would thus basically be a subjective assessment expressed in mathematical terms ("voodoo" calculation).

One reason for this is lack of scientific, high accuracy data from similar studies in tropical countries. Various strictly controlled experiments, spot studies and "cross checks" within the Biomass Study can make up for the lack of comparable studies, but that was not possible within the limited time. Some elements in Phase II (e.g., repeated measurements) will also be a "cross check" on some elements, and the Biomass Study will in addition promote and support research efforts in these areas.

# 15 Conclusions and Recommendations15 Conclusions and Recommendations

The supply and demand of woodfuel in peri-urban areas in Uganda are primarily governed by market forces. This study shows the distinct correspondence between the woodfuel resources and price levels - areas with woodfuel deficits also have high price levels. High prices might be linked to long transport distances, but that in turn reflects the biomass deficits in nearby areas.

The table in chapter 12.4 outlined the harvestable biomass potentials in tons per capita air dry weight. The project areas Kamuli, Kumi, Moroto and Jinja have an apparent *surplus* if the total figures for all biomass are considered. Jinja is still on the surplus side even though Mabira Forest Reserve is excluded from the results (though, almost break even). Kampala, Mbarara, Mbale, Kabale and Arua are clear biomass *deficit* areas.

Knowledge about a number of key issues related to woodfuel management in general is important in order to cope with the situation. Trees are used for many purposes (e.g., fruits, fodder, clothes, timber and poles, medicine, cultural purposes, fencing, soil protection, wind protection, shade, boundary demarcation, tools, woodfuel) and play a vital role in the life of most people. A deficit of trees will thus not only affect the supply of woodfuel, but lead to a complete breakdown of the entire socio-economic and socio-cultural infrastructure of the society.

A number of key questions related to this overall picture will be looked into below:

- What *types* of biomass are actually suitable and/or preferable for woodfuel purposes, and which consequences do various answers have for the woodfuel balance?

- How large are the variations within each project area, and what impact might that have on policies?

- What should be the priorities and policies when selecting and implementing counter-measures? Obviously, such measures can be both supply- and consumption oriented. Tree planting, facilitating supplies from far away surplus areas, better selection of trees for felling, improved kilns, improved stoves, switching from woodfuel to electricity, using new energy sources like biogas or solar cells - the issues are complex and alternatives many.

The National Biomass Study has yielded some of the information necessary to assess the various options facing decision-makers and planners on different administrative levels. The recommendations here are based on the project results, combined with other information readily available. It must be emphasized, though, that the capabilities of the project for more advanced analyses and scenarios will be better in Phase II, both due to a more extensive geographical coverage and due to the acquisition of a Geographical Information System (GIS). However, an equally important biomass study should take place on micro level. A study on village level would reveal the actual woodfuel habits among the people, and thus give more accurate guidelines for which efforts to pursue. That kind of study is unfortunately not part of the biomass study.

## 15.1 Woodfuel Preferences15.1 Woodfuel Preferences

Woodfuel consumers will presumably prefer *tree* biomass if price/cost considerations are excluded. Rural people are traditionally used to gathering /collecting firewood for free, either on public land or as a by-product from own trees. Woodfuel is also a by-product resulting from agricultural land clearing. Sufficient supplies of tree biomass as woodfuel is a primary long term objective, but less preferred types like bush and agricultural residues are presently being used in many areas and will most likely become more important due to the widening gap between available supply and demand.

- Scrubs and bush not developing into trees would be an environmentally and economically proper woodfuel resource, and cutting some might even give better conditions for nearby young trees and agricultural production. However, using this resource requires a lot of work and is thus not top listed as fuel.

- In urban areas charcoal is predominantly used and is preferable of several reasons. It creates less smoke, is a refined, energy-compact fuel and is favourable with regard to transport and handling. The problem with this fuel is related to the fact that it requires a lot of wood input, in particular when the conversion process is inefficient.

- Extensive use of agricultural residues is environmentally damaging in the long run, removing too many nutrients from the soil and subsequently inducing soil deterioration and possibly land degradation.

- Uganda has huge resources of fast growing, regenerable papyrus. Presently, papyrus is in very limited use, and substantial areas are put on fire every year. It can very well be used as fuel either directly after drying or after carbonization. The technology of such converting is well known, but require some investments. Large scale utilization of papyrus is a recommendable option - used as briquets either directly or carbonized. The problems are more related to people's fuel habits and the harvesting process (the new shots can easily be damaged).

There will of course be different views on what constitutes sustainable and/or optimum use of different fuel resources, and the reader can easily use the tables in chapter 12 for evaluating various alternatives.

As an example, *let us consider 80% of the tree biomass increment, 50% of the bush increment (20% for Moroto due to remoteness) and 25% of the agricultural residues as potential fuel material.* Using the tables in chapter 12.4, we find that six of the nine areas have a deficit and three a surplus:

- The Kampala project area can only cover 34% of the need;

- The Mbarara project area covers 36%;

- The Mbale project area covers 40%;

- The Kabale project area covers 44%;

- The Arua project area covers 50%;

- The Jinja project area covers 77%, or substantially less if the Mabira Forest Reserve is excluded.

- The Kumi project area covers 171%, but it is also supplying woodfuel to Mbale.;

- The Moroto project area covers 210%, but is not a woodfuel supply area for several reasons (most of it is bush, it is far from the consumption centres, and security along roads is poor);

- The Kamuli project area covers 286%. It is supplying woodfuel to for instance Kampala (CODA, 1990).

Varying the percentages regarded as harvestable will not radically change this overall picture.

## 15.2 Overall Surplus versus Local Deficits15.2 Overall Surplus versus Local Deficits

The National Biomass Study has examined each project area as a unit, and the woodfuel balance is calculated for each area as a whole. In principle, the findings can not be broken down to a lower level. (Phase II will mainly aim at producing data for county level.)

It must be emphasized that deviations from the general conclusions certainly occur. *There is a woodfuel deficit around almost all villages and population centres.* The reason for this should be obvious: Firewood is normally collected from resources available close to people's homesteads. When these resources are exhausted, the distance gradually increases. In addition, charcoal burning primarily meant for commercial trade, contributes to a growing depletion. The reason is evident; when woodfuel is harvested faster than it is being replenished, the vegetation is not sustainable, leading to an even more depletion of both the resource base and the soil. However, most people are not ignorant of the process of deforestation or blind to its effects; they cut because they must.

The societal cost of collecting/producing woodfuel has become an increasing burden to most people. As woodfuel diminish, the cost of obtaining it in terms of time, efforts and/or money increases. In rural areas women and children spend more time and energy carrying firewood loads. This in turn results in less time for food production and other domestic duties/ housework. In urban areas woodfuel prices go up and might be beyond the means of poor people, leading to a number of severe problems.

We stated earlier that each project area in principle should be self-sufficient with woodfuel. That is only a general guide-line, though, and the geographical extent of such self-sufficient areas will vary with many factors. Many factors are basically political in nature, and the measures adopted will reflect this. Short and long term measures might also differ.

## 15.3 Tree Planting15.3 Tree Planting

Massive, country-wide tree planting is more important than anything else if Uganda's trees and forests are going to survive the next decades! Investments in alternative sources of energy like hydro-electric power might alleviate the situation to some extent, but the big majority of Ugandans are and will in the foreseeable future be using woodfuel.

The Government of Uganda has clearly acknowledged this, but the National Tree Planting Agenda has so far had severe problems (Background to the Budget, 1992-93). In our opinion, some key reasons for this are that

- The programme is in practice too dependent upon donor funding, which has not been forthcoming. This is not only the case on the national level, it is even evident on the local level. All efforts have to be joined to get on with the job using whatever resources are locally available.

- Sub-projects outlined are heavily biased towards traditional development project strategies, with 50-80% of the funds allocated for professional staff and their equipment needs (transport etc). *Such approach cannot and must not be used as a template for massive afforestation.* The cost per seedling / tree is far too high and too dependent upon a well functioning organization and professional input.

- Responsibility for the programme has in practice been left to the Ministry of Water, Energy, Minerals, and Environment Protection - Forest Department in particular - even if it was initially envisaged to be a responsibility for all sectors of the Ugandan political / administrative system.

- The environmental awareness among many Ugandans is high, but there are still many who do not respond to positive rules, like "plant 10 trees for each you cut". Such bye-laws are seldom taken seriously by the people involved in tree felling.

Some key recommendations are that

- The National Tree Planting Agenda should be recognized as primarily a *mass mobilization programme* and not a traditional donor-financed project. The political will and drive behind the afforestation programme on both central and local levels must increase as a moral support and incentive to the process. Successful programs should be given publicity and rewarded.

- In some selected areas afforestation programmes should be implemented according to recent planning methods like **RRA - Rapid Rural Appraisal and PRA - Participatory Rural Appraisal.** RRA/PRA is both an attitude and a method, which help outsiders to quickly understand village systems, *from the villagers' point of view*. The key factor with these methods is that all planning is based upon the skills, knowledge and resources among the local inhabitants. Most Ugandans know how to plant trees and know best how to solve their own problems. The outsider's assignment is to start the process; assemble the dwellers, join the efforts, share people's knowledge, kindle the enthusiasm and let the people make all the decisions. There have been some positive signs of such developments.

- Countries like *Kenya, South Korea* and *China* have implemented similar massive afforestation programmes with great success, and their experiences are relevant for Uganda. For instance, the village forestry programme in South Korea resulted in more than a million hectares of local woodlots being planted by more than two million members of more than 22,000 village cooperatives in five years (FAO, 1986).

- The Tree Planting Programme must be closely linked to an *Awareness Campaign,* where all technical knowledge both at central and local levels (e.g., Forest Department, Makerere University local extension service) is shared with the people, and all resource-persons taking part. Such a campaign has been going on to some extent for years, but the lack of actual afforestation shows that it must be stepped up.

- The basis for the programme must be community forestry, but the active agents must be assumed to vary from area to area: RC's, women groups, private farmers, churches, schools, NGO's, private entrepreneurs and other interested parties. Nurseries must be established on local levels, containing a species composition desired by the people. There should be a minimum of trees or a woodlot on every farm.

- President Museveni's statement - that there should be a woodlot or a reserved area for trees on every farm, must be followed up.

- Matters related to the infrastructure of ownership and rights of land and trees are important when designing strategies for tree planting. In cases where the farmer is leasing the land and/or the rights to utilize the trees are not present, the incentive for tree panting is obviously missing. Legislative factors must hence be subjected to an open discussion and possible changes where the law makes obstacles for tree planting activities.

We have deliberately not made assessments of how much afforestation (hectares or trees planted) is needed at this stage, since any meaningful assessment not only depends on the information provided in this study but also on a number of "political" conditions (e.g., like the future use of electricity, which in turn depends on prices etc - see below). *Any reader can easily make his/her own assumptions and then use the information in the various tables to get a rough indication of the necessary scale of tree planting.* The Biomass Study will during Phase II, in close cooperation with the relevant planners and decision-makers on national and district level, produce more exact, alternative scenarios for the district, regional and national levels.

## 15.4 Harvesting, Processing and Transport15.4 Harvesting, Processing and Transport

Proper tools are in practice a pre-condition for improving the tree felling and processing. The pangas and axes used today cause a lot of waste and are not always appropriate. For instance, large, over-mature trees which should be cut are left out. Cross-cut saws should be subjected to large scale introduction, combined with training efforts.

Demonstration sites and mobile forestry/wood processing training units are key elements in a strategy to improve harvesting and processing of timber (pit-sawing) and woodfuel. Loggers have to be taught and convinced about the advantages holding and maintaining proper tools. A better utilization of the logs in terms of leaving less slabs and off-cuts should also constitute an important part of the training.

At present time cross-cut saws may be available only in Kampala. In case of extensive demand for such items, the situation will presumably be rectified. Otherwise The Forest Department should investigate how to help in establishing a proper distribution network for such tools.

Coniferous trees are traditionally not used as construction timber in Uganda. Unfortunately this group of species is called "softwood" which does not do justice to the actual properties of the wood. In fact the so called "softwood" is harder than many of the "hardwood" species. The Coniferous species are extensively used as construction timber in most of the industrialized world and as such should be applicable also for Ugandan conditions if properly treated. Uganda has a lot of Coniferous plantations which are mature. A broad introduction of this timber would significantly reduce the pressure on the Tropical High Forests.

The converting of charcoal is also an important process which has to be looked into. The HEPP report gave good recommendations on the promotion of improved kilns.

An important short-term measure is to identify new supply areas with a woodfuel surplus. The transport study has revealed that considerable quantities of woodfuel are transported long distances using simple transport means. A more extensive use of bicycles for this purpose should be introduced. This recommendation is especially addressed to areas where the problem stems from an adverse woodfuel allocation pattern, but where the resources are available within bicycle distance. This will not improve the overall woodfuel balance, but might temporarily reduce the level of over-cutting in areas close to the consumption centres.

Tree felling will continue in many areas, despite the growing conciousness of the potential future negative consequences. In order to reduce the effects thereof, the biggest, wide-crowned, over-mature and single-standing trees should be selected. Such trees have not only passed the optimal phase of increment, but often also started rotting. Removing such will give space for many seedlings.

## 15.5 Improved Stoves15.5 Improved Stoves

This issue has been subjected to a lot of research and many projects over a long period of time in Africa, and will thus not be further outlined here. (It is broadly mentioned in the HEPP report.) However, we will confidently join the general conclusions related to this discussion. There is no doubt that a more efficient combustion will have an immediate effect on the consumption.

Improved stoves are available, they are definitely economically beneficial, but not much used (except in Kabale). The traditional and inefficient types are mostly bought. The Department of Energy should examine the infrastructure of manufacture and application of firewood- and charcoal stoves in order to find out which measures should be taken to promote the improved types. The awareness campaign mentioned above, as well as for instance taxation/subsidies, could then be tailored to make improved stoves more attractive.

## 15.6 Electrification15.6 Electrification

Increased use of hydro-electric power is another important measure. The Owen Falls power plant is presently being upgraded from 150 MegaWatts to 180 MW, and plans have been drawn up for an additional 200 MW. The actual impact on the woodfuel demand depends on several factors: Time of completion, percentage exported to neighbouring countries, transmission losses, extension of power line grid, cost of electrical installation and electricity units and reliability of supply are some of them.

Let us assume that the whole upgrading will be completed within five years, and that electricity exports increase. Uganda today exports around 26% of the production to Kenya, but intends as well to export to Tanzania, Rwanda, Burundi and Eastern Zaire (Background to the Budget, 1992-93). We can then roughly estimate that another 300 GWh will be available for domestic consumption towards the end of the decade (the present 150 MW capacity yields 579 GWh, of which 275 GWh are sold under the domestic tariff).

The HEPP report (CODA, 1990) estimates that 1 kg of charcoal is equivalent to 2.4 kWh with the stoves being used in Uganda today. *300 GWh are thus equivalent to around 125,000 tons of charcoal, or a bit over half the estimated annual charcoal production (Background to the Budget, 1992-93) today.*

The major emphasis being put on developing Uganda's hydro-electric power potential is thus correct in principle, but it is an open question whether the price policies being pursued by the Government and **Uganda Electricity Board (UEB)** will result in the required large-scale substitution. The **Medium Term Sectoral Strategy 1991-95** (Ministry of Planning and Economic Development, January 1992), states that:

> *"Despite the recent increase (to Ush 44 per kWh, our comment), UEB tariffs are still well below marginal costs, undermining UEB's financial viability. Real tariff increases of the order of 150% will be required over the next 2-3 years."*

This would be equivalent to around Ush 170 per kWh (September-92 price level including 15% tax and estimated inflation), i.e. equivalent to a price of around Ush 400 per kg of charcoal (2.4 kWh = 1 kg charcoal). The present Kampala price of a 45 kg bag of charcoal is Ush 4,500, or around 100 shillings per kg. (Poor people normally buy in tins, and pay twice as much, but they cannot afford to install electricity anyhow). Most people have a strong preference for electricity (CODA, 1990), but the price cannot be too high compared to for instance charcoal. Unless the price of charcoal also rises sharply, electricity might be less attractive due to the price. A key factor here is that almost all households with electricity also have charcoal stoves, and they are thus highly flexible.

It is also worth mentioning that Ush 170 per kWh (around 14 US cents at present market exchange rate) is very high, especially when considering that the source is river-based hydro-electric power. For instance, most Norwegian households pay 5-8 cents per kWh, whereas US households pay 3-8 cents per kWh. *UEB should try to streamline its operations and reduce costs.*

It must be noted that the high cost of installation - both industrially and domestically - is another major obstacle to increased use of electricity, as are the relatively high prices of electrical equipment. The present power supply, with its frequent power cuts, voltage fluctuations and spikes, are also indirectly increasing the cost of electrical equipment, either through outright destruction of such equipment or through forcing consumers to invest heavily in protective gear (voltage regulators etc).

The major problem facing Uganda is that the real cost of woodfuel consumption is not reflected in the prevailing market prices: The cost of deforestation is simply being left for the future. *Revenue collection on woodfuel trading and transport should be earmarked for afforestation purposes.*

It is also recommended that the Department of Energy re-examines the planned price increase for electricity. A situation where few people can afford to shift from woodfuel to electricity, or even worse where present UEB customers shift from electricity to woodfuel, must be avoided. Some subsidies might be economically and environmentally sound in the long run.

## 15.7 Other Renewable Energy Sources15.7 Other Renewable Energy Sources

Biogas, solar cell panels, wind mills and other technological solutions to the energy crisis are always capturing a lot of political attention. Such renewable sources have a role to play and their use should be promoted, but they will under all circumstances play a minor role in Uganda's energy consumption in the foreseeable future.

Our main recommendation here is that the Government should leave such products to the private sector, and instead allocate its scarce resources towards the really important energy sectors: Tree planting, improved kilns, and improved stoves (and electricity, which already gets the major part of public expenditure).

## 15.8 Monitoring the Biomass Situation15.8 Monitoring the Biomass Situation

Phase II of the Biomass Study will cover the rest of the country (if satellite imagery for all areas becomes available). In addition, the project will start with dynamic monitoring (re-measurements at regular intervals) of all land use/cover classes. Such monitoring is important and should be continued in the next years and even decades. It would produce valuable information as well as function as an "early warning system" for woody biomass in Uganda, and thereby make interventions possible *before* a crisis hits the newspaper headlines.

## 15.9 Some Final Words15.9 Some Final Words

The NRM Government has since its coming to power in 1986 paid much attention to environmental issues, including the on-going deforestation. The political basis for interventions in the woodfuel energy sectors is therefore present, even if economic constraints and other problems severely reduce available options.

The National Biomass Study has during the last two and a half years collected and analyzed vast amounts of biomass data, and more is forthcoming. Our information therefore forms one important part of the knowledge necessary to implement Governmental policies.

Available information of reasonable quality does *not* necessarily imply that this information will be *utilized,* though. Communication and interaction with potential users of our data will therefore have top priority during Phase II, and we will to the best of our ability deliver data and information in whatever form required (reports, maps, digital files, etc).

The woody biomass situation in Uganda will get worse before it gets better - our hope is that our work can contribute towards reversing the present trend of deforestation before it becomes irreversible. This requires a joint effort by all positive forces in society - and we would like to do our part.

# 16 Reference Literature16 Reference Literature


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# Appendices:

Appendices:

## App. A Description of the Project AreasA Description of the Project Areas

### 1 Arua1 Arua

#### 1.1 Area and Topography1.1 Area and Topography

Arua's area coverage is about 1,050 km². The landscape is gently undulating with altitudes ranging from 700-1,500 m.

#### 1.2 Climate1.2 Climate

Arua has one rainy season from March to November and one dry season from December to February. The annual rainfall ranges from 1,000-1,500 mm. Temperatures range from 27.5-30.0 °C (mean annual maximum) to 17.5-20.0 °C (mean annual minimum).

#### 1.3 Vegetation1.3Vegetation

The original vegetation of Arua was composed of mixed woody savanna, which has greatly been reduced by subsistence farming that currently occupies about 80% of the total land area. The remaining woody vegetation is dominated by the Combretum-Acacia-Butyrospermum complex occupying about 5% and bush cover of about 13%.

The post cultivation vegetation, mainly composed of Imperata-panicum-Hyperhenia-Pteridium complex, has been reduced to smaller patches that can be seen scattered within the project area. A few Eucalyptus woodlots are occupying a small area of about 1%. These mainly belong to the tobacco curing industry. Wetland areas occupy about 0.1% of the total area.

Map over Arua

## 1.4 Geology and Soils1.4 Geology and Soils

The geology is the precambrian wholly granitized or high to medium grade, metamorphic formations with the banded gneiss of Aruan tectonic age.

The soils in this area are:

(1) Yellow-red sandy clay loams (latosols) varying from dark grey to dark brown, slightly acidic, mainly derived from granitic, gneissic and sedimentary rocks. They normally occur on gently undulating to hilly topography.

(2) Brown to yellow sandy clay loams with laterite horizon with variations of dark brown to dark greyish brown, and slightly acidic. They are mainly derived from transported material and occur on flat ridge tops representing remnants of old land surfaces or on the slopes of low undulating topography.

(3) Light grey to white mottled loamy sands with laterite horizon (ground-water laterite) structureless loamy sand. It ranges from slightly acidic to alkaline. This is mainly derived from colluvial and transported material occurring on the lower and bottom slopes in undulating topography.

# 2 Jinja2 Jinja

## 2.1 Area and Topography2.1 Area and Topography

This area covers parts of three districts: Jinja, Iganga and Mukono with a total coverage of about 1,590 square kilometres. It is characterized by gently undulating landscape with altitudes ranging from 1,140-1,350 m.

## 2.2 Climate2.2 Climate

The annual rainfall is 1,000-1,500 mm and is distributed into two peaks: March to May and October to December. The mean annual maximum temperatures range from 25.0-30.0 °C and the mean annual minimum temperatures range from 15.0-17.5 °C.

Map over Jinja.

## 2.3 Vegetation2.3Vegetation

Originally, this area was dominated by the Forest-Savanna mosaic occurring at medium altitudes. Due to increased population pressure on the vegetation cover, this has been reduced to mere patches. The remaining tropical forest covers about 6% of the total project area, while 0.5% is depleted forest cover.

The dry savanna grasslands of the Combretum-Cymbogon complex occasionally occur on a few of the high hills such as Wanyange, Bugembe and the peninsula north of the Napoleon Gulf. About 2% of the area is wetland while 0.5% and 0.2% are under coniferous and deciduous plantations, respectively. Examples are the Namafuma softwood and Mutayi Eucalyptus/Maesopsis plantations.

Subsistence farming is the dominant land use activity occupying about 52% of the total area, while 3.7% and 7.6% are under woodland and bush cover, respectively. Sugar and tea estates occupy about 4.5% of the project area. In general, most of the natural vegetation in this area is under threat of extinction due to human activity.

## 2.4 Geology and Soils2.4 Geology and Soils

Precambrian, partly granitized and metamorphosed, Buganda-Toro system. The rocks are the following: Argillites (phyllites and schists) basal quarzites and amphibolites.

The soils in some other parts are similar to those found in Kampala-Entebbe project area. These are:

(1) The brown to yellow-red sandy clay loams with laterite horizon on flat ridge tops.

(2) Alluvium, recent lacustrine deposits and peaty swamps (lithosols and regosols).

(3) Latosols or dark red friable clays which are derived from basement complex rocks and volcanic rocks.

(4) Shallow stony soils with rock outcrops.

# 3 Kabale3 Kabale

## 3.1 Area and Topography3.1 Area and Topography

This is one of the smallest areas in the project with a total of about 950 km². The landscape is very hilly with altitudes ranging from 1,400-2,500 m.

## 3.2 Climate3.2 Climate

The annual rainfall ranges from 1,000-1,500 mm and is distributed into two peaks. The first peak is from March to May followed by a dry period from June to July and second peak from September to November. The mean annual maximum temperature is below 22.5 °C while the mean annual minimum is below 10.0 °C. This area is one of the coldest in the country.

## 3.3 Vegetation3.3Vegetation

The vegetation in this area has greatly changed in recent decades. The original cover consisted mainly of the Forest-Savanna mosaic on medium and high altitudes, whereas the post cultivation communities - e.g the Hyperrhenia-Pteridium climax - were dominant in the valleys.

Presently, subsistence farming dominates the entire land use activity, occupying about 75% of the total area. This is mainly concentrated on terraced hill slopes.  Around 1.5% of the total is uniform farmland. Most wetland areas have been reclaimed for agricultural purposes, and the remaining portion occupies only 1.1% of the project area. Grasslands of the Hyperrhenia-Pteridium climax are evident on hill tops, occupying 3.5% of the area. Bush and scrub occupy about 12.4%.

The moist lower montane forest zone occurs at 1,500-2,450 metres in climatically moist places such as Kayonza, Bwindi, Mgahinga and Echuya Bamboo Forest. There are many small plantations of black wattle, *Acacia mearnsii* established in this area for tannin extraction. Some of these have been neglected and left to grow wild, and therefore look more like natural forests than established plantations. Eucalyptus is probably the most widely planted tree in Kabale, and a large number of woodlots are scattered within the project area. Both *Acacia mearnsii* and Eucalyptus plantations occupy a total of 5.2%, whereas Coniferous plantations such as Mafuga and Kiriima occupy only 1.4% of the total project area.

Map over Kabale

### 3.4 Geology and Soils3.4 Geology and Soils

The precambrian Karagwe-Ankolean System is the common type. This includes rocks such as argillites and arnenites with some basal metacalcareous rocks. Others are the Pleistocene to recent rocks such as sediments, alluvium, and black soils.

The general soil grouping in this area is under the highly dissected to broad ridge topography type. The following are the common types encountered in this area:

(1) Strong brown loams (ando-like soils) dark brown to dark greyish brown with very high humic content and are slightly acidic. Weakly, crumbly to structureless loam, derived from volcanic ash.

(2) Latosolic soils-reddish yellow sandy soils with variations from very dark grey to dark brown. This is derived from granitic and schistose rocks and occur on highly dissected topography.

(3) Shallow stony soils with rock outcrops. Variously developed soils which have been subjected to recent erosion. They are usually associated with escarpments and hill tops.

(4) Alluvium, recent lacustrine deposits and peaty swamps.

## 4 Kampala/Entebbe4 Kampala/Entebbe

### 4.1 Area and Topography4.1 Area and Topography

Kampala/Entebbe project area with a total coverage of about 3,000 km$^2$ is the largest of all the project areas. It covers the districts of Kampala, parts of Mpigi and Mukono. The landscape is high plateau which has been dissected into numerous hills and low ranges especially in the central and western parts. Elsewhere, particularly in the northern, eastern (Mukono) and southern (Entebbe) parts, the scenery is undulating high plain. The overall altitude ranges from 1,140-1,350 m. Extensive swamps occur along the lake shores, and also in the poorly drained valleys which are scattered here and there in the project area.

Map over Kampala/Entebbe

## 4.2 Climate4.2 Climate

The annual rainfall is 1,500-2,000 mm and is distributed into two peaks. The first being in the months of March to May and the second from September to November. The two peaks are separated by short dry spells from June to July and December to January. The mean annual maximum temperature range from 25.0-30.0 °C while the mean annual minimum temperatures range from 15.0-17.5 °C.

## 4.3 Vegetation4.3Vegetation

The vegetation of this area follows the relief pattern. The hill tops and ranges were originally covered by communities related to the mixed savanna woodland climax and the Combretum-Cympogon-Afronanards fire climax tree savanna. Whereas the lower well drained altitudes were covered by the moist semi-deciduous forest climax and the Chlorophora-Penisetum fire conditioned pseudo-savanna, the impeded drainage valleys were covered by the Cyperus-Seral herb and wetland grass which presently occupy 10% of the project area.

Due to increased urbanisation, most of the natural vegetation has been cleared for industrial, agricultural and other commercial activities. The remaining tropical forests occupy only 1% of the total land area, while the depleted THF occupy 0.6%. Woodlands and bush cover are estimated at 9.1% and 8.3% respectively, whereas grasslands cover only 0.9%.

Deciduous plantations, e.g, Kajansi, Namanve and other privately owned woodlots, occupy only 0.3%. Subsistence farmland covers about 58.6% and uniform farmland 2.6% of the total project area.

## 4.4 Geology and Soils4.4 Geology and Soils

The geology is of the precambrian gneissose terrain type. The Buganda-Toro system includes the argillites (phyllites and schists), with basal quartzite and grey rock types. Undifferentiated gneiss including elements of granulite facies are also found in this project area.

The soils in this project area are of the following types:

(1) Brown to yellow-red sandy clay loams with laterite horizon on flat ridge tops representing remnants of old land surfaces on the lower slopes of gently undulating topography.

(2) Alluvium, recent lacustrine deposits and peaty swamps (lithosols and regosols).

(3) Latosols or dark red friable clays which are derived from basement complex and volcanic rocks.

Note: The soil types range from the seasonally impeded drainage to the poorly drained types and are generally slightly acidic.

# 5 Kamuli5 Kamuli

## 5.1 Area and Topography5.1 Area and Topography

The area covered is about 1,260 km². The landscape is generally the undulating high plain type with altitude ranging from 1,100-1,300 m.

## 5.2 Climate5.2 Climate

The annual rainfall is 1,000-1,500 mm with a distribution of two peaks i.e. the first from March to May and second from September to November. The mean annual maximum temperatures range from 27.5-30.0 °C, while the mean annual minimum temperatures range from 15.0-17.5 °C.

## 5.3 Vegetation5.3Vegetation

The original vegetation of Kamuli was the Forest-Savanna mosaic, which has greatly been influenced by human activity. The present vegetation cover shows no trace of any tropical forest. The remaining savanna woodlands occupy only 1.5% of the total land area, while bush dominated by *Lantana camara* occupies 28.4%. The Lantana bush seems to be spreading very fast and striving to occupy any available space in the area. In some parts it has even tried to colonise some homesteads.

There is almost no trace of grassland, and wetland areas occupy about 2.3%.

Subsistence farmland covers almost 66% whereas uniform farmland covers 1.3%. The are no coniferous plantations and very few woodlots.

Map over Kamuli

### 5.4 Geology and Soils5.4 Geology and Soils

Precambrian wholly granitized or high to medium grade metamorphic formations of the undifferentiated gneiss. The soils in this area are grouped under the gently undulating to level topography types. They are of the following:

(1) Latosols (Red friable clays).

(2) Red to dark friable clays with laterite horizon.

(3) Brown to yellow-red, sandy clay loams with laterite horizon.

These soils are in general slightly acidic.

## 6 Kumi6 Kumi

### 6.1 Area and Topography6.1 Area and Topography

The area covered in this area is about 1,540 km². The general topography is of a high plain with altitudes ranging from 1,100-1,400 m above sea level. The landscape is gently undulating to level plains.

### 6.2 Climate6.2 Climate

The annual rainfall is 1,000-1,500 mm, with an annual distribution of two peaks. The highest amount is in the month of March to May and second highest is from August to October. The mean annual maximum temperatures vary from 27.5-30.0 °C, whereas the mean annual minimum temperatures range from 15.0-17.5 °C.

Map over Kumi

## 6.3 Vegetation6.3Vegetation

Originally, Kumi's vegetation was of the Hyperrhenia grassland complex derived from the Butyrospermum savanna climax. Areas with impeded drainage were mainly dominated by Echinochloa and Sorghastrum grass spp. and Combretum-Acacia-Butyrospermum woody savanna.

The vegetation has greatly changed in the recent decades. The existence of Hyperrhenia grassland savanna is almost insignificant. Currently, woodlands occupy only 0.9%, bush about 6.6% and wetland 8.8% of the total area.

Subsistence farmland covers 78.3% and uniform farmland 0.6%. Woodlots of mainly Eucalyptus spp. occupy only 0.1%, and there are no coniferous plantations in the area.

## 6.4 Geology and Soils6.4 Geology and Soils

Kumi's geology like most of central Uganda is the precambrian, wholly granitized or high to medium metamorphic formations with the undifferentiated gneiss and granulite.

The soils found here are:

(1) Yellow-red sandy clay loams (Latosols) varying from dark grey to dark brown, slightly acidic, are derived from granitic, gneissic and sedimentary rocks. They occur on gently undulating topography.

(2) The brown to yellow-red clay loams with laterite horizon, having low humic content which are slightly acidic, are mainly derived from transported material and occur on flat ridge tops representing remnants of old land surfaces or on the lower slopes of gently undulating topography.

(3) The light grey white, mottled loamy sands with laterite horizon having high humic content, slightly acidic; are derived from colluvial and transported material. They are also associated with old lacustrine deposits.

# 7 Mbale7 Mbale

## 7.1 Area and Topography7.1 Area and Topography

The area covered is about 1,950 km². The topography varies from the high plains West of the Mbale town, with altitudes ranging from 1,100-1,300 m; and Mount Elgon foot hills, East of the town, with altitudes ranging from 1,200 to 3,600 m.

## 7.2 Climate7.2 Climate

From the two distinct topographical variations two types of climatic conditions are experienced. In the low plains west of the town, the annual rainfall is less than 750 mm, but east of the town it ranges from 1,000-1,500 mm. The generalized annual distribution for this area is unimodal with the rains starting from February rising to a peak in March then gently slowing down to December. A short dry spell is experienced in the months of January to February. The mean annual maximum temperatures are as follows: Low plains; 25.0-27.5 °C, Mountain hills and ranges; 22.5-25.0 °C. The mean annual minimum temperatures are as follows: Low plains 12.5-15.0 °C, Mountain hills 10.0-12.5 °C.

## 7.3 Geology and Soils7.3 Geology and Soils

The two common geological systems found in this area are:

(1) The precambrian, wholly granitized or high to medium grade metamorphic formations with undifferentiated gneiss rocks.

(2) Tertiary volcanic rocks and associated sediments.

The soils vary according to the topography. On the higher altitudes East of the town where the soils are well drained, the commonest types are:

(1) The dark red friable clays (Latosols) with high humic content and are slightly acidic. These have been derived from both volcanic and basement complex rocks, and occur in undulating to hilly topography.

(2) Shallow stony soils with rock outcrops which have been variously developed and subjected to recent erosion. This type is usually associated with escarpments and hill tops.

In the plains west of the town the soil type is of alluvium recent lacustrine deposits and peaty swamps. It has been formed by old river sediments as well as those now being added to the plain from the mountains.

## 7.4 Vegetation7.4Vegetation

The original vegetation comprised two categories:

(1) The lower plains had two types; In the impeded drainage, the Acacia-Imperata savanna was common, whereas the Combretum-Terminalia-Albizia-Hyperrhenia occurred in the well drained areas.

(2) On high and medium altitudes, i.e east of Mbale town, the forest-savanna mosaic occured, whereas the high altitude forests of the pygeum moist montane type occured higher up in the mountains. Due to recent encroachment on Mt. Elgon Forest Reserve, this vegetation is believed to have changed significantly.

Presently, the intact and depleted THF each occupies only 0.4% of the total area. Woodland and bush cover about 0.6% and 4.3% respectively, whereas wetland occupy 3.9%. Subsistence farming dominates the land use/cover with 88.3%. Uniform farmland is only 1.3%. Deciduous plantations, mainly of Eucalyptus spp., occupy 0.1% whereas coniferous plantations are insignificant.

Map over Mbale

# 8 Mbarara8 Mbarara

## 8.1 Area and Topography8.1 Area and Topography

This area covers a total area of about 920 km². It is one of the smallest project areas. The landscape is dominated by hills, valleys and plains. The altitude ranges from 1,200-1,900 m.

## 8.2 Climate8.2 Climate

The area has low annual rainfall of 750-1,000 mm and is distributed into two peaks; March to May and September to November. The dry spells are in the months of June to July and sometimes January to February. The mean annual maximum temperatures range from 25.0-27.5 °C; while the mean annual minimum temperatures range from 12.0-15.0 °C.

## 8.3 Vegetation8.3Vegetation

In this area, the lower plains are mainly covered by the dry Acacia savanna with climax of Acacia-Cymbogon-Themeda complex. The hills and ranges are covered by grassland savanna of the Themeda-Chloris type.

This vegetation has been significantly influenced by human activity. Tree cover has greatly decreased with the present data showing no forest cover at all. Woodland occupy only 0.3%, whereas thickets of bush and scrub dominated by *Acacia hockii* cover only 2.6%.

The dry savanna grassland dominates the area with a cover of almost 67%, while wetland occupy about 4.2% of the total area. Subsistence farming covers only 24.2%, uniform farmland 0.2% and woodlots - mainly of Eucalyptus spp. - cover an area of 0.6%.

Map over Mbarara

### 8.4 Geology and Soils8.4 Geology and Soils

The precambrian Buganda-Toro system is the dominating type. Rocks are argillites (phyllites and schists) with basal quartzite and amphibolites.

The soils of this project area which are grouped under the well drained sub-humid regions are the latosolic red friable soils. The following are the most common types under this group:

(1) Yellow-red, sandy clay loams sometimes dark grey to dark brown derived from granitic, gneissic and sedimentary rocks occurring on gently undulating to hilly topography.

(2) Shallow stony soils which have been subjected to recent erosion.

(3) Alluvium, recent lacustrine deposits and peaty swamps.

## 9 Moroto9 Moroto

### 9.1 Area and Topography9.1 Area and Topography

Area covered is 1,310 km². The relief varies from the adverse plains in the West of the town to the mountain slopes of Moroto mountain in the East of the town. The altitude is 1,100-3,100 m.

### 9.2 Climate9.2 Climate

The annual rainfall in this area ranges from 750-1,000 mm, which is described as of the dry condition type. The distribution is of one prolonged rainy season March to August with a shortfall in June and a long dry season from December to February. The mean annual maximum temperatures range from 27.5-30.0 °C whereas the mean annual minimum temperatures range from 12.5-15.0 °C.

Map over Moroto

## 9.3 Vegetation9.3Vegetation

Four types of vegetation are encountered as one moves from the Western part of the town eastwards towards Moroto Mountains:

(1) Bushland of Acacia-Dichrostachys type;

(2) Tree and shrub steppes dominated by Acacias;

(3) Dry savanna ot the Combretum-Acacia-Themeda and Acacia-Commiphora types.

(4) In the higher mountain areas, the high altitude Juniperus-Pordocarpus dry mountain forests and forest/savanna mosaics.

Presently, the area under forest cover is very small and concentrated on the mountain tops. The Combretum-Acacia-Commiphora woodland areas cover only 1.5%, whereas bush coverage is estimated at 58.4%. Due to frequent fires and overgrazing, tree growth has been arrested to shrubs and or bushes. This is typical of *Acacia gourmensis* and *Dichrostachys glomerata.*

Grasslands occupy 15.8%, whereas subsistence farming is about 23.8%. Uniform farmland, forest plantations and woodlots are non-existent.

## 9.4 Geology and Soils9.4 Geology and Soils

There are mainly two geological types:

(1) The precambrian, wholly granitized or medium grade metamorphic formations of the Karasuk series. The rocks are acid gneiss, amphibolites, quartzite marbles and some granulite facies.

(2) Tertiary volcanic rocks and associated sediments.

The soil types are as follows:

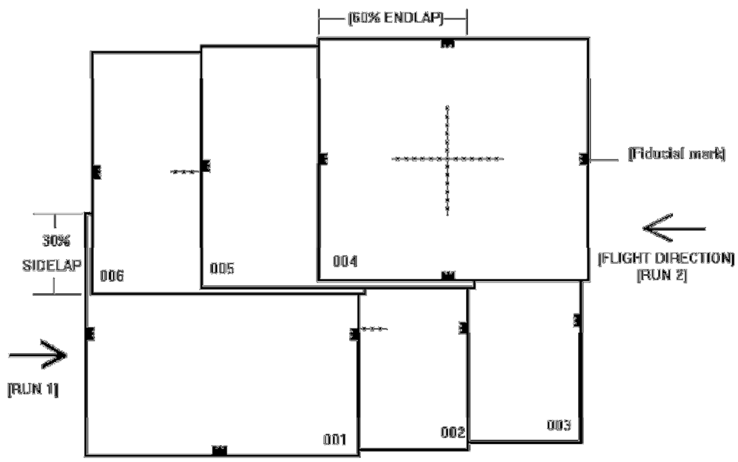
(1) Brown clay loams to clays, very dark grey to dark brown with high humic content and are alkaline. They are found overlying hard lava but they may be developed partly from volcanic ash.

(2) Shallow stony soils with rock outcrops.

(3) Black to dark grey clay (grumosolic soils) consisting of a range of black cotton soils and include the calcareous and non calcareous variants.

# App. B Photo Model OverlayB Photo Model Overlay

# App. C Stereo Pair SettingC Stereo Pair Setting



# App. D List of Common Species and Their Relative OccurrenceD

List of Common Species and Their Relative Occurrence

**Arua**

| Spp-Name | Frequency % | Weight % |
|---|---|---|
| FICUS NATALENSIS | 0.7 | 13.4 |
| MANGIFERA INDICA | 1.9 | 11.9 |
| EUCALYPTUS | 9.4 | 11.7 |
| COMBRETUM | 15.4 | 7.2 |
| BUTYROSPERMUM PARADOXUM | 1.7 | 6.3 |
| ACACIA | 12.9 | 5.6 |
| FICUS EXASPERATA | 1.1 | 5.0 |
| FICUS MUCUSO | 0.3 | 2.5 |
| TERMINALIA | 1.6 | 2.3 |
| GREWIA | 4.7 | 1.9 |
| CASSIA | 3.8 | 1.1 |
| BRIDELIA | 4.3 | 1.0 |
| ANNONA | 4.3 | 1.0 |
| RHUS | 1.9 | 0.7 |
| PSEUDOSPONDIAS MICROCARPA | 2.7 | 0.7 |
| VERNONIA | 2.4 | 0.5 |
| Total | 69.1 | 72.8 |

**Jinja**

| Spp-Name | Frequency % | Weight % |
|---|---|---|
| FICUS NATALENSIS | 2.7 | 18.6 |
| ALBIZIA | 3.4 | 4.7 |
| FICUS MUCUSO | 0.7 | 4.0 |
| CELTIS AFRICANA | 1.9 | 3.9 |
| ARTOCARPUS HETEROPHYLLUS | 1.6 | 3.8 |
| MANGIFERA INDICA | 1.6 | 3.4 |
| CHLOROPHORA EXCELSA | 0.5 | 3.2 |
| CELTIS DURANDII | 1.8 | 2.7 |
| MACARANGA SCHWEINFURTHII | 3.6 | 2.7 |
| MARKHAMIA PLATYCALYX | 12.6 | 0.4 |
| SAPIUM ELLIPTICUM | 4.7 | 0.4 |
| ACACIA | 3.3 | 0.3 |
| TECLEA NOBILIS | 5.0 | 0.2 |
| CASSIA | 4.3 | 0.1 |
| VERNONIA | 5.6 | 0.1 |
| SOLANUM | 4.3 | 0.1 |
| Total | 57.6 | 48.6 |

**Kabale**

| Spp-Name | Frequency % | Weight % |
|---|---|---|
| EUCALYPTUS | 50.9 | 51.4 |
| ACACIA | 25.7 | 11.7 |
| MARKHAMIA PLATYCALYX | 5.8 | 4.0 |
| FICUS NATALENSIS | 0.4 | 4.0 |
| ERYTHRINA ABYSSINICA | 4.7 | 2.5 |
| MITRAGYNA RUBROSTINELATA | 0.3 | 1.7 |
| NUXIA OPPOSITIFOLIA | 0.3 | 1.5 |
| TERMINALIA | 0.4 | 1.4 |
| RICINUS COMMUNIS | 2.1 | 0.5 |
| MAESA LANCEOLATA | 0.8 | 0.4 |
| ALLOPHYLLUS AFRICANUS | 0.6 | 0.2 |
| SOLANUM | 0.6 | 0.1 |
| PHILLIPIA BENGUELENSIS | 0.6 | 0.1 |
| Total | 93.2 | 79.5 |

**Kampala**

| Spp-Name | Frequency % | Weight % |
|---|---|---|
| FICUS NATALENSIS | 4.8 | 17.7 |
| MANGIFERA INDICA | 3.7 | 12.2 |
| ARTOCARPUS HETEROPHYLLUS | 5.1 | 9.7 |
| ALBIZIA | 3.9 | 7.1 |
| CANARIUM SCHWEINFURTHII | 0.3 | 6.5 |
| ANTIARIS TOXICARIA | 1.0 | 5.5 |
| CHLOROPHORA EXCELSA | 0.5 | 4.4 |
| SAPIUM ELLIPTICUM | 9.1 | 3.7 |
| FICUS MUCUSO | 1.1 | 3.3 |
| MARKHAMIA PLATYCALYX | 15.5 | 3.1 |
| CASSIA | 5.6 | 1.6 |
| VERNONIA | 13.3 | 1.4 |
| SPATHODEA CAMPANULATA | 2.0 | 0.6 |
| SOLANUM | 4.0 | 0.4 |
| Total | 69.9 | 77.2 |

**Kamuli**

| Spp-Name | Frequency % | Weight % |
|---|---|---|
| FICUS NATALENSIS | 14.5 | 42.9 |
| FICUS MUCUSO | 1.2 | 7.9 |
| ALBIZIA | 3.7 | 6.9 |
| ACACIA | 9.2 | 6.3 |
| MANGIFERA INDICA | 2.4 | 5.9 |
| CHLOROPHORA EXCELSA | 0.6 | 4.6 |
| ARTOCARPUS HETEROPHYLLUS | 2.1 | 3.0 |
| COMBRETUM | 8.5 | 3.0 |
| MARKHAMIA | 9.1 | 1.9 |
| FICUS BRACHYPODA | 0.5 | 1.8 |
| CASSIA | 6.8 | 1.6 |
| CITRUS SINENSIS | 3.7 | 0.9 |
| VERNONIA | 7.9 | 0.8 |
| RHUS | 5.2 | 0.7 |
| Total | 75.4 | 88.2 |

**Kumi**

| Spp-Name | Frequency % | Weight % |
|---|---|---|
| FICUS NATALENSIS | 1.4 | 16.7 |
| MANGIFERA INDICA | 2.2 | 13.6 |
| FICUS EXASPERATA | 1.5 | 9.3 |
| TAMARINDUS INDICA | 1.3 | 9.2 |
| FICUS MUCUSO | 0.8 | 6.9 |
| ACACIA | 13.3 | 5.8 |
| FICUS GLABERIMA | 0.6 | 4.7 |
| COMBRETUM | 20.4 | 4.6 |
| ALBIZIA | 3.1 | 4.3 |
| BUTYROSPERMUM PARADOXUM | 1.2 | 3.2 |
| CASSIA | 7.1 | 1.4 |
| GREWIA | 4.5 | 0.9 |
| LANNEA | 2.2 | 0.7 |
| RHUS | 4.0 | 0.5 |
| CASSINE AETHIOPICUM | 2.5 | 0.4 |
| PILIOSTIGMA THONNINGII | 2.2 | 0.3 |
| Total | 68.3 | 82.5 |

**Mbale**

| Spp-Name | Frequency % | Weight % |
|---|---|---|
| FICUS NATALENSIS | 4.8 | 17.5 |
| FICUS MUCUSO | 1.8 | 15.1 |
| ALBIZIA | 2.4 | 7.7 |
| MANGIFERA INDICA | 3.8 | 7.7 |
| EUCALYPTUS | 11.8 | 7.5 |
| ANTIARIS TOXICARIA | 0.1 | 5.1 |
| CHLOROPHORA EXCELSA | 0.5 | 5.0 |
| MARKHAMIA PLATYCALYX | 26.4 | 4.5 |
| CORDIA | 1.3 | 4.1 |
| FICUS BRACHYPODA | 0.7 | 3.4 |
| ACACIA | 5.0 | 1.3 |
| CASSIA | 7.6 | 0.9 |
| VERNONIA | 4.3 | 0.4 |
| RICINUS COMMUNIS | 2.3 | 0.1 |
| Total | 72.8 | 80.3 |

**Mbarara**

| Spp-Name | Frequency % | Weight % |
|---|---|---|
| EUCALYPTUS | 19.2 | 32.5 |
| ACACIA | 36.0 | 21.3 |
| ALBIZIA | 4.2 | 12.3 |
| FICUS NATALENSIS | 1.3 | 5.7 |
| EUPHORBIA | 1.7 | 4.8 |
| ERYTHRINA ABYSSINICA | 5.1 | 3.0 |
| MARKHAMIA PLATYCALYX | 4.5 | 3.0 |
| FICUS CAPENSIS | 0.1 | 2.0 |
| RHUS | 6.7 | 1.7 |
| CUPRESSUS LUSITANICA | 0.1 | 1.0 |
| VERNONIA | 2.1 | 0.9 |
| SECURINEGA VIROSA | 3.6 | 0.8 |
| GREWIA | 3.4 | 0.8 |
| Total | 88.0 | 89.8 |

**Moroto**

| Spp-Name | Frequency | Weight |
|---|---|---|

| | % | % |
|---|---|---|
| ACACIA | 46.8 | 48.9 |
| EUPHORBIA | 4.1 | 9.8 |
| FICUS NATALENSIS | 0.2 | 9.0 |
| BALANITE | 4.8 | 6.6 |
| TERMINALIA | 2.8 | 5.6 |
| COMMIPHORA | 5.7 | 4.0 |
| TAMARINDUS INDICA | 0.8 | 3.0 |
| LANNEA | 4.5 | 1.7 |
| FICUS MUCUSO | 0.1 | 1.3 |
| RHUS | 3.5 | 1.0 |
| COMBRETUM | 5.6 | 1.0 |
| GREWIA | 2.4 | 0.6 |
| CASSINE AETHIOPICUM | 1.6 | 0.4 |
| Total | 82.9 | 92.9 |

# App. E List of Species from the Plot MeasurementsE List of Species from the Plot Measurements

| Code | Botanical Name | Trade Name | Local Name |
|---|---|---|---|
| 330 | Acacia albida | | |
| 345 | Acacia gerrardii | | |
| 328 | Acacia hockii | | |
| 329 | Acacia macrothyrsa | | Mukonsoko(Lus) |
| 3 | Acacia senegal | | Kibeere/Muwawu(Lug) |
| 327 | Acacia sieberiana | | |
| 193 | Acalypha variagantum | | |
| 147 | Acanthus pubescens | | Amatovu(Lug) |
| 335 | Afrosersalisia cerasifera | | |
| 235 | Afzelia africana | Afzelia | |
| 236 | Albizia anthelmintica | | |
| 201 | Albizia coriaria | | Mugavu(Lug) |
| 238 | Albizia ferruginea | | |
| 237 | Albizia glaberrima | | Mushebeya(Lug) |
| 242 | Albizia grandibracteata | | |
| 239 | Albizia gummifera | | |
| 361 | Albizia macrophilla | | |
| 355 | Albizia malacoa | | |
| 1 | Albizia spp | | |
| 218 | Albizia zygia | Red nongo | Mulongo(Lug) |
| 106 | Alchornea cordifolia | | Inzibuziba(Lug) |
| 10 | Aleurites molucana | | Kabakanjagala(Lus) |
| 241 | Allanblackia kimbelensis | | Mutaka(Lukiga) |
| 88 | Allophylus africanus | | Mutwalabafu(Lus) |
| 199 | Alstonia boonei | Alstonia | Mujwa(Lug) |
| 134 | Anacardium occidentale | Cashnut | |
| 240 | Aningeria adolphi-friederici | | |
| 110 | Aningeria altissima | Osan | Nkalati(Lug) |
| 348 | Annona senegalensis | | |
| 44 | Annona spp. | Wild soursop | Staferi(Lus) |
| 27 | Antiaris toxicaria | Antiaris | Kirundo(Lug) |
| 220 | Apodytes dimidiata | White pear | Munyamazzi(Lug) |
| 219 | Araucaria cunninghamiana | | |
| 6 | Artocarpus heterophyllus | Jack fruit | Ffene(Lug) |
| 368 | Arudinaria alpina | Bamboo | Mibanda(Lug) |
| 367 | Azadirachita indica | Neem | |
| 243 | Baikiaea insignis | | Nkobankoba(Lug) |
| 336 | Balanites aegyptiaca | Egyptian myrobalan | Musongole(Lug) |
| 91 | Balanites wilsoniana | | Naligwalimu(Lug) |
| 244 | Balsamocitrus dawei | | |
| 205 | Bauhinia spp = 153 | | |
| 80 | Baulia pauprea | | |
| 246 | Beilschmiedia ugandensis | | Mwasa(Lug) |
| 349 | Bishori | | |
| 245 | Blighia unijugata | | Nkuzanyana(Lug) |
| 208 | Blighia welwitschii | | |
| 137 | Bombax buonopozensis | Cotton tree | Pamba(Lug) |
| 200 | Borassus aethiopum | Fan Palm | Ntungo(Lug) |
| 161 | Bosquiea phoberos | | Mugwi(Lug) |
| 82 | Bouganvillea | | |

| | | | |
|---|---|---|---|
| 248 | Brachylaena hutchinsii | | |
| 307 | Brachystegia boehmii | | |
| 309 | Brachystegia globifera | | |
| 308 | Brachystegia spiciformis | | |
| 54 | Bridelia micrantha | | Katazamiti(Lug) |
| 249 | Bridelia ndellensis | | Katazamiti(Lug) |
| 288 | Bridelia scleroneura = 143 | | Eriocho(Ateso) |
| 143 | Bridelia scleroneura = 288 | | Eriocho(Ateso) |
| 146 | Bridelia spp | | Katazamiti(Lug) |
| 250 | Burkea africana | | |
| 25 | Butydevia nyaska | | Mubajangabo(Lug) |
| 333 | Butyrospermum paradoxum | | |
| 194 | Calliandra calothyrsus | | |
| 22 | Callistemon citrinus | Bottle brush | |
| 37 | Canarium schweinfurthii | Incense tree | Muwafu(Lug) |
| 251 | Carapa grandiflora | Crabnut | |
| 252 | Casearia battiscombei | | |
| 253 | Casearia engleri | | |
| 181 | Cassia didymobotrya | | Omugabagaba(Luny) |
| 356 | Cassia petersiana | | |
| 145 | Cassia siamea | | |
| 313 | Cassia sieberiana | | |
| 222 | Cassia spectabilis | | |
| 4 | Cassia spp | | Ntanyenya(Lunyole) |
| 127 | Cassine aethiopica = 215 | | |
| 255 | Cassipourea elliotii | | |
| 256 | Cassipourea malosana | | |
| 78 | Casuarina | | |
| 342 | Catha edulis | Khat tree | Kitandwe(Lugishu) |
| 258 | Celtis adolfi-fridericii | | |
| 261 | Celtis africana | | Akasisa(Lug) |
| 260 | Celtis durandii | | Namanuka(Lug) |
| 38 | Celtis mildbraedii | African celtis | Lufugo(Lug) |
| 338 | Celtis wightii | | |
| 259 | Celtis zenkeri | | |
| 180 | Chaetacme aristata | | |
| 168 | Chiema | | |
| 35 | Chlorophora excelsa | Mvule | Muvule/Iroko(Lug) |
| 162 | Chrysophyllum albidum | White star apple | Mululu(Lug) |
| 262 | Chrysophyllum gorungosanum | | |
| 263 | Chrysophyllum perpulchrum | | |
| 264 | Cistanthera papaverifera | | |
| 46 | Citrus limonia | Lemon | Tokekulu(Lug) |
| 21 | Citrus sinensis | Orange | Omucungwa(Lug) |
| 340 | Cleistopholis patens | | |
| 77 | Coffea excelsa | Wild coffee | Mwanyi(Lug) |
| 155 | Cola gigantea | | Mutumbwe(Lug) |
| 204 | Combretum collinum | | |
| 105 | Combretum fragnans | | |
| 198 | Combretum gumii | | |
| 305 | Combretum molle | | |
| 29 | Combretum spp | | |
| 366 | Commiphora abssinica | | |
| 265 | Cordia africana | Mukebu | Mujugangoma(Luny) |
| 160 | Cordia millenii | | Mukebu(Lug) |
| 117 | Cordia ovalis | | Edomel(Luo) |
| 365 | Cordia sinensis | | |
| 121 | Cordia vulgaris | | |
| 144 | Crassocephalum | | Ekitalankuba(Lug) |
| 120 | Craterogyne kameruniana | | |
| 142 | Crossopteryx febrifuga | | Eterai(Ateso) |
| 18 | Croton macrostachys | | Muyembe(Lus) |
| 95 | Croton megalocarpus | | Nkulumire(Lug) |
| 266 | Croton oxypetalus | | |
| 57 | Cupressus lusitanica | Cypress | |
| 126 | Cupressus simpevirens | | |
| 93 | Cussonia arborea | | Kikopoka(Sebei) |

| | | | |
|---|---|---|---|
| 228 | Cynometra alexandri | Uganda ironwood | Muhimbi(Luny) |
| 267 | Dalbergia melanoxylon | | Motangu(Lug) |
| 268 | Daniellia oliveri | | |
| 13 | Delonix regia | Flamboant tree | Mwolola(Lug) |
| 169 | Dichrostachys glomerata | | Muwanika(Lug) |
| 163 | Diospyros abyssinica | Lusui | Mpimbya(Lug) |
| 269 | Diospyros mespiliformis | | |
| 270 | Dombeya goetzenii | | |
| 189 | Dombeya mukole | | |
| 364 | Dovyalis macrocalyx | | |
| 197 | Dracaena afromontana | | Luwanyi(lug) |
| 271 | Drypetes spp | | |
| 350 | Ehretia cymosa | | |
| 272 | Ekebergia capensis | | Mufumba(Luny) |
| 15 | Entada abyssinica | | Omwolola(Lug) |
| 273 | Entandrophragma angolense | | |
| 119 | Entandrophragma cylindricum | | Muyovu(Lug) |
| 274 | Entandrophragma excelsum | | |
| 275 | Entandrophragma utile | | |
| 24 | Erythrina abyssinica | Red-hot-poker tree | Girikiti(Lug) |
| 341 | Erythrophleum suaveolens | | |
| 276 | Eucalyptus saligna | | |
| 19 | Eucalyptus spp | Eucalyptus | Kalitunsi(Lug) |
| 128 | Euclea latidens | | Emwish(Ateso) |
| 344 | Euphorbia candelabrum | | |
| 40 | Euphorbia spp | | Nabanteta(Lug) |
| 358 | Euphorbia tirucalli | | |
| 61 | Fagara angolensis | | Mukarukati(Lug) |
| 277 | Fagara macrophylla | | |
| 111 | Fagaropsis angolensis | | Muyinja(Lug) |
| 301 | Faurea saligna | | |
| 302 | Ficalhoa laurifolia | | |
| 69 | Ficus brachypoda | | Mukokowe(Lug) |
| 96 | Ficus capensis | | Kabalira(Lug) |
| 36 | Ficus exasperata | | Kiwawu(Lus) |
| 184 | Ficus glaberima | | |
| 247 | Ficus glumosa | | |
| 182 | Ficus grandibractiata | | |
| 28 | Ficus mucuso | | Kabalira-Mukunyu(Lug) |
| 8 | Ficus natalensis | Fig tree | Mutuba(Lug) |
| 207 | Ficus platyphylla | | Obo |
| 278 | Ficus spp | | Mugwe |
| 64 | Ficus urceolaris | | Ntonto(Lug) |
| 79 | Ficus vallis-choudae | | |
| 279 | Funtumia africana | Bastard wild rubber | Namukago(Lug) |
| 92 | Funtumia elastica | African wildrubber | Namukago(Lug) |
| 351 | Garcinia buchananii | | |
| 303 | Garcinia huillensis | | Musali(Lug) |
| 140 | Gardenia jovis = 67 | | Ekore(Ateso) |
| 67 | Gardenia jovis-tonantis =140 | | Kauna(Lus) |
| 287 | Greenwayodendron suaveolensi | | |
| 176 | Grevillea robusta | | |
| 347 | Grewia bicolor | | |
| 104 | Grewia mollis | | Mukomakoma(Lug) |
| 304 | Guarea cedrata | | |
| 280 | Hagenia abbysinica | | |
| 188 | Harrisonia abyssinica | | Lusaikya(Lus) |
| 56 | Harungana madagascariensis | | Mulirira(Lug) |
| 86 | Holoptelea grandis | | Mumuli(Lug) |
| 196 | Howea foresteriana | | |
| 63 | Hymenocardia acida | | Nabuluka(Lug) |
| 306 | Ilex mitis | | |
| 51 | Jacaranda mimusifolia | | |
| 39 | Jambasa jambos | Rose apple | Mudalasini(Lus) |
| 230 | Jatropha podagrica | | |
| 17 | Juniperus procera | Cedar | Torokio(Seb) |
| 202 | Khaya anthoteca | Mahogany | Munyama(Luny) |

| | | | |
|---|---|---|---|
| 311 | Khaya senegalensis | | |
| 65 | Kigelia aethiopica | Forest sausage tree | Musa(Lug) |
| 337 | Klainedoxa gabonensis | | |
| 141 | Lannea kerstingii | | Mukontambale(Lus) |
| 190 | Lannea stuhlmannii | | Elogologo(Luo) |
| 360 | Lannea thorningii | | |
| 354 | Lannea welwitschii | | |
| 187 | Lantana camara | | |
| 72 | Leguminosea | | |
| 353 | Leucaena lecocephola | | |
| 49 | Lonchocarpus laxiflorus | | Ekaaka(Iteso) |
| 310 | Lophira alata | | |
| 281 | Lovoa swynnertonii | | Nabulugalu(Lug) |
| 112 | Lovoa trichillioides | Walnut | Nkoba(Lus) |
| 16 | M1 (Unidentified) | | |
| 315 | Macaranga conglome. | | |
| 314 | Macaranga kilimandscharica | | |
| 101 | Macaranga schweinfurthii | | Mweganza(Lug) |
| 312 | Maena duchenei | | Muzikiza |
| 133 | Maesa lanceolata | | Kiwondowondo(Lug) |
| 33 | Maesopsis eminii | | Musizi(Lug) |
| 2 | Mangifera indica | Mango | Muyembe(Lug) |
| 316 | Manilkara cuneifolia = 321 | | |
| 53 | Manioca spp | Shade cassava | Paala(Lug) |
| 7 | Markhamia platycalyx | | Musaambya (Lug) |
| 115 | Maytenus senegalensis | | Munabuliko(Lug) |
| 317 | Melia calliandra | | |
| 233 | Mildraediodendron Exelsum | | Nabulere(Lug) |
| 318 | Millettia stuhlmanni | | |
| 319 | Mimusops bagshaweii | | Musandasanda(Lug) |
| 321 | Mimusops cuneifolia = 316 | | |
| 320 | Mimusops heckelli | | |
| 173 | Mimusops kummel | | Elepolepo(Ateso) |
| 227 | Mitragyna rubrostinelata | | Nzingu(Lug) |
| 322 | Mitragyna stipulosa | | Nzingu(Lug) |
| 323 | Monodora myristica | Calbash wutmeg | Nagomola(Lug) |
| 116 | Morinda lucida | | Mulyambwa(Lus) |
| 167 | Morus lactea | Mulberry | Mukoge(Lus) |
| 165 | Myrianthus holstii | Yellow mulbery | Mugunga(Lug) |
| 215 | Mystroxylon aethiopicum =127 | | Omusongati(Lukiga) |
| 332 | Nauclea diderrichii | Opepe | Kibukilingi(Luamba) |
| 343 | Nauclea latifolius | | Ebwolo |
| 324 | Neoboutonia macrocalyx | | Kafunkura(Lug) |
| 285 | Newtonia buchananii = 286 | | Mpewere(Lug) |
| 286 | Newtonia buchanii = 285 | | Mpewere(Lug) |
| 130 | Nuxia oppositifolia | | Ekwanga(Ateso) |
| 282 | Ochna ovata | | |
| 284 | Olea welwitschii | | Musuga(Lug) |
| 283 | Olinia usambarensis | | |
| 254 | Oncoba routledgei | | Muyebe(Lus) |
| 138 | Ozoroa reticulata | | Mutumbwa(Sebei) |
| 74 | PD (Unidentified) | | |
| 334 | Pachystela brevipes | | Nkalate(Lug) |
| 234 | Parinari holstii | Grew plum | Namulambo(Lug |
| 113 | Parkia filicoidea | Locust bean | Omusheshe(Lukiga) |
| 9 | Persea americana | Avocado | Ovacedo(Lug) |
| 132 | Phialodiscus unijugatus | | Mukuzanyana(Lug) |
| 363 | Philippia benguelensis | | Omuhungye(Lukiga) |
| 12 | Phoenix reclinata | Wild date palm | Lukindu(Lug) |
| 123 | Phyllanthus discoideus | | kamenyambazi(Lug) |
| 153 | Piliostigma thonningii= 205 | Camel's foot leaftree | Kigali(Lug) |
| 43 | Pinus caribaea | Cuban pine | |
| 192 | Pinus elliotti | | |
| 211 | Pinus radiata | Radiata pine | |
| 107 | Piptadeniastrum africana | Dahoma | Mpewere(Lug) |
| 175 | Plumeria alba | | |
| 206 | Podocarpus dawei | | Musenene(Lug) |

| | | | |
|---|---|---|---|
| 71 | Polyscias fulva | | Setala(Lug) |
| 66 | Prunus africanum | Red stinkwood | Ntasesa(Lug) |
| 139 | Pseudocedrela | | |
| 257 | Pseudocedrela kotschyi | | |
| 11 | Pseudospondias microcarpa | | Muziru(Lug) |
| 23 | Psidium guajava | Guava | Omupeera(Lug) |
| 289 | Pterygota milbraedii | | Ndaula(Luny) |
| 31 | Punica granatum | Pomegranate | Mukomamawanga(Lus) |
| 136 | Pycnanthus angolensis | African nutmeg | Munaba(Lug) |
| 99 | Rapanea rhododendroides | | Kinolangombe(Lug) |
| 225 | Raphia monbuttorum | Raphia palm | Kibo(Lug) |
| 131 | Rhus natalensis | | Musese(Lug) |
| 357 | Rhus ruspolli | | |
| 55 | Rhus vulgaris | | Bukansikansi(Lug) |
| 290 | Ricinodendron africanum | | |
| 232 | Ricinodendron heudelotii | Cork wood | Musodo(Luny) |
| 76 | Ricinus commmunis = 171 | Castor oil | Nsogasoga(Lus) |
| 171 | Ricinus communis = 76 | Caster oil | Nsogasoga(Lug) |
| 339 | Rinorea ilicifolia | | |
| 362 | Ritchiea albersii | | |
| 124 | Roystonia regia | Royal palm | |
| 5 | Sapium ellipticum | | Omusasa(Lug) |
| 292 | Schrebera aborea | | |
| 291 | Schrebera alata | | |
| 97 | Sclerocarya birrea | | Kamunyemunye(Lus) |
| 177 | Scutia myrtina | | Omugasha(Luny) |
| 148 | Securidaca longipedunculata | Violet tree | Elila(Ateso)Liro(Lug) |
| 60 | Securinega virosa | | Lukandwa(Lus) |
| 20 | Sesbania sesban | | Ebisirye-sirye(Lug) |
| 47 | Solanum spp | | Setaaba(Lug) |
| 26 | Spathodea campanulata | Tulip tree | Ekifabakazi(Lug) |
| 166 | Spathodea nilotica | | |
| 229 | Steganotaenia | | Kibudubudu(Lus) |
| 203 | Steganotaenia araliacea | | |
| 151 | Sterculia dawei | | Musandasanda(Lus) |
| 84 | Stereospermum kunthianum | | Ndebeza(Lus) |
| 164 | Strombosia scheffleri | Strombosia | Munyankono(Luny) |
| 154 | Strychnos innocua | | Muswaki(Lug) |
| 293 | Strychnos mitis | | Mukusakusa(Lug) |
| 129 | Strychnos spinosa | | |
| 294 | Symphonia globulifera | | Muyanja(Lug) |
| 295 | Syzygium guineense | | Kalunginsanvu(Lug) |
| 70 | Syzygium spp. | | Kalunginsanvu(Lug) |
| 216 | Tabebuia rozea/chrysantha | | |
| 210 | Tabernaemontana | | Kitwe kyankima(Lug) |
| 30 | Tamarindus indica | Tarmarind | Mukoge(Lus) |
| 81 | Tangerina | | |
| 109 | Teclea nobilis | | Nzo(Lug) |
| 331 | Terminalia glane | | |
| 346 | Terminalia glaucescens | | |
| 103 | Terminalia ivorensis | | |
| 359 | Terminalia spinosa | | |
| 114 | Theobroma cacao | Cocoa | |
| 14 | Thevetia peruviana | Yellow oleander | Kasitani(Lug) |
| 90 | Toona serrata | | |
| 89 | Treculia africanum | | |
| 45 | Trema orientalis | | Kasisa(Lus) |
| 108 | Trichilia dregeana | | Sekoba(Lug) |
| 296 | Turraenthus africanus | | |
| 157 | U2 (Unidentified) | | |
| 62 | U5 (Unidentified) | | |
| 297 | Uapaca guinensis | | Mukusu(Lusese) |
| 41 | Vangueria apiculata | | Mutugunda(Lug) |
| 50 | Vernonia amygdalina | | Mululuza(Lug) |
| 100 | Vernonia auricurifela | | Kikooma(Lug) |
| 122 | Vernonia madagasgarinesco | | |
| 73 | Vitex doniana | Black plum | Mufudumbwa(Lus) |

| | | | |
|---|---|---|---|
| 75 | Vitex fischeri | | Mukeremba(Lus) |
| 226 | Vitex madiensis | | Ogwero(Luo) |
| 298 | Voacanga thoursii | | Musanvuma(Lug) |
| 191 | Vuabas | | |
| 299 | Warburgia ugandensis | Kenya green heart | Balwegira(Lus) |
| 224 | Ximenia americana | Wild plum | Museka(Lug) |
| 325 | Xylopia eminii | | Nsagalane(Lug) |
| 326 | Xylopia monospora | | |
| 300 | Zanthoxylum spp | | |
| 209 | Zizyphus abyssinica | | |
| 172 | | | Acoge(Luo) |
| 186 | | | Akalema(Luny) |
| 150 | | | Alira(Luo/Langi) |
| 352 | | | Asakasaka(Lug) |
| 231 | | | Ekamurei(Ateso) |
| 212 | | | Ekinyanya(Lug) |
| 158 | | | Jerengesa(Lug) |
| 87 | | | Kamyufu(Lug) |
| 102 | | | Kanyumba(Lug) |
| 68 | | | Katungafulu(Lug) |
| 214 | | | Kikakara |
| 52 | | | Kilobe(Lus) |
| 221 | | | Kinyamazi |
| 34 | | | Kirowa(Lus) |
| 179 | | | Kisambwe(Lug) |
| 59 | | | Lugaba(Lus) |
| 85 | | | Lumanyo |
| 135 | | | Mbiryango(Lus) |
| 152 | | | Miguasero(Samia) |
| 83 | | | Mukapa(Lus) |
| 149 | | | Mulyanda(Lus) |
| 156 | | | Musandikirampindi(Lug) |
| 159 | | | Mutakula(Lug) |
| 195 | | | Mutura mugina |
| 170 | | | Muyombwe |
| 118 | | | Muyuki(Lus) |
| 48 | | | Ochawo(Luo) |
| 174 | | | Omubwera(Luny) |
| 183 | | | Omukobakoba(Luny) |
| 58 | | | Omuyebeyebe(Lus) |
| 185 | | | Orukaaka(Luny) |
| 223 | | | Rusima |
| 98 | | | Sekibembe(Lug) |
| 178 | | | Serik(Luo) |
| 94 | | Care apple | |
| 213 | | Cherry | |
| 217 | | Egg plant | Biriganya(lug) |
| 42 | | Hibiscus | |
| 32 | | Queen of the Night | |
| 125 | | Town road tree | |

# App. F Field Instructions for the Plot MeasurementsF Field Instructions for the Plot Measurements

1. PREPARATION

1.1 List of equipment.

Check that you have the following equipments at your disposal before you set off for the field:

a) The set of selected photo models (stereo pairs)
b) The fixed photo plot overlay
c) The photo index plan
d) Photo carrier - metal with magnet weights
e) Fixing cello tape - removable
f) Stereoscope - 3x field mirror stereoscope
g) Caliper
h) Hypsometer - Suunto with Range finder
i) Compass
j) Distance tape (25 m)
k) Pangas
j) Pen/pencil and a clipboard
k) Field forms (at least enough for the day's work)

1.2 Other materials and documents.

a) First-Aid kit + snake bite kit
b) Letter of introduction from the District Administrator to the Resistance Committees and the Local Authorities of the area you are going to work in.

2. SELECTION OF THE PHOTO PLOTS FOR GROUND LOCATION

Mount the relevant stereo pair of the photographs under the mirror stereoscope. Fix the overlay. Always mount the key overlay on photos with an even number, and arrange it in such a way that the top writing of the photo is on the left hand side when the overlay is in readable position with the numbering starting from the top. Fix the overlay on this photograph so that the fiducial marks on the overlay fit exactly with those on the photo.

Study the current photographs carefully; visually and stereoscopically. Look for landmarks around and within those photo plots which are accessible. Unless you have got a list of plots to measure, make a decision of which plots to go work on that day. Plan your access route to the relevant plots.

## 3. LOCATION OF THE PLOT

Using the landmarks and distinct objects so identified above, proceed to identify one of the corners of the plot exactly on the ground. This corner shall be your starting point. Take a compass bearing to the next corner. This bearing you have to find out from the relevant run of the photo index plan. Measure the distance with a tape up to the 50 m mark. Take a right angle turn to the third corner and measure the distance (50 m). Take another right angle turn to the fourth corner. Measure the distance (50 m). Then finally take the last right angle turn to your starting point and measure the distance (50 m). The allowable error at the close in corner should not exceed 5 m.

You have now identified and measured the photo plot exactly on the ground herein afterwards called the field plot or simply the plot with its corresponding number on the photograph. It is an area of 50 by 50 m (2,500 square meters).

The boundaries of the plot on the photo and in the field may not fit exactly in case of deviation from the presumed photo scale of 1:25.000. In those cases check that the plot centre is identic on the photo and in the field.

*NB: If a significant number of trees recently are cut within the plot (after the photography), abandon the plot and go to the next.*

## 4. TREE PARAMETER MEASUREMENTS

Having located your plot on the ground proceed to enumerate all the trees in the plot and measure the following parameters:

### 4.1 Diameter.

By means of a caliper placed at the tree at breast height (1.3 m), read off the diameter to the nearest whole number in centimetres. Always measure the diameter at 1.3 m above the ground.

NB:

a. Where the tree forks below the DBH i.e. 1.3 m, then take the stems as two or more trees.

b. In case of buttresses, swells etc. around the DBH, take two readings above the defect and make an average.

c. Elliptical trees: Take two readings at perpendicular sides and make an average of the two readings.

d. On sloppy grounds always stand on the upper side of the slope while taking the diameter reading.

e. In the case of a tree being too big for the caliper, then use an ordinary distance tape to measure the girth or the circumference. Make sure you indicate on the recording form by the symbol "G".

4.2 Height.

The height is hereby defined as the total height of the tree from the ground to the top of the crown.

Fix the range finder scale to either 15 m or 20 m. Determine the distance by looking through the range finder window of the Suunto hypsometer at the fixed scale distance. Read the height through the eye piece of the hypsometer in the usual way to the nearest decimeter.

4.3 Bole.

The bole height is hereby defined as the height of the stem from the ground to the first main branch of the tree. The bole height is measured in the same way as explained above for the total tree height.

4.4 Crown Width.

The crown is the part of the tree above the bole consisting of the branches and the leaves. In this measurement the crown diameter therefore, is the projected distance on the ground covered by the crown presumed to be almost circular. Either you stretch a distance tape or you pace from one side of the crown to the opposite side and then take a similar measurement perpendicular to the first.

Make an average of the two readings rounded to the nearest dm.

## 5. RELATIVE AREA COVERAGE (%).

The area covered by trees, coffee, maize, cassava etc. encountered in the plot should be assessed for relative cover in terms of percent of the total area of the plot. That is to say how much of the area (2,500 square meters) is occupied by say trees. In a similar way you should systematically go through all the other land cover/use types covering the plot until you arrive at a total of 100% for the plot.

Example:

Measure by means of the tape, pacing or visually the size of each "element" in the plot, length times width. By quick calculations estimate the area in square m it occupies. Divide this figure by 2,500, then multiply by 100 to obtain the percentage.

As a guide: 10% is an area of 250 m² (10 m by 25 m)
25% " " " " 625 m² (25 m by 25 m)
50% " " " " 1250 m² (25 m by 50 m)

## 6. LAND USE/COVER CLASS

The land use/cover class is filled in as a code ranging from 1 to 12 as outlined below. The land use/cover class to be recorded is the one which dominates the plot or the one which covers most of the area.

PLANTATIONS

1: Plantation and woodlots with deciduous trees/broadleaves ("hardwood").
2: ---"--- ---- " ---- with coniferous trees ("softwood").

TROPICAL HIGH FOREST

3: Tropical High Forest - normally stocked.
4: " " " - depleted.

WOODLAND - BUSHLAND

5: Woodland - trees and shrubs (average height greater than 4 m).
6: Bushland - bush, thickets and scrubs (average height less than 4 m),

some shrubs may occur.

7: Grassland, range land, open savannah, some scattered trees shrubs, and scrubs may occur.

WETLAND

8: Wetland vegetation, swamp areas, papyrus.

FARMLAND

9: Mixed farmland with scattered trees; cropped agricultural land and fallow land.

10: Plain, uniform farmland without trees and shrubs.

IMPEDIMENTS

11: Urban or rural built area, roads miscellaneous impediment.

12: Water.

7. OTHER INFORMATION

Finally complete the tally sheet with other information required such as photo number, plot number, area, date and name of the booker.

# App. G Distribution of Test TreesG
Distribution of Test Trees

*Table 84: Distribution of the test trees felled on dbh and groups.*

| DBH | Groups 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 5 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 2 | 2 | 0 | 1 | 0 | 5 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 |
| 4 | 6 | 7 | 4 | 0 | 3 | 1 | 7 | 0 | 1 | 3 | 0 | 4 | 0 | 5 | 2 | 0 | 3 | 3 | 16 | 3 | 3 | 0 | 11 | 0 | 6 | 5 | 3 | 2 | 1 | 2 | 6 | 1 | 0 | 7 | 3 | 3 | 5 | 0 | 126 |
| 5 | 19 | 8 | 8 | 4 | 3 | 3 | 13 | 0 | 4 | 6 | 0 | 3 | 2 | 4 | 15 | 0 | 3 | 2 | 11 | 0 | 7 | 4 | 13 | 1 | 7 | 2 | 7 | 2 | 1 | 4 | 13 | 0 | 0 | 2 | 1 | 3 | 2 | 2 | 179 |
| 6 | 33 | 13 | 6 | 13 | 4 | 3 | 14 | 0 | 9 | 5 | 0 | 5 | 4 | 2 | 16 | 3 | 2 | 2 | 18 | 4 | 3 | 8 | 21 | 6 | 5 | 6 | 8 | 2 | 0 | 7 | 18 | 2 | 1 | 2 | 1 | 3 | 7 | 3 | 259 |
| 7 | 19 | 22 | 9 | 8 | 2 | 6 | 22 | 0 | 7 | 10 | 1 | 5 | 6 | 3 | 16 | 4 | 6 | 6 | 17 | 5 | 1 | 6 | 14 | 5 | 7 | 9 | 7 | 1 | 1 | 10 | 11 | 3 | 2 | 3 | 2 | 7 | 7 | 3 | 273 |
| 8 | 18 | 10 | 6 | 6 | 1 | 2 | 11 | 0 | 8 | 4 | 0 | 2 | 14 | 5 | 8 | 5 | 3 | 6 | 6 | 7 | 3 | 5 | 12 | 2 | 3 | 5 | 7 | 3 | 1 | 9 | 7 | 1 | 1 | 4 | 4 | 1 | 10 | 5 | 205 |
| 9 | 24 | 10 | 12 | 2 | 2 | 7 | 14 | 0 | 10 | 11 | 1 | 2 | 5 | 5 | 7 | 6 | 7 | 13 | 7 | 5 | 4 | 9 | 5 | 4 | 4 | 5 | 4 | 1 | 1 | 8 | 6 | 2 | 3 | 4 | 4 | 6 | 6 | 3 | 229 |
| 10 | 23 | 15 | 6 | 4 | 0 | 7 | 22 | 0 | 9 | 9 | 3 | 2 | 6 | 2 | 7 | 9 | 4 | 12 | 11 | 4 | 4 | 6 | 6 | 9 | 3 | 12 | 5 | 5 | 0 | 7 | 5 | 4 | 4 | 4 | 5 | 0 | 2 | 3 | 239 |
| 11 | 13 | 12 | 2 | 5 | 1 | 7 | 3 | 1 | 14 | 6 | 1 | 4 | 7 | 3 | 4 | 7 | 3 | 7 | 6 | 1 | 5 | 8 | 3 | 3 | 1 | 3 | 0 | 3 | 1 | 4 | 3 | 2 | 5 | 2 | 3 | 1 | 5 | 4 | 163 |
| 12 | 14 | 12 | 5 | 3 | 5 | 2 | 10 | 2 | 6 | 7 | 2 | 1 | 2 | 0 | 2 | 3 | 3 | 2 | 4 | 2 | 8 | 6 | 1 | 5 | 2 | 10 | 1 | 2 | 1 | 1 | 2 | 5 | 5 | 2 | 3 | 2 | 4 | 3 | 150 |
| 13 | 13 | 8 | 1 | 2 | 2 | 5 | 3 | 1 | 6 | 5 | 2 | 2 | 5 | 3 | 3 | 1 | 1 | 12 | 3 | 2 | 4 | 3 | 2 | 3 | 0 | 2 | 4 | 0 | 1 | 6 | 0 | 1 | 2 | 0 | 1 | 0 | 3 | 1 | 113 |
| 14 | 10 | 11 | 3 | 6 | 0 | 6 | 11 | 1 | 7 | 2 | 1 | 4 | 9 | 1 | 2 | 2 | 2 | 3 | 4 | 2 | 2 | 3 | 1 | 1 | 2 | 4 | 5 | 2 | 4 | 3 | 2 | 0 | 1 | 0 | 2 | 1 | 4 | 1 | 125 |
| 15 | 4 | 9 | 4 | 1 | 3 | 1 | 6 | 0 | 2 | 1 | 1 | 1 | 5 | 1 | 2 | 2 | 3 | 5 | 4 | 0 | 3 | 3 | 0 | 1 | 0 | 2 | 2 | 1 | 2 | 3 | 0 | 0 | 5 | 3 | 3 | 0 | 2 | 2 | 87 |
| 16 | 9 | 5 | 1 | 5 | 0 | 5 | 5 | 2 | 3 | 3 | 0 | 2 | 4 | 0 | 3 | 1 | 3 | 3 | 1 | 1 | 4 | 2 | 2 | 0 | 1 | 3 | 0 | 0 | 1 | 0 | 2 | 0 | 6 | 1 | 1 | 1 | 2 | 0 | 82 |
| 17 | 4 | 9 | 2 | 0 | 0 | 1 | 4 | 1 | 4 | 2 | 1 | 1 | 2 | 1 | 1 | 2 | 3 | 6 | 0 | 1 | 2 | 2 | 1 | 2 | 0 | 3 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 61 |
| 18 | 6 | 10 | 2 | 1 | 0 | 3 | 5 | 1 | 0 | 0 | 3 | 2 | 4 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 55 |
| 19 | 4 | 3 | 0 | 0 | 0 | 2 | 4 | 1 | 1 | 0 | 0 | 2 | 1 | 0 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 2 | 2 | 0 | 0 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 41 |
| 20 | 3 | 4 | 1 | 2 | 0 | 1 | 3 | 0 | 2 | 0 | 0 | 2 | 5 | 0 | 1 | 2 | 3 | 3 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 2 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 47 |
| 21 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 2 | 1 | 0 | 0 | 2 | 1 | 2 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 28 |
| 22 | 1 | 3 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 1 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 25 |
| 23 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 13 |
| 24 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 14 |
| 25 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 0 | 2 | 1 | 0 | 1 | 1 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 23 |
| 26 | 2 | 2 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 16 |
| 27 | 0 | 3 | 0 | 0 | 0 | 1 | 1 | 0 | 4 | 1 | 1 | 1 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 22 |
| 28 | 0 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 1 | 1 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 17 |
| 29 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 30 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 |
| 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 6 |
| 33 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| 35 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 36 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| 37 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 38 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 39 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 41 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 42 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 45 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 48 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 61 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 62 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 63 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 65 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 75 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 76 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 79 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 3 |
| 81 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 3 |
| 110 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| 120 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | 239 | 204 | 72 | 62 | 33 | 70 | 171 | 10 | 111 | 85 | 21 | 64 | 99 | 39 | 96 | 66 | 62 | 96 | 121 | 38 | 55 | 71 | 100 | 54 | 43 | 94 | 58 | 25 | 21 | 73 | 78 | 27 | 49 | 59 | 34 | 30 | 60 | 31 | 2721 |

# App. H Field Instructions for the Felling of Trees for Volume / Weight DeterminationH

Field Instructions for the Felling of Trees for Volume / Weight Determination

1 DETERMINATION OF THE TREE FOR FELLING

The following are the morphological features to be considered:

1.1 The first branching should be above the DBH (Diameter at Breast Height).

1.2 The tree must be entirely alive. That is to say no dead branches or parts thereof.

1.3 The minimum diameter should be 3 cm at DBH.

2 MEASUREMENTS OF THE TREE STANDING PARAMETERS

2.1 Identify the tree species for felling.

2.2 The diameter at breast height (DBH).

By means of a caliper placed at 1.3 m above the ground read off the diameter to the nearest whole number in centimetres.

Where the tree is bigger than the diameter tape or the tree caliper can stretch, then use an ordinary distance tape by placing it around the tree at DBH and read off the girth or the circumference in centimetres.

Note: In the case of buttressed trees or swellings around the tree at the DBH, take the diameter readings above the buttress/swelling. Where the tree is elliptical, take two crosswise readings and make an average. Where the tree forks below the DBH then take the two stems as two separate trees. On sloppy grounds always stand at the upper side of the slope to the tree.

2.3 The Height.

The tree height is hereby defined as the total height from the ground to the tip of the crown.

Steps to follow when using Suunto Hypsometer:
Arrange the range finder for appropriate distances of 15 m or 20 m. Determine the distance by looking through the range finder window of the hypsometer. Take the total height readings of the selected distance by looking through the hypsometer window pointing at the foot and top of the tree relatively. Alternative way or method for the estimation of the height particularly for the smaller trees could be by ocular means.

2.4 The Bole Height.

The bole is here by defined as that part of the stem of the tree from the ground to the first main branch. The estimation of the bole height is the same as that of the height.

2.5 The Crown Width.

The crown is the part of the tree above the bole consisting of the branches and the leaves. In this measurement, the crown diameter therefore, is the projected distance on the ground covered by the crown presumed to be almost circular. EITHER: you stretch a distance tape from one side of the crown to the opposite side and then take a similar measurement perpendicular to the first. OR: pace in similar manner twice and make an average of the two readings. In both cases take the reading to the nearest decimeter.

Having finished all these measurements and recorded all the data in the appropriate columns in Form 1 provided, then proceed to cut the tree down.

## 3 TREE PARAMETER MEASUREMENTS WHILE THE TREE IS FELLED

### 3.1 Tape measurements.

3.1.1 The Height.

Stretch the distance tape along the axis of the stem from the cutting up to the crown point and read off to the nearest decimeter.

3.1.2 The Bole Height.

Repeat the steps in 3.1.1 for the bole.

3.1.3 The Stem Height or Trunk Height

This is defined as the main part of the tree running through the first branching right into the crown where there is finally no continuity of the stem except several branches. Stretch the tape from the base of the stem up to this point and take a reading to the nearest decimeter.

3.1.3 The Stump Height:

This is the height of the remaining part of the stem after cutting. It is measured from the ground to the point of cutting.

3.2 Weight measurements.

Having finished the tape measurements, then proceed to measure the following:

3.2.1 The Stem Weight.

Chop up the stem into manageable pieces for weight measurements. Make bundles from the pieces and weigh each bundle separately by tying a rope around it and hang up onto the weighing scales attached to a pole. Lift the whole bundle off the ground and read off the weight to the nearest tenth of a kg. Proceed to the next bundles systematically until you have finished all the pieces belonging to the stem/trunk and recorded the weights on Form 2.

3.2.2 The Branch Weight.

Chop all the branches in manageable pieces. Then tie the pieces to make manageable bundles. Hook the bundles one by one up to the weighing scales similarly as for the stem until all the branches are finished. Each reading is recorded on Form 2 provided.

3.3 Volume measurements.

Where the tree size is too big for weight measurements, then the following measurements should be taken for volume determination:

3.3.1 The Trunk Volume.

Take the mid diameter and the length in centimetres of the trunk sectioned into first log, second log, up to the n-th. log.

Note: The log length should be up to a point whereby serious tapering is minimized; that is to say the log should be as cylindrical as possible.

3.3.2 The Branch Volume.

Similarly where the branches are also too big to be managed for weight measurements, do the same measurements for mid diameter and length as for the trunk above. Take care to record all measurements under the appropriate columns in Form 2.

**List of Equipment required for the felling process:**

a. Caliper
b. Hypsometer, Suunto with range finder
c. Distance tape
d. Pangas, shears, axes and bow saws
e. Power saw and its tool kit
f. Fuel and lubricants
g. Ropes
h. Weighing scales
i. Clip board, pen, Form 1 and 2
j. First-Aid kit
k. Hand gloves

Others:

a. Letters of introduction from the District Administrator to the Local Authorities of the area in which you are going to work.

# App. I Field Questionnaire for the Transport StudyI Field Questionnaire for the Transport Study

Questionnaire No.......

1. Date_____________Time________Interviewer________________.

2. Respondent: Transporter (TR), Dealer (DL).

3. Project area:____________________.

4. Location:_____________________ (road or market).

5. What type of transport do you use for transporting fuelwood or charcoal to the market.

   Foot (F) Bicycle (B) Vehicle (V) Canoe (C)

6. Type of Woodfuel transported: Fuelwood (FW) Charcoal (CH).

7. What are the common tree species used.

   Scientific name____________________(local)___________.

   ____________________ __________

   ____________________ ___________.

8a. From where do you obtain the woodfuel? Give the name of the place and the time taken to collect the fuelwood or charcoal:

   Place____________________. Time taken ______________.

b. Where do you sell your load.__________________________.

9a. What is the approximate distance from the source to the market: _____________kms.

b. Route description.______________________________.

10. What is the approximate weight of the load transported per trip in kgs. ____________no of bags__________.

11a. What is the market value of a trip.__________.

b. How much do you buy the load.__________.

12. How many times do you collect the load per

Day_____________(e.g. two times)

Week____________.

Month___________.

# App. J Instructions for Moisture Content and Density MeasurementsJInstructions for Moisture Content and Density Measurements

## 1 FIELD DATA COLLECTION

### 1.1 Equipment required.

The following are the equipment which may be used in the field for collecting data for determining moisture content and density.

a: Power saws (chain saws)
b: Bow saws
c: Axes
d: Pangas
e: Beaker, preferably a suitable container
f: Weighing scales, up to 2-5 kg, accuracy 1 gram
g: Needles
h: Thread
i: Pen/pencil and clipboard
j: Water proof, thick ink pen
k: Field forms
l: Calculator
m: Clean water - container with at least 10 litres each day
n: First-Aid Kit and Snake Bite Kit.

### 1.2. Work instructions.

A: Identify the tree to be felled and record its name (botanical name, trade name or any suitable name in which it is widely known).

B: Fell the tree and cut suitable sample blocks/disks (specimens) randomly from the main stem and branches, consider the limitations of the weighing scales.

C: Write an identification/number on each of the specimens by means of the water proof ink pen, and mark whether it is from a stem or a branch. Record similarly on the field form.

D: Weigh the specimen as soon as possible on the scales and record the weight in grams, wet weight.

E: Fill a beaker (suitable container) with water to the depth adequate to submerge the specimen. Put the beaker containing water on the scale and record its weight in grams, (W1) (weight of beaker together with water). Leave the beaker on the scales.

F: Take the specimen fixed to the end of the needle with thread and lower it into the beaker until it is completely submerged below the water surface. The specimen must not touch the bottom or sides of the beaker. Read and record the new weight of the system in grams, (W2).

G: The difference between the weights (W2-W1) is equal to the wet volume of the test specimen in cubic centimetres, since 1 gram of water is equal to 1 $cm^3$.

H: Transfer the specimens carefully without loosing any section of it where it will be dried, in the laboratory.

## 2 LABORATORY DATA COLLECTION

### 2.1 Equipment required.

The following are the equipment which may be used in the laboratory for collecting data for determining moisture content and density.

e: Beaker - preferably a suitable container
f: Weighing scales - up to two kg, accuracy 1 gram
g: Needles
h: Thread
i: Pen/pencil and clipboard
k: Laboratory forms
l: Calculator
m: Clean water - container with at least 10 litres each day

### 2.2 Work instructions.

A: When coming from the field, all specimens should be arranged, sorted and recorded on proper forms.

B: All specimens collected should first be allowed to air dry in the laboratory on a proper raised base above the floor. As the aim here is to obtain the air dry weight, the laboratory is a shed with open walls. After the specimens are assumed air dried, after 6 -12 weeks depending on the species and the size of the specimen, weighing is frequently done until there is no appreciable difference between the last two readings. Care must be taken not to allow fungi to grow on or borers or any breakages that may course reduction of the weight.

C: The moisture content is determined directly by means of a moisture meter.

D: Air dry volume is subsequently found similarly to the method described in 1.2 E, F, G.

# App. K List of Basic Density and Moisture Content at Air Dry Condition of Species MeasuredK List of Basic Density and Moisture Content at Air Dry Condition of Species Measured

(1) Number of specimens measured.

(2) Average air dry moisture content related to weight of completely dry matter.

(3) Average air dry weight divided by wet volume. (Basic Density is not a quite correct term as we are dealing with air dry weight - not oven dry weight.)

(4) Average air dry weight divided by wet weight.

| BOTANICAL SPECIES NAME | PART A=STEM B=BRA. | MOISTURE CONTENT NO. 1) | MOISTURE CONTENT % 2) | "BASIC" DENSITY NO. 1) | "BASIC" DENSITY 3) | AIR DRYWEIGHT/ WETWEIGHT NO. 1) | AIR DRYWEIGHT/ WETWEIGHT 4) |
|---|---|---|---|---|---|---|---|
| Acacia gerrardii | A | 15 | 13.2 | 8 | 0.81 | 15 | 0.70 |
| Acacia gerrardii | B | 14 | 14.2 | 8 | 0.71 | 14 | 0.63 |
| Acacia hockii | A | 79 | 13.8 | 50 | 0.76 | 79 | 0.67 |
| Acacia hockii | B | 73 | 14.1 | 49 | 0.69 | 74 | 0.62 |
| Acacia macrothyrsa | A | 14 | 13.9 | 9 | 0.78 | 14 | 0.68 |
| Acacia macrothyrsa | B | 11 | 13.1 | 9 | 0.71 | 12 | 0.65 |
| Acacia senegal | A | 25 | 15.3 | 13 | 0.62 | 25 | 0.61 |
| Acacia senegal | B | 25 | 15.7 | 10 | 0.54 | 25 | 0.52 |
| Acacia sieberiana | A | 12 | 14.4 | 6 | 0.69 | 12 | 0.62 |
| Acacia sieberiana | B | 12 | 14.0 | 7 | 0.63 | 13 | 0.57 |
| Albizia coriaria | A | 51 | 15.3 | 27 | 0.60 | 51 | 0.57 |
| Albizia coriaria | B | 45 | 16.0 | 24 | 0.56 | 45 | 0.55 |
| Albizia grandibracteata | A | 3 | 14.5 | 1 | 0.69 | 3 | 0.61 |
| Albizia grandibracteata | B | 5 | 14.6 | 3 | 0.56 | 5 | 0.53 |
| Albizia malacoa | A | 11 | 14.1 | 10 | 0.68 | 11 | 0.61 |
| Albizia malacoa | B | 9 | 13.1 | 10 | 0.65 | 10 | 0.60 |
| Albizia zygia | A | 79 | 15.5 | 47 | 0.67 | 79 | 0.63 |
| Albizia zygia | B | 70 | 16.0 | 49 | 0.62 | 71 | 0.61 |
| Aleurites molucana | A | 3 | 15.0 | 2 | 0.30 | 3 | 0.36 |
| Aleurites molucana | B | 2 | 17.8 | 2 | 0.26 | 2 | 0.30 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Allophylus africanus | A | 7 | 14.1 | 6 | 0.67 | 7 | 0.61 |
| Allophylus africanus | B | 7 | 14.9 | 6 | 0.64 | 7 | 0.59 |
| Alstonia boonei | A | 2 | 12.8 | 1 | 0.48 | 2 | 0.51 |
| Alstonia boonei | B | 1 | 13.3 | 1 | 0.45 | 1 | 0.45 |
| Annona senegalensis | A | 43 | 14.4 | 24 | 0.55 | 43 | 0.54 |
| Annona senegalensis | B | 40 | 14.8 | 24 | 0.45 | 40 | 0.45 |
| Annona spp. | A | 4 | 18.7 | | | 4 | 0.50 |
| Annona spp. | B | 3 | 15.6 | | | 3 | 0.50 |
| Artocarpus heterophyllus | A | 8 | 14.7 | 2 | 0.36 | 8 | 0.49 |
| Artocarpus heterophyllus | B | 3 | 15.7 | 2 | 0.28 | 3 | 0.40 |
| Bosquiea phoberos | A | 3 | 13.7 | | | 3 | 0.64 |
| Bosquiea phoberos | B | 2 | 19.8 | | | 2 | 0.65 |
| Bridelia micrantha | A | 15 | 13.6 | 8 | 0.67 | 15 | 0.62 |
| Bridelia micrantha | B | 14 | 14.7 | 10 | 0.63 | 14 | 0.61 |
| Bridelia scleroneura | A | 68 | 13.8 | 47 | 0.79 | 68 | 0.68 |
| Bridelia scleroneura | B | 65 | 14.1 | 48 | 0.71 | 65 | 0.66 |
| Butyrospermum paradoxum | A | 1 | 11.9 | 1 | 0.75 | 1 | 0.66 |
| Butyrospermum paradoxum | B | 1 | 12.6 | 1 | 0.69 | 1 | 0.63 |
| Calliandra calothyrsus | A | 2 | 13.9 | | | 2 | 0.54 |
| Calliandra calothyrsus | B | 2 | 14.4 | | | 2 | 0.53 |
| Canarium schweinfurthii | A | 27 | 14.4 | 8 | 0.51 | 27 | 0.55 |
| Canarium schweinfurthii | B | 13 | 14.8 | 7 | 0.39 | 13 | 0.47 |
| Cassia petersiana | A | 1 | 14.2 | 1 | 0.80 | 1 | 0.73 |
| Cassia petersiana | B | 1 | 14.9 | 1 | 0.82 | 1 | 0.69 |
| Cassia siamea | A | 16 | 13.6 | 7 | 0.69 | 16 | 0.63 |
| Cassia siamea | B | 13 | 13.3 | 7 | 0.62 | 13 | 0.67 |
| Cassia sieberiana | A | 1 | 13.7 | 1 | 0.69 | 1 | 0.63 |
| Cassia sieberiana | B | 1 | 14.9 | 1 | 0.65 | 1 | 0.56 |
| Cassia spectabilis | A | 29 | 13.5 | 11 | 0.59 | 29 | 0.64 |
| Cassia spectabilis | B | 22 | 13.6 | 9 | 0.56 | 22 | 0.62 |
| Cassine aethiopica | A | 19 | 14.2 | 19 | 0.79 | 19 | 0.68 |
| Cassine aethiopica | B | 18 | 14.1 | 19 | 0.76 | 19 | 0.67 |
| Chlorophora excelsa | A | 44 | 14.0 | 8 | 0.61 | 44 | 0.59 |
| Chlorophora excelsa | B | 30 | 14.9 | 8 | 0.57 | 30 | 0.56 |
| Citrus sinensis | A | 16 | 13.3 | 5 | 0.76 | 16 | 0.71 |
| Citrus sinensis | B | 10 | 13.6 | 5 | 0.73 | 10 | 0.69 |
| Combretum collinum | A | 86 | 14.0 | 47 | 0.82 | 87 | 0.70 |
| Combretum collinum | B | 68 | 14.2 | 48 | 0.76 | 69 | 0.68 |
| Combretum fragnans | A | 12 | 13.8 | 6 | 0.83 | 12 | 0.68 |
| Combretum fragnans | B | 10 | 13.9 | 7 | 0.74 | 11 | 0.64 |
| Combretum gumii | A | 2 | 13.6 | 1 | 0.87 | 2 | 0.73 |
| Combretum gumii | B | 1 | 13.2 | 1 | 0.74 | 1 | 0.68 |
| Combretum molle | A | 60 | 14.1 | 41 | 0.77 | 60 | 0.65 |
| Combretum molle | B | 53 | 14.4 | 41 | 0.67 | 57 | 0.61 |
| Combretum spp. | A | 5 | 13.5 | | | 5 | 0.69 |
| Combretum spp. | B | 4 | 16.0 | | | 4 | 0.61 |
| Cordia millenii | A | 3 | 16.0 | 1 | 0.57 | 3 | 0.46 |
| Cordia millenii | B | 3 | 17.3 | 1 | 0.56 | 3 | 0.45 |
| Cordia ovalis | A | 4 | 14.4 | 2 | 0.86 | 4 | 0.66 |
| Cordia ovalis | B | 2 | 14.8 | 2 | 0.79 | 2 | 0.69 |
| Croton macrostachys | A | 1 | 13.2 | 1 | 0.53 | 1 | 0.60 |
| Croton macrostachys | B | 1 | 14.4 | 1 | 0.52 | 1 | 0.63 |
| Croton megalocarpus | A | 2 | 14.7 | | | 2 | 0.55 |
| Croton megalocarpus | B | 2 | 13.2 | | | 2 | 0.46 |
| Cussonia arborea | A | 53 | 14.8 | 37 | 0.37 | 53 | 0.38 |
| Cussonia arborea | B | 45 | 14.4 | 36 | 0.33 | 47 | 0.35 |
| Delonix regia | A | 6 | 15.1 | 2 | 0.57 | 6 | 0.56 |
| Delonix regia | B | 4 | 15.2 | 2 | 0.54 | 4 | 0.47 |
| Dicrostachys glomerata | A | 3 | 14.9 | 1 | 0.73 | 3 | 0.61 |
| Dicrostachys glomerata | B | 2 | 13.2 | 1 | 0.50 | 2 | 0.59 |
| Dombeya goetzenii | A | 2 | 16.5 | 2 | 0.62 | 2 | 0.64 |
| Dombeya goetzenii | B | 2 | 17.1 | 2 | 0.55 | 2 | 0.59 |
| Entada abyssinica | A | 21 | 16.9 | 10 | 0.53 | 21 | 0.50 |
| Entada abyssinica | B | 17 | 15.9 | 9 | 0.47 | 17 | 0.47 |
| Erythrina abyssinica | A | 64 | 15.6 | 40 | 0.38 | 64 | 0.40 |
| Erythrina abyssinica | B | 55 | 15.6 | 41 | 0.38 | 55 | 0.40 |
| Euphorbia candelabrum | A | 15 | 14.1 | 8 | 0.30 | 15 | 0.38 |
| Euphorbia candelabrum | B | 13 | 14.1 | 8 | 0.25 | 13 | 0.32 |
| Euphorbia spp. | A | 4 | 14.7 | | | 4 | 0.52 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Euphorbia spp. | B | 2 | 16.2 | | | 2 | 0.29 |
| Euphorbia tirucalli | A | 2 | 14.4 | 2 | 0.73 | 2 | 0.65 |
| Euphorbia tirucalli | B | 2 | 13.1 | 2 | 0.64 | 2 | 0.62 |
| Fagara angolensis | A | 1 | 21.2 | | | 1 | 0.67 |
| Fagara angolensis | B | 1 | 13.2 | | | 1 | 0.54 |
| Ficus brachypoda | A | 26 | 15.3 | 9 | 0.56 | 26 | 0.50 |
| Ficus brachypoda | B | 22 | 15.4 | 9 | 0.52 | 22 | 0.48 |
| Ficus capensis | A | 15 | 16.7 | 9 | 0.47 | 15 | 0.40 |
| Ficus capensis | B | 16 | 15.8 | 8 | 0.46 | 16 | 0.42 |
| Ficus exasperata | A | 33 | 16.5 | 15 | 0.47 | 33 | 0.42 |
| Ficus exasperata | B | 31 | 16.8 | 15 | 0.45 | 31 | 0.41 |
| Ficus glumosa | A | 20 | 15.7 | 11 | 0.56 | 20 | 0.52 |
| Ficus glumosa | B | 20 | 15.7 | 11 | 0.52 | 20 | 0.49 |
| Ficus mucuso | A | 26 | 15.3 | 20 | 0.53 | 26 | 0.47 |
| Ficus mucuso | B | 23 | 15.4 | 20 | 0.48 | 23 | 0.44 |
| Ficus natalensis | A | 59 | 16.5 | 19 | 0.49 | 59 | 0.48 |
| Ficus natalensis | B | 46 | 16.5 | 19 | 0.49 | 46 | 0.47 |
| Ficus vallis-choudae | A | 20 | 17.8 | 14 | 0.37 | 20 | 0.36 |
| Ficus vallis-choudae | B | 19 | 17.2 | 14 | 0.36 | 19 | 0.37 |
| Gardenia jovis-tonantis | A | 50 | 13.9 | 36 | 0.75 | 50 | 0.64 |
| Gardenia jovis-tonantis | B | 49 | 13.7 | 36 | 0.71 | 50 | 0.61 |
| Grewia bicolor | A | 8 | 14.5 | 7 | 0.71 | 8 | 0.64 |
| Grewia bicolor | B | 7 | 15.0 | 6 | 0.63 | 7 | 0.60 |
| Grewia mollis | A | 81 | 14.3 | 41 | 0.72 | 81 | 0.65 |
| Grewia mollis | B | 56 | 14.6 | 40 | 0.61 | 61 | 0.59 |
| Guarea cedrata | A | 2 | 13.1 | 2 | 0.78 | 2 | 0.66 |
| Guarea cedrata | B | 2 | 13.7 | 2 | 0.75 | 2 | 0.64 |
| Harungana madagascariensis | A | 5 | 12.8 | 1 | 0.55 | 5 | 0.62 |
| Harungana madagascariensis | B | 2 | 13.2 | 1 | 0.50 | 2 | 0.58 |
| Hymenocardia acida | A | 25 | 14.8 | 14 | 0.75 | 25 | 0.63 |
| Hymenocardia acida | B | 24 | 14.3 | 14 | 0.67 | 24 | 0.58 |
| Kigelia aethiopica | A | 1 | 13.3 | 1 | 0.75 | 1 | 0.66 |
| Kigelia aethiopica | B | 1 | 14.0 | 1 | 0.58 | 1 | 0.53 |
| Kirowa | A | 9 | 17.7 | 3 | 0.27 | 9 | 0.31 |
| Kirowa | B | 7 | 17.6 | 3 | 0.25 | 7 | 0.34 |
| Lannea kerstingii | A | 69 | 14.8 | 48 | 0.56 | 69 | 0.50 |
| Lannea kerstingii | B | 64 | 14.6 | 49 | 0.55 | 67 | 0.49 |
| Lannea stuhlmannii | A | 4 | 14.8 | 3 | 0.56 | 4 | 0.56 |
| Lannea stuhlmannii | B | 4 | 13.9 | 3 | 0.52 | 4 | 0.54 |
| Lannea thorningii | A | 3 | 13.2 | 3 | 0.60 | 3 | 0.59 |
| Lannea thorningii | B | 3 | 13.4 | 3 | 0.61 | 3 | 0.62 |
| Lantana camara | A | 13 | 13.8 | 8 | 0.53 | 13 | 0.50 |
| Lantana camara | B | 10 | 14.3 | 8 | 0.51 | 10 | 0.50 |
| Leucaena lecocephola | A | 5 | 13.8 | 3 | 0.73 | 5 | 0.65 |
| Leucaena lecocephola | B | 5 | 14.6 | 3 | 0.67 | 5 | 0.61 |
| Lonchocarpus laxiflorus | A | 9 | 14.4 | 8 | 0.60 | 9 | 0.54 |
| Lonchocarpus laxiflorus | B | 11 | 14.4 | 8 | 0.55 | 11 | 0.50 |
| Lumanyo | A | 2 | 13.7 | 1 | 0.69 | 2 | 0.61 |
| Lumanyo | B | 2 | 14.8 | 1 | 0.56 | 2 | 0.56 |
| Maesopsis eminii | A | 13 | 13.2 | 4 | 0.41 | 13 | 0.56 |
| Maesopsis eminii | B | 10 | 14.1 | 4 | 0.41 | 10 | 0.58 |
| Mangifera indica | A | 63 | 13.7 | 22 | 0.62 | 63 | 0.61 |
| Mangifera indica | B | 46 | 13.9 | 23 | 0.59 | 48 | 0.59 |
| Markhamia platycalyx | A | 73 | 15.1 | 27 | 0.55 | 73 | 0.57 |
| Markhamia platycalyx | B | 58 | 15.6 | 27 | 0.52 | 61 | 0.54 |
| Maytenus senegalensis | A | 52 | 14.4 | 33 | 0.59 | 52 | 0.54 |
| Maytenus senegalensis | B | 44 | 14.8 | 33 | 0.53 | 47 | 0.53 |
| Mellia calliandra | A | 2 | 14.6 | 2 | 0.48 | 2 | 0.56 |
| Mellia calliandra | B | 2 | 14.8 | 2 | 0.43 | 2 | 0.53 |
| Mukapa | A | 2 | 13.7 | 1 | 0.42 | 2 | 0.45 |
| Mukapa | B | 2 | 14.2 | 1 | 0.39 | 2 | 0.44 |
| Ozoroa reticulata | A | 19 | 14.1 | 14 | 0.67 | 19 | 0.61 |
| Ozoroa reticulata | B | 17 | 15.0 | 15 | 0.56 | 18 | 0.51 |
| Persea americana | A | 36 | 14.1 | 10 | 0.53 | 36 | 0.54 |
| Persea americana | B | 16 | 14.9 | 9 | 0.44 | 16 | 0.47 |
| Piliostigma thonningii | A | 64 | 14.2 | 42 | 0.70 | 64 | 0.60 |
| Piliostigma thonningii | B | 60 | 14.7 | 42 | 0.57 | 62 | 0.55 |
| Polyscias fulva | A | 10 | 13.9 | | | 10 | 0.56 |
| Polyscias fulva | B | 2 | 14.0 | | | 2 | 0.56 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pseudocedrela | A | 12 | 14.3 | | | 12 | 0.58 |
| Pseudocedrela | B | 11 | 15.1 | | | 11 | 0.54 |
| Pseudocedrela kotschyi | A | 11 | 13.3 | 11 | 0.67 | 11 | 0.59 |
| Pseudocedrela kotschyi | B | 12 | 14.5 | 12 | 0.58 | 12 | 0.54 |
| Psidium guajava | A | 25 | 16.5 | 10 | 0.66 | 25 | 0.60 |
| Psidium guajava | B | 17 | 16.8 | 10 | 0.62 | 17 | 0.55 |
| Pyllanthus discoideus | A | 29 | 14.3 | 9 | 0.73 | 29 | 0.61 |
| Pyllanthus discoideus | B | 18 | 14.6 | 9 | 0.69 | 18 | 0.59 |
| Rhus natalensis | A | 19 | 14.3 | 15 | 0.76 | 19 | 0.65 |
| Rhus natalensis | B | 21 | 14.5 | 15 | 0.69 | 21 | 0.64 |
| Rhus ruspolli | A | 2 | 14.1 | 2 | 0.47 | 2 | 0.49 |
| Rhus ruspolli | B | 2 | 14.8 | 2 | 0.47 | 2 | 0.50 |
| Rhus vulgaris | A | 36 | 13.3 | 24 | 0.83 | 36 | 0.71 |
| Rhus vulgaris | B | 34 | 14.0 | 23 | 0.73 | 35 | 0.67 |
| Ricinus communis | A | 2 | 16.6 | 1 | 0.31 | 2 | 0.33 |
| Ricinus communis | B | 2 | 16.1 | 1 | 0.33 | 2 | 0.39 |
| Sapium ellipticum | A | 26 | 14.5 | 17 | 0.53 | 26 | 0.59 |
| Sapium ellipticum | B | 19 | 14.2 | 17 | 0.52 | 19 | 0.58 |
| Securidaca longipedunculata | A | 31 | 13.7 | 20 | 0.67 | 31 | 0.59 |
| Securidaca longipedunculata | B | 20 | 13.9 | 19 | 0.64 | 21 | 0.60 |
| Securinega virosa | A | 16 | 14.5 | 4 | 0.70 | 16 | 0.59 |
| Securinega virosa | B | 9 | 14.7 | 4 | 0.66 | 10 | 0.60 |
| Sesbania sesban | A | 11 | 17.4 | 11 | 0.47 | 11 | 0.54 |
| Sesbania sesban | B | 11 | 16.8 | 11 | 0.51 | 11 | 0.57 |
| Solanum spp. | A | 15 | 18.0 | 9 | 0.40 | 15 | 0.51 |
| Solanum spp. | B | 10 | 16.8 | 10 | 0.41 | 10 | 0.55 |
| Spathodea campanulata | A | 61 | 15.9 | 25 | 0.33 | 61 | 0.41 |
| Spathodea campanulata | B | 40 | 16.2 | 22 | 0.35 | 42 | 0.44 |
| Steganotaenia araliacea | A | 18 | 14.1 | 15 | 0.42 | 18 | 0.43 |
| Steganotaenia araliacea | B | 15 | 14.7 | 13 | 0.34 | 16 | 0.36 |
| Steganotaenia spp. | A | 7 | 15.2 | | | 7 | 0.37 |
| Steganotaenia spp. | B | 6 | 15.3 | | | 6 | 0.34 |
| Stereospermum kunthianum | A | 74 | 14.5 | 40 | 0.66 | 74 | 0.58 |
| Stereospermum kunthianum | B | 58 | 14.1 | 39 | 0.56 | 61 | 0.50 |
| Strychnos mitis | A | 23 | 12.7 | 18 | 0.76 | 23 | 0.67 |
| Strychnos mitis | B | 22 | 12.6 | 18 | 0.70 | 22 | 0.63 |
| Syzygium guineense | A | 18 | 15.5 | 5 | 0.60 | 18 | 0.53 |
| Syzygium guineense | B | 14 | 16.1 | 5 | 0.53 | 14 | 0.50 |
| Syzygium spp. | A | 7 | 13.8 | | | 7 | 0.63 |
| Syzygium spp. | B | 5 | 14.2 | | | 5 | 0.56 |
| Tamarindus indica | A | 11 | 14.1 | 7 | 0.84 | 11 | 0.72 |
| Tamarindus indica | B | 13 | 13.6 | 7 | 0.81 | 13 | 0.72 |
| Teclea nobilis | A | 8 | 12.2 | 5 | 0.90 | 8 | 0.74 |
| Teclea nobilis | B | 7 | 12.4 | 5 | 0.88 | 7 | 0.75 |
| Terminalia glaucescens | A | 64 | 14.3 | 45 | 0.76 | 64 | 0.69 |
| Terminalia glaucescens | B | 56 | 14.5 | 45 | 0.69 | 57 | 0.66 |
| Terminalia ivorensis | A | 21 | 14.9 | 9 | 0.76 | 21 | 0.67 |
| Terminalia ivorensis | B | 17 | 15.2 | 8 | 0.67 | 18 | 0.63 |
| Terminalia spinosa | A | 1 | 12.9 | 1 | 0.51 | 1 | 0.47 |
| Terminalia spinosa | B | 1 | 12.2 | 1 | 0.55 | 1 | 0.53 |
| Theobroma cacao | A | 5 | 16.0 | 1 | 0.44 | 5 | 0.50 |
| Theobroma cacao | B | 2 | 15.7 | 1 | 0.42 | 2 | 0.44 |
| Thevetia peruviana | A | 6 | 13.2 | 2 | 0.68 | 6 | 0.62 |
| Thevetia peruviana | B | 3 | 14.5 | 2 | 0.68 | 3 | 0.61 |
| Toona serrata | A | 8 | 13.8 | 4 | 0.44 | 8 | 0.49 |
| Toona serrata | B | 5 | 14.0 | 4 | 0.43 | 6 | 0.44 |
| Trema orientalis | A | 27 | 15.2 | 10 | 0.37 | 27 | 0.51 |
| Trema orientalis | B | 13 | 16.6 | 10 | 0.36 | 13 | 0.48 |
| Vernonia amygdalina | A | 60 | 16.5 | 32 | 0.63 | 60 | 0.56 |
| Vernonia amygdalina | B | 44 | 16.6 | 32 | 0.58 | 45 | 0.52 |
| Vitex doniana | A | 25 | 14.1 | 18 | 0.49 | 25 | 0.47 |
| Vitex doniana | B | 25 | 15.0 | 19 | 0.46 | 25 | 0.46 |
| Vitex fischeri | A | 3 | 14.9 | 1 | 0.66 | 3 | 0.63 |
| Vitex fischeri | B | 3 | 16.1 | 1 | 0.66 | 3 | 0.65 |
| Zizyphus abyssinica | A | 24 | 14.0 | 14 | 0.71 | 24 | 0.65 |
| Zizyphus abyssinica | B | 24 | 14.3 | 14 | 0.65 | 24 | 0.60 |
| Total No / Average | | 4508 | 14.7 | 2670 | 0.61 | 4556 | 0.56 |

# App. L List of Species and Their Densities at Various Moisture ContentsL List of Species and Their Densities at Various Moisture Contents

Sources of data and description of each column are found below. Density figures are in g/cm³.

*Columns A and B:* The source is **Uganda Timbers.** Column A shows density values at 50% moisture content (MC), whereas column B shows density values at 12% MC.

*Columns C and D:* The source is **Indigenous Trees of Uganda.** Column C shows density lower values, whereas column D shows density upper values. All are quoted at air dry conditions.

*Columns E, F, G, and H:* The source is file records from The **Utilization Section** of the Forest Research Office, Forest Department. Column E shows density values at 50% MC, column F shows density lower values, and column G shows density upper values. For columns F and G, moisture content is quoted in column H. Where MC is quoted at air dry conditions (AD), i.e. no figures given, a code AD is filled in.

| BOTANICAL NAME | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Acacia albida | 0.00 | 0.00 | 0.56 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Acacia hockii | 0.00 | 0.00 | 0.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Acacia macrothyrsa | 0.00 | 0.00 | 1.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Acacia sieberiana | 0.00 | 0.00 | 0.72 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Afzelia africana | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 12 |
| Albizia anthelmintica | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 | 12 |
| Albizia ferruginea | 0.00 | 0.54 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 12 |
| Albizia glaberrima | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.53 | 0.00 | 15 |
| Albizia gummifera | 0.00 | 0.48 | 0.54 | 0.61 | 0.00 | 0.54 | 0.61 | 15 |
| Allanblackia kimbelensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.69 | 0.00 | 12 |
| Allophylus africanus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.54 | 0.70 | 12 |
| Alstonia boonei | 0.50 | 0.40 | 0.42 | 0.45 | 0.00 | 0.43 | 0.00 | AD |
| Aningeria adolphi-friederici | 0.00 | 0.00 | 0.45 | 0.54 | 0.00 | 0.45 | 0.54 | 12 |
| Aningeria altissima | 0.66 | 0.50 | 0.00 | 0.00 | 0.69 | 0.51 | 0.00 | 12 |
| Antiaris toxicaria | 0.00 | 0.43 | 0.37 | 0.54 | 0.00 | 0.37 | 0.54 | 12 |
| Baikiaea insignis | 0.00 | 0.80 | 0.00 | 0.00 | 0.00 | 0.75 | 0.83 | AD |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Balanites aegyptiaca | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.77 | 0.80 | 12 |
| Balsamocitrus dawei | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.00 | 12 |
| Beilschmiedia ugandensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 15 |
| Blighia unijugata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.64 | 0.00 | 12 |
| Bosquiea phoberos | 0.67 | 0.50 | 0.00 | 0.00 | 0.00 | 0.54 | 0.59 | 12 |
| Brachylaena hutchinsii | 0.00 | 0.00 | 0.96 | 0.00 | 0.00 | 0.96 | 0.00 | 15 |
| Brachystegia boehmii | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 12 |
| Brachystegia globifera | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 12 |
| Brachystegia spiciformis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 12 |
| Bridelia micrantha | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 12 |
| Bridelia ndellensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.96 | 0.00 | 15 |
| Burkea africana | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 12 |
| Butyrospermum paradoxum | 0.00 | 0.00 | 1.28 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Canarium schweinfurthii | 0.59 | 0.45 | 0.00 | 0.00 | 0.00 | 0.50 | 0.61 | 12 |
| Carapa grandiflora | 0.91 | 0.67 | 0.64 | 0.00 | 0.00 | 0.64 | 0.00 | 12 |
| Casearia battiscombei | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.53 | 0.58 | AD |
| Casearia engleri | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.59 | 0.00 | 12 |
| Cassipourea elliotii | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.74 | 0.00 | 12 |
| Cassipourea malosana | 0.99 | 0.74 | 0.00 | 0.00 | 0.00 | 0.67 | 0.83 | 12 |
| Catha edulis | 0.00 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Celtis adolfi-fridericii | 0.00 | 0.00 | 0.62 | 0.00 | 0.00 | 0.80 | 0.00 | 12 |
| Celtis africana | 0.00 | 0.00 | 0.77 | 0.00 | 0.00 | 0.77 | 0.00 | AD |
| Celtis durandii | 0.00 | 0.56 | 0.00 | 0.00 | 0.00 | 0.56 | 0.00 | 12 |
| Celtis mildbraedii | 0.00 | 0.00 | 0.77 | 0.00 | 0.00 | 0.77 | 0.00 | 12 |
| Celtis zenkeri | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 12 |
| Chlorophora excelsa | 0.82 | 0.66 | 0.00 | 0.00 | 0.00 | 0.64 | 0.88 | 12 |
| Chrysophyllum albidum | 0.00 | 0.72 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 15 |
| Chrysophyllum gorungosanum | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.72 | 0.00 | 12 |
| Chrysophyllum perpulchrum | 0.95 | 0.70 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | 12 |
| Cistanthera papaverifera | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.75 | 0.00 | 12 |
| Cola gigantea | 0.00 | 0.00 | 0.56 | 0.00 | 0.00 | 0.59 | 0.00 | 12 |
| Cordia africana | 0.00 | 0.00 | 0.42 | 0.46 | 0.00 | 0.42 | 0.00 | AD |
| Cordia millenii | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 | 0.00 | 12 |
| Crossopteryx febrifuga | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Croton macrostachys | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.61 | 0.00 | 15 |
| Croton megalocarpus | 0.96 | 0.70 | 0.70 | 0.75 | 0.00 | 0.70 | 0.75 | 12 |
| Croton oxypetalus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.46 | 0.00 | 12 |
| Cupressus lusitanica | 0.56 | 0.42 | 0.00 | 0.00 | 0.00 | 0.46 | 0.00 | AD |
| Cynometra alexandri | 1.12 | 0.86 | 0.88 | 0.00 | 0.00 | 0.88 | 0.00 | 12 |
| Dalbergia melanoxylon | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.31 | 0.00 | 15 |
| Daniellia oliveri | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | AD |
| Diospyros abyssinica | 0.00 | 0.00 | 0.00 | 0.00 | 1.09 | 0.75 | 0.83 | 12 |
| Diospyros mespiliformis | 0.00 | 0.00 | 0.80 | 1.04 | 0.00 | 0.80 | 1.04 | 15 |
| Dombeya goetzenii | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.58 | 0.75 | AD |
| Dombeya mukole | 0.00 | 0.00 | 0.00 | 0.77 | 0.00 | 0.00 | 0.00 | 0 |
| Drypetes spp | 0.00 | 0.70 | 0.00 | 0.00 | 0.00 | 0.72 | 0.00 | 12 |
| Ekebergia capensis | 0.00 | 0.00 | 0.51 | 0.64 | 0.00 | 0.50 | 0.72 | 12 |
| Entandrophragma angolense | 0.70 | 0.56 | 0.00 | 0.00 | 0.00 | 0.56 | 0.00 | 12 |
| Entandrophragma cylindricum | 0.82 | 0.64 | 0.00 | 0.00 | 0.00 | 0.56 | 0.00 | 12 |
| Entandrophragma excelsum | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.56 | 0.00 | 12 |
| Entandrophragma utile | 0.83 | 0.64 | 0.00 | 0.00 | 0.00 | 0.56 | 0.00 | 12 |
| Eucalyptus saligna | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.00 | AD |
| Fagara macrophylla | 0.90 | 0.67 | 0.59 | 0.74 | 0.90 | 0.67 | 0.00 | 12 |
| Fagaropsis angolensis | 0.00 | 0.00 | 0.64 | 0.67 | 0.00 | 0.67 | 0.00 | 12 |
| Faurea saligna | 0.00 | 0.00 | 0.72 | 0.00 | 0.00 | 0.72 | 0.77 | 12 |
| Ficalhoa laurifolia | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.69 | 0.00 | 0 |
| Funtumia africana | 0.00 | 0.51 | 0.00 | 0.00 | 0.00 | 0.51 | 0.00 | 12 |
| Funtumia elastica | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.51 | 0.00 | 15 |
| Garcinia huillensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.85 | 0.00 | 12 |
| Greenwayodendron suaveolensi | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 | 0.00 | 12 |
| Guarea cedrata | 0.70 | 0.54 | 0.00 | 0.00 | 0.70 | 0.56 | 0.64 | AD |
| Hagenia abbysinica | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.59 | 0.64 | AD |
| Holoptelea grandis | 0.00 | 0.64 | 0.00 | 0.00 | 0.00 | 0.64 | 0.00 | 12 |
| Ilex mitis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 | 12 |
| Juniperus procera | 0.78 | 0.00 | 0.51 | 0.61 | 0.78 | 0.58 | 0.00 | 12 |
| Khaya anthoteca | 0.66 | 0.51 | 0.00 | 0.00 | 0.00 | 0.54 | 0.00 | 12 |
| Khaya senegalensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.77 | 0.00 | 15 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Klainedoxa gabonensis | 0.00 | 0.00 | 0.96 | 1.04 | 0.00 | 0.00 | 0.00 | 0 |
| Lonchocarpus laxiflorus | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.04 | 0.00 | 12 |
| Lovoa swynnertonii | 0.83 | 0.62 | 0.00 | 0.00 | 0.83 | 0.62 | 0.00 | 12 |
| Lovoa trichillioides | 0.00 | 0.00 | 0.56 | 0.59 | 0.00 | 0.56 | 0.59 | AD |
| Macaranga conglome. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 | 0.00 | 12 |
| Macaranga kilimandscharica | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.43 | 0.54 | AD |
| Maesopsis eminii | 0.61 | 0.48 | 0.45 | 0.46 | 0.61 | 0.48 | 0.00 | 12 |
| Manilkara cuneifolia =321 | 0.00 | 0.00 | 1.06 | 0.00 | 0.00 | 0.98 | 1.14 | 12 |
| Markhamia platycalyx | 0.00 | 0.00 | 0.56 | 0.59 | 0.00 | 0.56 | 0.59 | AD |
| Mildraediodendron Exelsum | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.90 | 0.00 | 12 |
| Millettia stuhlmanni | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | AD |
| Mimusops bagshaweii | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 12 |
| Mimusops cuneifolia =316 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | 12 |
| Mimusops heckelli | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.64 | 0.00 | 12 |
| Mitragyna rubrostinelata | 0.00 | 0.00 | 0.54 | 0.00 | 0.00 | 0.54 | 0.00 | 15 |
| Mitragyna stipulosa | 0.69 | 0.54 | 0.46 | 0.70 | 0.00 | 0.46 | 0.70 | 12 |
| Monodora myristica | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.58 | 0.00 | 12 |
| Morus lactea | 0.99 | 0.77 | 0.69 | 0.80 | 0.00 | 0.69 | 0.80 | 12 |
| Neoboutonia macrocalyx | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.37 | 0.58 | 12 |
| Olea welwitschii | 1.04 | 0.80 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 | AD |
| Olinia usambarensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.85 | AD |
| Pachystela brevipes | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.96 | 0.00 | AD |
| Parinari holstii | 0.00 | 0.75 | 0.77 | 0.00 | 0.00 | 0.75 | 0.00 | AD |
| Parkia filicoidea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.45 | 0.51 | 12 |
| Piptadeniastrum africana | 0.85 | 0.72 | 0.00 | 0.00 | 1.12 | 0.70 | 0.00 | 12 |
| Podocarpus dawei | 0.64 | 0.51 | 0.00 | 0.00 | 0.64 | 0.51 | 0.00 | 12 |
| Polyscias fulva | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.35 | 0.42 | 12 |
| Pterygota milbraedii | 0.80 | 0.59 | 0.00 | 0.00 | 0.00 | 0.59 | 0.00 | 12 |
| Pycnanthus angolensis | 0.58 | 0.48 | 0.00 | 0.00 | 0.00 | 0.40 | 0.48 | 12 |
| Ricinodendron africanum | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.19 | 0.00 | 12 |
| Ricinodendron heudelotii | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.26 | 0.32 | 12 |
| Sapium ellipticum | 0.00 | 0.00 | 0.59 | 0.64 | 0.00 | 0.59 | 0.64 | 12 |
| Schrebera aborea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.85 | 0.00 | 12 |
| Schrebera alata | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.78 | 0.83 | 12 |
| Securidaca longipedunculata | 0.00 | 0.00 | 0.88 | 0.00 | 0.00 | 0.00 | 0.00 | 0 |
| Sterculia dawei | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.00 | 12 |
| Strombosia scheffleri | 1.03 | 0.77 | 0.00 | 0.00 | 1.02 | 0.77 | 0.00 | 12 |
| Strychnos mitis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.98 | 12 |
| Symphonia globulifera | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.54 | 0.64 | 12 |
| Syzygium guineense | 0.00 | 0.00 | 0.77 | 0.00 | 0.00 | 0.77 | 0.00 | 12 |
| Tamarindus indica | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | AD |
| Teclea nobilis | 0.00 | 0.00 | 0.80 | 0.85 | 0.00 | 0.80 | 0.85 | 12 |
| Terminalia ivorensis | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01 | 12 |
| Uapaca guinensis | 0.96 | 0.72 | 0.00 | 0.00 | 0.00 | 0.61 | 0.72 | 12 |
| Vitex doniana | 0.00 | 0.00 | 0.85 | 0.00 | 0.00 | 0.85 | 0.00 | 12 |
| Voacanga thoursii | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | AD |
| Warburgia ugandensis | 0.00 | 0.00 | 0.83 | 0.90 | 0.00 | 0.83 | 0.90 | 12 |
| Xylopia eminii | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.88 | 0.00 | 12 |
| Xylopia monospora | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.58 | 0.62 | 12 |
| Zanthoxylum spp | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.62 | 0.00 | 12 |

# App. M Grouping of Species for the Biomass FunctionsM

Grouping of Species for the Biomass Functions

| Group Number | Test-tree species represented in the biomass function: Spec.code | No of trees | | Grouping of remaining non-test-tree species: Spec.code |
|---|---|---|---|---|
| 1 Acacia | 3 | 196 | | 330 |
| | 13 | 1 | | |
| | 15 | 16 | | |
| | 169 | 3 | | |
| | 327 | 4 | | |
| | 328 | 11 | | |
| | 329 | 4 | | |
| | 345 | 4 | 239 | |
| 2 Albizia | 1 | 80 | | 136, 163, 167, 173, 235, |
| | 11 | 1 | | 236, 237, 238, 239, 242, |
| | 18 | 1 | | 266, 268, 269, 280, 316, |
| | 65 | 1 | | 319, 320, 321, 323, 355, |
| | 66 | 2 | | 361 |
| | 88 | 7 | | |
| | 95 | 1 | | |
| | 139 | 1 | | |
| | 201 | 36 | | |
| | 218 | 58 | | |
| | 257 | 15 | | |
| | 333 | 1 | 204 | |
| 3 Bridelia | 54 | 59 | | 91, 146, 249, 250, 336 |
| | 288 | 13 | 72 | |
| 4 Cassia | 4 | 33 | | 39, 181, 271, 313, 318, |
| | 145 | 17 | | 356 |
| | 222 | 12 | 62 | |
| 5 Celtis | 38 | 18 | | 110, 137, 155, 162, 164, |
| | 123 | 11 | | 206, 227, 240, 241, 243, |
| | 132 | 1 | | 258, 259, 260, 261, 262, |
| | 199 | 3 | 33 | 263, 289, 297, 322, 332, |
| | | | | 338 |
| 6 Chlorophora | 35 | 30 | | 86, 111, 176, 202, 228, |
| | 61 | 1 | | 232, 233, 234, 273, 274, |
| | 107 | 1 | | 275, 276, 277, 281, 284, |
| | 108 | 1 | | 285, 286, 290, 299, 304, |

| | | | |
|---|---|---|---|
| 109 | 19 | | 311, 337, 341 |
| 112 | 2 | | |
| 117 | 2 | | |
| 119 | 4 | | |
| 160 | 5 | | |
| 161 | 5 | 70 | |

| Group Number | Test-tree species represented in the biomass function: Spec.code | No of trees | | Grouping of remaining non-test-tree species: Spec.code |
|---|---|---|---|---|
| 7 Combretum | 29 | 93 | | 165, 177 |
| | 63 | 24 | | |
| | 105 | 4 | | |
| | 198 | 1 | | |
| | 204 | 28 | | |
| | 305 | 21 | 171 | |
| 8 Cypress/pine | 17 | 1 | | 43, 126, 192, 211, 248 |
| | 57 | 9 | 10 | |
| 9 Erythrina | 24 | 91 | | 215, 300 |
| | 127 | 20 | 111 | |
| 10 Eucalyptus | 19 | 85 | 85 | |
| 11 Euphorbia | 40 | 20 | | 106, 358 |
| | 344 | 1 | 21 | |
| 12 Ficus natalensis | 8 | 64 | 64 | |
| 13 Ficus spp. | 28 | 28 | | 64, 182, 184, 207, 278 |
| | 36 | 24 | | |
| | 69 | 21 | | |
| | 79 | 9 | | |
| | 96 | 9 | | |
| | 247 | 8 | 99 | |
| 14 Funtumia | 92 | 39 | 39 | 246, 279 |
| 15 Grewia | 104 | 91 | | 134 |
| | 347 | 5 | 96 | |
| 16 Lannea | 141 | 66 | 66 | 190, 354, 360 |
| 17 Maesopsis | 33 | 25 | | 113, 244, 272, 302, 325, |
| | 37 | 13 | | 326, 334, 340 |
| | 45 | 17 | | |
| | 101 | 7 | 62 | |
| 18 Mangifera/ Artocarpus | 2 | 64 | | 208, 210, 245, 350 |
| | 6 | 25 | | |
| | 30 | 7 | 96 | |
| 19 Markhamia | 7 | 121 | 121 | |
| 20 Maytenus | 115 | 38 | 38 | 291, 292 |

| Group Number | Test-tree species represented in the biomass function: Spec.code | No of trees | | Grouping of remaining non-test-tree species: Spec.code |
|---|---|---|---|---|
| 21 Persea | 9 | 27 | | 31, 46, 81 |
| | 21 | 13 | | |
| | 23 | 15 | 55 | |
| 22 Piliostigma | 153 | 71 | 71 | 99, 121, 205, 265, 365 |
| 23 Rhus | 55 | 84 | | 128 |
| | 131 | 15 | | |
| | 357 | 1 | 100 | |
| 24 Sapium | 5 | 50 | | 287 |
| | 90 | 4 | 54 | |
| 25 Securidaca/ Securinega | 56 | 11 | | |
| | 60 | 14 | | |
| | 148 | 18 | 43 | |
| 26 Spathodea | 26 | 72 | | 97, 166, 251, 264, 296, 339, 342, 362 |
| | 83 | 1 | | |
| | 114 | 2 | | |
| | 138 | 17 | | |
| | 254 | 2 | 94 | |
| 27 Stereospermum | 49 | 9 | | |
| | 84 | 49 | 58 | |
| 28 Strychnos | 129 | 22 | | 89, 130, 142, 154, 188, 298 |
| | 317 | 3 | 25 | |
| 29 Syzygium | 70 | 9 | | 293, 294, 306 |
| | 295 | 12 | 21 | |
| 30 Terminalia | 103 | 57 | | 301, 359 |
| | 331 | 1 | | |
| | 346 | 15 | 73 | |
| 31 Vernonia | 50 | 77 | | 100, 120, 133, 144, 180, 189, 267, 270, 314, 315 |
| | 122 | 1 | 78 | |
| 32 Vitex | 73 | 25 | | 41, 51, 226, 252, 253, 283, 303, 310, 324, 351 |
| | 75 | 2 | 27 | |
| 33 Cussonia | 93 | 49 | 49 | |
| 34 Antiaris | 10 | 1 | | 255, 256 |
| | 14 | 9 | | |
| | 27 | 49 | 59 | |

| Group Number | Test-tree species represented in the biomass function: Spec.code | No of trees | Total | Grouping of remaining non-test-tree species: Spec.code |
|---|---|---|---|---|
| 35 Annona | 44 | 33 | | |
| | 348 | 1 | 34 | |
| 36 Gardenia | 67 | 29 | | 78, 140, 224 |
| | 116 | 1 | 30 | |
| 37 Ornamentals/ Shrubs | 20 | 7 | | 12, 16, 22, 25, 32, |
| | 34 | 7 | | 42, 48, 52, 53, 58, |
| | 47 | 18 | | 59, 62, 68, 72, 74, |
| | 71 | 7 | | 76, 80, 82, 85, 87, |
| | 77 | 4 | | 94, 98, 102, 118, 124, |
| | 147 | 1 | | 125, 135, 143, 149, 150, |
| | 171 | 12 | | 151, 152, 156, 157, 158, |
| | 175 | 2 | | 159, 168, 170, 172, 174, |
| | 200 | 1 | | 178, 179, 183, 185, 186, |
| | 352 | 1 | 60 | 187, 191, 193, 194, 195, |
| | | | | 196, 197, 212, 213, 214, |
| | | | | 216, 217, 219, 220, 221, |
| | | | | 223, 225, 230, 231, 282, |
| | | | | 307, 308, 309, 312, 335, |
| | | | | 343, 349, 353, 363, 364, |
| | | | | 366, 367, 368 |
| 38 Steganotaenia | 203 | 15 | | |
| | 209 | 15 | | |
| | 229 | 1 | 31 | |

# App. N Sub-County Areas in Square km Inside and Outside the Project AreasN Sub-County Areas in Square km Inside and Outside the Project Areas

| PROJECT AREA | DISTRICT | COUNTY | SUB-COUNTY | OUTSIDE SQ KM | INSIDE SQ KM | TOTAL SQ KM | PERCENT INSIDE |
|---|---|---|---|---|---|---|---|
| ARUA | ARUA | AYIVU | OLUVU | 88.13 | 47.50 | 135.63 | 35.0 |
| | | | NYADRAI | 48.13 | 6.88 | 55.00 | 12.5 |
| | | | KIJOMORO | 0.00 | 69.38 | 69.38 | 100.0 |
| | | | KATRINI | 0.00 | 63.13 | 63.13 | 100.0 |
| | | | AII-VU | 74.38 | 42.50 | 116.88 | 36.4 |
| | | | AROI | 0.00 | 83.13 | 83.13 | 100.0 |
| | | | OLUKO | 20.00 | 117.50 | 137.50 | 85.5 |
| | | | ADUMI | 55.00 | 68.75 | 123.75 | 55.6 |
| | | | ARUA TOWNSHIP | 0.00 | 11.25 | 11.25 | 100.0 |
| | | | PAJULU | 0.00 | 68.75 | 68.75 | 100.0 |
| | | | YIVU | 109.38 | 5.63 | 115.00 | 4.9 |
| | | TEREGO | BILEAFE | 466.88 | 76.88 | 543.75 | 14.1 |
| | | VURRA | ARIVU | 78.13 | 94.38 | 172.50 | 54.7 |
| | | | VURRA | 22.50 | 105.63 | 128.13 | 82.4 |
| | | | AJIA | 100.63 | 166.88 | 267.50 | 62.4 |
| Arua Project Area - Total | | | | | 1028.13 | | |

| PROJECT AREA | DISTRICT | COUNTY | SUB-COUNTY | OUTSIDE SQ KM | INSIDE SQ KM | TOTAL SQ KM | PERCENT INSIDE |
|---|---|---|---|---|---|---|---|
| JINJA | IGANGA | BUNYA | IMMANYIRO | 221.25 | 154.38 | 375.63 | 41.1 |
| | | | BAITAMBOGWE | 40.63 | 146.88 | 187.50 | 78.3 |
| | | | WAIBUGA | 73.75 | 6.25 | 80.00 | 7.8 |
| TOTAL PROJECT AREA INSIDE IGANGA DISTRICT | | | | | 307.50 | | |
| JINJA | JINJA | BUTEMBE | BUSEDE | 66.88 | 84.38 | 151.25 | 55.8 |
| | | | JINJA MUNICIP | 0.00 | 53.13 | 53.13 | 100.0 |
| | | | KAKIRA | 0.00 | 100.00 | 100.00 | 100.0 |
| | | | MAFUBIRA | 0.00 | 62.50 | 62.50 | 100.0 |
| | | KAGOMA | BUDONDO | 0.00 | 91.25 | 91.25 | 100.0 |
| | | | BUTAGAYA | 87.50 | 24.38 | 111.88 | 21.8 |
| | | | BUWENGE | 69.38 | 37.50 | 106.88 | 35.1 |
| | | | BUYENGO | 61.25 | 10.63 | 71.88 | 14.8 |
| TOTAL PROJECT AREA INSIDE JINJA DISTRICT | | | | | 463.75 | | |
| JINJA | MUKONO | BUIKWE | NYENGA | 0.00 | 215.63 | 215.63 | 100.0 |
| | | | NGOGWE | 460.63 | 6.88 | 467.50 | 1.5 |
| | | | BUIKWE | 142.50 | 130.00 | 272.50 | 47.7 |
| | | | NAJJEMBE | 60.63 | 213.13 | 273.75 | 77.9 |
| | | | WAKISI | 0.00 | 103.75 | 103.75 | 100.0 |
| | | | NJERU | 0.00 | 19.38 | 19.38 | 100.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | BUVUMA | BUSAMUZI | 120.63 | 96.25 | 216.88 | 44.4 |
| | | NTENJERU | KANGULUMIRA | 76.25 | 31.25 | 107.50 | 29.1 |

TOTAL PROJECT AREA INSIDE MUKONO DISTRICT 816.25

TOTAL AREA JINJA PROJECT AREA 1587.50

| PROJECT AREA | DISTRICT | COUNTY | SUB-COUNTY | OUTSIDE SQ KM | INSIDE SQ KM | TOTAL SQ KM | PERCENT INSIDE |
|---|---|---|---|---|---|---|---|
| KABALE | KABALE | RUBANDA | IKUMBA | 164.38 | 38.75 | 203.13 | 19.1 |
| | | | MUKO | 136.88 | 20.63 | 157.50 | 13.1 |
| | | | HAMURWA | 18.75 | 96.88 | 115.63 | 83.8 |
| | | | BUBALE | 14.38 | 130.00 | 144.38 | 90.0 |
| | | NDORWA | KITUMBA | 13.75 | 28.75 | 42.50 | 67.6 |
| | | | RUBAYA | 100.00 | 14.38 | 114.38 | 12.6 |
| | | | KAMUGANGUZI | 15.00 | 69.38 | 84.38 | 82.2 |
| | | | BUHARA | 26.25 | 48.13 | 74.38 | 64.7 |
| | | | KABALE MUNICI | 0.00 | 34.38 | 34.38 | 100.0 |
| | | | KYANAMIRA | 0.00 | 64.38 | 64.38 | 100.0 |
| | | | MAZIBA | 95.00 | 40.63 | 135.63 | 30.0 |
| | | | KAHARO | 0.00 | 66.25 | 66.25 | 100.0 |
| | | RUKIGA | KAMWEZI | 128.75 | 15.63 | 144.38 | 10.8 |
| | | | BUKINDA | 8.13 | 53.75 | 61.88 | 86.9 |
| | | | RWAMUCUCU | 10.63 | 98.13 | 108.75 | 90.2 |
| | | | KASHAMBYA | 11.88 | 112.50 | 124.38 | 90.5 |

TOTAL PROJECT AREA INSIDE KABALE DISTRICT 932.50

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| KABALE | RUKUNGIRI | RUBABO | NYAKISHENYI | 123.13 | 5.63 | 128.75 | 4.4 |
| | | | NYARUSHANJE | 153.75 | 14.38 | 168.13 | 8.6 |

TOTAL PROJECT AREA INSIDE RUKUNGIRI DISTRICT 20.00

TOTAL AREA KABALE PROJECT AREA 952.50

| PROJECT AREA | DISTRICT | COUNTY | SUB-COUNTY | OUTSIDE SQ KM | INSIDE SQ KM | TOTAL SQ KM | PERCENT INSIDE |
|---|---|---|---|---|---|---|---|
| KAMPALA | MUKONO | MUKONO | NTENJERU | 246.88 | 393.75 | 640.63 | 61.5 |
| | | | NAKISONGA | 64.38 | 140.00 | 204.38 | 68.5 |
| | | | A | 0.00 | 58.13 | 58.13 | 100.0 |
| | | | B | 0.00 | 103.13 | 103.13 | 100.0 |
| | | | GOMA | 0.00 | 103.75 | 103.75 | 100.0 |
| | | | KYAMPISI | 0.00 | 134.38 | 134.38 | 100.0 |
| | | NAKIFUMA | NABBALE | 22.50 | 86.25 | 108.75 | 79.3 |
| | | | KASAWO | 148.75 | 9.38 | 158.13 | 5.9 |
| | | | NAKIFUMA | 36.88 | 70.63 | 107.50 | 65.7 |
| | | | NAGOJJE | 84.38 | 14.38 | 98.75 | 14.6 |

TOTAL PROJECT AREA INSIDE MUKONO DISTRICT 1113.75

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| KAMPALA | MPIGI | BUSIRO | KATABI | 247.50 | 135.63 | 383.13 | 35.4 |
| | | | ENTEBBE MUNIC | 187.50 | 73.13 | 260.63 | 28.1 |
| | | | KASANJE | 535.63 | 124.38 | 660.00 | 18.8 |
| | | | SISA | 6.25 | 159.38 | 165.63 | 96.2 |
| | | | MAKINDYE | 5.00 | 87.50 | 92.50 | 94.6 |
| | | | NSANGI | 0.00 | 108.13 | 108.13 | 100.0 |
| | | | WAKISO | 0.00 | 200.63 | 200.63 | 100.0 |
| | | | KAKIRI | 45.00 | 132.50 | 177.50 | 74.6 |
| | | | MASULITA | 19.38 | 95.63 | 115.00 | 83.2 |
| | | KYADONDO | GOMBE | 0.00 | 145.00 | 145.00 | 100.0 |
| | | | KYAMBOGO | 0.00 | 113.75 | 113.75 | 100.0 |
| | | | NANGABO | 0.00 | 98.13 | 98.13 | 100.0 |
| | | | KIRA | 0.00 | 92.50 | 92.50 | 100.0 |
| | | | NABWERO | 0.00 | 41.88 | 41.88 | 100.0 |
| | | | KAMPALA CITY | 0.00 | 188.75 | 188.75 | 100.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | MAWOKOTA | MUDUMA | 86.25 | 75.00 | 161.25 | 46.5 |
| | | | KIRINGENTE | 0.00 | 71.88 | 71.88 | 100.0 |
| | | | MPIGI | 118.75 | 36.25 | 155.00 | 23.4 |
| TOTAL PROJECT AREA INSIDE MPIGI DISTRICT | | | | | 1980.00 | | |
| KAMPALA | LUWERO | WABUSANA | KALAGALA | 91.88 | 46.25 | 138.13 | 33.5 |
| | | KATIKAMU | MAKULUBITA | 123.75 | 46.88 | 170.63 | 27.5 |
| | | | NYIMBWA | 66.88 | 28.13 | 95.00 | 29.6 |
| | | | BOMBO TOWN | 2.50 | 6.88 | 9.38 | 73.3 |
| TOTAL PROJECT AREA INSIDE LUWERO DISTRICT | | | | | 128.13 | | |
| TOTAL AREA KAMPALA PROJECT AREA | | | | | 3221.88 | | |

| PROJECT AREA | DISTRICT | COUNTY | SUB-COUNTY | OUTSIDE SQ KM | INSIDE SQ KM | TOTAL SQ KM | PERCENT INSIDE |
|---|---|---|---|---|---|---|---|
| KAMULI | KAMULI | BUGABULA | NAMASAGALI | 201.25 | 8.13 | 209.38 | 3.9 |
| | | | NABWIGULU | 141.88 | 3.13 | 145.00 | 2.2 |
| | | | BALAWOLI | 70.63 | 287.50 | 358.13 | 80.3 |
| | | BUDYOPE | BUGAYA | 103.75 | 196.88 | 300.63 | 65.5 |
| | | | KAGULU | 319.38 | 95.00 | 414.38 | 22.9 |
| | | | BUYENDE | 0.00 | 416.88 | 416.88 | 100.0 |
| | | | NKONDO | 70.00 | 185.63 | 255.63 | 72.6 |
| | | | KIDERA | 339.38 | 75.63 | 415.00 | 18.2 |
| TOTAL PROJECT AREA INSIDE KAMULI DISTRICT | | | | | 1268.75 | | |
| KAMULI | SOROTI | KASILO | PINGIRE | 518.75 | 15.63 | 534.38 | 2.9 |
| TOTAL PROJECT AREA INSIDE SOROTI DISTRICT | | | | | 15.63 | | |
| TOTAL AREA KAMULI PROJECT AREA | | | | | 1284.38 | | |

| PROJECT AREA | DISTRICT | COUNTY | SUB-COUNTY | OUTSIDE SQ KM | INSIDE SQ KM | TOTAL SQ KM | PERCENT INSIDE |
|---|---|---|---|---|---|---|---|
| KUMI | KUMI | KUMI | KUMI | 1.25 | 189.38 | 190.63 | 99.3 |
| | | | ONGINO | 93.13 | 260.63 | 353.75 | 73.7 |
| | | | ATUTUR | 0.00 | 103.75 | 103.75 | 100.0 |
| | | | NYERO | 0.00 | 110.63 | 110.63 | 100.0 |
| | | | KANYUM | 5.63 | 144.38 | 150.00 | 96.3 |
| | | | MUKONGORO | 60.00 | 165.00 | 225.00 | 73.3 |
| | | NGORA | NGORA | 83.13 | 73.75 | 156.88 | 47.0 |
| | | | KOBWIN | 178.13 | 41.88 | 220.00 | 19.0 |
| | | | KAPIR | 83.75 | 92.50 | 176.25 | 52.5 |
| | | | MUKURA | 8.75 | 145.00 | 153.75 | 94.3 |
| | | BUKEDEA | BUKEDEA | 51.25 | 90.00 | 141.25 | 63.7 |
| | | | KIDONGOLE | 89.38 | 0.63 | 90.00 | 0.7 |
| | | | KOLIR | 254.38 | 8.13 | 262.50 | 3.1 |
| | | | MALERA | 238.13 | 148.13 | 386.25 | 38.3 |
| TOTAL PROJECT AREA INSIDE KUMI DISTRICT | | | | | 1573.75 | | |
| KUMI | PALLISA | PALLISA | KAMUGE | 61.25 | 12.50 | 73.75 | 16.9 |
| TOTAL PROJECT AREA INSIDE PALLISA DISTRICT | | | | | 12.50 | | |
| KUMI | SOROTI | KATAKWI | MAGORO | 325.63 | 1.25 | 326.88 | 0.4 |

| | |
|---|---|
| TOTAL PROJECT AREA INSIDE SOROTI DISTRICT | 1.25 |
| TOTAL AREA KUMI PROJECT AREA | 1587.50 |

| PROJECT AREA | DISTRICT | COUNTY | SUB-COUNTY | OUTSIDE SQ KM | INSIDE SQ KM | TOTAL SQ KM | PERCENT INSIDE |
|---|---|---|---|---|---|---|---|
| MBALE | MBALE | BUBULO | BUMBO | 109.38 | 3.13 | 112.50 | 2.8 |
| | | | BUTIRU | 83.13 | 8.75 | 91.88 | 9.5 |
| | | | BUBUTU | 74.38 | 5.00 | 79.38 | 6.3 |
| | | | BUGOBERO | 40.00 | 52.50 | 92.50 | 56.8 |
| | | | BUWAGOGO | 0.00 | 50.63 | 50.63 | 100.0 |
| | | | BUPOTO | 3.13 | 45.63 | 48.75 | 93.6 |
| | | | BUWABWALA | 94.38 | 25.00 | 119.38 | 20.9 |
| | | MANJIYA | BUBIITA | 88.13 | 8.13 | 96.25 | 8.4 |
| | | | BUKIGAI | 0.00 | 24.38 | 24.38 | 100.0 |
| | | | BUDUDA | 0.00 | 35.00 | 35.00 | 100.0 |
| | | | BUSAIKA | 3.75 | 28.75 | 32.50 | 88.5 |
| | | | BULUCHEKE | 80.63 | 2.50 | 83.13 | 3.0 |
| | | BUDADIRI | BUSULANI | 31.25 | 46.25 | 77.50 | 59.7 |
| | | | BUYOBO | 0.00 | 69.38 | 69.38 | 100.0 |
| | | | BUWALASI | 0.00 | 80.00 | 80.00 | 100.0 |
| | | | BUMASIFA | 92.50 | 6.25 | 98.75 | 6.3 |
| | | | BUHUGU | 6.25 | 80.00 | 86.25 | 92.8 |
| | | | N | 5.00 | 23.75 | 28.75 | 82.6 |
| | | BULAMBULI | BULAGO | 94.38 | 21.88 | 116.25 | 18.8 |
| | | | BUGINYANYA | 83.75 | 0.63 | 84.38 | 0.7 |
| | | | BUYEMBE | 88.13 | 2.50 | 90.63 | 2.8 |
| | | | SISIYI | 26.88 | 6.25 | 33.13 | 18.9 |
| | | BUNGOKHO | NAKALOKE | 0.00 | 71.25 | 71.25 | 100.0 |
| | | | BUNGOKHO | 0.00 | 98.75 | 98.75 | 100.0 |
| | | | BUFUMBO | 0.00 | 61.25 | 61.25 | 100.0 |
| | | | WANALE | 0.00 | 29.38 | 29.38 | 100.0 |
| | | | BUSOBA | 0.00 | 64.38 | 64.38 | 100.0 |
| | | | BUKIENDE | 0.00 | 80.63 | 80.63 | 100.0 |
| | | | BUSIU | 14.38 | 68.75 | 83.13 | 82.7 |
| | | | MBALE MUNICIP | 0.00 | 25.00 | 25.00 | 100.0 |
| TOTAL PROJECT AREA INSIDE MBALE DISTRICT | | | | | 1125.63 | | |
| MBALE | PALISA | KIB.BUDAKA | KAKORO | 3.75 | 55.00 | 58.75 | 93.6 |
| | | | KABWANGASI | 0.00 | 61.25 | 61.25 | 100.0 |
| | | | KAMONKOLI | 0.00 | 66.88 | 66.88 | 100.0 |
| | | | KACHONGA | 0.00 | 84.38 | 84.38 | 100.0 |
| | | | MAZIMASA | 0.00 | 91.25 | 91.25 | 100.0 |
| | | | LYAMA | 68.75 | 5.63 | 74.38 | 7.6 |
| | | | BUDAKA | 36.88 | 18.75 | 55.63 | 33.7 |
| | | | NABOWA | 3.75 | 58.75 | 62.50 | 94.0 |
| | | | IKIKI | 10.00 | 84.38 | 94.38 | 89.4 |
| TOTAL PROJECT AREA INSIDE PALISA DISTRICT | | | | | 526.25 | | |
| MBALE | TORORO | BUNYOLE | BUTALEJA | 141.88 | 51.88 | 193.75 | 26.8 |
| | | KISOKO | PAYA | 117.50 | 3.13 | 120.63 | 2.6 |
| | | | MOLO | 76.88 | 18.75 | 95.63 | 19.6 |
| TOTAL PROJECT AREA INSIDE TORORO DISTRICT | | | | | 73.75 | | |
| MBALE | KUMI | BUKEDEA | KIDONGOLE | 48.75 | 41.25 | 90.00 | 45.8 |
| | | | BUKEDEA | 134.38 | 6.88 | 141.25 | 4.9 |
| | | | KACHUMBALA | 13.75 | 138.13 | 151.88 | 90.9 |
| | | | KOLIR | 243.13 | 18.13 | 261.25 | 6.9 |
| TOTAL PROJECT AREA INSIDE KUMI DISTRICT | | | | | 204.38 | | |

TOTAL AREA MBALE PROJECT AREA 1930.00

| PROJECT AREA | DISTRICT | COUNTY | SUB-COUNTY | OUTSIDE SQ KM | INSIDE SQ KM | TOTAL SQ KM | PERCENT INSIDE |
|---|---|---|---|---|---|---|---|
| MBARARA | MBARARA | ISINGIRO | BIRERE | 236.25 | 180.63 | 416.88 | 43.3 |
| | | KASHARI | BUBAARE | 41.25 | 153.75 | 195.00 | 78.8 |
| | | | KAKIIKA | 4.38 | 121.25 | 125.63 | 96.5 |
| | | | RUBAYA | 122.50 | 156.88 | 279.38 | 56.2 |
| | | | RWANYAMUHEMBE | 127.50 | 51.25 | 178.75 | 28.7 |
| | | NYABUSHOZI | LAKE MBURO | 499.38 | 8.13 | 507.50 | 1.6 |
| | | | SANGA | 405.63 | 1.88 | 407.50 | 0.5 |
| | | RWAMPARA | BUGABA | 160.00 | 16.88 | 176.88 | 9.5 |
| | | | NDEIJA | 157.50 | 0.63 | 158.13 | 0.4 |
| | | | NYAKAYOJO | 25.00 | 126.88 | 151.88 | 83.5 |
| | | | RUGANDO | 26.25 | 100.63 | 126.88 | 79.3 |

TOTAL AREA MBARARA PROJECT AREA 918.75

| PROJECT AREA | DISTRICT | COUNTY | SUB-COUNTY | OUTSIDE SQ KM | INSIDE SQ KM | TOTAL SQ KM | PERCENT INSIDE |
|---|---|---|---|---|---|---|---|
| MOROTO | MOROTO | BOKORA | LOTOME | 329.38 | 103.75 | 433.13 | 24.0 |
| | | | MATANY | 566.88 | 40.63 | 607.50 | 6.7 |
| | | | NGOLERIET | 15.00 | 150.00 | 165.00 | 90.9 |
| | | | LOPEI | 747.50 | 5.63 | 753.13 | 0.7 |
| | | MATHENIKO | RUPA | 1635.00 | 475.63 | 2110.63 | 22.5 |
| | | | KATIKEKILE | 506.88 | 314.38 | 821.25 | 38.3 |
| | | | NADUNGET | 266.88 | 325.00 | 591.88 | 54.9 |
| | | PIAN | LORENGEDWAR | 358.13 | 72.50 | 430.63 | 16.8 |

TOTAL AREA MOROTO PROJECT AREA 1487.50

# App. O Population Figures for the relevant Project Areas broken down to Sub-County LevelO Population Figures for the relevant Project Areas broken down to Sub-County Level

**PROJECT AREA: ARUA**

| | | | POPULATION | | RATIO | POPULATION |
|---|---|---|---|---|---|---|
| DISTRICT: | | ARUA | SUB-COUNTY | COUNTY | AREA INSIDE | INSIDE PROJ.AREA |
| County | 2 | ARUA MUNICIPALITY | | 20907 | | |
| Sub-County | 1 | ARUA HILL | 7256 | | 1 | 7256 |
| Sub-County | 2 | OLI RIVER | 13651 | | 1 | 13651 |
| County | | AYIVU | | 110745 | | |
| Sub-County | 1 | ADUMI | 26458 | | 0.556 | 14711 |
| Sub-County | 2 | AROI | 29321 | | 1 | 29321 |
| Sub-County | 3 | OLUKO | 33251 | | 0.855 | 28430 |
| Sub-County | 4 | PAJULU | 21715 | | 1 | 21715 |
| County | 6 | MARACHA | | 88532 | | |
| Sub-County | 1 | KIJOMORO | 17962 | | 1 | 17962 |
| Sub-County | 2 | NYADRI | 16388 | | 0.125 | 2049 |
| Sub-County | 4 | OLUVU | 30557 | | 0.35 | 10695 |
| Sub-County | 5 | YIVU | 23625 | | 0.049 | 1158 |
| County | 7 | TEREGO | | 59444 | | |
| Sub-County | 1 | AII-VU/AJIVU | 22276 | | 0.364 | 8108 |
| Sub-County | 2 | BELEAFE | 18437 | | 0.141 | 2600 |
| Sub-County | 3 | KATRINI | 18731 | | 1 | 18731 |
| County | 8 | VURRA | | 42193 | | |
| Sub-County | 1 | AJIA | 13464 | | 0.624 | 8402 |
| Sub-County | 2 | ARIVU | 9998 | | 0.547 | 5469 |
| Sub-County | 4 | VURRA | 18731 | | 0.824 | 15434 |
| TOTAL ARUA PROJECT AREA | | | | | | 205690 |

**PROJECT AREA: JINJA**

| | | | | | | |
|---|---|---|---|---|---|---|
| DISTRICT: | | IGANGA | | | | |
| County | 3 | BUNYA | | 84976 | | |
| Sub-County | 1 | BAITAMBOGWE | 40562 | | 0.7 | 28393 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sub-County | 3 | IMANYIRO | 44414 | | 0.3 | 13324 |
| | | | | | | |
| County | 6 | LUUKA | | 20592 | | |
| Sub-County | 7 | WAIBUGA | 20592 | | 0.078 | 1606 |
| | | | | | | |
| DISTRICT: | | JINJA | | | | |
| | | | | | | |
| County | 1 | BUTEMBE | | 97051 | | |
| Sub-County | 1 | BUSEDDE | 23277 | | 0.558 | 12989 |
| Sub-County | 2 | KAKIRA | 24601 | | 1 | 24601 |
| Sub-County | 3 | MAFUBIRA | 49173 | | 1 | 49173 |
| | | | | | | |
| County | 2 | JINJA MUNICIPALITY | | 59058 | | |
| Sub-County | 1 | CENTRAL JINJA | 26664 | | 1 | 26664 |
| Sub-County | 2 | KIMAKA | 13985 | | 1 | 13985 |
| Sub-County | 3 | MASESE/WALUKUBA | 18409 | | 1 | 18409 |
| | | | | | | |
| County | 3 | KAGOMA | | 126507 | | |
| Sub-County | 1 | BUDONDO | 33773 | | 1 | 33773 |
| Sub-County | 2 | BUTAGAYA | 33600 | | 0.218 | 7325 |
| Sub-County | 3 | BUWENGE | 40109 | | 0.351 | 14078 |
| Sub-County | 4 | BUYENGO | 19025 | | 0.148 | 2816 |
| | | | | | | |
| DISTRICT: | | MUKONO | | | | |
| | | | | | | |
| County | 2 | BUIKWE | | 203872 | | |
| Sub-County | 1 | BUIKWE | 43018 | | 0.477 | 20520 |
| Sub-County | 4 | NAJJEMBE | 21984 | | 0.779 | 17126 |
| Sub-County | 5 | NGOGWE | 43857 | | 0.02 | 877 |
| Sub-County | 6 | NJERU TOWN COUNCIL | 37110 | | 1 | 37110 |
| Sub-County | 7 | NYENGA | 29577 | | 1 | 29577 |
| Sub-County | 8 | AKISI | 28326 | | 1 | 28326 |
| | | | | | | |
| County | 3 | BUVUMA ISLANDS | | 4691 | | |
| Sub-County | 2 | BUSAMUZI | 4691 | | 0.35 | 1642 |
| | | | | | | |
| County | 6 | NTENJERU | | 34885 | | |
| Sub-County | 2 | KANGULUMIRA | 34885 | | 0.291 | 10152 |
| TOTAL JINJA PROJECT AREA | | | | | | 392465 |

**PROJECT AREA: KABALE**

| | | | | | | |
|---|---|---|---|---|---|---|
| DISTRICT: | | KABALE | | | | |
| | | | | | | |
| County | 2 | KABALE MUNICIPALITY | | 26878 | | |
| Sub-County | 1 | KABALE CENTRAL | 26878 | | 1 | 26878 |
| | | | | | | |
| County | 3 | NDORWA | | 151687 | | |
| Sub-County | 1 | BUHARA | 24621 | | 0.647 | 15930 |
| Sub-County | 2 | KAHARO | 17420 | | 1 | 17420 |
| Sub-County | 3 | KAMUGANGUZI | 23922 | | 0.822 | 19664 |
| Sub-County | 4 | KITUMBA | 14599 | | 0.676 | 9869 |
| Sub-County | 5 | KYANAMIRA | 18555 | | 1 | 18555 |
| Sub-County | 6 | MAZIBA | 18641 | | 0.3 | 5592 |
| Sub-County | 7 | RUBAYA | 33929 | | 0.126 | 4275 |
| | | | | | | |
| County | 4 | RUBANDA | | 118028 | | |
| Sub-County | 1 | BUBALE | 39441 | | 0.9 | 35497 |
| Sub-County | 3 | HAMURWA | 21911 | | 0.838 | 18361 |
| Sub-County | 4 | IKUMBA | 25676 | | 0.191 | 4904 |
| Sub-County | 5 | MUKO | 31000 | | 0.131 | 4061 |
| | | | | | | |
| County | 5 | RUKIGA | | 85053 | | |
| Sub-County | 1 | BUKINDA | 17973 | | 0.869 | 15619 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sub-County | 2 | KAMWEZI | 22682 | | 0.108 | 2450 |
| Sub-County | 3 | KASHAMBYA | 21739 | | 0.905 | 19674 |
| Sub-County | 4 | RWAMUCUCU | 22659 | | 0.902 | 20438 |
| DISTRICT: | | RUKUNGIRI | | | | |
| County | 2 | RUBABO | | 53493 | | |
| Sub-County | 3 | NYAKISHENYI | 23547 | | 0.044 | 1036 |
| Sub-County | 4 | NYARUSHANJE | 29946 | | 0.086 | 2575 |
| TOTAL KABALE PROJECT AREA | | | | | | 242798 |

**PROJECT AREA: KAMPALA**

| | | | | | | |
|---|---|---|---|---|---|---|
| DISTRICT: | | KAMPALA | | 773500 | | |
| County | | KAMPALA CITY COUNCIL | 773500 | | 1 | 773500 |
| DISTRICT: | | MPIGI | | | | |
| County | 1 | ENTEBBE MUNICIPALITY | | 41414 | | |
| Sub-County | 1 | KATABI/CENTRAL ENTEBBE | 24923 | | 1 | |
| Sub-County | 2 | KIWAFU/KIGUNGU | 16491 | | 1 | 16491 |
| County | 2 | BUSIRO | | 230368 | | |
| Sub-County | 1 | KAKIRI | 25914 | | 0.746 | 19332 |
| Sub-County | 2 | KASANJE | 25074 | | 0.7 | 17552 |
| Sub-County | 3 | KATABI | 33713 | | 1 | 33713 |
| Sub-County | 4 | KIZIBA (MASULIITA) | 14742 | | 0.832 | 12265 |
| Sub-County | 6 | NSANGI (MUKONO) | 44183 | | 1 | 44183 |
| Sub-County | 7 | SSISA | 34253 | | 1 | 34253 |
| Sub-County | 8 | WAKISO | 52489 | | 1 | 52489 |
| County | 5 | KYADONDO | | 270852 | | |
| Sub-County | 1 | GOMBE | 29040 | | 1 | 29040 |
| Sub-County | 2 | KIRA | 64688 | | 1 | 64688 |
| Sub-County | 3 | KYAMBOGO | 20526 | | 1 | 20526 |
| Sub-County | 4 | MAKINDYE | 70786 | | 1 | 70786 |
| Sub-County | 5 | NABWERU | 46794 | | 1 | 46794 |
| Sub-County | 6 | NANGABO | 39018 | | 1 | 39018 |
| County | 6 | MAWOKOTA | | 49919 | | |
| Sub-County | 3 | KIRINGENTE | 10068 | | 1 | 10068 |
| Sub-County | 5 | MPIGI | 21905 | | 0.25 | 5476 |
| Sub-County | 7 | MUDUMA | 17946 | | 0.465 | 8345 |
| DISTRICT: | | MUKONO | | | | |
| County | 4 | MUKONO | | 175343 | | |
| Sub-County | 1 | GOMA | 28002 | | 1 | 28002 |
| Sub-County | 3 | KYAMPISI | 23836 | | 1 | 23836 |
| Sub-County | 4 | MUKONO (KAUGA) | 40690 | | 1 | 40690 |
| Sub-County | 5 | MUKONO TOWN COUNCIL | 7376 | | 1 | 7376 |
| Sub-County | 6 | NAKISUNGA | 33262 | | 0.685 | 22784 |
| Sub-County | 7 | NTENJERU | 42177 | | 0.615 | 25939 |
| County | 5 | NAKIFUMA | | 124671 | | |
| Sub-County | 1 | KASAWO | 26879 | | 0.059 | 1586 |
| Sub-County | 2 | NABBALE | 23408 | | 0.793 | 18563 |
| Sub-County | 3 | NAGOJJE | 22943 | | 0.146 | 3350 |
| Sub-County | 4 | NAKIFUMA | 23798 | | 0.657 | 15635 |
| Sub-County | 6 | SEETA | 27643 | | 1 | 27643 |

DISTRICT: LUWERO

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 2 | KATIKAMU | | 50775 | | |
| Sub-County | 1 | BOMBO TOWN COUNCIL | 10514 | | 0.733 | 7707 |
| Sub-County | 6 | MAKULUBITA | 20384 | | 0.275 | 5606 |
| Sub-County | 7 | NYIMBWA | 19877 | | 0.296 | 5884 |
| County | 4 | WABUSANA (BAMUNANIKA) | | 26146 | | |
| Sub-County | 2 | KALAGALA | 26146 | | 0.335 | 8759 |
| TOTAL KAMPALA PROJECT AREA | | | | | | 1541878 |

**PROJECT AREA: KAMULI**

DISTRICT: KAMULI

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 1 | BUDIOPE | | 128523 | | |
| Sub-County | 1 | BUGAYA | 30015 | | 0.655 | 19660 |
| Sub-County | 2 | BUYENDE | 24989 | | 1 | 24989 |
| Sub-County | 3 | KAGULU | 30475 | | 0.229 | 6979 |
| Sub-County | 4 | KIDERA | 30412 | | 0.4 | 12165 |
| Sub-County | 5 | NKONDO | 12632 | | 0.95 | 12000 |
| County | 2 | BUGABULA | | 64995 | | |
| Sub-County | 1 | BALAWOLI | 20399 | | 0.803 | 16380 |
| Sub-County | 4 | KAMULI TOWN COUNCIL | 5354 | | 1 | 5354 |
| Sub-County | 6 | NABWIGULU | 24119 | | 0.022 | 531 |
| Sub-County | 7 | NAMASAGALI | 15123 | | 0.039 | 590 |

DISTRICT: SOROTI

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 5 | KASILO | | 13811 | | |
| Sub-County | 3 | PINGIRE | 13811 | | 0.029 | 401 |
| TOTAL KAMULI PROJECT AREA | | | | | | 99048 |

**PROJECT AREA: KUMI**

DISTRICT: KUMI

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 1 | BUKEDEA | | 49991 | | |
| Sub-County | 1 | BUKEDEA | 16436 | | 0.637 | 10470 |
| Sub-County | 3 | KIDONGOLE | 10092 | | 0.07 | 706 |
| Sub-County | 4 | KOLIR | 8190 | | 0.05 | 410 |
| Sub-County | 5 | MALERA | 15273 | | 0.45 | 6873 |
| County | 2 | KUMI | | 101470 | | |
| Sub-County | 1 | ATUTUR | 13381 | | 1 | 13381 |
| Sub-County | 2 | KANYUM | 15158 | | 0.963 | 14597 |
| Sub-County | 3 | KUMI | 13635 | | 1 | 13635 |
| Sub-County | 4 | KUMI TOWN COUNCIL | 11560 | | 1 | 11560 |
| Sub-County | 5 | MUKONGORO | 18683 | | 0.733 | 13695 |
| Sub-County | 6 | NGERO | 9314 | | 1 | 9314 |
| Sub-County | 7 | ONGINO | 19739 | | 0.95 | 18752 |
| County | 3 | NGORA | | 58957 | | |
| Sub-County | 1 | KAPIR | 13035 | | 0.65 | 8473 |
| Sub-County | 2 | KOBUIN | 10924 | | 0.3 | 3277 |
| Sub-County | 3 | MUKURA | 16170 | | 1 | 16170 |
| Sub-County | 4 | NGORA | 18828 | | 0.55 | 10355 |

DISTRICT: PALLISA

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 6 | PALLISA | | 12745 | | |
| Sub-County | 4 | KAMEKE | 12745 | | 0.169 | 2154 |

DISTRICT: SOROTI

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 9 | USUK | | 8614 | | |
| Sub-County | 3 | MAGORO | 8614 | | 0.004 | 34 |

TOTAL KUMI PROJECT AREA 153856

**PROJECT AREA: MBALE**

DISTRICT: MBALE

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 1 | BUBULO | | 174261 | | |
| Sub-County | 1 | BUBUTU | 25875 | | 0.063 | 1630 |
| Sub-County | 2 | BUGOBERO | 31530 | | 0.568 | 17909 |
| Sub-County | 3 | BULWABWALA | 19232 | | 0.209 | 4019 |
| Sub-County | 4 | BUMBO | 35864 | | 0.028 | 1004 |
| Sub-County | 5 | BUPOTO | 18328 | | 0.936 | 17155 |
| Sub-County | 6 | BUTIRU | 22212 | | 0.095 | 2110 |
| Sub-County | 7 | BUWAGOGO | 21220 | | 1 | 21220 |
| County | 2 | BUDADIRI | | 146919 | | |
| Sub-County | 1 | BUHUGU | 34334 | | 0.928 | 31862 |
| Sub-County | 2 | BUMASIFWA | 12730 | | 0.063 | 802 |
| Sub-County | 3 | BUSULANI | 25327 | | 0.597 | 15120 |
| Sub-County | 4 | BUWALASI | 43218 | | 1 | 43218 |
| Sub-County | 5 | BUYOBO | 31310 | | 1 | 31310 |
| County | 3 | BULAMBULI | | 59143 | | |
| Sub-County | 1 | BUGINYANYA | 10838 | | 0.007 | 76 |
| Sub-County | 2 | BULAGO | 17487 | | 0.188 | 3288 |
| Sub-County | 4 | MUYEMBE | 16691 | | 0.028 | 467 |
| Sub-County | 5 | SISIYI | 14127 | | 0.189 | 2670 |
| County | 4 | BUNGOKHO | | 186730 | | |
| Sub-County | 1 | BUFUMBO | 29731 | | 1 | 29731 |
| Sub-County | 2 | BUKHIENDE | 24010 | | 1 | 24010 |
| Sub-County | 3 | BUNGOKHO | 46636 | | 1 | 46636 |
| Sub-County | 4 | BUSIU | 19148 | | 0.827 | 15835 |
| Sub-County | 5 | BUSOBA | 19352 | | 1 | 19352 |
| Sub-County | 6 | NAKALOKE | 38418 | | 1 | 38418 |
| Sub-County | 7 | WANALE | 9435 | | 1 | 9435 |
| County | 5 | MANJIYA | | 78675 | | |
| Sub-County | 1 | BUBIITA | 16738 | | 0.084 | 1406 |
| Sub-County | 2 | BUDUDA | 17687 | | 1 | 17687 |
| Sub-County | 3 | BUKIGAI | 16380 | | 1 | 16380 |
| Sub-County | 4 | BULUCHEKE | 16003 | | 0.03 | 480 |
| Sub-County | 5 | BUSHIKA | 11867 | | 0.885 | 10502 |
| County | 6 | MBALE MUNICIPALITY | | 52039 | | |
| Sub-County | 1 | INDUSTRIAL BOROUGH | 23978 | | 1 | 23978 |
| Sub-County | 2 | NORTHERN BOROUGH | 20365 | | 1 | 20365 |
| Sub-County | 3 | WANALE BOROUGH | 7696 | | 1 | 7696 |

DISTRICT: PALLISA

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 1 | BUDAKA | | 84403 | | |
| Sub-County | 1 | BUDAKA | 16698 | | 0.337 | 5627 |
| Sub-County | 2 | IKI-IKI | 24886 | | 0.894 | 22248 |
| Sub-County | 4 | KAMONKOLI | 17378 | | 1 | 17378 |
| Sub-County | 5 | LYAMA | 12247 | | 0.076 | 931 |
| Sub-County | 6 | NABOA | 13194 | | 0.94 | 12402 |
| County | 3 | BUTEBO | | 25735 | | |
| Sub-County | 2 | KABWANGASI | 13628 | | 1 | 13628 |
| Sub-County | 3 | KAKORO | 12107 | | 0.936 | 11332 |

DISTRICT: TORORO

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 2 | BUNYOLE | | 63068 | | |
| Sub-County | 4 | BUTALEJA | 25873 | | 0.268 | 6934 |
| Sub-County | 5 | KACHONGA | 18890 | | 1 | 18890 |
| Sub-County | 6 | MAZIMASA | 18305 | | 1 | 18305 |
| County | 5 | KISOKO (WEST BUDAMA) | | 23309 | | |
| Sub-County | 7 | PAYA | 23309 | | 0.026 | 606 |
| County | 8 | TORORO | | 22861 | | |
| Sub-County | 2 | MOLO | 22861 | | 0.196 | 4481 |

DISTRICT: KUMI

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 1 | BUKEDEA | | 59659 | | |
| Sub-County | 1 | BUKEDEA | 16436 | | 0.049 | 805 |
| Sub-County | 2 | KACHUMBALA | 24941 | | 0.909 | 22671 |
| Sub-County | 3 | KIDONGOLE | 10092 | | 0.458 | 4622 |
| Sub-County | 4 | KOLIR | 8190 | | 0.069 | 565 |
| TOTAL MBALE PROJECT AREA | | | | | | 637199 |

**PROJECT AREA: MBARARA**

DISTRICT: MBARARA

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 3 | ISINGIRO | | 41461 | | |
| Sub-County | 1 | BIRERE | 41461 | | 0.433 | 17953 |
| County | 4 | KASHARI | | 77328 | | |
| Sub-County | 1 | BUBAARE | 12844 | | 0.788 | 10121 |
| Sub-County | 2 | KAKIIKA | 13090 | | 0.965 | 12632 |
| Sub-County | 4 | RUBAYA | 24246 | | 0.562 | 13626 |
| Sub-County | 6 | RWANYAMAHEMBE | 27148 | | 0.287 | 7791 |
| County | 6 | MBARARA MUNICIPALITY | | 37598 | | |
| Sub-County | 1 | KAKOBA | 16995 | | 1 | 16995 |
| Sub-County | 2 | KAMUKUZI | 12455 | | 1 | 12455 |
| Sub-County | 3 | NYAMITANGA | 8148 | | 1 | 8148 |
| County | 7 | NYABUSHOZI | | 15109 | | |
| Sub-County | 5 | SANGA | 15109 | | 0.005 | 76 |
| County | 9 | RWAMPARA | | 86823 | | |
| Sub-County | 1 | BUGAMBA | 22265 | | 0.095 | 2115 |
| Sub-County | 4 | NDEIJA | 20708 | | 0.004 | 83 |
| Sub-County | 5 | NYAKAYOJO | 25007 | | 0.835 | 20881 |
| Sub-County | 6 | RUGANDO | 18843 | | 0.793 | 14942 |
| TOTAL MBARARA PROJECT AREA | | | | | | 137818 |

**PROJECT AREA: MOROTO**

DISTRICT: MOROTO

| | | | | | | |
|---|---|---|---|---|---|---|
| County | 1 | BOKORA | | 25165 | | |
| Sub-County | 3 | LOPEI | 2990 | | 0.007 | 21 |
| Sub-County | 4 | LOTOME | 5527 | | 0.24 | 1326 |
| Sub-County | 5 | MATANY | 9512 | | 0.067 | 637 |
| Sub-County | 6 | NGOLERIAT | 7136 | | 0.909 | 6487 |
| County | 3 | MATHENIKO | | 46259 | | |
| Sub-County | 1 | KATIKEKILE | 9007 | | 0.383 | 3450 |
| Sub-County | 2 | NADUNGET | 23387 | | 0.549 | 12839 |
| Sub-County | 3 | RUPA | 13865 | | 0.225 | 3120 |
| County | 4 | MOROTO MUNICIPALITY | | 9984 | | |
| Sub-County | 1 | SOUTH DIVISION | 4059 | | 1 | 4059 |
| Sub-County | 2 | NORTH DIVISION | 5925 | | 1 | 5925 |
| County | 5 | PIAN | | 2776 | | |
| Sub-County | 2 | LORENGEDWAT | 2776 | | 0.168 | 466 |
| TOTAL MOROTO PROJECT AREA | | | | | | 38330 |
| TOTAL ALL PROJECT AREAS | | | | 3749094 | | 3449083 |

# App. P Regression Analysis - A Simple ExplanationP Regression Analysis - A Simple Explanation

Multiple regression is used to find the "best fit" function explaining the relationship between a dependent variable *y* (e.g. fresh weight of a tree) and a set of variables regarded as independent (e.g. dbh etc). The coefficient 'R square' is used to denote the degree of "fitness". A "perfect fit" would give an R square of 1.0. An R square of 0.82 indicates that the regression function explains 82% of the variation of the data, e.g. observed points/values clustered around the function in a scatter diagram. We also denote this as good *correlation.* An R square of 0.20, though, would indicate that only 20% of the observed variation of the data is explained by the function (i.e. the observed *y* values are scattered around).

If the maximum R square obtained is high, it indicates that the independent variables are well selected, strong causal relationship with the dependent variable. A low R square indicates the opposite. The strength of the causal relationship will of course vary for instance from species to species in our context: Some species are reasonably uniform (e.g. plantation trees), others might vary considerably (e.g. trees found in a large variety of locations, densities, etc). Note also that the actual R square obtained depends on the number of observations, i.e. that a certain minimum of observations are necessary to get a sound basis for regression. In our case, 20-25 observations (trees felled)per group were regarded as sufficient, but there were actually an *average* of 73.5 observations (trees felled) in each group.