THE NATIONAL FORESTRY AUTHORITY

MINISTRY OF WATER AND ENVIRONMENT

UGANDA NATIONAL FOREST INVENTORY (NFI)

2019

FOREWORD

Uganda is a partner of the United Nations programme on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD), and presented its REDD+ Readiness package in 2018 and its REDD+ Forest Reference Emission Level (FREL) in 2018.

Uganda is signatory to the United Nations Framework Convention on Climate Change (UNFCCC), since 1993, ratified the Kyoto Protocol in 2002 and Paris Agreement in 2016.

Uganda has been fulfilling its obligations in taking stock of its GHG emissions and sinks and sharing its efforts with the international community by submitting its First National Communication in 2002, the second National Communication in 2014, its FREL for REDD+ in 2017 and most recently the first Biennial Update Report (BUR) in 2019.

The National Forest Inventory Report presents Uganda's efforts to improve estimation of the country's forest biomass and associated carbon stock. This report provides a more detailed account of how the biomass and carbon stocks have been estimated, including gaps and areas for improvement. The NFI report provides important data and information that will guide REDD+ strategic interventions.

Most importantly, the NFI provides important information for national planning and other international reporting requirements. NFI data is a key input for the assessment of tree species diversity, fuelwood availability and timber stocks in various forests and trees outside forests.

For international reporting purposes NFI data is a key input in the computation of Greenhouse Gas (GHG) emissions and sinks related to land and forestry under National Greenhouse Gas Inventories for National Communications and Biennial Update Reports and for the national Forest Reference emission Level and/or Forest Reference Level (FREL/FRL) under the UNFCCC. NFI data are also essential for national forest monitoring systems and systems for providing information on safeguards, which along with the FREL/FRL, are essential pillars of REDD+. For the implementation of the Paris Agreement, NFIs will be important for the establishment of a more robust MRV framework known as the Enhanced Transparency Framework, which seeks greater transparency in data.

ACKNOWLEDGEMENTS

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The Government of Uganda provided office space, human resources and logistical support and through the Ministry of Water and Environment (MWE) provided technical oversight.

We are very highly indebted to the various government ministries, agencies and department, as well as the civil society organisations and individuals that made the work of preparing Uganda's NFI report possible. We are equally highly appreciative of our own team that made this work possible, mainly the Forest Inventory Team and the GIS and Mapping team.

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ED NFA.

Executive Summary

The National Forest Inventory (NFI) report 2019 provides information on the status of forests across Uganda's landscape with special focus on the forest biomass and the carbon stock therein. Historically (in the 1990s and before), Uganda has had several forest inventories preliminarily designed to provide information on timber stocks in Central Forest Reserves and fuel wood stocks in other lands.

With Uganda being one of many countries committed to participating in the global effort to Reduce Emissions from Deforestation and Forest Degradation (REDD+), the forest inventory approaches were refined to be one of the pillars for the establishment of the a robust and transparent National Forest Monitoring System (NFMS) that meets the Measurement Reporting and Verification (MRV) requirements for REDD+. In addition, the information generated by the NFI informs other REDD+ framework aspects such as the national strategies or action plans.

The National Forest Inventories and Land use change data and mapping are key pillars of Uganda's National Forest Monitoring System (NFMS). The two inventory types that inform this report at the Exploratory Inventory (EI) and the National Biomass Survey (NBS).

EI is more of a traditional forest inventory that was designed for timber stock assessment in a forest being brought under management or management being re-introduced after a significant time lapse. EI is used to decide at a forest management level which species to promote and protect, the appropriate diameter limit classes, and sequence compartments into felling series and is used to determine Annual Allowable Cut (AAC). NBS was designed to quantify biomass stock across the landscape in all woody formations including bush and agricultural residues.

FOREST INVENTORY REPRESENTATION

EI data used is from the most recent sample units measured between 2016 and 2019. These samples were measured in Mabira and Mt Elgon National Park, in the Kyoga Water management zones and Bugoma, Budongo, Kangombe CFRS and Kibale Forest Park which fall in the Albertine water management zone. EI survey also includes woodlands in protected areas mainly from Budongo CFR.

About 10% of NBS plots used in this report were measured between 2016 and 2019, mainly from the central Uganda woodlands. Other areas covered by the NBS survey are Hoima, Kikube, Kiboga, Ntoroko, Bundibugyo and Rubirizi in the Albertine Water Management zone and Amudata, Nakapirpiti, Moroto, kadam, Kitido in the Karamoja sub region, in the Kyoga Water Management zone.

At a national level, the sampling intensity is about 0.06% and 0.04% for the low stocked THF and well stocked respectively. Sampling intensity in woodlands is about 0.01%. About 33% of the forest samples were in protected areas under the jurisdiction of either UWA or NFA. The sampling intensity of non-forest land is about 0.005%.

In addition to national level reporting, NFI includes Water Management Zones (WMZs) as one of the reporting areas given that MWE’s strategic plans and operations are largely based on water catchments. Where feasible, reporting may be at the management unit level such as forest reserve or forest park. Forest management level is considered beneficial to the two major custodians of the forest estate in Uganda, i.e. NFA and UWA.

KEY RESULTS

Tree Density

In all forest types, tree density decreases as the diameter size increases. This trend is more pronounced in woodlands than in other forest types. Woodlands have the highest density of trees with an average of over 1,200 trees per hectare. Tree density in well stocked THF and low stocked THF is about 250 and 120 stems per hectare respectively.

Diameter class distributions in Uganda’s natural forests exhibit what is commonly known as the inverse J shape. In all forest types, tree density decreases as the diameter size increases. This trend is more pronounced in woodlands than in other forest types.

In non- forest areas, bush contains about 1,100 stems per hectare which is just slightly lower or almost the same as woodland. Tree size distribution in non- forest vegetation also exhibit the inverse J shape curve (figure ES 1). Compared to cropland and grassland, bush tends to have a greater share of smaller trees than other non-forest areas. About 92% of the trees in bush are less than 10 cm in diameter. In grassland and cropland the trees less than 10cm account for 90% and 87% of the tree stock, respectively.

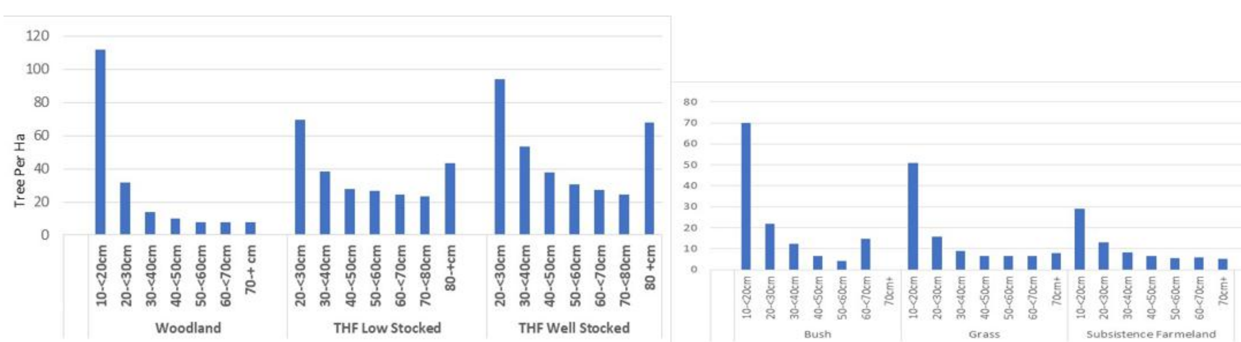

Figure ES 1. Tree density in forest and non- forest land

Stem Volume

Average stem volume of all measurable trees in the well-stocked THF is estimated at over 300 m^3 per hectare while in low stoked THF is estimated to just over 190 m^3 per hectare. Stem volume in woodlands is estimated at 36 m^3 per hectare which about a tenth of the volume of degraded THF (Table ES 1).

Table ES 1 Stem Volume

Forest Type	Stem Volume (m^3 ha^{-1})	STDV	Plots	95% Confidence
Tropical high forest low stock	191	186	1,089	±11
Tropical High Forest well stocked	303	225	3,006	±8
Woodland	36	40	998	±2

Unlike other forest stand characteristics, stem volume tends to be concentrated in the very large trees. In well stocked THF, the 70cm+ DBH has more than double the volume in any diameter class. In low stocked THF, the 70cm+ DBH accounts for more than thrice any other diameter class. There is however no clear volume trend or pattern in the other smaller DBH classes (figure ES 2).

In woodlands the smaller trees generally contribute higher stem volume than the larger diameter trees (figure ES 2). Stem diameter being a function of basal area and height, much of the volume in THF is in the tall trees with large DBH. In woodlands, trees are relatively shorter and volume is determined by tree numbers and not tree size (i.e. height and DBH).

Bush and grasslands exhibit similar characteristics as woodlands. In bush and grassland, trees less than 10 cm DBH hold about 8.9 m3 and 6m3 respectively. In subsistence farmland, volume is generally more evenly distributed in the small to medium DBH classes. Though very few in numbers, the 70cm+ DBH class trees hold about 30% of the volume in subsistence farmland (figure ES 2). Unlike in woodlands, volume in subsistence farmland is primarily determined by tree girth and height (i.e. height and DBH).

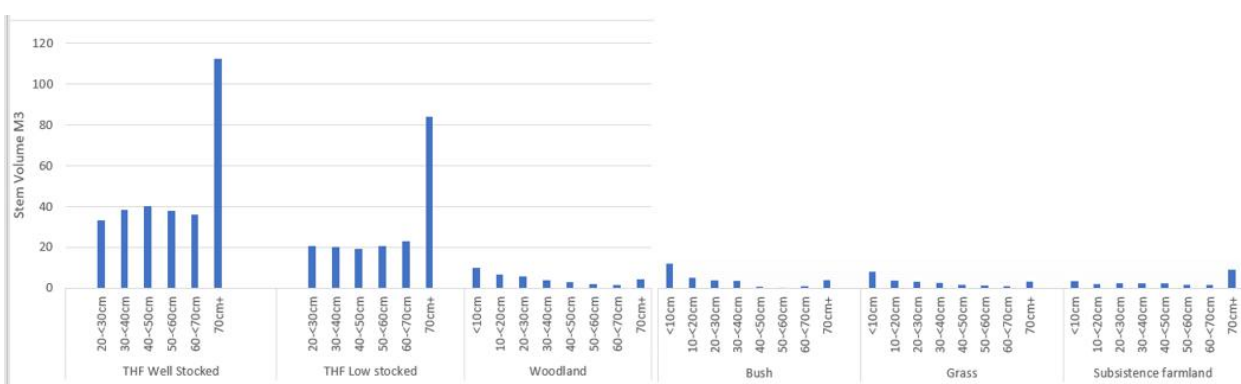

Figure ES 2. Stem volume in forest and non- forests

Tree Diversity

To ascertain the species evenness, the Simpson's Species Diversity index was used. The Simpson's Species Diversity Index, with a value between 0 and 1, takes into account the number of species present as well as the relative abundance of each species. As species richness and evenness increase, so diversity increases. The findings from the index indicate that the well stocked THF and Low Stocked THF exhibited the highest equal abundancy of 0.83 and 0.77 respectively. Woodlands diversity ranking of 0.73 (Figure ES 3).

Figure ES 3. Tree Species diversity in forest (Simpson's Index)

Despite having the lowest species count, species richness by Simpson's index showed that bushland was highest of the non-forest classes at (0.722). Small scale farmland which has the highest species count in non forest areas had the lowest index of 0.67 (Figure ES 4).

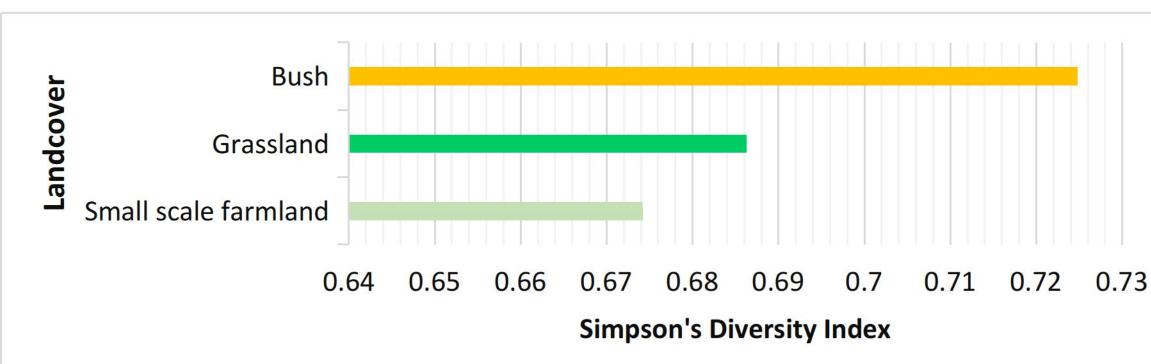

Figure ES 4. Tree Species diversity in non-forest (Simpson's Index)

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List of Acronyms

AFOLU	Agriculture Forestry and Other Land Use
BURs	Biennial Update Reports
CBD	Convention on Biological Diversity
CCD	Climate Change Department
CCPC	Climate Change Policy Committee.
CFM	Community/Collaborative Forest Management
CFR	Central Forest Reserve
CITES	Convention on International Trade in Endangered Species
COP	Conference of the Parties
DC	District Council
DEA	Directorate of Environment Affairs
DFOs	District Forest Officers
DFS	District Forest Services
EI	Exploratory Inventory
EU	European Union
FAO	Food and Agriculture Organization
FIEFOC	Farm Income Enhancement and Forestry conservation Project
FMIS	Forest Management Information System
FRCPM	Forest Resources Management and Conservation Programme
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
FRLS	Forest Reference Levels
FSIS	forestry spatial information system
FSSD	Forestry Sector Support Department
GHG	Greenhouse Gas
GHG-I	Greenhouse Gas Inventory
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
ISSMI	Integrated Stock Survey and Management Inventory
LC	Local Council
LULC	Land Use and Land Cover
LULUCF	Land Use Land Use Change and Forestry
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MEMD	Ministry of Energy and Mineral Development;
MFED	Ministry of Finance and Economic Development,
MoFPED	Ministry of Finance Planning and Economic Development
MoLG	Ministry of Local Government
MRV	Measuring/Monitoring, Reporting and Verification
MWE	Ministry of Water and Environment
NAFFORI	National Forestry Resources Research Institute
NARO	National Agricultural Research Organization
NBS	National Biomass Study
NCCAC	National Climate Change Advisory Committee
NCCP	National Climate Change Policy

NDC	Nationally Determined Contributions
NEMA	National Environment Management Authority,
NFA	National Forestry Authority,
NFI	National Forestry Inventory
NFIs	National Forest Inventories
NFMS	National Forest Monitoring System
NFTPA	National Forestry and Tree Planting Act
NGHG	National Green House Gas Inventory
NGO	Non-governmental Organisation
NGOs	Non-Government Organizations
NORAD	Norwegian Agency for International Development
NWSC	National Water and Sewerage Corporation,
PCE	Policy Committee on Environment
PFCC-U	Parliamentary Forum on Climate Change-Uganda
PSPs	Permanent Sample Plots
QA/QC	Quality assurance/Quality Control
REDD (+)	Reduced Emissions from Deforestation and Degradation (and enhancements)
RS	Remote Sensing
SNC	Second National Communication
SPGS	Saw log Production Grant Scheme
THF	Tropical High Forests
UBOS	Uganda Bureau of Statistics
UNDP	United Nations Development Program
UNFCCC	United Nations Framework on Climate Change
UNMA	Uganda National Meteorological Authority
URA	Uganda Revenue Authority
USFS	United States Forest Services
UWA	Uganda Wildlife Authority

1 Introduction

1.1 Forest Inventories General

National Forest Inventories (NFIs) are conducted in many countries worldwide where their typical purpose is to provide information for strategic level forest and environmental decisions at sub-national, national as well as larger geographical scales (Tomppo *et al.* 2010).

The first forest inventories were predominantly designed to provide information for the estimation of wood for commercial use and forest management plans. However, with developments in the field of natural resources management, new information needs and technological progress, forest inventories need to be able to adapt to new requirements and as such to adopt new strategies, methodologies and technologies. New information needs have led to the inclusion of additional variables in the inventory and the improvement of measurement techniques. At the same time, a balance must be struck between inclusion of new variables in field surveys and the costs in terms of time and funds to conduct the surveys. The skills of surveyors and the potential for error must also be weighed up (Ringvall *et al.* 2005).

1.2 Forest Inventories in Uganda

Forest inventory in Uganda started as early as the 1930s and 1940s in Budongo forest reserve with establishment of seven Permanent Sample Plots (PSPs) mainly to describe forest succession (Eggeling, 1947). These PSPs exist up to today and five of them were last measured in 1993.

In the 1950s there was the Exploratory Sampling (ES) inventory which focused on desirable species referred to as merchantable species mainly in productive natural forests. It basically addressed timber harvesting needs. As years passed, ES identified and incorporated other management gaps. Alongside ES, the Forest Department also carried out Diagnostic Sampling (DS) to tend to the leading desirable species to prepare them for timber harvesting.

In the 1960s and 80s stock survey and stock mapping was carried out in compartments earmarked for harvesting in Budongo and Mabira forest reserve. Every tree that had a diameter of 50 cm or more was marked with a stock number. However not all stock trees were logged, some healthy trees were selected as mother trees for the gene bank to maintain the integrity and stability of the forest ecosystem.

From the early 1990s, forest inventories in Uganda have undergone significant changes as collaboration between national and international teams intensified. With support from the Norwegian Agency for International Development (NORAD) the Forest Department (FD) initiated a Biomass Assessment Study (from 1989 to 1992), in seven peri-urban areas of Uganda deemed to be fuelwood deficient. Four out of the selected places showed that fuelwood demand was not sustainable. This led to the National Biomass study (NBS) which is a country-wide survey for the assessment of woody biomass stocks across landscapes.

Within the same period, the Forest Department initiated the Forest Resources Management and Conservation Programme (FRCPM) with support European Union. FRCPM supported the development of Exploratory Inventory (EI), Integrated Stock Survey and Management Inventory (ISSMI) plus Permanent Sample Plots (PSPs) as key data providers for the management of Tropical High Forest (THF).

From 1989 up until 2002, EI was conducted in three Central Forest Reserves (CFR) of Mabira, Budongo and Bugoma (table 1-1). By the end of 2003, EI had covered other CFRs such as Matiri, SangoBay and Kalinzu. From 2001 until 2005, ISSMI was carried out in concession blocks of Nyakafunjo and Biso in Budongo CFR. PSPs were established in Budongo, Mabira, Kalinzu, Kashoha Kitomi and Bugoma CFR to monitor growth trends of forests within those landscapes ((Alder 1991, Alder 1998, Alder 2000).

From 1991 to 1995, FRCPM supported biodiversity inventory surveys in 65 CFRS of which 12 were major Tropical High Forest CFRs. Based on this inventory, three of these reserves were found to be of high conservation value and were later put under the management of Uganda Wildlife Authority (UWA) so that they be accorded appropriate protection. Close to 50% of the THF not under UWA were marked as non- productive zones with higher level of protection such as nature reserves, buffer zones or recreation areas. From 2006 to 2015 there was limited forest inventory activity. The few inventories that took place were limited to stock assessment for timber valuation.

Forest inventories in Uganda were revived with REDD+ with support from multiple agencies to achieve REDD+ readiness. The Forest Carbon Partnership Fund (FCPF) and the Austrian Development Corporation provided financial resources. The Government of Uganda provided the human resource, logistics (vehicles and tools) and salaries of key staff. The UNREDD Programme provided financial and technical support. UNDP (as part of UNREDD) supported stakeholder engagement.

FAO provided technical support for the construction of Uganda’s baseline for REDD+ known as its Forest Reference (Emission) Level (FRL/FREL). In addition, FAO provided technical support in designing Uganda’s National Forest Monitoring System of which NFI is a key component. NFI support includes data infrastructure, improvements in tools for field data collection and analysis as well as facilitation of the actual field data collection.

NFI data collection under REDD+ was majorly EI and NBS surveys. Some PSPs were re-measured in Budongo CFR and Mabira CFR (Table 1.1).

Table 1- 1. Major Forest Inventories projects in Uganda (1989-2016)

NFI Project Name	Year	Area of Focus	Implementing Agency	International Collaborative Agency
Exploratory Inventory (EI)	1990 to 1995	Timber stock assessments in several CFRs; such as Mabira, Budonga, Matiri, Sango Bay, Budongo, Bugoma	Forest Resources Management and Conservation Programme (FRCPM) under Forest Department Uganda	European Union
Biodiversity Survey	1992 to 1995	12 Major CFRs. Management of 4 out of 12 was later transferred to UWA	Forest Resources Management and Conservation Programme (FRCPM) under Forest Department Uganda	European Union
Integrated Stock Survey and Management Inventory (ISSMI)	1995 to 2000	Timber Harvesting and Monitoring tool in CFR with timber harvesting concessions	Forest Resources Management and Conservation Programme (FRCPM) under Forest Department Uganda	European Union

The National Biomass Study	First Phase 1989 to 1990 2nd Phase 1990 to 2002. 3rd Phase 2003 to 2006 under NFA	Woody biomass assessment in 7 Peri Urban areas Woody biomass assessment at National Level. Mainly outside protected areas	Norwegian Forestry Association and NBS under Forest Department Uganda	NORAD
National Forest Inventory under Uganda's REDD+ readiness	2016 to 2019	Woodlands and THF not covered in previous NBS and EI in THF both well stocked and degrading. Re-measuring of PSPs in THF	MWE with NFA as technical agencies and FSSD providing oversight	FCPF, Austria Development Corporation, UNREDD, FAO

2 National Forest Monitoring System for Uganda

Under REDD+ readiness for Uganda, FAO has been providing support towards the establishment and implementation of a multipurpose National Forest Monitoring System. In the context of results-based payment for REDD+, the NFMS is intended to meet MRV requirements, as set out in UNFCCC decisions (Cancun, Warsaw and others). Uganda communicated its Nationally Determined Contribution (NDC) in accordance with the 2015 Paris Agreement. This agreement also outlined how MRV will evolve towards the Enhanced Transparency Framework that is expected to be implemented once the NDC comes into force in 2020.

"Robust and transparent NFMS are essential for countries that would like to establish effective national decision-making processes and to comply with international procedures. For countries participating in REDD+, NFMS represent one of the four core mandatory elements to be developed and strengthened. In addition, NFMS play a crucial role in improving the transparency of information under the Paris Agreement and other processes such as the Bonn Challenge, Sustainable Development Goals (especially SDG 15), as well as the objective 5 of the Aichi Goals, and the New York Declaration on Forests."

Uganda's NFMS builds on historical data at NFA - mainly Forest Inventories and Land use change data and maps that have been compiled since the early 1990s. NFA will remain the main technical institution supporting NFMS in terms of Geographical Information Systems (GIS) and NFI data. The role of the Forestry Sector Support Department (FSSD) in NFMS is mainly to provide supervision and coordination while the Climate Change Department (CCD) is in charge of international reporting and ensuring the coherence and quality of the final outputs. It is anticipated that the local government technical teams and the Uganda Wildlife Authority (UWA) might play more active roles in data collection in the future. Figure 1.1 shows these institutional roles and relations and details on roles of other NFMS collaborators can be found in *Action Plan and Best Practices for the National Forest Monitoring System institutionalization in Uganda, 2019*.

Two elements of NFMS that FAO has been providing technical support on since 2015 are: improvements to remotely sensed based land use and land use change monitoring system or the Satellite Land Monitoring Systems (SLMS) and the NFI. The SLMS and NFI are developed and based at the National Forest Authority (NFA) under the Directorate of Corporate affairs.

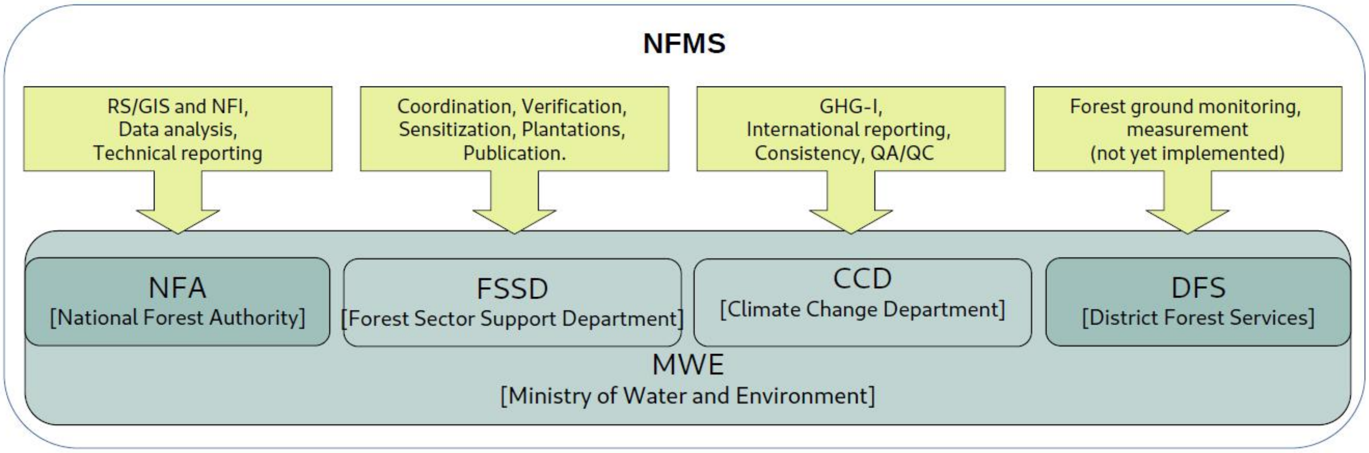


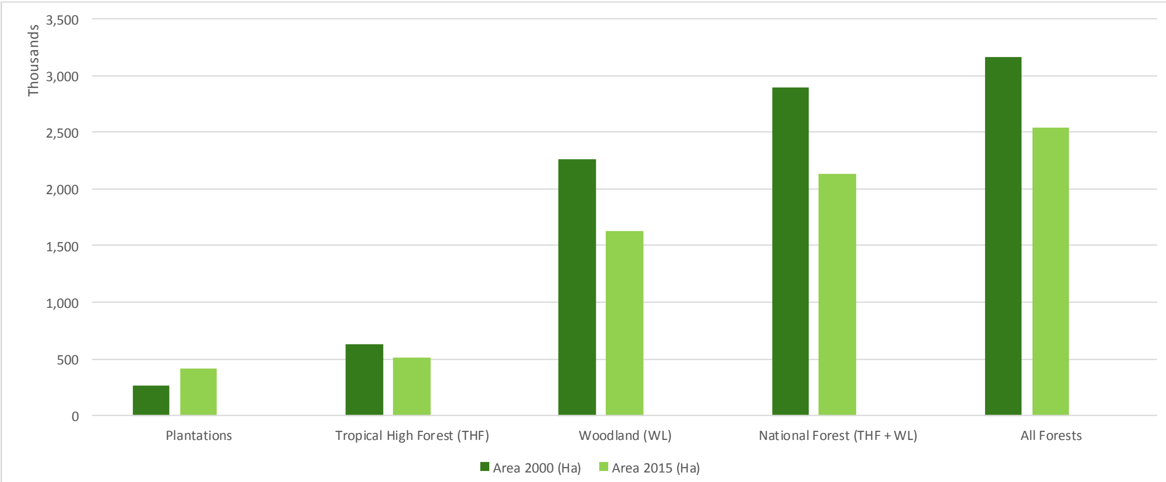
Figure 2- 1 Diagram of institutional arrangements

During the REDD+ readiness phase, forest inventories and the related biomass stock assessment was intended to collect data to better understand the forest strata and its geographical scope. The three types of forest strata reported in Uganda are: Tropical High (or Rain) Forest (THF), Woodlands (also commonly known as open dry forests) and forest plantations. THFs are occasionally subdivided into well stocked and low stocked (or degraded forests). This subdivision is however not used for reporting purposes as it is considered subjective. A more systematic identification and reporting on degraded rainforest is still being developed. The ongoing inventory in forest plantations is expected to provide better scope than what is present in this report.

2.1 Land use change and Forest Statistics (2000 to 2015)

There have been important changes in Uganda's land use since 1990 when Uganda made its first wall to wall mapping. The greatest change has been the conversion from forest to agricultural land with natural forest covering 24% of land area in 1990, being reduced to 10% in 2015. According to the FREL 2018, Uganda has lost over 760,000 hectares of natural forests from 2000 to 2015 with a deforestation rate of 2% per year (Figure 2-2).

However, there were some significant gains in the broad-leaved and conifer plantations as a result of tree planting efforts by NFA and the private sector. Between 2000 and 2015 the area of forest plantations of both conifers and broadleaved trees increased by over 140,000 hectares, which is close to 3% per year.



Forest type	Plantations	Tropical High Forest (THF)	Woodland (WL)	National Forest (THF + WL)	All Forests
Area 2000 (Ha)	268,363	633,864	2,260,718	2,894,582	3,162,945
Area 2015 (Ha)	415,958	505,617	1,622,588	2,128,205	2,544,163
Rate/yr	**+2.96%** A/Reforestation	**-1.5%** Deforestation	**-2.2%** Deforestation	**-2.03%** Deforestation	**-1.4%** Deforestation

Figure 2- 2. Rate of forest change in Uganda 2000 to 2015, source Uganda FREL 2018

The highest loss of forest occurred on private land. Protected areas under UWA's prerogative showed very little or no deforestation over the years.

2.2 The National Forest Inventory

In Uganda, the history of forest inventories is very long. The earliest recorded forest inventories are from the 1930s in the form of permanent sample plots that were established in Budongo and Mpanga forests. Since then, forest inventories in Uganda have evolved from a narrow focus on wood resources to a National Forest Inventory (NFI) that aims at providing multiple purpose information about a variety of forest ecosystem services including wood and non-timber forest products.

In the early 1990s, Uganda adopted four forest inventory systems that were designed to provide specific information needs regarding timber stocks in natural forests and forest plantations, wood fuel availability in areas close to human settlements, forest growth and forest dynamics. The same inventories have been maintained over time with slight modifications to fine-tune to new information requirements (e.g emission factors for computation of Greenhouse Gases (GHG) and the FRL.

Though Uganda's NFI is a combination of several surveys this report is mainly based on data from NBS and EI and are briefly explained here after. Other major forest inventories in Uganda are described in appendix 1.

Exploratory inventory (EI) – is forest stock assessment in a forest being brought under management or management being re-introduced after a significant time lapse. EI aims at 1% sampling intensity and defines the available species in a forest, their stem quality, the size classes, the available quantities, and distribution at compartment level. It is used to decide at a reserve level which species to promote and protect, the appropriate diameter limit classes, and sequence compartments into felling series. From EI results, Annual Allowable Cut (AAC) for the forest can be derived to guide the level of harvesting that can be allowed.

National Biomass Survey (NBS) - Cognizant of the fact that biomass energy contributes over 90% of Uganda's total delivered energy (charcoal, firewood and agricultural residues), the National Biomass Study was initiated in 1989 under the Ministry of Energy and Mineral Development to ensure that biomass energy supply and demand starts to be captured in Uganda's energy balance. The component of assessing biomass supply was delegated to the forestry sector which has the competency to carry out vegetation mapping and quantification of biomass stocks therein. Consequently, the NBS was thus designed to quantify biomass stock across the landscape in all woody formations including bush and agricultural residues. Biomass information is also required for climate change studies.

NBS deals with periodic assessments of biomass resources across the landscape especially in areas outside the CFRs. The goal was and still is to provide statistics based on empirical data on land cover/use for the purposes of implementing relevant actions to safeguard the future availability of wood, and provide for the development of the agriculture and forest sectors in harmony with the natural resource base.

The periodic monitoring of biomass resources acts as an important tool for the three pillars of sustainable development; the economy, society and environment. NBS reports provide very reliable statistics on biomass resources down to Sub-county level which enable grassroots planning.

These two inventories are the core sources of information for this study and provide multi-disciplinary information which includes conventional forest inventory parameters (e.g. volume and biomass), other benefits from the forest (e.g. biodiversity) and economic factors (e.g. products use and land tenure).

NBS occasionally collects data in forest plantations. Data collection from forest plantations is however more effectively collected by point crews and specially designed Permanent Sample Plots (PSPs). This report however does not cover forest plantations due to lack of representative samples in forest plantations.

2.3 Key Definitions

Forest definition in the Context of Reporting on REDD+:

The term "Forest" has been defined in many ways by different countries to reflect the diversity of forests and forest ecosystems in the world and to define the diversity of human approaches to forests. The guidance on forest definition for international reporting is that it should be consistent with that used in the national GHG inventory and reporting to other international organizations. The Ministry of Water and Environment in its (2017) preliminary document presenting the Proposed FRLs for Uganda, defined a forest as an area with predominantly trees, having a minimum area of one hectare (1 ha) with a minimum crown cover of 30%, and comprising of trees that are able to attain a height of 4 meters and above. The same document defined a tree as a woody perennial plant excluding woody forms that may last for only a few seasons such as the *Solanum giganteum* or *Acanthus pubescens.* Bamboo is regarded as a special tree under REDD+ in Uganda while orchards are considered under agricultural crops.

Uganda has adopted the same global definition for deforestation, forest management, afforestation and reforestation especially as they apply to the REDD+ implementation modalities and agreed international decisions.

Deforestation:

"Deforestation" is the direct human-induced conversion of forested land to non-forested land.

Forest management:

"Forest management" is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner.

Reforestation:

"Reforestation" is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989.

Afforestation

"Afforestation" is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources.

Tropical High Forest (THF)

Tropical High Forest are multi-layered or have a multi-storey structure of woody formations, shrubs and lianas where the most spectacular component is the dominant and emergent trees that grow 40 metres high and above.

Woodland

The National Biomass (NBS) classifies all woody formations equal to or greater than 4meters but not as tall as Tropical High forests as woodlands. This is close to what Langdale Brown et la 1964 described as evergreen or mixed evergreen deciduous shrubs and trees of 5 metres to 15 metres. Most of the woodlands in central and northern Uganda are important charcoal producing area because of the density of tree species.

Forest Plantation

Forest plantations in Uganda are grouped into broad-leaved plantation and coniferous plantations. This definition includes small woodlots scattered over the landscape majority of them fall under the minimum area threshold of a forest definition. In the highland areas of Southwestern Uganda, coniferous plantations are predominantly composed of *Pinus patula*. In the rest of the country *Pinus caribea* and *Pinus Occarpa* are the dominant coniferous tree species. Eucalyptus is the most dominant or preferred species in broad-leaved plantations. Occasionally, broad-leaved plantations may be composed of indigenous species like *Maesopsis eminni* and *Terminalia* spp. In parts northern Uganda, teak (Tectona grandis) is the a common broad-leaved plantations.

3 Methodology

The methodology focuses on data collection of the surveys that are the source of data for this report, that is, the EI and NBS.

3.1 EI Sampling Design

Exploratory Inventory was designed to primarily provide information about the forest stock in areas that are deemed potential sources of timber production. The design is stratified and partially randomized (details in section 3.21). Key outputs of EI are to:

a) Show the available species in a forest, giving indications of their stem quality and size classes, the total quantities available, and distribution at the compartment level.

b) Decide at a reserve level which species should be promoted and which protected, and appropriate diameter class limits for harvesting.

c) Prepare in sequence the compartments into felling series.

d) Determine approximate annual allowable cut (AAC) for the forest through a growth model (EiPac1), which has been specifically designed to analyse EI inventory data. The growth model gives the level of harvesting that may be permitted and encouraged.

e) Provide information to produce a concise forest management plan for the forest management unit.

f) Provide information on forest stocks in zones intended for production. After EI, Integrated Stock Survey and Management Inventory (ISSMI) is carried out only in forest management zones/compartments that reveal sufficient timber stocks in the required diameter class to warrant timber harvesting.

g) Estimate biomass and carbon stocks.

Though traditionally not designed for biomass estimation, modification in data collection and analysis have been implemented to enable EI be an important component of Uganda's NFI that will continuously update and inform the NFMS. The NFA and inventory teams are well conversant with EI and a few parameters like tree height (modelled and measured) have been introduced into EI in order to improve biomass estimates in addition to timber stock assessments (Vesa *et al*, 2016)

1 EiPac access base transect generating application developed by Jame Alder, 1990

3.1.1 Blocks and Transect Layout

Exploratory Inventory sample plots are established along randomly selected transects that are referenced from the south western corner of 100 ha blocks. The blocks are systematically located along baselines that originate from a tie point that is georeferenced.

A complete EI block is comprised of plots, transects and blocks (see Figure 3-1).

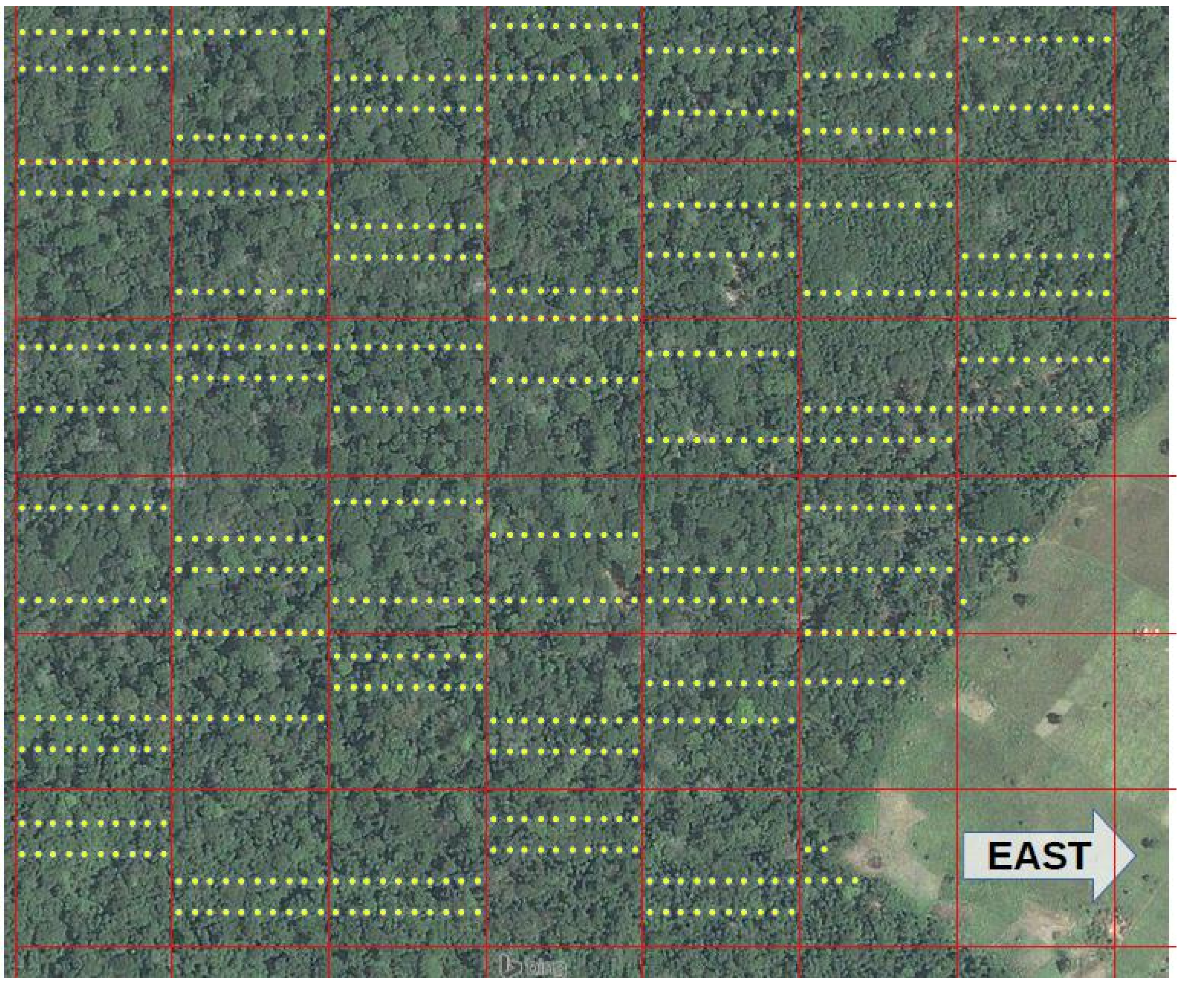


Figure 3- 1: Illustration of sampling design over an area of forest for Exploratory Inventory. Red outlines show 100 ha blocks, yellow dots are sample plots and the rows of yellow dots are the transects.

The generation of EI blocks and transects starts with the identification and preparation of a shapefile of the proposed inventory area and a Microsoft (MS) Access-based application (EIMap), is used to generate EI blocks.

The EI Block grids are 1000 by 1000 metres (100 ha) and are uniquely described by the geographical coordinates (UTM coordinates) of the south western corner. Each block is assigned a number, usually in sequence of access and is identified geographically by its coordinates relative to its South Western corner (Base). Each EI block has two transects located randomly at either 200 m, 400 m, 600 m, 800 m or 1000 m from the base, running

West to East, commonly referred to as transect 1, 2, 3, 4 and 5 respectively. At 100m intervals along the transect, 10 temporary plots are laid starting at 50 m, 150 m, 250 m, up to 950 as indicated in Figure 3-1.

3.2 NBS Sampling and Plot Design

NBS is designed to collect data from generally open landscapes which include cropland (the land use with the largest extent of all), grasslands (both open and bushy) and open dry forests or woodlands. The NBS is based on a systematic sampling grid (with a random start) covering the entire country. NBS sample grids may occasionally include data from closed forests and forest plantations.

The inventory deliverables include:

- Assessment of biomass stock and biomass dynamics by vegetation type;
- Information on biomass stock by vegetation type and by administrative units or any official zonation;
- Information on trends in biomass stocks by vegetation types and administrative units or any official zonation.

3.2.1 NBS Systematic Grid

The current NBS sampling design uses a systematic grid of 5 km by 5 km (figure 3-2). This a slight modification of the NBS – phase II sampling which was at 5 km by 10 km intervals stratified by three population intensities of less than 50 people per km, between 50 and 100 people per km and above 100 people per km. Another modification was that unlike the previous design, the sampling included protected areas.

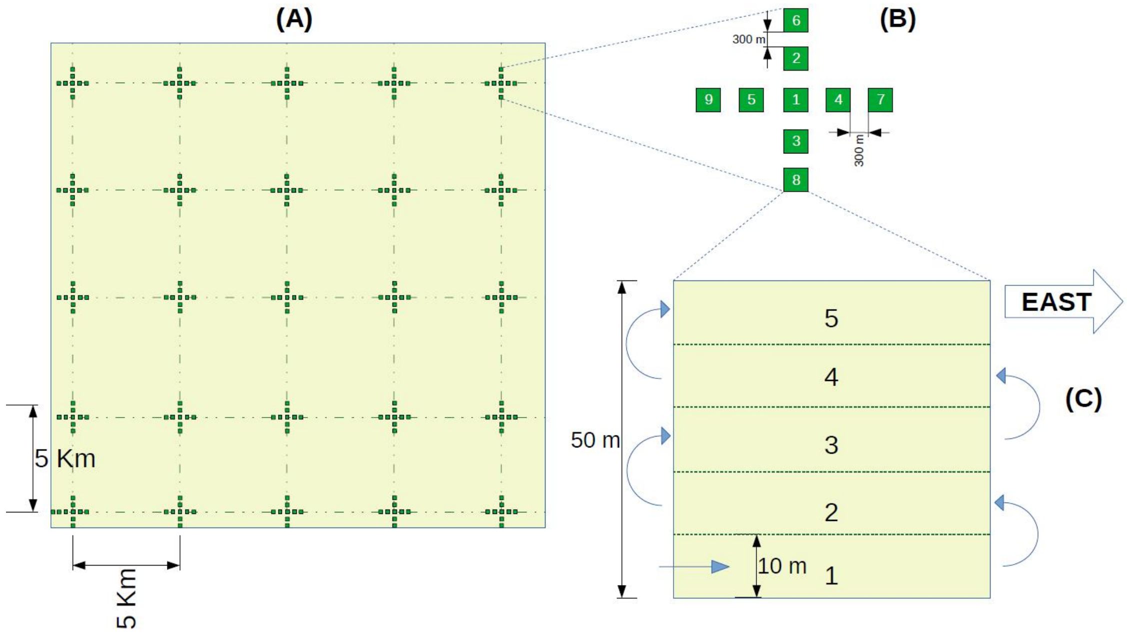


Figure 3- 2. NBS Plot clusters across the landscape (A), sequential orientation of sampling units (B) and tree mensuration execution within a single plot (C)

Out of a cluster of nine plots on each grid intersection a minimum of three plots are measured. The plot selection is made during the planning phase by the field Inventory Supervisor, the Field team leaders are allowed to make alternative selections only if a preselected plot(s) is inaccessible. Selection priority is given to the plot numbers 1, 2 and 3 at the centre although any other plot may be measured as replacement of any of the three key plots. Interest in getting information on certain vegetation types may influence plot selection.

NBS being a landscape inventory, occasionally some samples fall in forest plantation which are relatively more homogenous. In such instances a smaller plot of 400M2 square is used (Figure 3-3).

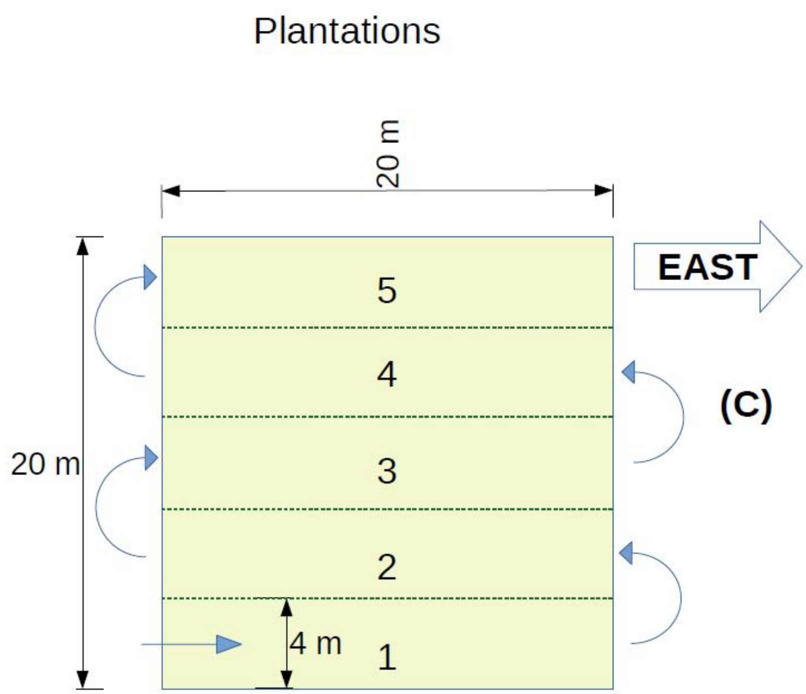


Figure 3- 3. NBS plot size and tree mensuration execution within a forest plantation plot

3.3 Description of the Sample Units

3.3.1 EI sample Unit

Exploratory Inventory (EI) uses a 500 m^2 (0.05 ha) circular plot (i.e. 12.6 meters radius) with a nested quadrant occupying the first quarter of the plot. The nested quadrant occupies the first ninety degrees of the circle from north to east direction of a compass or 0 bearing to 90^0 bearing from the plot centre.

Within the plot, tree enumeration follows a clockwise direction with smaller trees being measured in the small nested quadrant and bigger trees in the rest of the plot. See Figure 3-4.

In addition, deadwood on the forest floor is enumerated along a transect that runs west to east through the centre of the plot. Details of tree and deadwood enumeration are discussed further in section 3.5.2.

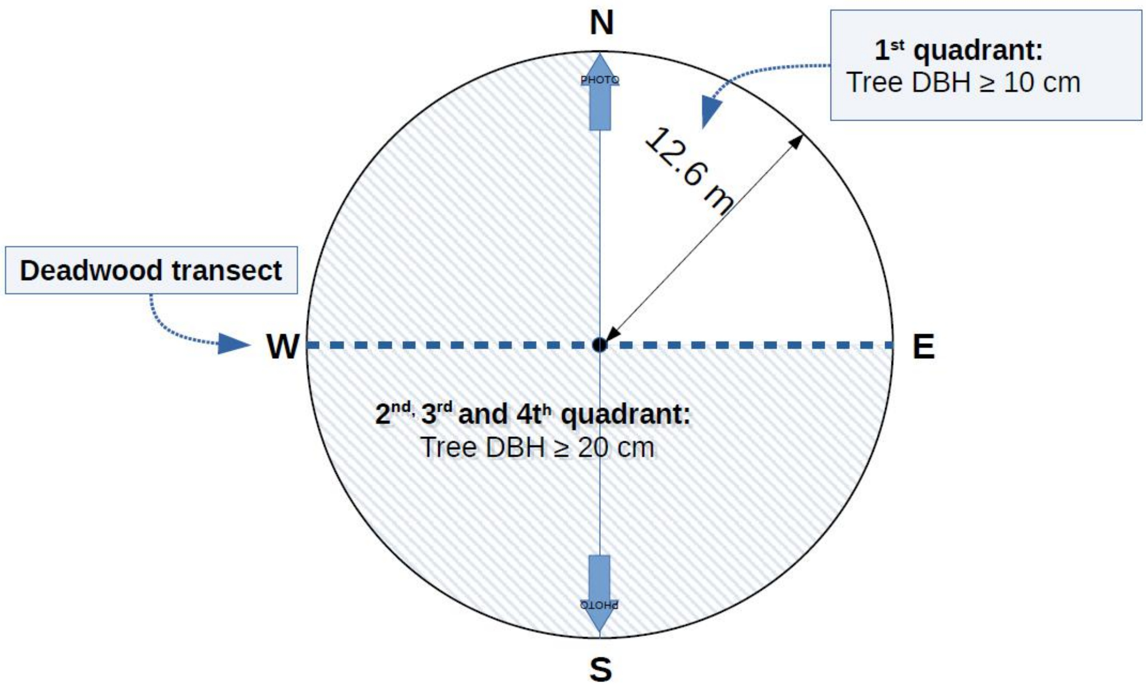


Figure 3- 4. Exploratory Inventory Plot design

3.3.2 NBS Sample Unit

The standard NBS plot design is 50 m by 50 m aligned in east-west and north-south orientation. Each square plot is subdivided into five strips measuring 10 by 50 metres, running in the east-west direction (Figure 3.2). Tree measurements are done systematically from one strip to another, and tree numbering is based on the location of the tree in the strip. This is intended to make tree re-identification easier during subsequent visits.

In 2016 the NBS adopted a nested plot approach whereby the minimum measurable DBH in the first strip is 3cm. In the rest of the plot, the DBH threshold is trees of 5cm and above.

3.3.3 Change in Plot size and Shape in the NBS survey

The NBS survey has adopted the EI circular plot design only in specific circumstances like in the assessment of the impact of refugees and charcoal extraction on the biomass stock resources in the charcoal producing open dry forests in central and mid-west areas region of Uganda.

In such instances, a nested circular plot design ranging from 500 m² to 1,000 m² has been used. As described in section 3.2.1 a smaller plot size (400m2) is used in forest plantations.

3.4 Field Data Collection Procedures

3.4.1 Stakeholder Engagement

Field enumeration is preceded by a sensitization initiative that informs the district authorities and the local communities about the forest inventory exercise. In addition to preparing the ground for the core inventory team, this is one of the avenues where the central government (MWE) discusses broader environmental and governance issues with local government.

About two to three weeks prior to the commencement of forest inventory, a team comprised of key personnel from the MWE, NFA and REDD+ secretariat visits the areas where the field exercise is due to take place. The team meets key district leaders namely; Chief Administrative Officer (CAO), Resident District Commissioner (RDC), the District Forest Officer (DFO), the District Natural Resources Officer (DNR), the NFA senior management team of the areas to be visited and any other relevant district technical offers.

Depending on the unique circumstances of the area, the sensitization team may organize meetings with lower local government structures such as Sub County and where necessary community leaders (traditional leaders and or elected village council members).

The team normally organizes talk shows with the local FM radio stations where members of the community call in and ask issues concerning the environment, governance, REDD+ and NFI.

3.4.2 EI Plot demarcation

EI plots are mainly located in dense rain forests where the multi-storey structure and the canopy of the dominant and emergent trees (that may grow 40 metres high) is often a hindrance to GPS signal. Location of EI plots thus traditionally relied heavily on numbering blocks and transects with the blocks. Along the transect, plots are counted from 1 to 10 in the west to east direction.

Recent technological advancement has made it possible to use GPSs also in rainforest and to a good extent GPS enabled mobile devices like tablets and phones are able to find a location fix in a short time, with horizontal positional errors commonly in the range 10-30 metres.

Avenza Application on such devices enables location of the plots on a georeferenced digital map. Currently, the EI team uses a combination of the traditional methods that are based on recording on paper and mobile devices.

Before field work, the map of the inventory area containing EI block and transect layers are processed in a GIS and exported and saved as a PDF map. The maps are uploaded on Android tablets with Avenza map application installed helping the operator to arrive at the desired transect. Even though this approach helps the field teams to quickly navigate to the plots, there is still the need to do light slashing and demarcation of block lines and transact lines.

Because of the possibility of having a weak signal of the GPS signal in the rain forest, the positioning of the plot is done by pulling of a linear tape along the transect starting from the baseline. The coordinates of the centre of the plot are taken and used to identify the position of the plot.

3.4.3 NBS Plot Location and demarcation

As part of field preparation and similarly to the EI procedure, the maps showing location of the NBS and all possible access routes are planned and each field team given a paper map and a digital copy. Georeferenced digital files are uploaded on mobile devices and the Avenza application is used for navigation from base up to the point where it is decided is the best place to park the vehicle.

Given that NBS plots are mainly located in relatively open landscape, the GPS is the main tool for navigating to the plot.

Plot coordinates are uploaded on a handheld GPS and the operator navigates to the desired plot ID. The operator uses the distance and the azimuth functionality to navigate to the plot until within a distance of 10 metres to the plot.

For square quadrants, the location is the quadrant in the South Western corner. Once the corner is located the position E and N and coordinate reference system (CRS) is registered[2]. In order to re-locate the plot easily in future, other descriptive information like distance and the angle of proximity to any conspicuous landmark are noted. If for some special reason a different corner is used to reference the quadrant, it is a requirement that such information is recorded (e.g. obstacle to GPS signal or SW corner inaccessible).

From the SW corner the NBS square plot is laid west to east at the base (southernmost length of the plot) and south to north; a clear line of sight is then made by using a tape measure to mark the 50 metre position in the east and in the north.

Thereafter, a linear tape and a compass is again set to a direction perpendicular to the first line demarcated in order to determine and establish the fifty-meter line perpendicular to the first line.

Back and forth bearings and adjustments are made repeated until a square plot of 50 by 50 meter is demarcated. The plot is then subdivided into five strips running East-West to form a 10 by 50 metre strips as shown in Figure 3-2. In instances where the NBS survey adopts the circular plot, the location of the plot is the centre of the plot as in EI.

[2] The default CRS used is the Universal Transverse Mercator (UTM) WGS1984 zone 36 North which is the same as EPSG 32636.

3.5 Plot Enumeration

Once the plot is demarcated, the enumerator records the coordinates of the plots, the vegetation where the plot is located and any socio-economic related activity within the forest or immediate vicinity of the plot. For future planning purposes, the enumerator records the start time and end time of the entire plot demarcation and plot enumeration exercise. If deemed necessary, the enumerator may make notes on the other unique characteristics of the area.

After general information about the plot are recorded, specific parameters that are needed for the computation of biomass and carbon stock in living trees, deadwood standing and deadwood on the floor are measured.

3.5.1 Description of Plot Location

Both EI and NBS data collection forms include an option for recording administrative unit information e.g., Region, Agro-Ecological Zone and Water Management Zone. Plot Cluster and Cluster Number, Plot ID, land use, Accessibility, Enumeration Date, Start and End time, Block and Plot coordinates, Inventory Area, Forest Reserve or UWA forest park are mandatory.

Sample specific area information mandatory for EI includes: EI Block Number, Transect Number, Plot Number, Team Leader, Land Use and canopy cover. Sample specific area information mandatory for NBS includes: Cluster Number, Plot Number and Land use. All tree parameters specific to EI and NBS survey are mandatory and Collect Mobile highlights data gaps with a red star on the data collect form.

3.5.2 Enumeration Procedures for the Nested Plot

The NBS plot being a square, enumeration is done following strips (see figure 3-2). In strip one (1), the most southerly strip, enumeration and recording of all the required parameters is done for all trees with a DBH of 3 cm and above. In the rest of the strips, (strips 2, 3, 4 and 5), tree enumeration threshold DBH is 10 cm.

The EI plot being a circle, the enumeration procedure follows a clockwise direction starting from bearing zero (or the north). In quadrant one (1), which is the angle between bearing north and bearing east from the centre of the plot (i.e. 0^{o} to 90^{o} from the centre of the plot), the minimum DBH threshold is 10 cm and in the rest of the plot the minimum threshold is 20 cm.

3.5.3 Tree Mensuration

For the estimation of biomass in living trees, the key parameters measured are Diameter at Breast Height (DBH), total tree height and species. For EI measurements, total tree height is occasionally measured. The NBS, in addition to total height, records bole height and crown diameter. For each measurement, the tree species is identified and recorded.

Diameter at Breast Height (DBH): Diameter at breast height is the diameter of a tree measured at a standard height of 1.3 m above ground. The height at 1.3 m corresponds to the position of the chest or breast of an average person. It is measured with diameter measuring tools such as diameter tapes or callipers among others. Linear tapes may also be used to derive tree diameter by measuring girth at breast height and dividing the value by pi (pi or π = 3.1428). Diameter measurements are recorded to the nearest centimetre. Procedures for measuring diameter are described in the inventory manual (MWE 2015 NFI manual for Uganda).

Total Tree Height: This is the height measured from the ground to the top of the crown (figure 3-5) or highest growing point (Michael, 1983). It is measured by using hypsometers, which are instruments for measuring heights based on either geometric or trigonometric principles, calibrated to give readings of the height directly in meters or degrees (heights at slopes). Procedures for measuring height are described in details in the inventory manual (See MWE 2015 NFI manual for Uganda).

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

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

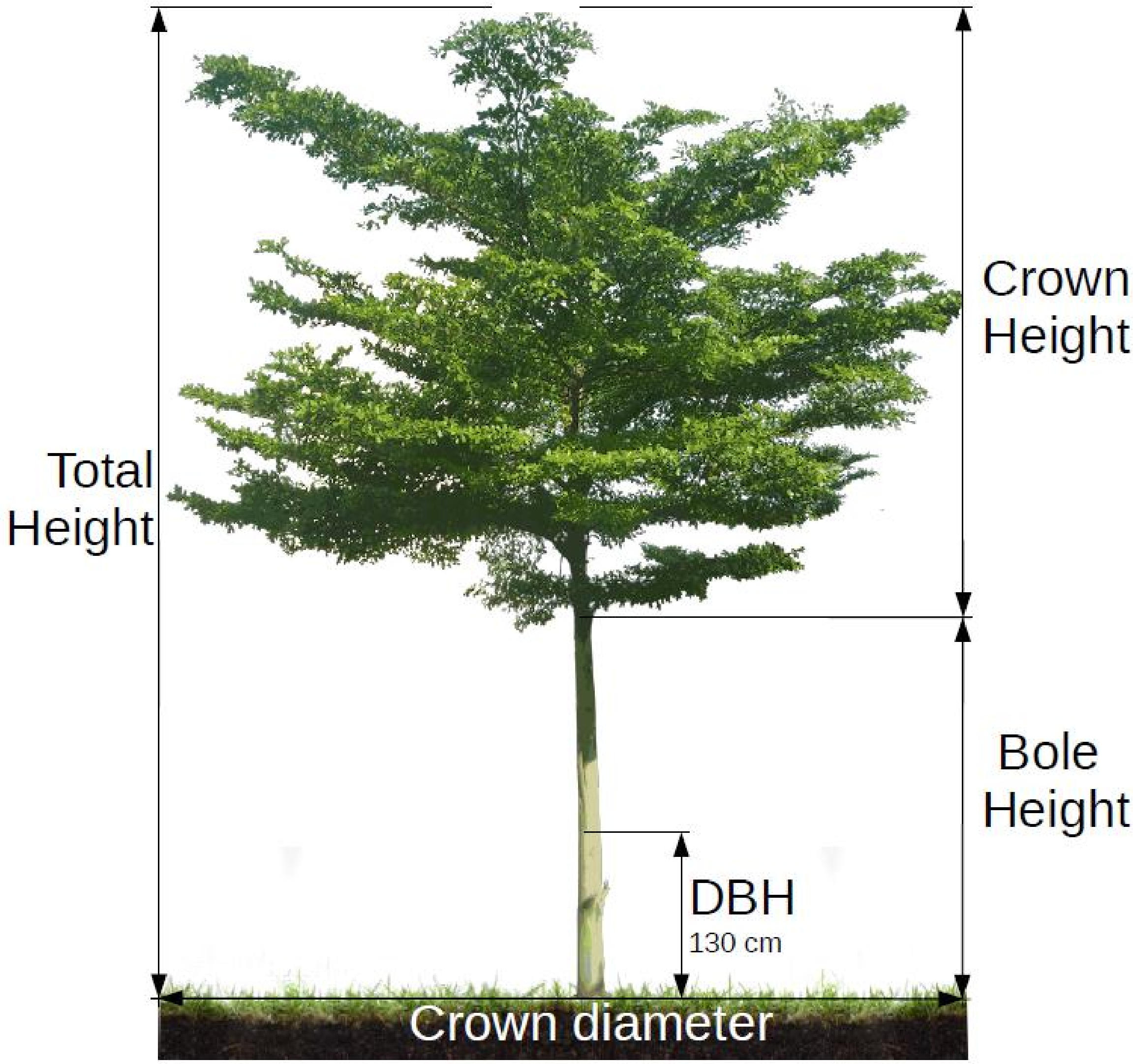


Figure 3- 5. Enumeration and recording of Tree parameters

Dead standing trees are recorded using the same procedures as for living trees but indicating their status as dead. Recording of broken crown tops is mandatory where observed.

Species Identification: A species identification control has been added on the form to avoid typographical errors. If the enumerator team fails to identify any of the tree species, a sample (leaf, bark, fruits) of the trees is collected for identification by the wider inventory team and a sample is taken to Makerere University Herbarium for identification by the botany experts, if the sample is particularly difficult to be identified. A space for local name is included in the field mobile form to further help on species identification.

3.5.4 Measurement of stumps and Deadwood (on forest floor)

3.5.4.1 Tree Stump

All tree stumps within the set diameter threshold, encountered in both NBS and EI sample plots are measured and recorded in terms of stump diameter and height. Stumps taller than a height of 1.5 metres are regarded as dead standing trees with either broken stem or broken top depending on the height. Identification of the tree stump species is optional for dead and debarked stumps that are beyond recognition. Recording of the stumps is done in the same way live trees are recorded. The decomposition status of the encountered stumps are recorded as: (i) Sound; (ii) Intermediate; or (iii) Rotten, on the basis of a machete test[3].

3.5.4.2 Deadwood on forest floor

In EI plots, measurement is done on all logs of 10cm and above encountered along the North-South axis that divides the plot into two equal parts. Log diameter at the point of cross of the north-south axis and the entire log length is measured and recorded. The decomposition status of the encountered logs is recorded in the same way stump status is recorded.

In NBS, measurement is done on all logs 10cm and above in diameter that are found in the plot. Log length and mid log diameter are recorded. For borderline cases, only the length of the log that is within the plots is measured as the log length.

3.5.5 Summary of Field Measurements

Direct measurements carried out in the field are for the estimation of carbon pools in above ground biomass (living) and carbon deadwood (Table 3-1). For living biomass, DBH and Height are minimum requirements. Crown diameter and Bole height are important for other estimates like stem volume and branch biomass. Branch biomass is of significant stock in some of Uganda's agroforesty systems. Belowground biomass is not measured but is rather derived as explained in section 4.2.1.1 that explains the computation of tree biomass.

Table 3- 1. Summary of actual measurements for the estimation of carbon pools

Pools	Measurements	Qualifiers for Uganda
Aboveground Biomass	DBH and Height are measured. Where height is not measured like in some EI plots, it is derived using the Curtis model	Min DBH 10cm for THF Min DBH 3cm for Woodlands
Deadwood	Measured. EI uses transect. NBS uses plot area	Min log diameter of 10cm

[3] The stump wood is struck with a machete—if the blade bounces off, it is sound; if it enters slightly into the wood, is it intermediate; and if it causes the wood to fall apart, it is rotten. IPCC GPG LULUCF 2003

3.6 Field level Quality Control

Both NBS and EI have Quality Control (QC) processes embedded in the data collection procedures both for enumeration and data recording on the tablets. For every inventory, about 10% of the sample plots are measured by a different team to check the following:

- Number of trees not correctly identified
- Number of trees that are supposed to be in a plot but were omitted
- Number of trees that were not supposed to be in a plot but were included
- DBH error measurements in percent error from the correct measurement
- Height error measurement percent error from the correct measurement
- Incorrect recording of plot coordinates
- Incorrect recording of land use\cover

Quality control done at data entry level involves the selection of a number of teams to check the data quality captured by other teams, the Quality Control team is also checked by another team. Quality control is like an appraisal "You appraise a team; another team also appraises you".

Other controls are inbuilt on the data entry form (e.g. minimum and maximum limits to DBH value, minimum and maximum limits to height values). Fields like DBH are mandatory for EI and NBS surveys, and height measurement is mandatory for the NBS survey.

3.7 Tools and Equipment

The NBS and EI inventory teams have the same sets of tools and equipment and these include;

- Plot navigation tools; GPS, Avenza software
- Data capture tools e.g., tablets and other android devices
- Tree diameter measuring tools (Callipers and diameter tapes),
- Distance measuring tools (linear tape, Vertex and transponder),
- Height measuring tools include Trupulse360, Vertex and Suunto
- Bush clearing tools such as machetes
- Stationery.

3.8 Data Capture

National Forest Inventory data is captured directly from the field into Open Foris Collect on Android tablets. There has been a deliberate effort to digitize data collection in the NFI since 2016 with the main purpose of eliminating data entry errors that arise from capturing data from field paper forms long after team members have dispersed, and memory is constrained. However, a paper form is recorded as a backup. The details that are recorded in the plot are presented in the enumeration form in Appendix IIa and IIb.

3.8.1 Open Foris Collect

Open Foris Collect is a data collection tool developed under FAO with focus on forest related data. It can run on both mobile and desktop environments, with the mobile platform based on Android devices and the design and server environment based on desktop operating systems (Windows and Linux).

Open Foris Collect allows for rapid data capture in any language, even in remote areas. With a web-based application capable of running on any desktop computer with a web browser, Open Foris Collect provides an easy to use making conversion from paper forms to digital quick and seamless. It supports any type of data including location and photos even in areas without internet.

With Open Foris, complex validation rules can be integrated into a survey allowing for data quality control. Open Foris also provides a flexible solution for field data management, allows full customization of inventory structure, variables and data checks, promotes data quality through an integrated data entry and data cleansing workflow. Both standalone (offline) and web-based (online) Collect versions were used.

Box 3.1: Open Foris Collect at a glance

- **Rapid Data Entry**: Limited use of mouse needed; Data entry using only keyboard, Auto-complete, Species list search, immediate feedback on errors/warnings.
- **Highly Configurable**: Design the survey from scratch or starting from a template; Data entry user interface is automatically generated and metadata driven; Validation rules (distance, comparison, pattern...); Multiple layouts (form, table, multiple columns form).
- **Multiple data types:** Basic Types – Text, Number, Boolean, Date, Time. Complex types – Range, Coordinate, File, Taxon. Plus, support for calculated values.
- **Multi-user or standalone:** It can be used in a standalone environment with no need for internet connection; Data can be exported from single/standalone installations and imported into a centralized installation to create a complete data set; In multiuser environment, users can work only on owned records.
- **Controlled QA workflow:** Record goes through different steps: Data entry, Data cleansing, Data analysis. Minimized "data cooking".
- **Rich metadata:** XML format, Complex nested structure of the survey, Validation rules, Multiple Spatial Reference Systems.
- **Multilingual:** Define the survey in multiple languages - Tab labels, Input field labels, Validation messages, Code item labels, and Element info tooltips. The user will see the survey in the language of his/her web browser or in the survey default language.
- Multiple data export/import formats XML, CSV, and Relational database

The process starts with survey design with the help of Open Foris Collect Survey Designer and a survey file is loaded onto Android tablets, which are then taken for field data collection. The most important feature of the data collection process is the availability of an offline data staging point on the Android devices. Once there is access to a mobile network, the data entrant can then command Open Foris Collect to upload data onto a server.

As much as Open Foris is a highly stable software, due to the difficult environment encountered by field teams especially in the tropical high forests, the same data that is captured on the tablets is written on paper forms as a form of redundancy and cross-checking capability to ensure a complete and accurate data set from the field.

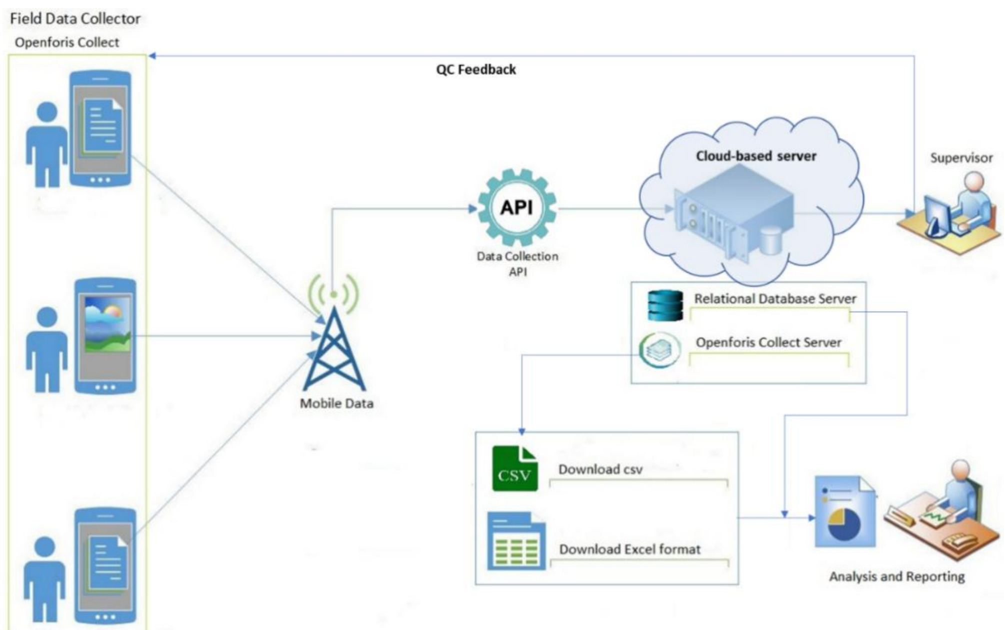


Figure 3- 6. High level NFI data flow, including office and field feedback

The supervisor reviews data as it is uploaded on the server. This is to ensure that data is of good quality and where need be the relevant data collector will be asked to revisit the data. This is made possible because the system configuration that specifically identifies the data collector of the uploaded data.

From the Open Foris Collect server data can be downloaded in three file formats (. xlsx,. csv, collect). The *Collect* file format is mainly for backup in the original field data format or transfer to another Open Foris Collect instance and for analysis. The Excel and or CSV formats can be exported, normalised and uploaded into any relational database management system.

3.9 Inventory Team composition

Field Inventory teams for both NBS and EI are comprised of a team leader, assistant team leader, data entrant and four skilled helpers. The field team is headed by a biomass inventory supervisor for NBS and EI supervisor respectively. The entire inventory crew is routinely checked and supervised by a Biomass and Inventory Officer and Coordinator of inventory and Surveys for data quality control and assurance. Forest Managers of respective management areas (NFA and UWA) where inventory is conducted are often integrated into the inventory teams.

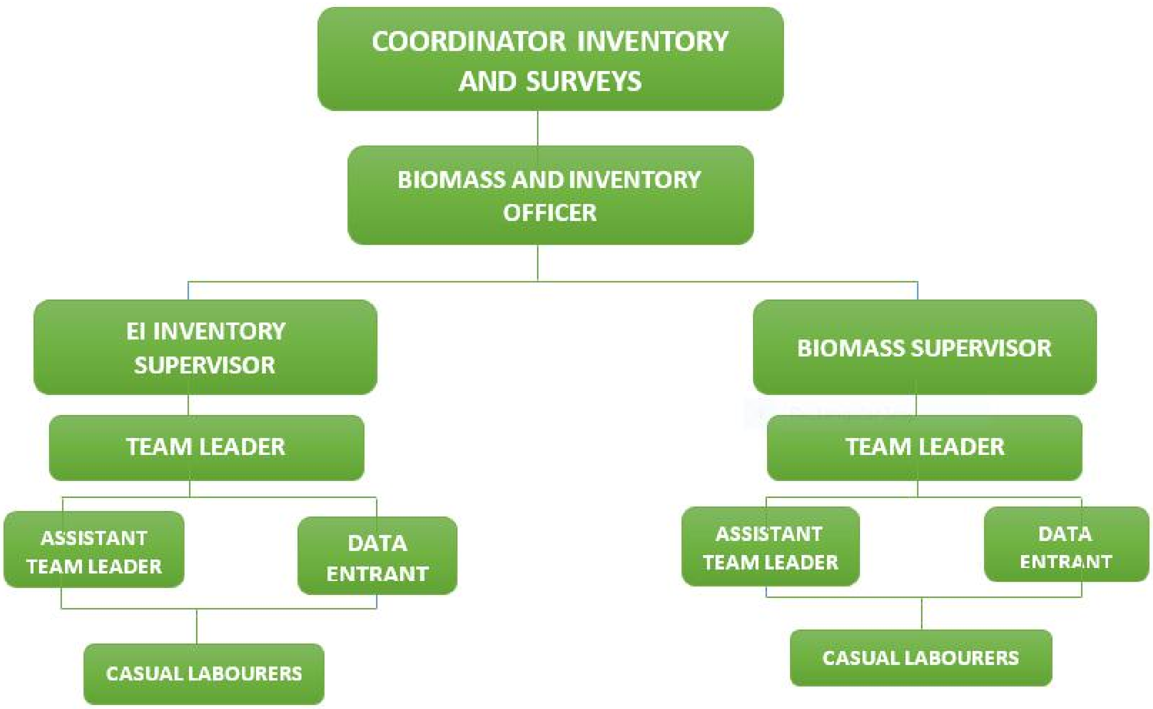


Figure 3- 7. Schema of the structure of NFI in the field

Table 3- 2. Roles and responsibilities of team members

Team composition	Responsibility
Coordinator Inventory and surveys	Overall Quality control and quality assurance for field data collection
Biomass and Inventory officer	Overall data quality control and field supervision of the two inventories Biomass and Exploratory

	Inventory
Inventory Supervisor	Full time field supervision of the Exploratory Inventory team
Biomass Supervisor	Full time field supervision of the Biomass team
Team Leader	Overall leader of the unit of the inventory team who conducts field measurements
Assistant Team Leader	Assist the team leader in field measurements
Data Entrant	Digital Data capture of all plot and tree parameters
Casual labourer	Assist with bush clearing along the lines and plots

The photo below shows a typical team of NFI technicians just before they set off for the field. The camp site can be seen in the background (Plate 3-1).

Plate 3- 1. A field team before setting off for work, Karamoja 2019

4 Data Analysis

National Forest Inventory data analysis is a multi-stage process that involves data access, modelling, aggregation and reporting. The data model for NFI data analysis will vary depending on the analysis need. In order to ensure a seamless data analysis process, it is important that all the data needed to deliver the required reports is acquired, modelled and the relationships between the different entities are well established. Figure 4.1 shows the model that was used to deliver the results in this report.

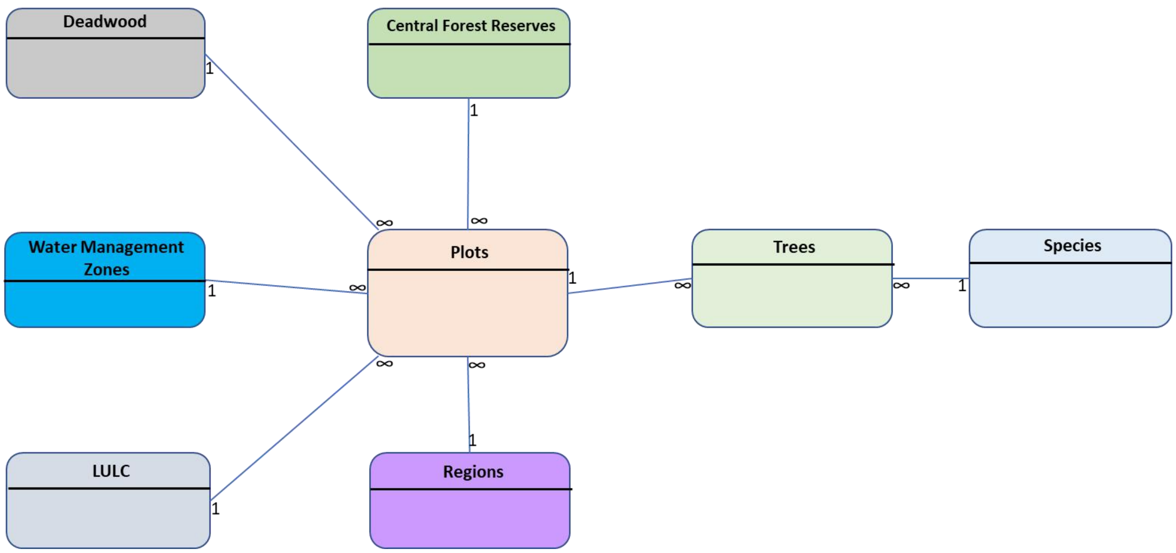


Figure 4- 1 NFI Data Analysis Model

The ∞ represents the many-sided relationships while the 1 represents the one-side relationships. The description of the entities of the model is as follows:

Table 4- 1 Description of NFI data model entities

Entity	Description
Deadwood	Contains data on fallen and standing deadwood
Central Forest Reserves	Describes parameters associated with CFRs under NFA and protected areas under UWA

Trees	Contains data on tree parameters
Species	Contains data on tree species
LULC	Contains data on land-use and land-cover classes
Water Management Zones	Contains data on water management zones as reported by the water sector in MWE
Regions	Describes the regions as demarcated by UBOS
Plots	This is the central entity in the model that describes the plots visited during inventory.

4.1 Data Integration

The national forest inventory data is from two structurally different inventories (EI and NBS), hence the need to integrate data from these inventories into the model in figure 4-1. In order to minimize the number of transformations that are required and in order to have an integration of EI and NBS data, it was decided that they share certain entities for instance, the two inventories share the same LULC codes, the species list, the deadwood parameters, stump parameters and obviously regions and water management zones. However, the plot size differs, and some trees parameters are not captured in EI, for instance tree heights due to the nature of the canopy in tropical high forests. Thus, there are some data transformations carried out to ensure seamless integration of data from the two inventories that are used in this report.

4.1.1 Data Transformations

Uganda's NFI uses different plot sizes and shapes for different surveys as described in sections 3.3.1 and 3.3.2. In addition, both EI and NBS use a nested plot approach. There is thus a need to harmonize data to a comparable reporting unit, i.e. a hectare basis.

Historically, EI surveys did not include height measurements as described in section 3. Given that Uganda has chosen to use an allometric equation that includes height parameter, the approach where height is modelled from secondary data sources and to a limited number of height measurements in recent EI surveys has been used.

4.1.1.1 Expansion factors for plots

Plot expansion factors are computed in order to convert the recorded attributes into a per hectare basis. For instance, the sample plot area in NBS is 0.25 ha while the EI plot is 0.05 ha. During analysis, the single tree results are transformed into hectares by an expansion factor of 4 and 20 for NBS and EI, respectively. The small nested plot in NBS is 0.05 ha (a fifth of 0.25 ha) while that of EI is 0.0125 ha (a quarter of 0.05Ha). An expansion factor of 20 for NBS nested plots and 80 for EI nested plot respectively are applied.

4.1.1.2 Tree Heights

While in NBS measures data on tree heights, bole heights, crown diameter and DBH, EI only measures data on DBHs. In order to use the same formula in determining biomass and carbon stocks, the missing tree heights in EI are estimated using the following Height-diameter and height-diameter age equations (Curtis 1967).

$$h = 1.3 + a\left(\frac{dbh}{1 + dbh}\right)^{b}$$

Where;

h = estimated top height [m];

dbh = Diameter at Breast Height (cm);

a, b = parameters (refer to table 4-2)

The parameters were estimated using nonlinear estimation techniques, and height model parameters were computed by site types (Table 4.2) by calibrating the model by sampling unit.

Table 4- 2 Height model parameters by strata for Curtis height model.

Site type	a	b
Hardwood plantation	2.74110	0.48191
Conifer plantation	1.70710	0.46696
Tropical High forest	2.546011	0.444472
Woodland	1.080915	0.365996
Bushland	1.131130	0.428399
Grassland	0.901513	0.367906

4.2 Data processing

The first level of computations is single entity computations which include single tree stocking, basal area, tree volume, biomass (above-ground, below-ground, total) and carbon. These data are summed up at plot level and converted into hectare basis with the help of expansion factors.

4.2.1.1 Computing Single Tree Biomass

The Chave *et al.* (2014) equation estimates above ground biomass based on three parameters: DBH, Height and Wood density. DBH and height measurement or estimates are described in section 3.5.3. Wood density used is derived from the NBS studies of 1992 and 2002.

Above ground biomass (AGB)

$$AGB = 0.0673(WD \cdot dbh^2 \cdot h)^{0.976}$$ (Chave et al., 2014)

Where;

AGB = Above Ground Biomass [kg];

WD = Wood Density [t /m^3]; The default value for the WD is 0.615 t/m^3.

Blow ground biomass (BGB)

Below ground biomass is computed as a factor of root to shoot ratio. The IPCC guidelines provides default factors to use where countries do not have locally generated values. The values used in the computations are in table 4-3.

$$BGB = AGB * RS$$

Where;

BGB = Below Ground Biomass [kg];

RS = Root Shoot Ratio (fraction), by Vegetation types

Table 4- 3. Root shoot ratio values

Uganda Land Strata	Corresponding IPCC type	Default Root- Shoot Ratio
THF	Rain Forest	0.24
Woodland	Dry Forest	0.36
Eucalyptus	Eucalyptus	0.24
Coniferous	Coniferous	0.24

Total Biomass (TB)

Total Biomass is derived as the sum of AGB and BGB.

$$TB = AGB + BGB$$

Where;

TB = Total Biomass [kg];

AGB = Above Ground Biomass [kg];

BGB = Below Ground Biomass [kg];

4.2.1.2 Computing Single Tree Carbon

Tree biomass to carbon is derived by multiplying biomass by a carbon conversion factor. The default value used is 0.5.

$$C = Biomass * 0.5$$

Where;

C = Carbon [kg] or tonnes;

Biomass= Biomass Dry Matter [kg] or tonnes;

0.5 = Biomass to carbon conversion factor of a tree

4.2.1.3 Computing Single Tree Basal Area

Basal Area (BA) or cross section area of a tree at breast height is derived from DBH using the equation below and is expressed in metres squared (m^2).

$$.BA = \pi \cdot \left(\frac{DBH}{2}\right)^2$$

Where;

BA = Basal Area (m^2);

DBH = Diameter at Breast Height;

4.2.1.4 Computing Single Tree Volume

The volume of the stem is a function of basal area and other factors that characterizes the shape of the tree, mainly the bole and three height and rate of taper or form factor. Tree volume is expressed in cubic metres (m^3).

$$Tvol = BA * h * Ff$$

Where;

$Tvol$ = Tree Volume [m^3];

BA = Basal Area in meters squared [m^2];

h = Tree height [metres];

Ff = Form factor (fraction, dimensionless)

4.2.1.5 Deadwood Volume in EI Plot

De Vries' formula that is used to estimate deadwood volume of logs along the transect directly on to a hectare basis (De Vries P.G. 1986). The input variables are length of the transect (L) in metres and the log diameter (d) in centimetres at the point of intersection, as follows:

$$V = \frac{\pi^2 \sum d^2}{8L}$$

V = volume per hectare of deadwood in m^3;

d = log diameter (cm) at the point of intersection of the transect perpendicular to the axis of the log;

L = length of the transect (metres).

4.2.1.6 Deadwood Volume in NBS Plot

Log volume in the NBS plot are calculated from the measurement of the length of the log and a single diameter measurement on the outside of the bark (dob) from the middle of the log using Huber's formula.

$$V = L \cdot (dob)^2 \cdot C$$

Where;

V = volume of a single log of deadwood in m^3;

L = Tree Volume [m];

dob = Diameter outside of the back at a point midway [cm];

C = 0. 0000785 (unit conversion factor);

4.2.1.7 Deadwood biomass

Estimating biomass of deadwood requires state of decomposition of deadwood. Three decomposition classes are recorded for deadwood particles: sound, intermediate and rotten. Because rotten wood is lighter than sound wood, the dry wood density of deadwood is scaled down using lower wood densities than for standing trees, as follows:

Sound deadwood WD: 90% * Default WD;

Intermediate deadwood WD: 70% * Default WD.

Rotten deadwood WD: 50% * Default WD.

Deadwood mass is derived as a factor of Wood Density (WD) and Deadwood Volume. The default wood density used is 0.640.

4.2.1.8 Estimating Deadwood Carbon

Deadwood weight is converted into carbon using the default carbon conversion factor of 0.5.

$$C = DBiomass * 0.5$$

Where;

C = Carbon [kg] or tonnes;

DBiomass= Deadwood Biomass Dry Matter [kg] or tonnes;

0.5 = Biomass to carbon conversion factor of a tree

4.2.2 Estimating Carbon General

Carbon stocks or carbon pool refers to a system that has the capacity to store or release carbon. The Marrakesh Accords recognize five main carbon pools or reservoirs in forests: above-ground biomass, below-ground biomass, deadwood, litter and soil organic matter.

As alluded to in the NFI improvements in section 4.5, collection of data for the estimation of soil carbon pools is an ongoing exercise.

5 NFI data Aggregation

5.1 Land Use / Cover Class for NFI Reporting

NFI results are presented by land use / land cover or forest strata at various levels of administration or management units and at a national level. Since 1990, eleven land categories have been used to represent the vegetation of Uganda under a classification developed by the National Biomass Study. NBS has five forest strata and six non- forest land categories.

For the construction of Uganda's baseline for REDD+ (2018), the NBS forest strata were aggregated into only three categories (table 5-1). Recent map production has mainly been based on computer aided classification with minimum field verification. For international reporting, it was not feasible to disaggregate forest strata to a level of the maps produced in the 1990s.

Inadequacies in forest disaggregation notwithstanding, the NFI report provides statics for the six forest strata based on field information about sample unit location for purposes of making comparison with previous biomass reports / studies.

NFI was not carried out in large scale cropland (or commercial plantations), impediments and permanently wet areas (mainly papyrus, floats and permanently wet grass). Open water is a non- land category and is thus not included in NFI reporting.

Table 5- 1. Comparison of NBS Land Categories to categories used for international reporting

<table>
<tr><th>IPCC Land Use Category</th><th>NBS Land categories</th><th>Land categories that have been used for international reporting (REDD+/BUR)</th></tr>
<tr><td rowspan="5">Forest</td><td>THF (Well stocked)</td><td rowspan="2">THF</td></tr>
<tr><td>DTHF (Low stocked or degraded)</td></tr>
<tr><td>Woodland</td><td>Woodland</td></tr>
<tr><td>Forest Plantations (broad leaved)</td><td rowspan="2">Forest Plantations</td></tr>
<tr><td>Forest Plantations (coniferous)</td></tr>
<tr><td rowspan="6">Non- Forest</td><td>Bush</td><td rowspan="2">Grassland</td></tr>
<tr><td>Grassland (including Seasonally wet valleys)</td></tr>
<tr><td>Subsistence and Commercial farmland</td><td>Cropland</td></tr>
<tr><td>Settlement (Built up area)</td><td>Settlement</td></tr>
<tr><td>Impediments</td><td>Other land</td></tr>
<tr><td>Permanently wet (papyrus)
Permanently wet (floats, other sedges, grass)</td><td>Wetland</td></tr>
</table>

	Open water	

*Key differences between data used for domestic purposes and the two reports submitted to UNFCCC (i.e., Uganda's FREL 2018 and BUR 2019) is that for the purposes of international reporting, **THF well stocked** and **THF low stocked** were combined into one stratum of **THF**, broadleaved forest plantations and coniferous forests plantations were also combined into one stratum of **forest plantation.** For each forest strata, weighted average Carbon Stock values were applied.*

Change between forest and non- forest was reported as deforestation (conversion of forest to non-forest) or afforestation /reforestation for conversion of non-forest land into forest.

5.2 NFI Data used in the Report

NFI data used in this report covers about 75% of the country (figure 5-1). EI data used is from the most recent sample units measured between 2016 and 2019. These samples were measured in Mabira and Mt Elgon National Park, in the Kyoga Water management zones and Bugoma, Budongo, Kangombe CFRS and Kibale Forest Park which fall in the Albertine water management zone (figure 5-1). EI adequately covers majority of the THF save for a few forests in the south west and Zoka forest in the north. EI survey also includes woodlands in protected areas mainly from Budongo CFR.

About 10% of NBS plots used in this report were measured between 2016 and 2019, mainly from the central Uganda woodlands that have been a source of charcoal for the major Urban centres. NBS plots measured since 2016 under the readiness phase of REDD+ programme fall in the districts of Kiboga, Lwero, Kasongola, Hoima, Kikube, Kiboga, Ntoroko, Bundibugyo and Rubirizi. Most of these districts fall within the Albertine Water Management zone. Other district covered under the recent NBS plot measurements include the districts of Amudata, Nakapirpiti, Moroto, kadam, Kitido in the Karamoja sub region, in the Kyoga Water Management zone. For purposes of having a national coverage, data from older NBS plots is used in this report but does not include data prior to the year 2003 i.e., not exceeding 15 years from the year 2019 (figure 5-1).

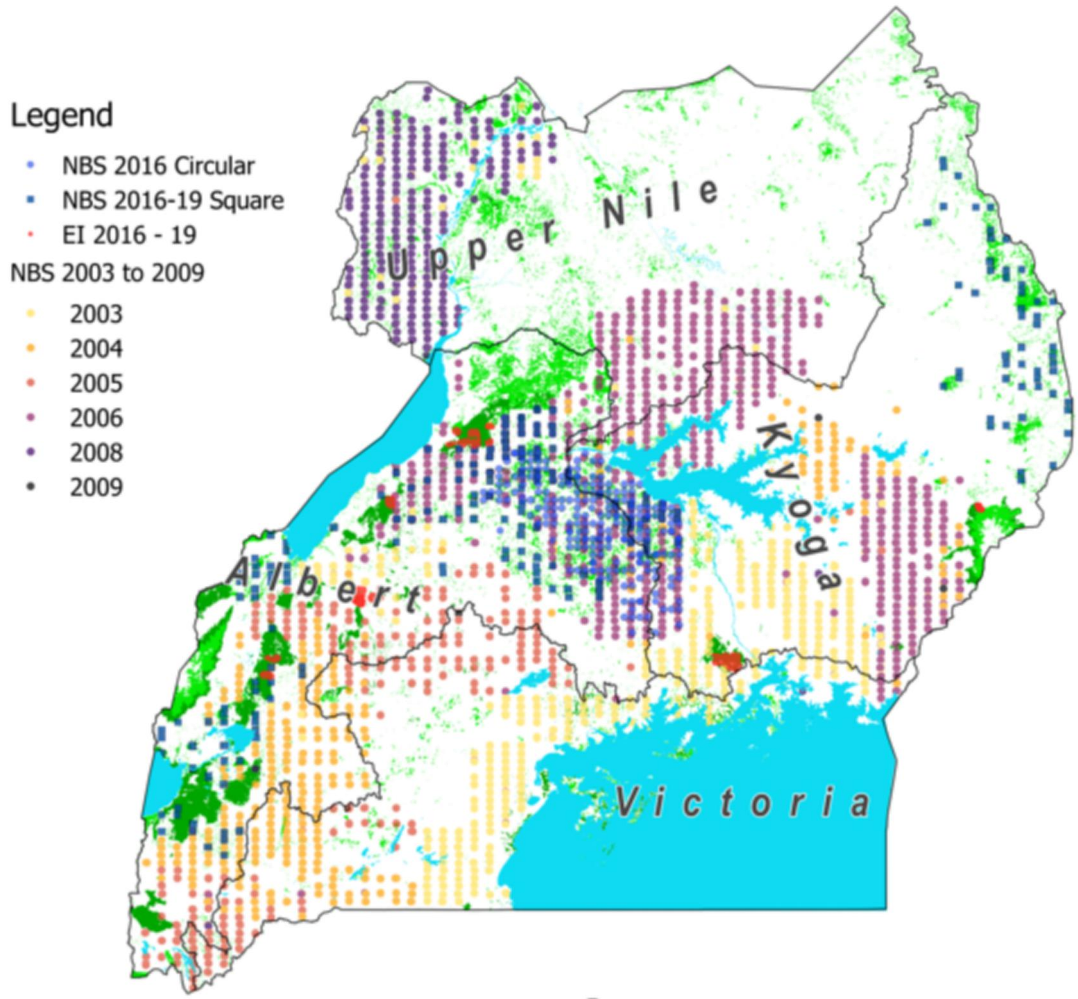


Figure 5- 1. NFI sample sites used in this Report

5.2.1 Sample size

A total of 10,595 plots are used in this report of which 4,668 are from the EI survey representing a sampled area of 233ha. NBS survey had a total of 5,927 plots (of different shapes and size measured over a long period of time) representing as sampled area of 1,219 hectares. EI plots were predominantly measured in THF while majority of NBS plots are in Woodlands. Notwithstanding the data gaps in the northern part of Uganda or Upper Nile WMZ (figure 5-1), the sample points are generally well spread across the country.

Table 5- 2. Number of Sample units at the national level

NFI Type	Year	Number of samples	Sample Area (ha)	Sample Area by Survey
EI - 0.05ha circular	2016-19	4668	233	233
NBS - 0.05ha circular	2016-19	1315	66	1219
NBS - 0.25ha square	2016-19	439	110	
NBS - 0.25ha square	2003-2008	4173	1043	
Total		10595	1,452	1452

5.2.2 Sampling intensity at National Level

At a national level, about 80 hectares and 155 hectares were sampled in THF low stocked and well stock respectively. This is equivalent to a sampling of 0.06% and 0.04% in THF low stock and well stocked respectively. About 158 hectares were measured in woodlands corresponding to a sampling intensity of 0.01% (Table 5-3). About 33% of the forest samples were in protected areas under the jurisdiction of either UWA or NFA. Samples size in non-forest land is about 1,051 heaters or a sampling intensity of 0.005%.

Table 5- 3. National Level Sampling Intensity

Land unit	Strata	Area (ha)	Sample size	Sampling Intensity
Forest	THF Low stocked	138,354	80	0.06%
	THF well stocked	432,069	155	0.04%
	Woodland	1,160,667	158	0.01%
Non- Forest		21,909,845	1,051	0.005%

5.3 MWE Zonation

In addition to national level reporting NFI includes Water Management Zones (WMZs) as one of the reporting areas given that MWE's strategic plans and operations are largely based on water catchments. Where feasible, reporting may be at the management unit level such as forest reserve or forest park. Forest management level is considered beneficial to the two major custodians of the forest estate in Uganda, i.e. NFA and UWA.

5.3.1 Description of Water Management Zones

Uganda is divided into four WMZs: Kyoga, Lake Victoria, Albertine and Upper Nile. WMZ zones are named according to catchment areas or major drainage systems.

The Kyoga WMZ has a total area of about 6.1 million hectares and derives its name from a combination of rivers and wetland systems that drain into Lake Kyoga. The most prominent of these include the Okaka and River Manafa that drain into Lake Kyoga from the Karamoja region and Mount Elgon respectively (figure 5-2). From the south, the Mpologoma Wetland system and the Victoria Nile are the major drainage systems.

The Victoria WMZ covers an area of about 6.2 million hectares and encompasses the wetlands and rivers that ultimately drain into Lake Victoria. Key of these are the River Katonga and River Rwizi that sluggishly drain eastward through wide valleys of papyrus swamp (figure 5-2). The largest river is Kagyera which for most of the part traverses Rwanda and Tanzania before it enters into Uganda and drains into Lake Victoria only 10km north of the boundary with Tanzania. Its catchment area includes the highland areas of southwestern Uganda.

The Albertine WMZ cover the catchment area of Lake Albert that is within Uganda and is estimated at 5.6 million hectares. It extends from the Ice capped Mt Rwenzori in the far west and the Maghinga Gorilla sanctuary area in the far south western. Major drainage systems include River Nyamwamba from Mr Rwenzori, Ishasha and Semiliki Rivers at the border DRC, River Mpanga and River Muzizi in from the Kibale and Kangombe Forests, and River Kafu and Albert Nile in the north east. The eastern extent stretches up to Lubinji wetland in Bwaise, which is part of Kampala Capital City.

The upper Nile WMZ lies north of the Kyoga WMZ and the Albertine WMZ. It is estimated to have an area of over 6.2 million hectares and generally drains towards South Sudan. The major drainage systems are the Achwa river and While Nile which drains north from Lake Albert.

5.3.2 Forest distribution in the WMZ

All WMZs have a fair share of the various types of forest strata. Their occurrence is to a good extent influenced by rainfall regime. The highest rainfall in each zone is around 2,000 mm per year. The lowest is at about 700 to 500 mm per year (figure 5-2).

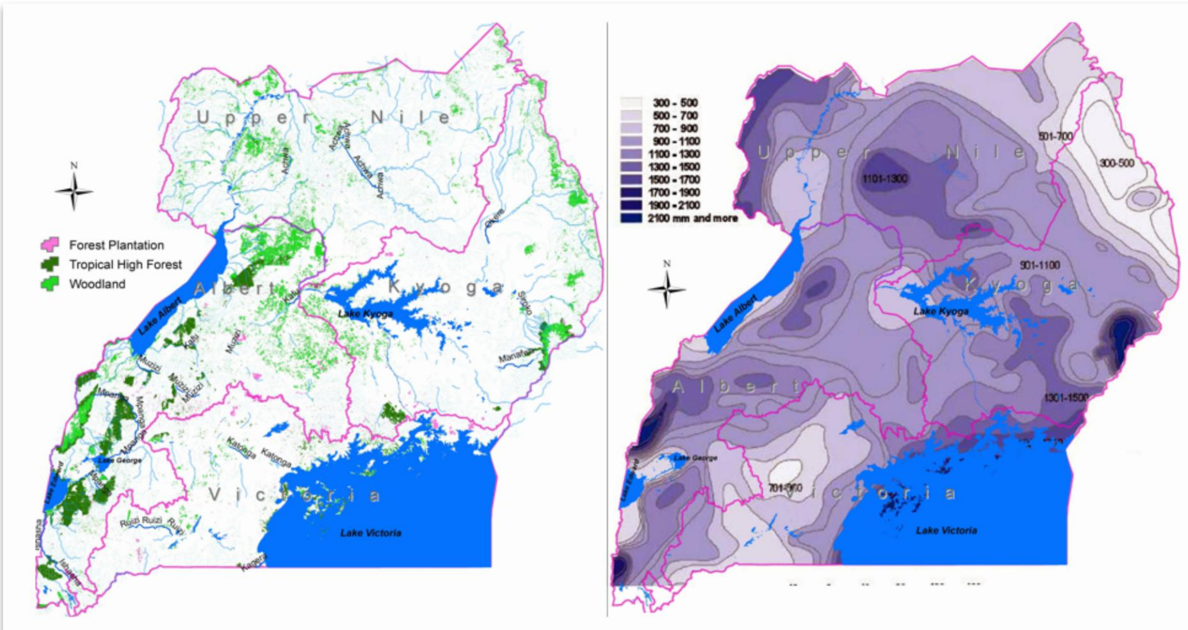


Figure 5- 2. Rainfall (right) and forest types (left) in the four MWE Management Zones

Tropical High Forests tend to occur in areas with at least 1,000 mm of rainfall per year. Woodland occur in generally drier areas with at least 700 mm of rain per year. With high population levels, the remaining forests are almost exclusively found in protected areas e.g. Forest Reserves and National park and to some extent highly inaccessible areas e.g., steep or high mountains (majority of which are also protected).

Table 5- 4. Summary of forest and non- forest areas by WMZs

WMZ				Non - Forest		All Land	
	THF	Low Stocked THF	Woodland	Bush	Other Non-Forest	Total	Total Area
Victoria	13,265	33,376	73,567	241,394	5,680,786	6,042,388	6,188,624
Albertine	382,375	80,442	474,255	500,540	3,974,117	5,411,729	5,658,210
Kyoga	36,250	22,839	277,219	519,283	5,183,309	6,038,900	6,095,184
Upper Nile	178	1,698	335,626	611,691	5,198,725	6,147,918	6,200,017
Total	432,069	138,354	1,160,667	1,872,908	20,036,937	23,640,935	

5.3.2.1 Forest distribution and rainfall in the Kyoga WMZ

In terms of rainfall, Mt Elgon area has the highest rainfall of over 2,000 followed by areas north of Lake Victoria. Most of the THF are found in these areas. Mabira CFR in the south is about 30,000 hectares and Mt Elgon Forest National park is about 25,000 hectares. The two protected areas account for 98% of the 59,089 hectares of THF in this WMZ (table 5-2).

The mountains of Zulia NP, Mt Moroto CFR, Kadam (ranges) CFR and Napaka (ranges) receive about 700 mm of rain and accounting for 70% of the woodlands in this region which are estimated at 519,283 hectares.

The far north eastern areas of Karamoja is the driest, with some areas receiving as low as less than 500 mm of rain (Figure 5-1). These areas are predominantly bush which is estimated to cover about 500,000 hectares of the WMZ. The rest of 5million is shared between cropland, grassland and seasonally wet grasslands.

5.3.2.2 Forest distribution and rainfall in the Lake Victoria WMZ

Kalangala archipelago and other neighbouring islands have the highest rainfall of over 2,100 mm and the majority of the remaining THF in these areas. Areas around Ntungamo in the west and Sango bay in south are the driest and receive less than 700 mm of rain. The WMZ is estimated to have about 13,265 hectares of well stocked THF and 33,376 of low stocked THF. The high acreage of low stocked THF is attributable several years of degradation due proximity to high population centres of Kampala, Entebbe, Jinja and Masaka.

5.3.2.3 Forest distribution and rainfall in the Albertine WMZ

The south west highland areas of Kabale and Kisoro, the Rweinzori Mountains and areas east of the rift the valley escarpment which include Bushenyi, Rubrizi, Kibaale, FortPoral, Bugoma forest and Budongo forest are among the wettest areas (receive over 1,200 mm of rainfall). The remaining THF estimated at about 380,00ha are found in these areas. Most of the THF are in protected areas such as Budongo, Bugoma, Kangobe, Matiri, Kashoha Kitomi, Echya, and Karinzu CFR. Forest parks include Kibale, Bwindi, Maghinga. Some of the THF are degraded or low stocked and are estimated at 80,000ha.

The WMZ has over 400,000 ha of woodlands and majority in protected area of Semiliki Valley, Queen Elizabeth and Murchison falls. Other woodlands that are a major source of charcoal are found in the cattle corridor of central Uganda in the districts of Kyankwanzi, Nakasogola, Ngoma.

5.3.2.4 Forests distribution and rainfall in the Upper Nile WMZ

Areas around Gulu town and Phaidha at the border with DRC have the highest rainfall of 2,000 mm. About 178 THF and 1,690 low stock THF are in Zoka just north of Gulu.

Areas with mid rainfall regime (about 700 mm of rainfall per year) are associated with woodlands, estimated at about 335,000 hectares. Most the woodlands are found in areas north of the Murchsion falls NP, areas east and west of the Nile some of which are protected as Wildlife reserves. Recent influx of refugees into areas have impacted negatively on the woodlands.

The driest areas are in the far eastern part of the MWZ, northern parts of Abim and the border with Karamoja. These areas are associated with bush vegetation cover. Bush is estimated to cover about 600,000 hectares of the Upper Nile WMZ.

5.3.3 Sampling by WMZ

Forested areas of the Albertine WMZ are the most well sampled with all of them having a sample size of 70 hectares (table 5-5). In terms of sampling intensity, low stocked THF has the highest sampling intensity of 0.1% followed by woodland and well stocked THF with of 0.02% each (Table 5-6).

In the Kyoga WMZ, THF well stocked are most sampled with a sample size of 81 hectares (Table 6-5) which gives a sampling intensity 0.22% (Table 5-6). Woodlands are the second most sampled at 43 hectares (Table 5-5), a sampling intensity of 0.02% (Table 5-6). Sampling of low stocked THF is almost negligible, 1 hectare (Table 5-5) or 0.004% sampling intensity (Table 5-6).

Table 5- 5. Sample Size (Ha) by WMZ

Strata		Albert	Kyoga	Upper Nile	Victoria
		Sample Size (ha)			
Woodland	Forest	76	43	35	4.5
THF Well stocked		74	81	-	-
THF Low stocked		78	1	0.25	0.5
Non Forest	Non Forest	364	317	243	127

The sample size of woodlands in the Upper Nile is 35 hectares while the sample size of low stocked THF is only 0.25 hectares. Both woodlands and low stocked THF however have the sample sampling intensity of 0.01% (table 5-6). Upper Nile WMZ has no samples in well stocked THF.

The woodlands in the Victoria WMZ have a sampled size of 4.5 hectares (Table 5-5) or a sampling intensity of 0.01% (Table 5-6). Low stocked THF are sampled at 0.001% (Table 5-6) at a sample size of only 0.5 hectares (table 5-5). There are no samples in well stock THF.

Table 5- 6. Sample Intensity (%) by WMZ

WMZ	Albert	Kyoga	Upper Nile	Victoria
Woodland	0.02%	0.02%	0.01%	0.01%
THF Well stocked	0.02%	0.22%	-	-
THF Low stocked	0.10%	0.004%	0.01%	0.001%
Non Forest	0.01%	0.01%	0.004%	0.002%

6 Results

Results are presented by forest and non-forest strata at the national level and by the management units described in Chapter 5. Key parameters reported on are tree count, basal area, stem volume, above ground biomass, below ground biomass and carbon stocks therein, as well as species diversity. In some instances, it is more informative to further separate strata information into tree diameter classes.

6.1 Tree Count

A total of 256,471 trees were enumerated in a total sample area of 1,400 hectares. Most of the trees were enumerated in woodland (71,754 trees), followed by small scale farmland (63,000), grassland (57,968) Tropical High Forest Well stocked (38,575) table 6-1.

Table 6- 1, Number of Trees Enumerated

Land cover	TREE COUNT
Broad leaved plantations	2,048
Built up area	423
Bush	13,102
Coniferous plantation	255
Grassland	57,968
Impediments	32
Small scale farmland	63,028
Tropical high forest low stock	8,846
Tropical High Forest well stocked	38,575
Grass seasonally wet	440
Woodland	71,754
Total	**256,471**

6.2 Tree Density by forest type

At a national level, woodlands have got the highest density of trees with an average of over 1,200 trees per hectare. Tree stock in well stock THF and low stocked THF is about 250 and 120 stems per hectare respectively (figure 6-1).

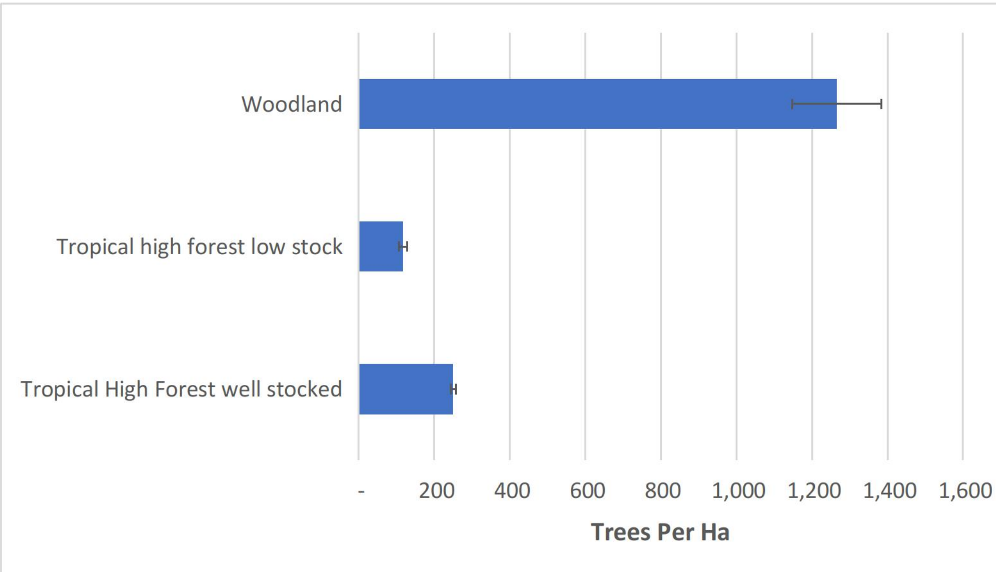


Figure 6- 1. Tree density by forest strata

6.2.1 Tree Density by Diameter class (in forests)

Diameter class distributions in Uganda's natural forests exhibit what is commonly known as the inverse J shape (figure 6-2). In all forest types, tree stock decreases as the diameter size increases. This trend is more pronounced in woodlands than in other forest types.

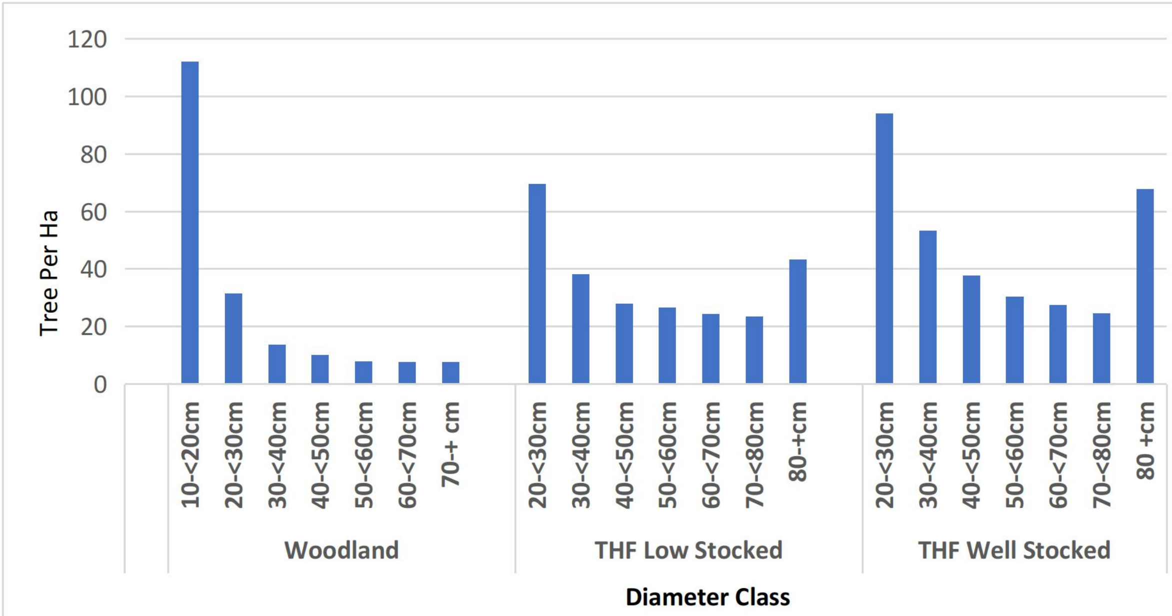


Figure 6- 2. Tree Density Distribution by DBH in Uganda's natural forests

The small diameter classes account for about 63% of the trees stock in degraded THF. Trees number drop significantly to 7% in the 10 to 20cm but slightly rise in the 20 to 30cm diameter class. The number of trees in the 40 cm to 80cm diameter range tends to be stable at around 3% for every 10cm diameter interval. Trees of 100cm diameter and more are very few, at about 20 trees per hectare or less.

Table 6- 2. Tree density distribution (per ha & percent) by DBH in forest

Forest Type	DBH Class	<10	10-<20	20-<30	30-<40	40-<50	50-<60	60-<70	70-<80	80-<90	90-<100
Woodland	Trees Ha	1507	112	31	14	10	8	8	8		
	Perc	89%	7%	2%	1%	1%	0.47%	0.46%	0.45%		
DTHF	Trees Ha	576	62	70	38	28	27	24	24	23	21
	Perc	63%	7%	8%	4%	3%	3%	3%	3%	2%	2%
THF	Trees Ha	187	74	94	53	38	30	28	25	23	22
	Perc	29%	12%	15%	8%	6%	5%	4%	4%	4%	3%

In well stock (less disturbed) THF, the 10cm diameter class and below represent about 29% of the tree stock. The 10 cm to 20cm and 20cm to 30cm diameter class represent about 12% and 15% of the trees stock respectively. Tree numbers reduce gradually from about 50 trees per hectare in the 30 to 40 cm to 25 trees per hectare in 70 to 80cm diameter class.

Woodlands have significantly higher tree density (about 1,600 trees per hectare) than Tropical high forests (600 to 900 stems per hectare). Conversely, THF have significantly larger trees than woodlands (Figure 6-2 and Table 6-2).

6.3 Tree density outside forests

In non- forest areas, bush has about 1,100 stems per hectare which is just slightly lower or almost the same as woodland (figure 6-3). This is perhaps explained by the factor that differences between bush and woodland in most instances are not clear. This is subject to the enumerators' interpretation of whether the trees are able to attain a minimum height of 4 metres and above, and thus distinguish between woodland and bush.

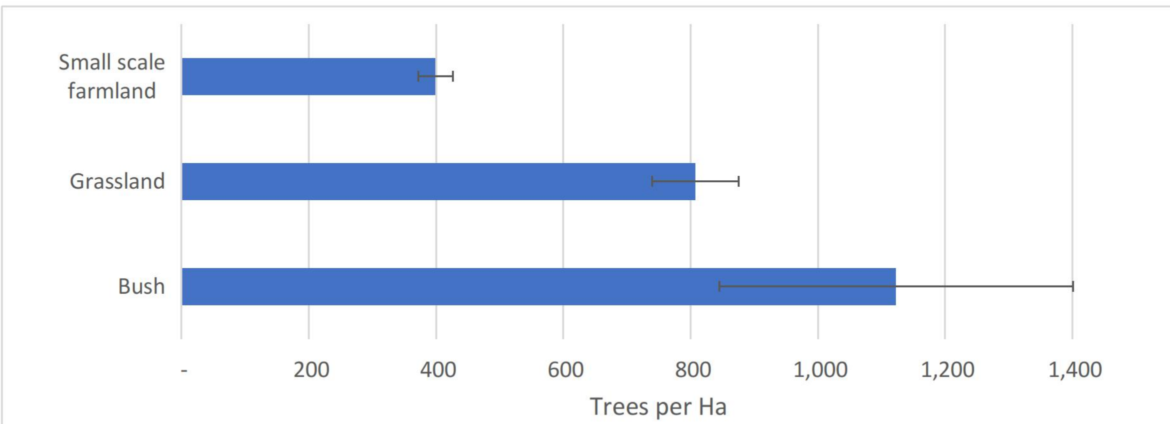


Figure 6- 3. Tree density outside forests

Tree density in grassland is the second highest in non- forested areas estimated to be almost 800 trees per hectare. Tree density in farmland is estimated at about 400 trees per hectare. Based on the area covered by each vegetation type and the tree count, it is estimated that Uganda has a total of 14 billion trees with forests accounting for about 16% of these trees. Bush is estimated to account for 19% of total trees in Uganda. Most of the trees (65%) are in non-forested areas.

6.3.1 Tree density by diameter class (outside forests)

Tree size distribution in non- forest vegetation also exhibit the inverse J shape curve (Figure 6-4). Compared to cropland and grassland, bush tends to have more of smaller trees than other non-forest areas (figure 6-4). About 92% of the trees in bush are in the less than 10 cm diameter class (Table 6-3). In grassland and cropland the trees less than 10cm account for 90% and 87% of the tree stock respectively (Table 6-3).

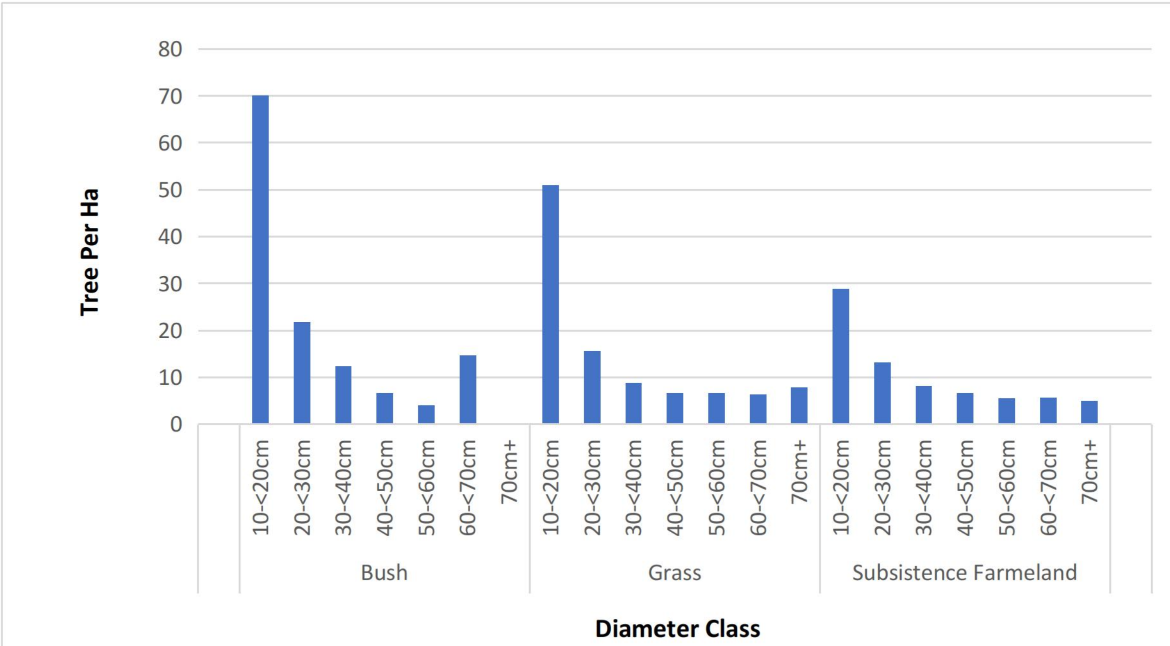


Figure 6- 4. Tree density by DBH outside forest

Both in bush and grassland, trees less than 20cm diameter account for more 95% or more of total number of trees (table 6-3). Tree distribution in cropland is however more spread. The 95% percent of trees include the diameter class of 40cm and below (table 6-3).

Table 6- 3. Tree density distribution (per ha & percent) by DBH outside forest

Forest Type	DBH Class	<10	10-<20	20-<30	30-<40	40-<50	50-<60	60-<70	70-<80
Bush	Trees Ha	1498	70	22	12	7	4	15	
	Perc	92%	4%	1%	1%	0%	0%	1%	
Grass	Trees Ha	923	51	16	9	7	7	6	8
	Perc	90%	5%	2%	1%	1%	1%	1%	1%
Cropland	Trees Ha	482	29	13	8	7	6	6	5
	Perc	87%	5%	2%	1%	1%	1%	1%	1%

6.4 Basal Area

Basal Area (BA) is the sum of all cross-section area at breast height of all the trees in the plot. It is presented as square meters per hectare. The BA gives an insight of the stocking and is used to derive the stem volume.

6.4.1 Basal Area Forest Types

Out of the three natural forest strata, THF has the highest basal area of about 25 m^2/ha followed by DTHF with 16 m^2/ha and woodlands at approximately 7 m^2/ha (figure 6-5). Basal area in forest plantations is not presented due to lack of representative data at a national level.

Figure 6- 5. Basal Area in forest lands.

6.4.2 Basal Area outside Forests

In non-forested areas bush has the highest basal area of 5 m^2per ha followed by grassland with basal area of 3.8 m^2 per ha (Figure 6-6). The basal area of Cropland is about 2.7 m^2per ha.

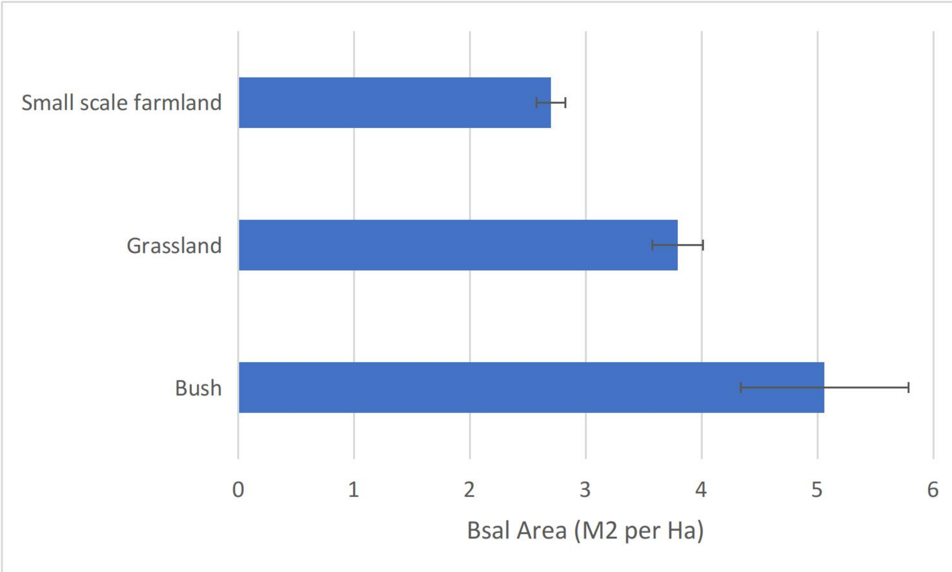


Figure 6- 6. Basal area on non- forest land

6.5 Tree Volume

Volume is presented as stem volume and bole volume. Stem volume may go well above the first major branches. Stem volume is thus generally more than sawable timber or merchantable volume especially in natural forests where branches may account for about half of the tree height.

Instead, bole volume is closer to harvestable volume. It represents the stem up to the first major branch. Allowable cut volume incorporates other parameters like timber species grades, allowable cut DBH class, log grade etc.

6.5.1 Stem Volume by forest type

Average stem volume of all measurable trees in the well stocked THF is estimated at over 300 m^3 per hectare while in low stocked THF is estimated to just over 190 m^3 per hectare (Table 6-4). Stem volume in woodlands is estimated at 36 m^3 per hectare which about a tenth of the volume of degraded THF.

Table 6- 4. Stem volume by forest type

Forest Type	Stem Volume (m^3 ha^{-1})	STDV	Plots	95% Confidence
Tropical high forest low stock	191	186	1,089	±11
Tropical High Forest well stocked	303	225	3,006	±8
Woodland	36	40	998	±2

Bole volume, which approximates merchantable volume, is about a half of the stem volume. Bole volume in well stocked THF and low stocked (or degraded) THF are respectively estimated at 146 m^3 per hectare and 82 m^3 per hectare (figure 6-7). By contrast, bole volume in woodlands is estimated at 7.5 m^3**.**

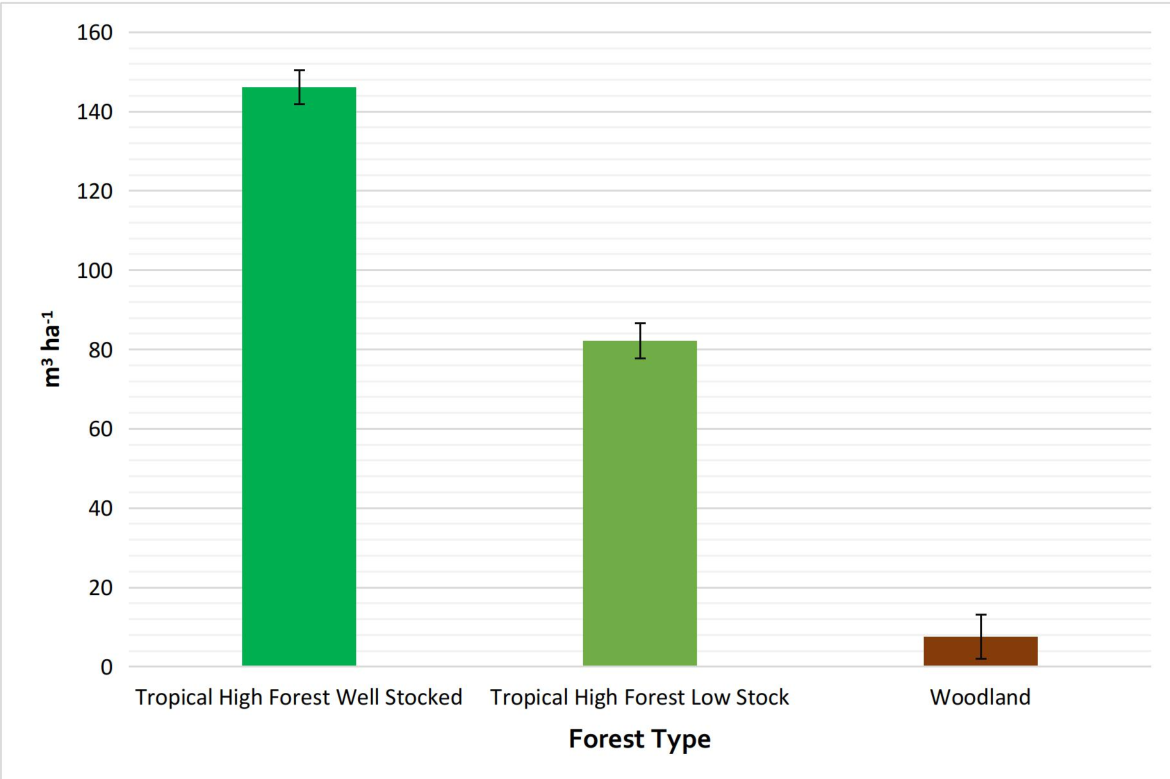


Figure 6- 7: Bole volume by forest type

6.5.2 Stem Volume by diameter class in forests

Unlike other forest stand characteristics, stem volume tends to be concentrated in the very large trees. In well stocked THF, the 70cm+ DBH class has more than double the volume of any other diameter class. In this forest type, there is also a tendency of stem volume to be higher in the medium range diameters of between 40cm to 60cm than in the rest of the smaller DBH classes (Figure 6-8). In low stocked THF, the 70cm+ DBH accounts for more than thrice any other diameter class. There is however no clear volume trend or pattern in the other smaller DBH classes.

In woodlands the smaller trees generally contribute higher stem volume than the larger diameter trees. There is slight volume increase in the 70cm+ DBH class (Figure 6-8).

Stem diameter being a function of basal area and height, much of the volume in THF is in the tall trees with large DBH. In woodlands, trees are relatively shorter and volume is determined by tree numbers and not tree size (i.e. height and DBH).

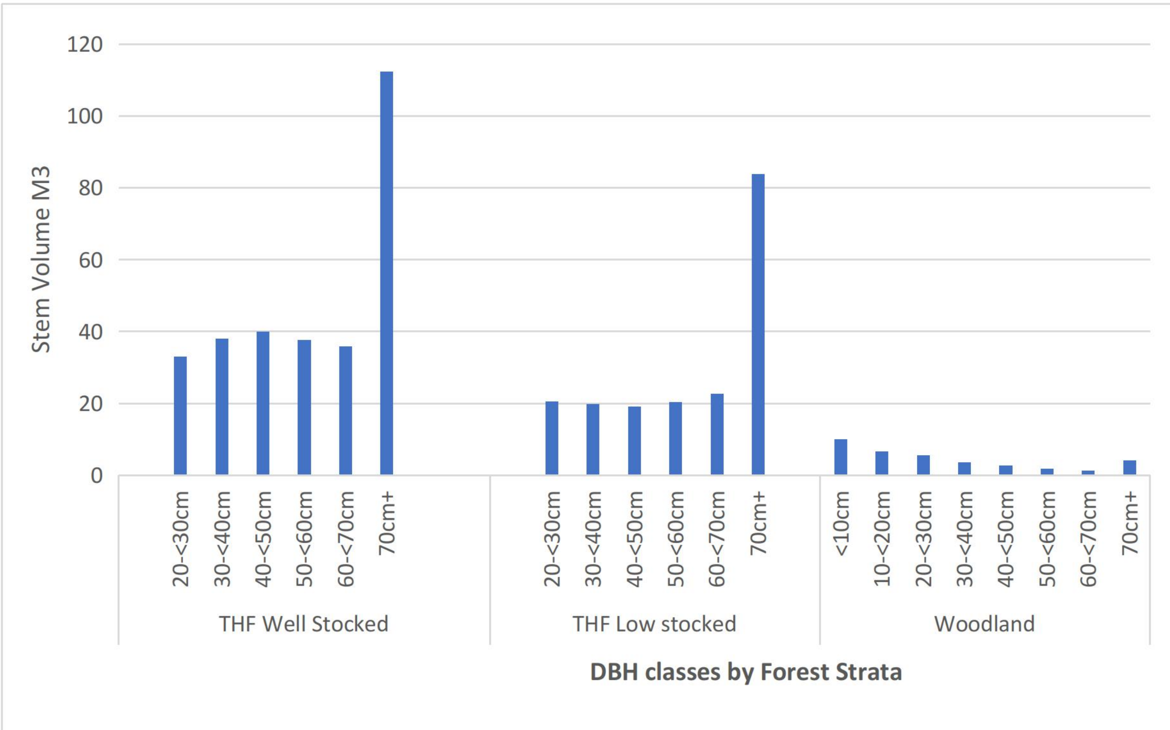


Figure 6- 8. Volume by DBH class in forests

6.5.3 Volume by diameter class in non-forest land

Bush and grasslands exhibit similar characteristics as woodlands. In bush and grassland, trees less than 10 cm DBH hold about 8.9 m3 and 6m3 respectively (Figure 6-9). This is about 39% and 32 % of stem volume in bush and grassland respectively. In subsistence farmland, volume is generally more evenly distributed in the small to medium DBH classes. Though very few in numbers (Figure 6-4), the 70cm+ DBH class trees hold about 30% of the volume in subsistence farmland (Figure 6-9). Unlike in woodlands, volume in subsistence farmland is majorly determined by tree girth and height (i.e. height and DBH) rather than density.

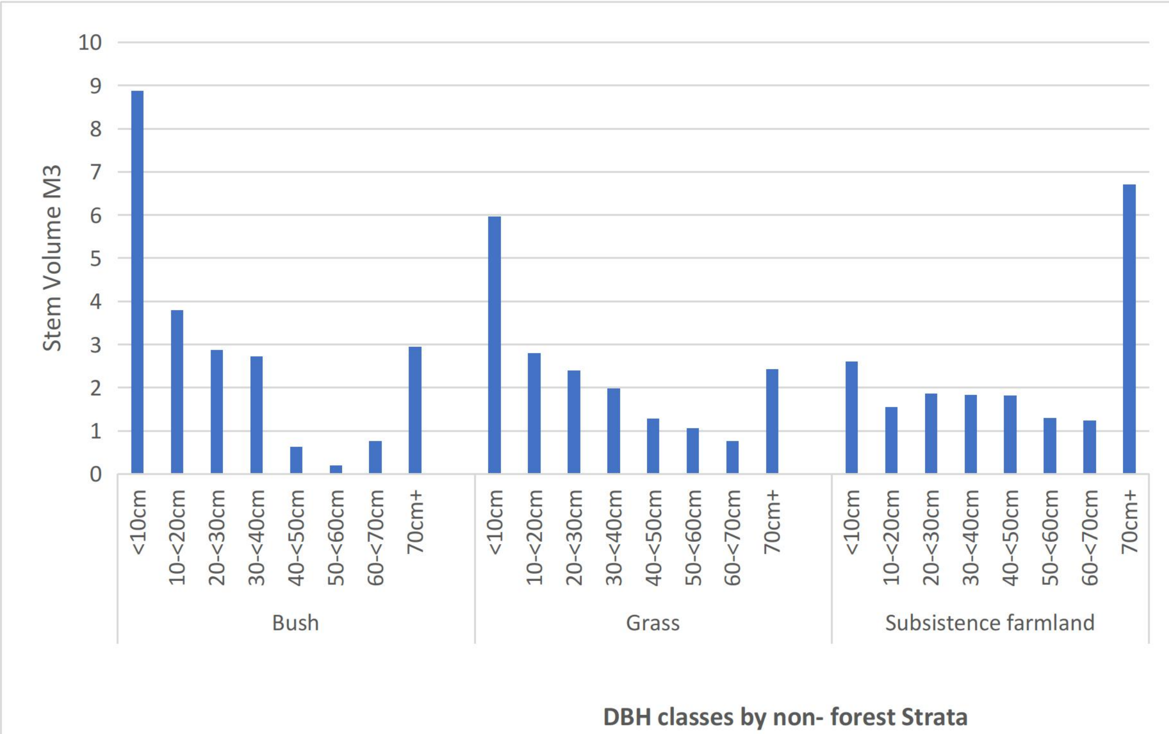


Figure 6- 9. Stem Volume by DBH class on non-forest land

6.6 Biomass stocks

Tree stock, basal area, and tree volume are long time traditional methods of quantifying biological and physical characteristics of trees and forest. Biomass may be derived from the above or derived directly using allometric equations. The global efforts to combat climate change and thus the need to estimate Greenhouse Gas (GHG) emissions and or sinks attributable for forestry (e.g. deforestation, degradation, reforestation, afforestation, restoration) have renewed efforts to quantify biomass (and related carbon stocks) within some reasonable level of precision and consistency.

Biomass stock is estimated as both above ground and below ground biomass. In many instances, above ground biomass is what is extracted (e.g., fuelwood harvests) and thus biomass demand and supply analyses are mainly concerned with above ground biomass. However, biomass extraction leaves tree stumps that eventually rot especially for trees that do not coppice or where tree stumps are too old to regenerate. Greenhouse Gases Inventories (GHGI) thus account for both above ground biomass and the below ground carbon pools.

6.6.1 Biomass stocks by forest types

Above ground biomass dry matter in THF forests is estimated to be between 161 tonnes (for low stocked THF) to 257 tonnes per hectare (for well stock THF). Aboveground biomass stock in woodland is estimated at 25 tonnes per hectare which is just a tenth of that found in a well stocked THF (Table 6-5).

Table 6- 5. Above Ground Biomass in Forest (2003 to 2019)

Forest Class	AG Biomass (Tons)	Std Deviation	Plots	95% Confidence
Tropical high forest low stock	161	154	1,089	±9
Tropical High Forest well stocked	257	186	3,006	±7
Woodland	25	27	998	±2

The below ground biomass is estimated to be about 24% of the above ground which translates into 39, 62 and 6 tonnes per hectare for THF low stock, THF well stocked and woodlands respectively (Figure 6-10).

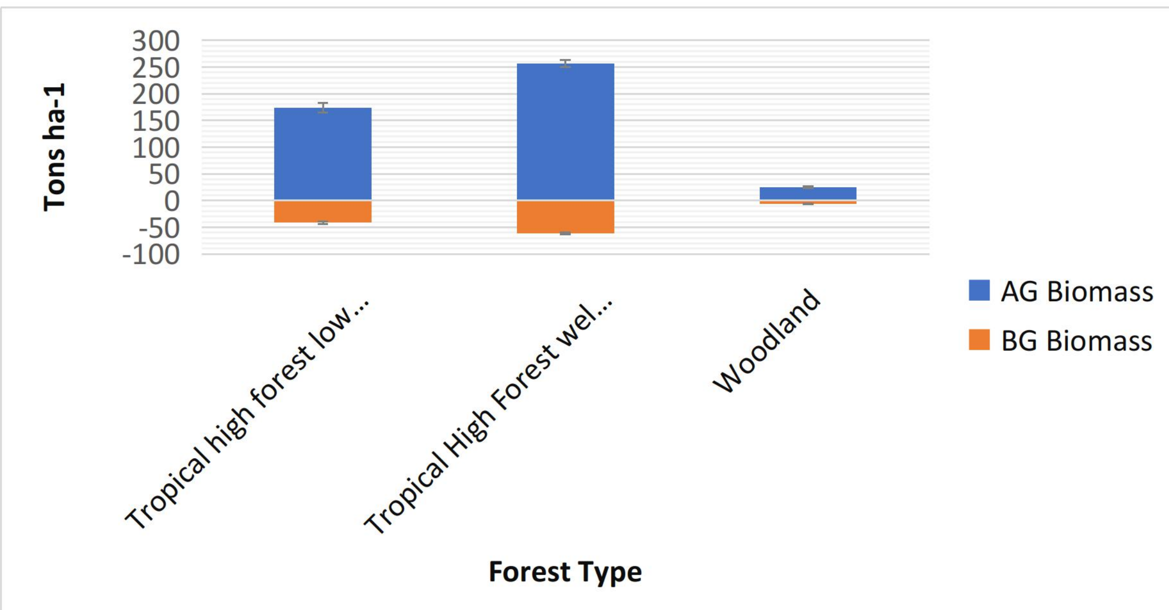


Figure 6- 10 Biomass stocks by forest type

6.6.2 Biomass dynamics in Forests

From the late 1990s to early 2000s, average above ground biomass in THF forests well stocked and low stocked stood at 223 and 94 tonnes per hectare respectively (NBS 2002). In the early phase of NBS, sample plots in low stocked THF were localised around Mabira forest which at the time was severely degraded and this may have contributed to the local stock values.

Surveys carried out from 2016 to 2019 estimate ground biomass in well stocked THF and low stocked THF at 254 and 162 tonnes per hectare (Table 6-6), which is very close to the long term average of 257 and 174 tonnes per hectare (Table 6-5).

In the period from the late 1990s to early 2000s, average above ground biomass in woodlands was at 35 tonnes per hectare (NBS 2002). In the wet areas of central Uganda biomass in woodland was in the range of 73 tonnes (high stock) to 18 tonnes (low stock) . In the drier parts of the country, the range was from 57 tonnes to 17 tonnes per hectare.

From the recent surveys (2016 to 2019) overall average of above ground biomass is estimated at 19 tomes per hectare (Table 6-6), a reduction of about 46% from 35 tonnes per hectare of the 2002 NBS report.

Table 6- 6. Above ground Biomass stock in in forests -country average (2016 to 2019)

Forest Class	AG Biomass (Tons)	Std Deviation	Plots	95% Confidence
Tropical high forest low stock	162	154	1,083	±9
Tropical High Forest well stocked	254	181	2,901	±7
Woodland	19	25	621	±2

Comparison of above ground biomass in woodlands in protected areas to those outside protected areas indicates that there is a difference of 25 tonnes (Table 6-7). This indicates that biomass in woodlands outside protected areas is about 58% less in stock than woodlands in protected areas.

Table 6- 7. AG Biomass stock in and outside protected areas (2016 to 2019)

Forest Class	AG Biomass (Tonnes)	Std Deviation	Plots	95% Confidence
Woodland (Protected area)	42.6	44.6	39	±14
Woodland (Private land)	17.8	26.0	582	±2

6.6.3 Biomass dynamics non forest areas

Above ground biomass in grassland, small-scale farmland and bush are estimated at 13, 13 and 16 tonnes per hectare respectively (Table 6-8). These values are comparable with the NBS 2002 estimates of grassland 8, small-scale farmland 11 and bush 13. Recently, a reasonable number of plots were measured in seasonally wet grasslands with the above ground biomass estimate at 7 tonnes per hectare.

Above ground biomass in built up areas is currently estimated at 13 tonnes compared to 22 tonnes in the 2002 NBS study.

Table 6- 8 Biomass outside forest areas (tonnes per hectare)

Land Cover	AG Biomass	St Dev	Count
Built up area	13	12	37
Bush	16	25	225
Grassland	13	18	1412
Seasonally Wetland	7	7	23
Impediments	7	9	15
Small scale farmland	13	23	3118

6.7 Carbon Stocks in Uganda forests

Carbon stocks are related to and are derived from biomass stocks. Three carbon pools of above-ground biomass, below-ground biomass and carbon pools in deadwood are included here below.

THF well stocked and low stocked have the highest carbon stocks of about 160 and 100 tonnes per hectare respectively. Carbon stocks in woodlands is estimated at about 16 tonnes tons per hectare (Figure 6-11).

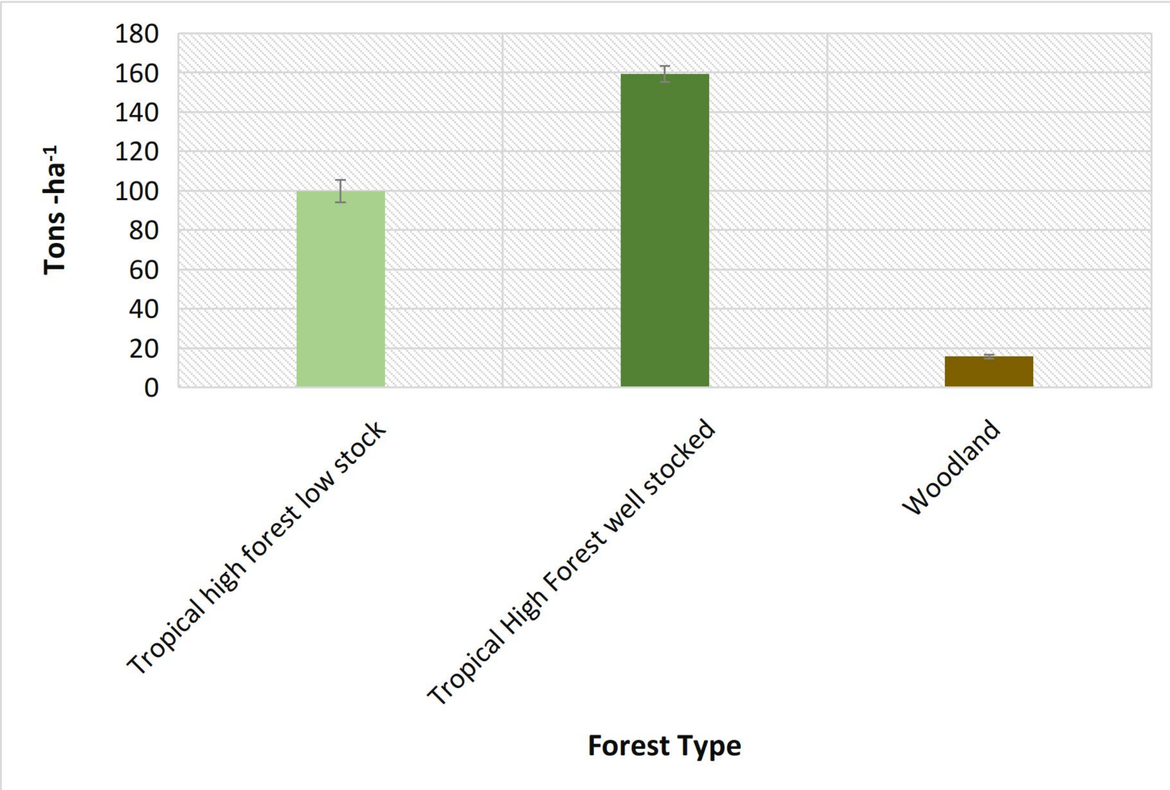


Figure 6- 11. Tree Carbon Stocks in Forests

6.7.1 Tree Carbon Stocks in forests by Management types

Well stocked THF in parts of Mt Elgon Forest Park, Mabira CFR and Kibale Forest Park have the highest carbon stocks estimated at 194, 173, 146 tonnes per hectare respectively. The woodlands of Kangombe and Bugoma have the lowest carbon stocks of 9 and 7 tonnes per hectare respectively (Table 6-9).

Table 6- 9. Tree carbon stocks in Forest Management

Forest	Vegetation Class	Carbon (tone per ha)
Budongo	Tropical high forest low stock	136
Budongo	Tropical High Forest well stocked	139
Budongo	Woodland	31
Bugoma	Tropical high forest low stock	145
Bugoma	Tropical High Forest well stocked	212
Bugoma	Woodland	7
Elgon	Tropical high forest low stock	93
Elgon	Tropical High Forest well stocked	194

Kagombe	Tropical high forest low stock	44
Kagombe	Tropical High Forest well stocked	51
Kagombe	Woodland	9
Kibale NP	Tropical High Forest well stocked	146
Kibale NP	Woodland	17
Mabira	Tropical high forest low stock	110
Mabira	Tropical High Forest well stocked	173

6.7.2 Tree Carbon stocks outside forests

Carbon stocks outside forested areas is highest in bush land at 10 tonnes per hectare, followed by grassland and subsistence farmland at about 8 tonnes of carbon per hectare (Figure 6-12).

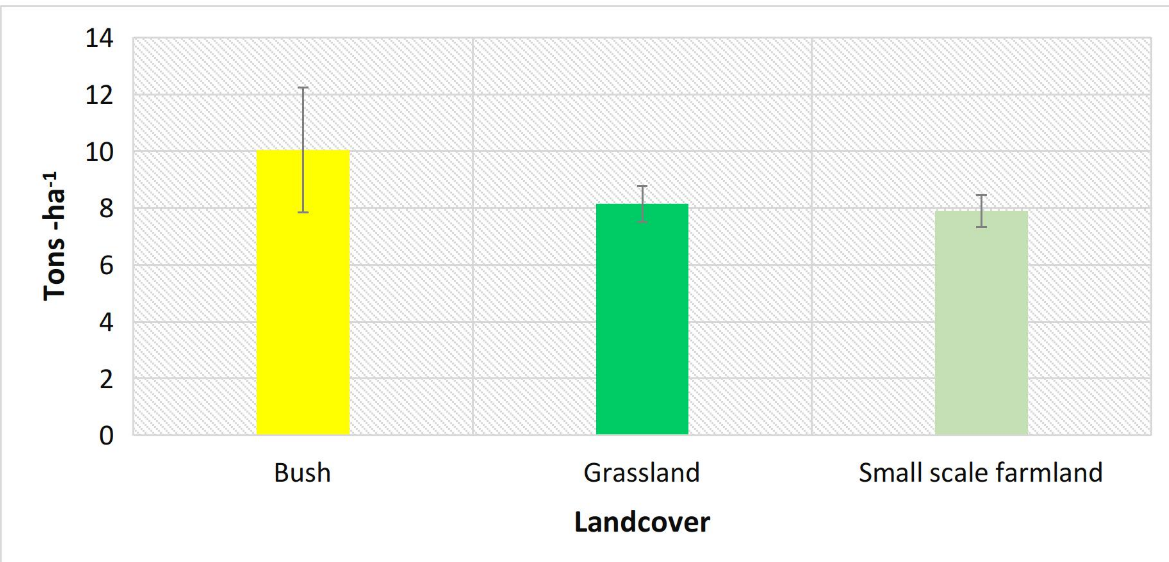


Figure 6- 12. Tree Carbon stocks in non-forested area

6.7.3 Carbon Stocks in Deadwood

Although all surveys have included estimation of deadwood since 2016, deadwood carbon has been found to be insignificant in may vegetation types save for THF. Bugoma CFR has the highest amount of carbon in deadwood (1.7 tons per hectare) followed by Elgon (1.6 tons per hectare) and Budongo (1.5 tones tons per hectare). Kangombe CFR has the lowest carbon in deadwood estimated at 0.7 tons per hectare (Figure 6-13).

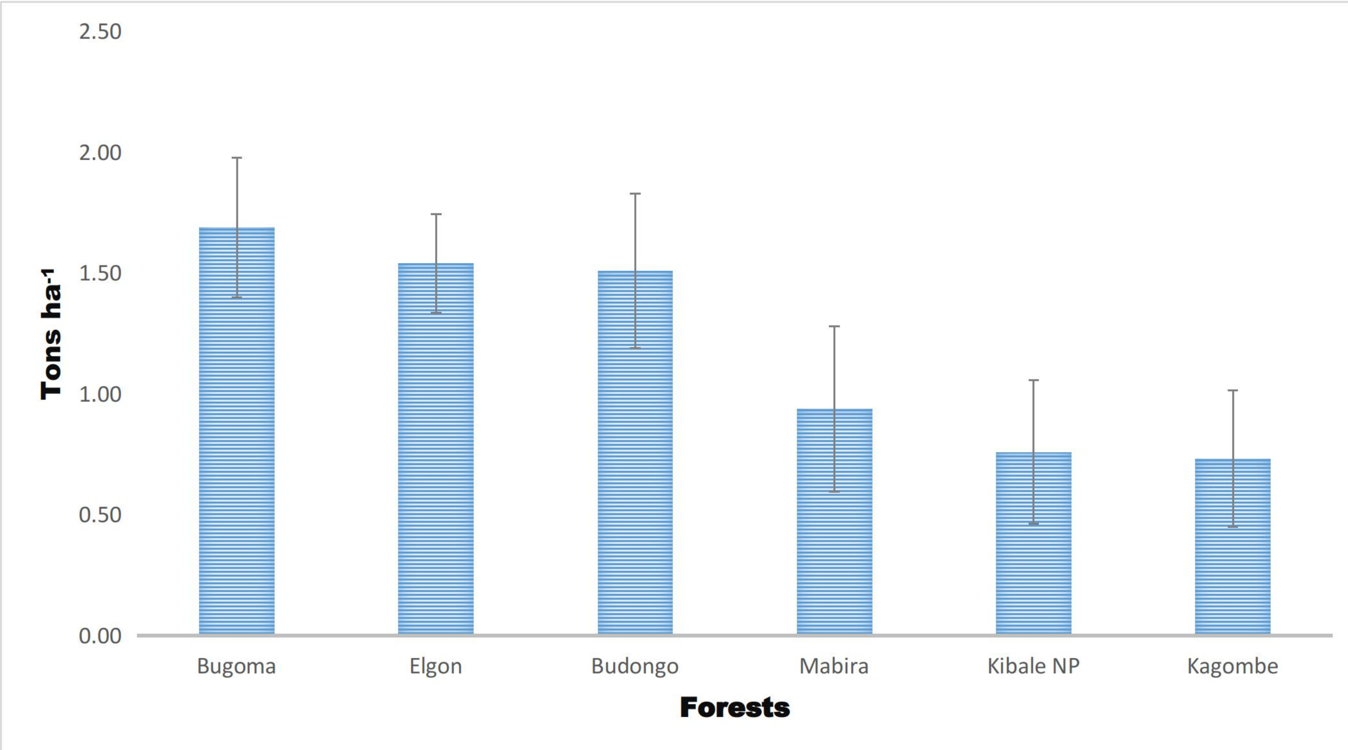


Figure 6- 13: Carbon stock in deadwood

6.8 Species Diversity Overall

The number of species represented in a given community is referred to as species diversity. Species diversity is comprised of three components: species evenness, species richness, and taxonomic or phylogenetic diversity. Species richness is simply a count of species, phylogenetic diversity refers to the genetic relationship between different groups of species, whereas species evenness quantifies how equal the abundances of the species are. The NFI encountered a total of 945 unique species that belong to 415 genera in Uganda. Among these, the following tree map shows the 10 most abundant (Figure 6-12).

6.8.1 Species Count across the landscape

Among the tree species, the most common species is *Combretum collinum*, followed by *Acacia hockii*, *Rhus vulgaris Combretum mole*. The most common or abundant shrubs are *Vernonia amygadalina* (Figure 6- 14)

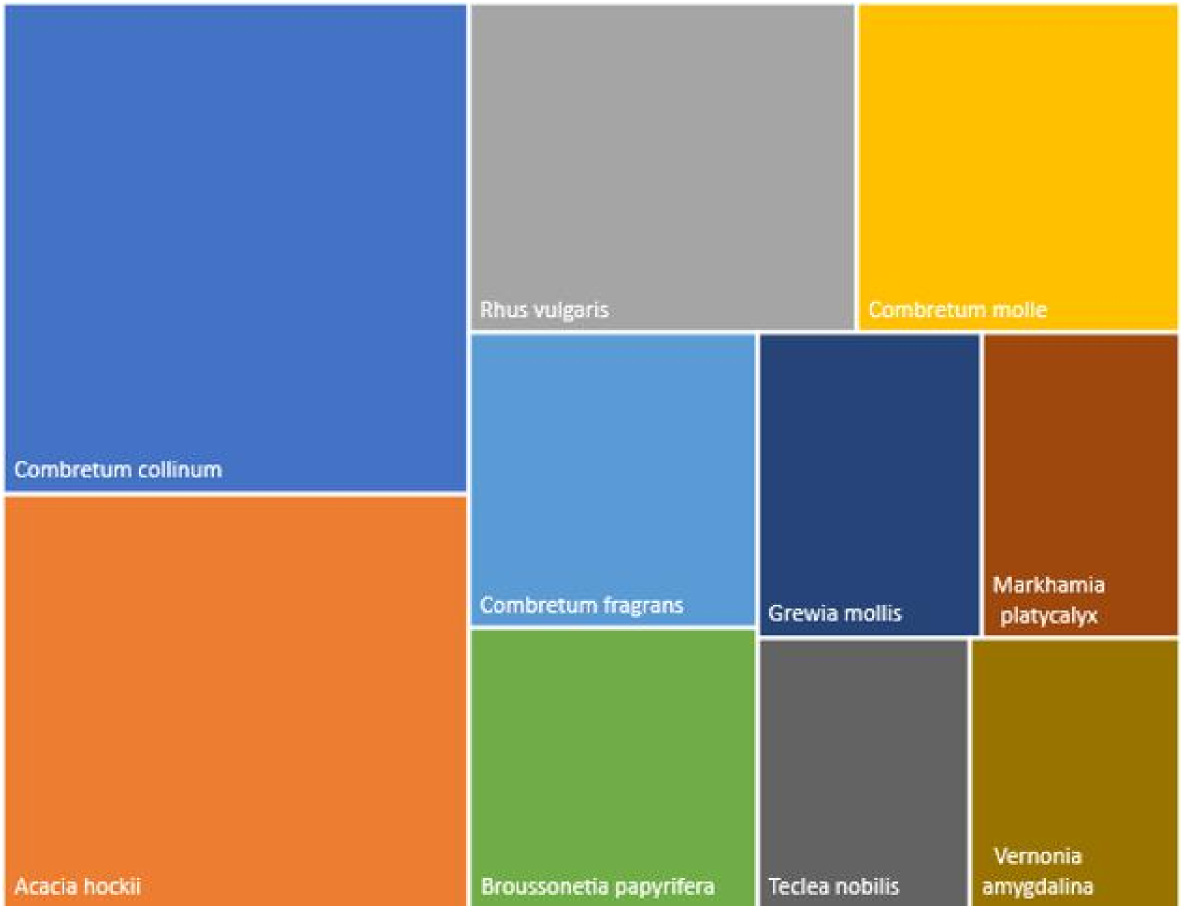


Figure 6- 14 Species abundancy

6.8.2 Species of IUCN Importance (across the landscape)

IUCN Red List of Threatened Species is the best way of evaluating the status of each species. This report referenced the IUCN Red List of 2015 to study the current state of NFI species dataset. In that List, species in the wild are either critically endangered (CR), endangered (EN) or vulnerable (VU) in terms of threat categories. The List further registers other categories for those species which are not currently known to be threatened or are extinct. These include near threatened (NT), least concern (LC), data deficient (DD), extinct (EX), and not evaluated (NE). In addition, there are cases when species are regionally extinct in the wild (RE).

Table 6- 10 below summarizes the threat status of the species within the NFI database by Genera and tree count nationally and internationally as either being EN, NE, NT or VU. Table 6-10 then enlightens on where these species were found within and outside of Protected Areas.

Table 6- 10. Red List species by global and national threat categories

Genus	Species	Global Status	Uganda Status	Tree Count
Albizia	*Albizia ferruginea*	VU	EN	22
Beilschmiedia	*Beilschmiedia ugandensis*	VU	VU	12
Chrysophyllum	*Chrysophyllum albidum*	NE	VU	1224
Chrysophyllum	*Chrysophyllum muerense*	NE	VU	37
Erythrophleum	*Erythrophleum suaveolens*	NE	VU	11
Irvingia	*Irvingia gabonensis*	NT	EN	1
Lovoa	*Lovoa swynnertonii*	NT	EN	5
Lovoa	*Lovoa trichiliodes*	VU	EN	36
Milicia	*Milicia excelsa*	NE	EN	49
Olea	*Olea welwitschii*	NE	VU	182
Prunus	*Prunus africana*	VU	VU	58
Warbugia	*Warbugia ugandensis*	NE	VU	129

Among Red List species *Albizia ferruginea* was the most common across the landscape. *Beilschmiedia ugandensis* was least common, mainly found in subsistence farmland (Table 6-11). *Chrysophyllum albidum* and *Olea welwitschii* were the most common in Tropical High Forests. *Chrysophyllum muerense* was most in bush. *Dalbergia melanoxylon* most common in woodland to some extent grassland. *Milicia excels* most common on subsistence farmland. This indicates that interventions intended for conservation and protection of vulnerable or threatened species need to include non- forested areas.

Table 6- 11. Red List species across the landscape

Species	Bush	Grassland	Small Scale Farmland	THF-L	THF-H	Woodland
Albizia ferruginea	1	96	47	8	14	75
Antrocaryon micraster			1			2
Beilschmiedia ugandensis			1	1	11	
Chrysophyllum albidum		3	1	62	1164	
Chrysophyllum muerense	37					
Chrysophyllum perpulchrum				36	43	
Dalbergia melanoxylon		28	3			156
Erythrophleum suaveolens				2	9	
Irvingia gabonensis	1					
Khaya senegalensis			3			10
Lovoa swynnertonii				4	5	3
Lovoa trichilioides			1	23	29	5
Milicia excelsa		3	151	6	39	20
Olea welwitschii				133	49	

Pinus Africana		5	4	6	52	1
Tamarindus indica	4	63	71			72
Vitellaria paradoxa		193	168			156
Warburgia ugandensis	1			2	130	33

6.8.3 Species Diversity

6.8.3.1 Species Count in forests

Among the different forest types, THF well stocked have the highest species count (532) followed by woodlands (422). Low stocked THF has the lowest species count at 361 (Figure 6-15).

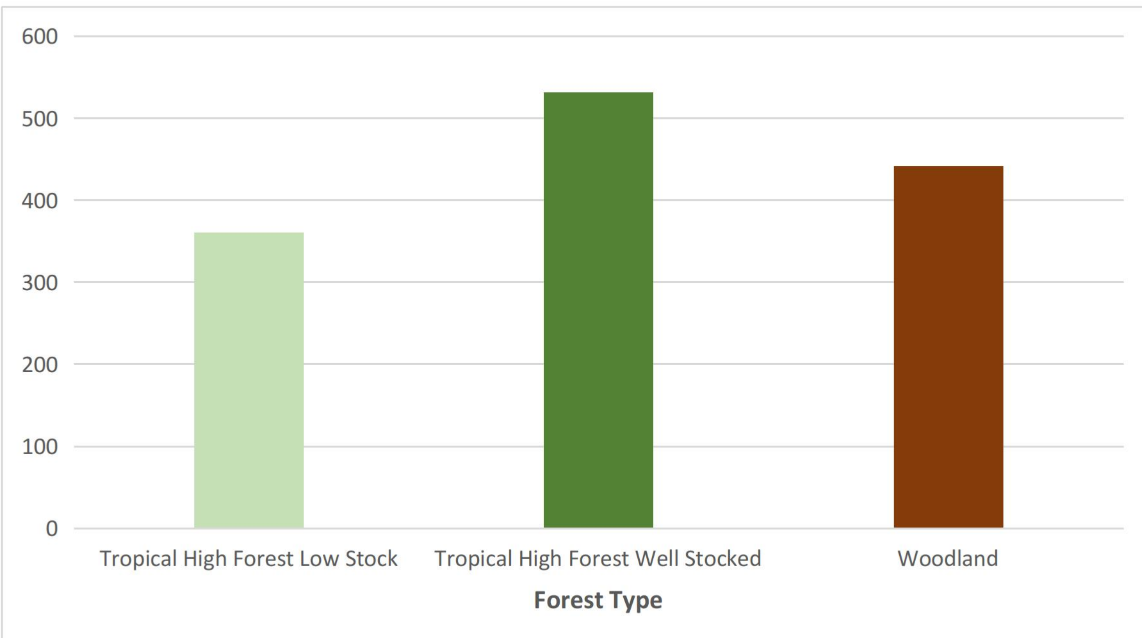


Figure 6- 15. Tree species count by forest types

6.8.3.2 Species Diversity in forests (Simpson's index)

To ascertain the species evenness, the Simpson's Species Diversity index was used. The findings from the index relay that the well stocked THF and Low Stocked THF classes exhibited the highest equal abundancy of 0.83 and 0.77 respectively. Woodlands diversity resulted with a ranking of 0.73 (Figure 6-16).

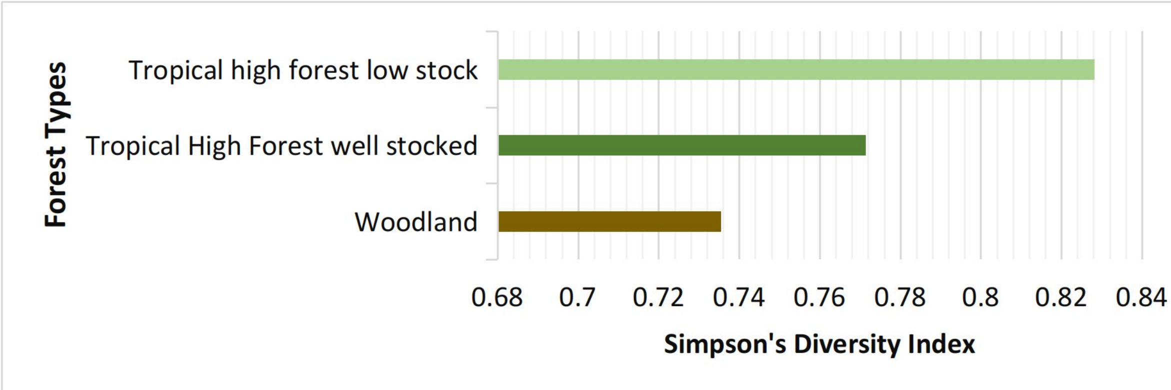


Figure 6- 16: Species Diversity index by forest type

6.8.3.3 Species Count in Non- Forested areas

Among the non- forested areas, subsistence farmland have the highest tree species count of over 450 species followed by grasslands at over 360 species (Table 6-11). Species count in bush was slightly above 170 species (Figure 6-17).

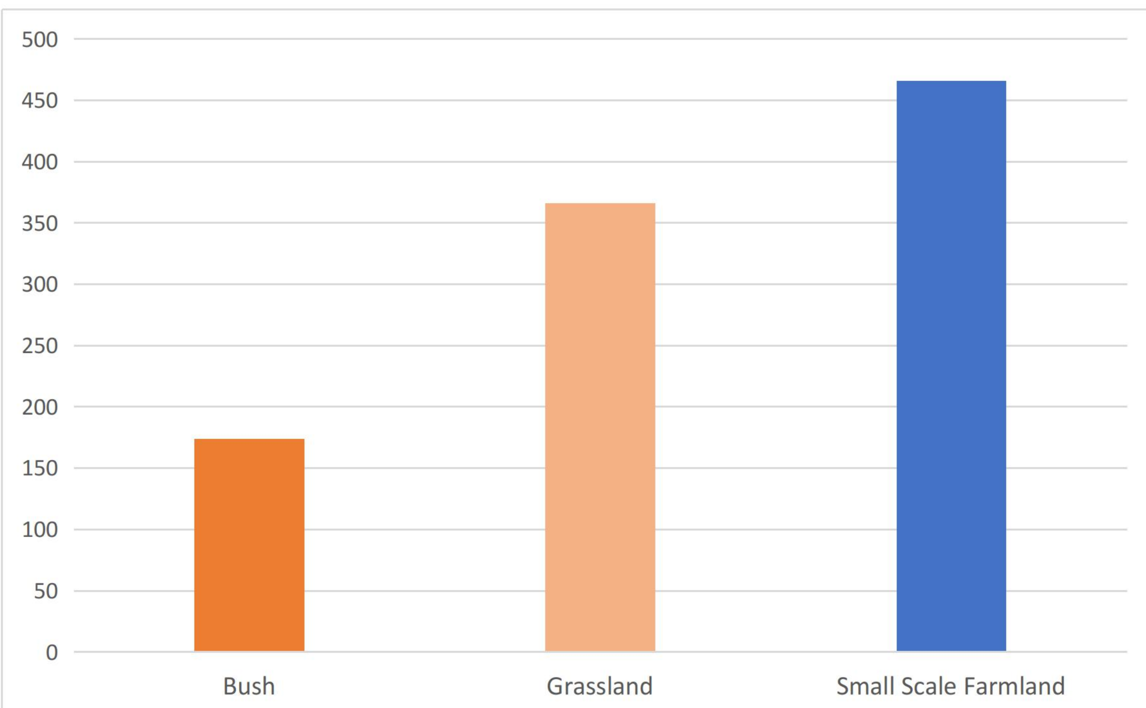


Figure 6- 17. Tree species count outside forests

6.8.3.4 Species Diversity in Non- Forested areas (Simpson's index)

Despite having the lowest species count, species richness by Simpson's index showed that bushland was highest at (0.722). Farmland which has the highest species count in non-forest areas had the lowest index of 0.67 (Figure 6-18).

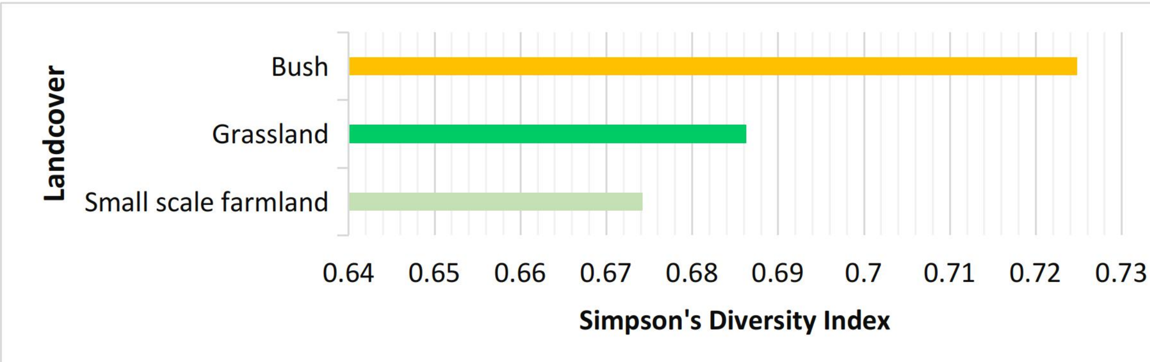


Figure 6- 18: Species diversity outside forest, based on Simpsons' Diversity Index

6.8.4 Key Stone Species

Keystone species are those which have an extremely high impact on a particular ecosystem relative to its population. Such species play decisive roles in the overall structure and function of an ecosystem or biome by influencing which other types of plants and animals make up that ecosystem. The oversimplification of one animal or plant's position in intricate habitats and food webs can in other cases be used as a way to help the public understand how important one species can be to the survival of many others in a particular ecosystem.

The three major categories of keystone species named by many scientific scholars are either ecosystem engineers, mutualists or predators. Ecosystem engineers alter the ecosystem while mutualists enhance some aspects of the ecosystem for the benefit of many within the habitat/biome. Predators especially apex predators, control the population numbers of some species.

Though vegetation may not explicitly exhibit predatory and mutualistic characteristics within a habitat, trees are used as sources of food, homes and breeding ground for many vertebrates and invertebrates. They also promote or suppress existence of specific vegetative species. Therefore, their absence may lead to failure of certain ecosystems.

In relation to the roles in the ecosystem, different species are useful in different ways. Based on the NFA database, notable keystone species in Uganda's forests include the following: *Annona senegalensis, Baikiaea insignis, Balanites wilsoniana, Broussonetia papyrifera, Caloncoba* *schweinfurthii, Irvingia gabonensis, Irvingia Ugandensis, Kigelia africana, Musanga cecropoides, Myrianthus salicifolia, Pseudospondias microcarpa, Trema orientalis, and Vitex amboniensis.*

7 Reporting by WMZ

7.1 Tree Density by WMZ

As described in Table 5-5 and Table 5-6 of section 5.3.3, THFs in the Victoria and Upper Nile WMZ were not well sampled. The discussion in the two WMZs in limited only to woodland. In addition, the discussion on forest plantations in all WMZs is limited due to insufficient data.

7.1.1 Tree Density by forests in WMZ

In all WMZs, woodlands have a high tree stock compared to tree stock in other natural forests. The woodlands of Victoria WMZ have the highest density of trees of close to 2,700 trees per hectares followed by those in Kyoga WMZ that have close to 2,000 trees per hectare. In the Albertine and Upper Nile WMZs, tree stock in woodlands is about 1,400 and 900 tree stems per hectare, respectively (Figure 7-1).

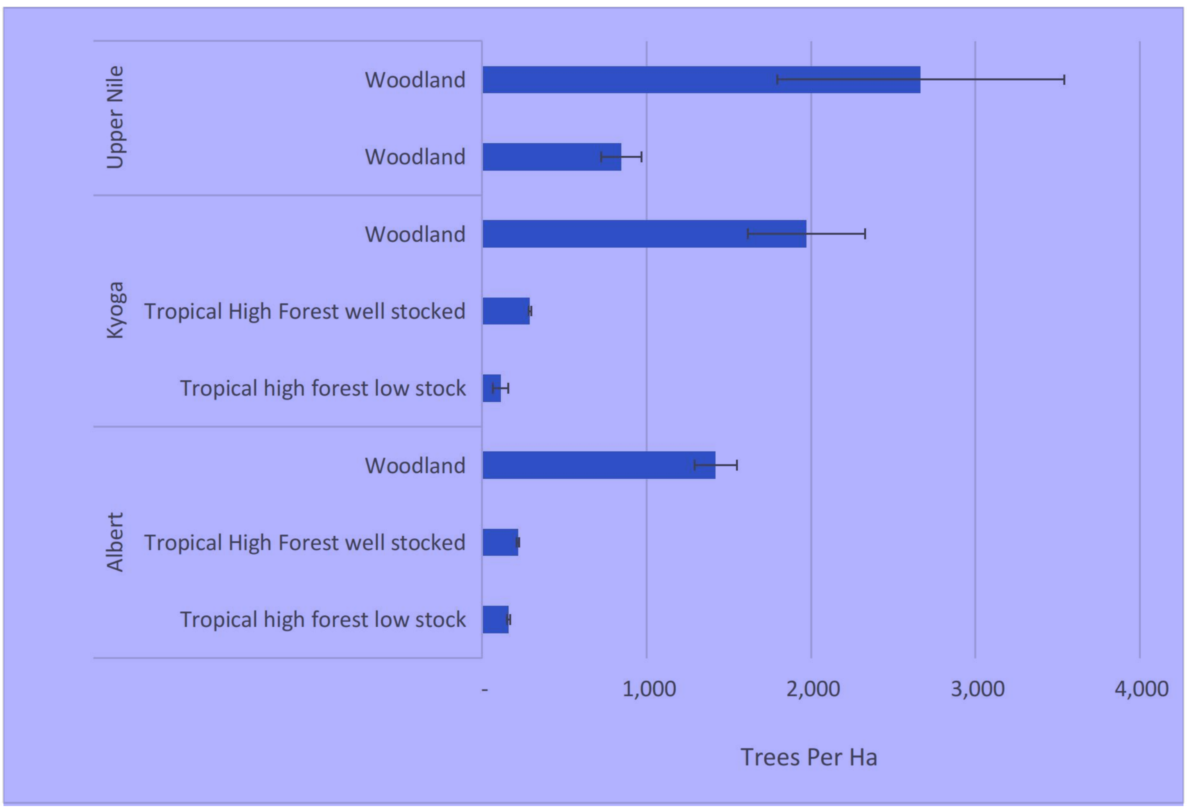


Figure 7- 1. Tree density in forests by WMZs

7.1.2 Tree Density outside forests in WMZ

Bush in the Kyoga WMZ has over 3,000 stems per hectare followed by the Victoria WMZ with has about 2,900 stems per hectare and the Albertine WMZ which just over 900 stems per hectare. Upper Nile has only 9 plots in the bush category and thus may not adequately represent the bush in that area (Figure 7-2).

Cropland (subsistence farmland) in the Albertine has got substantial tree stock of close to 600 trees per hectare followed by Victoria WMZ with over 500 stems per hectare. Cropland in the Kyoga WMZ has 360 and that of the Upper Nile has below 200 trees per hectare. This partly reflects the cropping system with the Albertine and Victoria WMZs majorly having Agroforestry while the Kyoga and upper Nile WMZs practice cereal cropping with little or no tree cover.

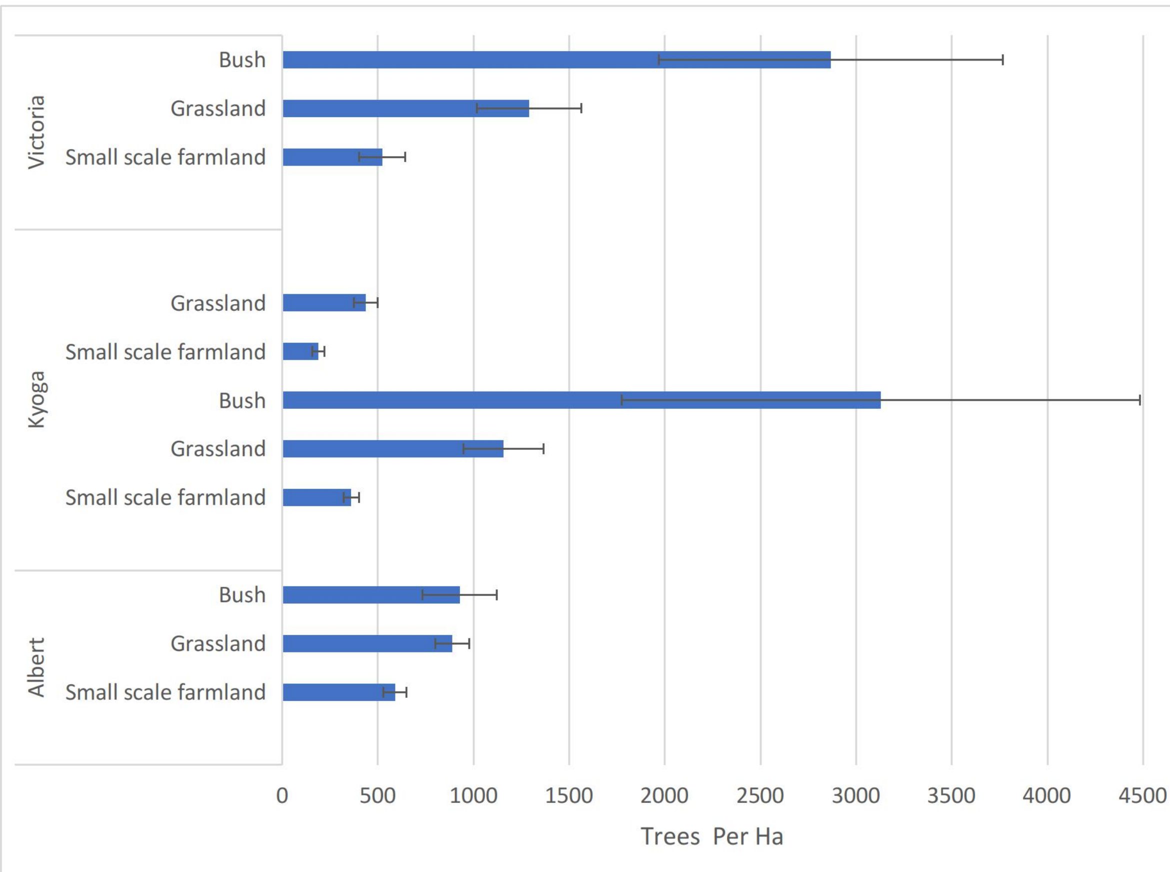


Figure 7- 2. Tree density on non- forest land by WMZs

7.2 Basal Area by Management Zones

The basal area in well stocked THF of the Albertine and Kyoga WMZs is about 21 m^2 and 27 m^2 respectively. In low stocked THF, the basal area is about 16 m^2 and 14 m^2 respectively in the Albertine and Kyoga WMZs.

The basal area in woodlands range from 5 m^2 in the Upper Nile WMZ to 13 m^2 in Victoria WMZ. The woodlands in Kyoga and Albertine WMZs have a basal area of 8 m^2 and 7 m^2 per hectare respectively.

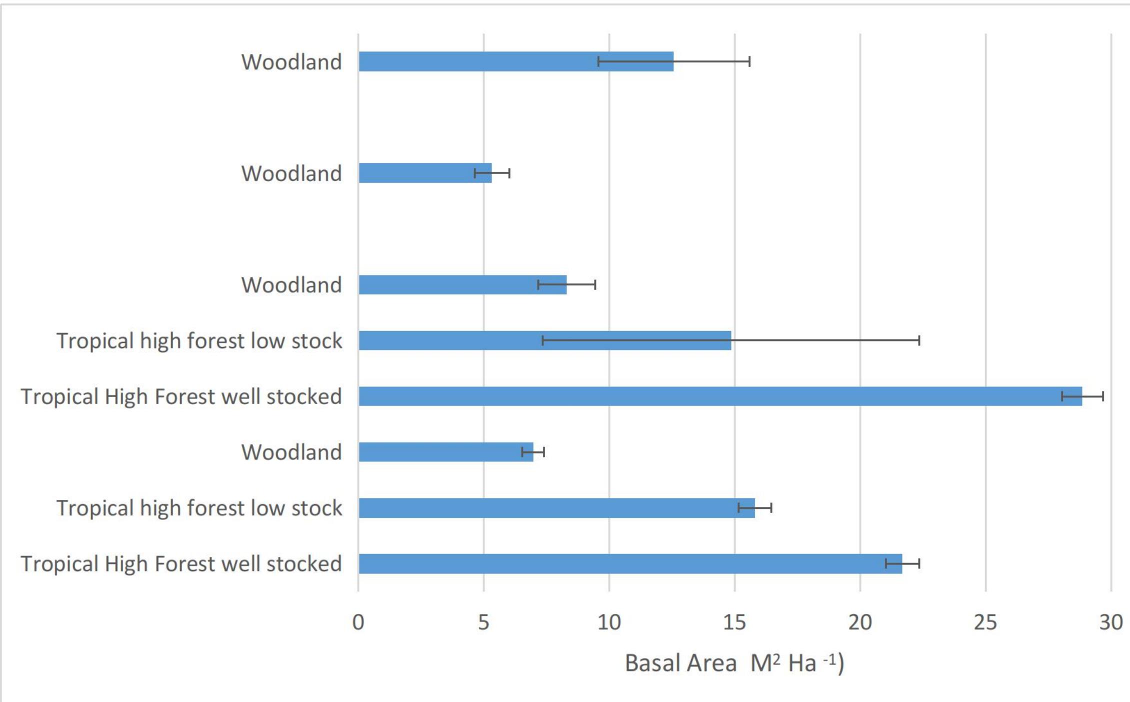


Figure 7- 3. Basal area in forests by WMZs

In non- forested areas, bush generally has the highest basal area and in non-forest land ranging from 3.6 m^2 per hectare in the Upper Nile WMZ to 8.4 m^2 in the Kyoga WMZ. Bush in in Victoria WMZ is second basal area at 8.3 m^2 per hectare. Bush in in the Albertine WMZ is second last with that the basal area 4 m^2 per hectare (Figure 7-4).

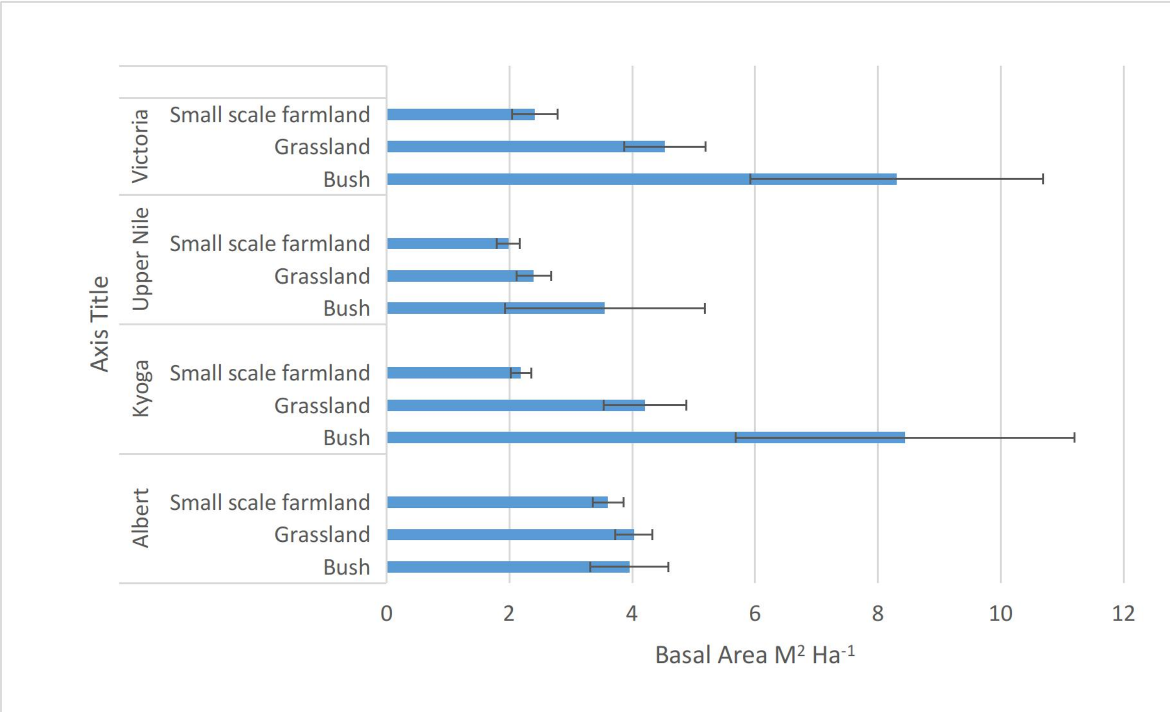


Figure 7- 4. Basal area in non-forest land by WMZs

7.3 Stem volume by WMZ

Well stocked THFs in the Kyoga and Albertine WMZs have the highest stem volume of 339 m^3 and 264 m^3 per ha respectively. The stem volume in low stocked THF are 195 m^3 and 191 m^3 per ha in Kyoga and Albertine WMZ respectively (Figure 7-5).

The woodlands of the Victoria WMZ have the highest stem volume estimated 79 m^3 and followed by Albertine at 41 m^3 per hectare. The woodlands of Kyonga and Upper Nile WMZ have got the lowest stock at 26 m^3 and 29m^3 per hectare respectively (Figure 7-5).

The stem volume of broadleaved forest plantation in Victoria and Albertine WMZs is estimated at 22 m^3 and 21m^3 per hectare respectively (Figure 7-5).

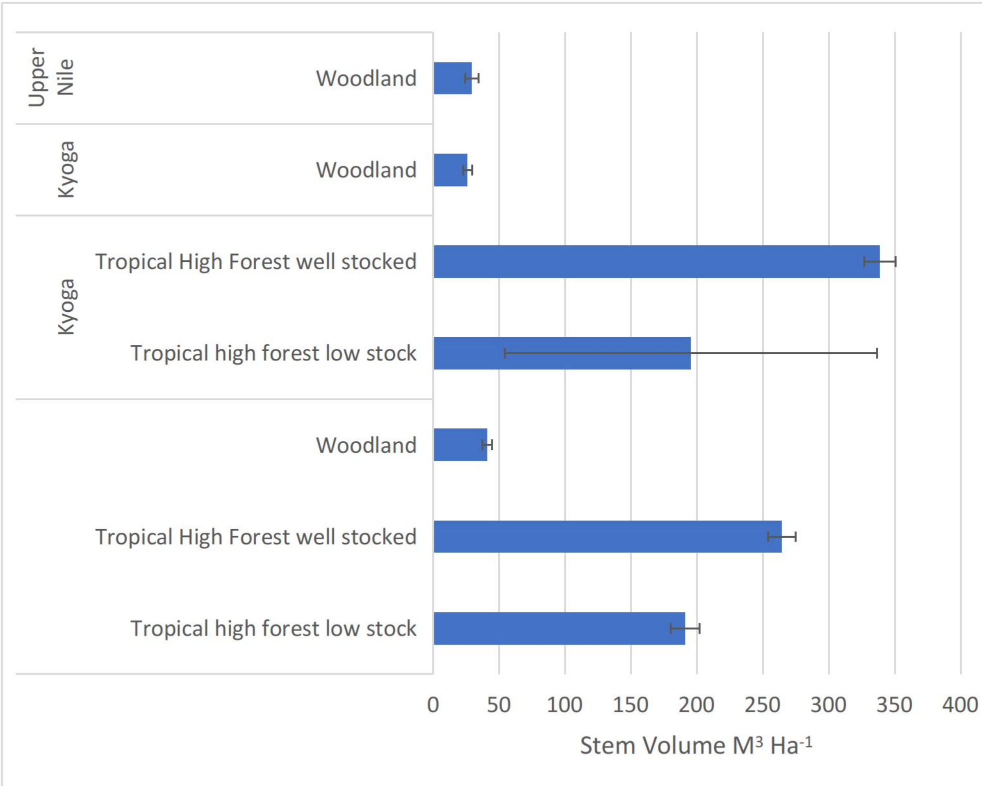


Figure 7- 5. Stem Volume in forest by WMZs

In non-forested areas, bush has the highest stem volume ranging from 21m^3 per hectare in the Albertine WMZ to 30 m^3 per hectare in the Upper Nile WMZ. Subsistence farmland comes next to bush in stem volume ranging from 13 m^3 in the Victoria WMZ to 24 m^3 per hectare in the Albertine WMZ, where it actually has more stem volume than bush.
Stem volume in grassland ranges from 14 m^3 in the Upper Nile WMZ to 21 m^3 per hectare in the Albertine WMZ (Figure 7-6).

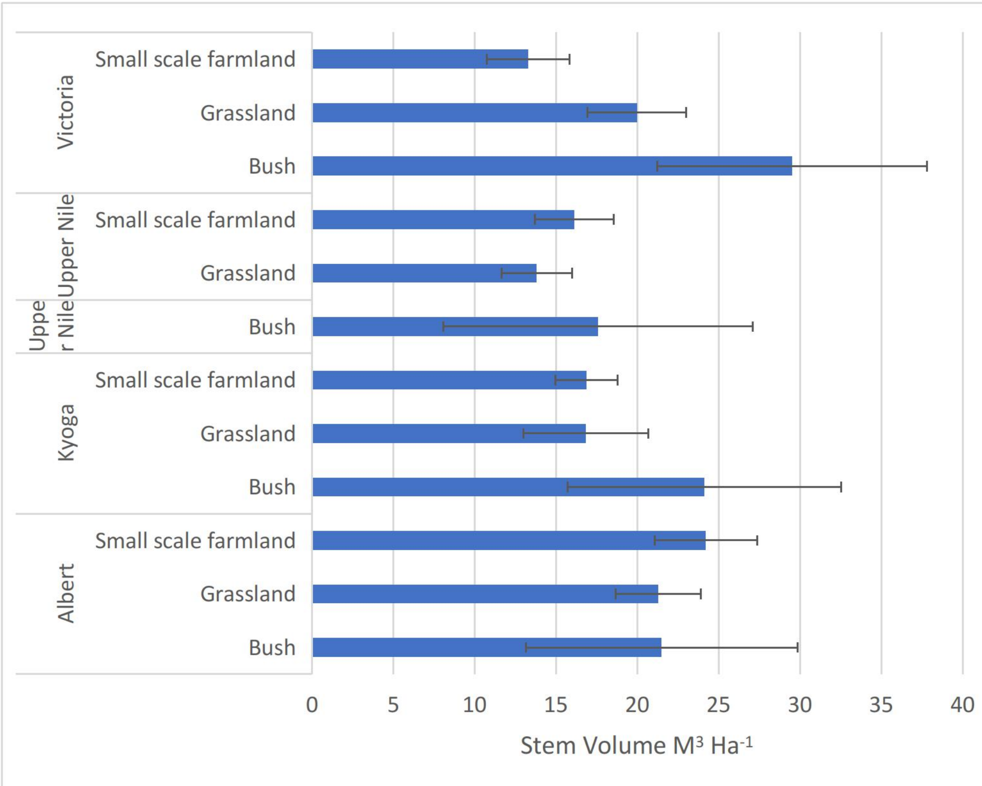


Figure 7- 6. Stem Volume in non-forest land by WMZs

7.4 Biomass stocks by WMZs

In forested area, above ground biomass in well stocked THF forests ranges from 223 tons to 287 tons per hectare in the Albertine and Kyoga WMZ respectively. Above ground biomass in low stocked THFs of the Albertine and Kyoga WMZ range from 161 tons to 164 tons per hectare, respectively (Figure 7-7).

The woodlands of Victoria WMZ have the highest stock of biomass at 53 tones followed by those of the Albertine at 29 tons per hectare (Figure 7-7). Woodlands in in Kyoga and Upper Nile have the lower stocks of biomass of 19 and 20 tons per hectare, respectively (Figure 7-7).

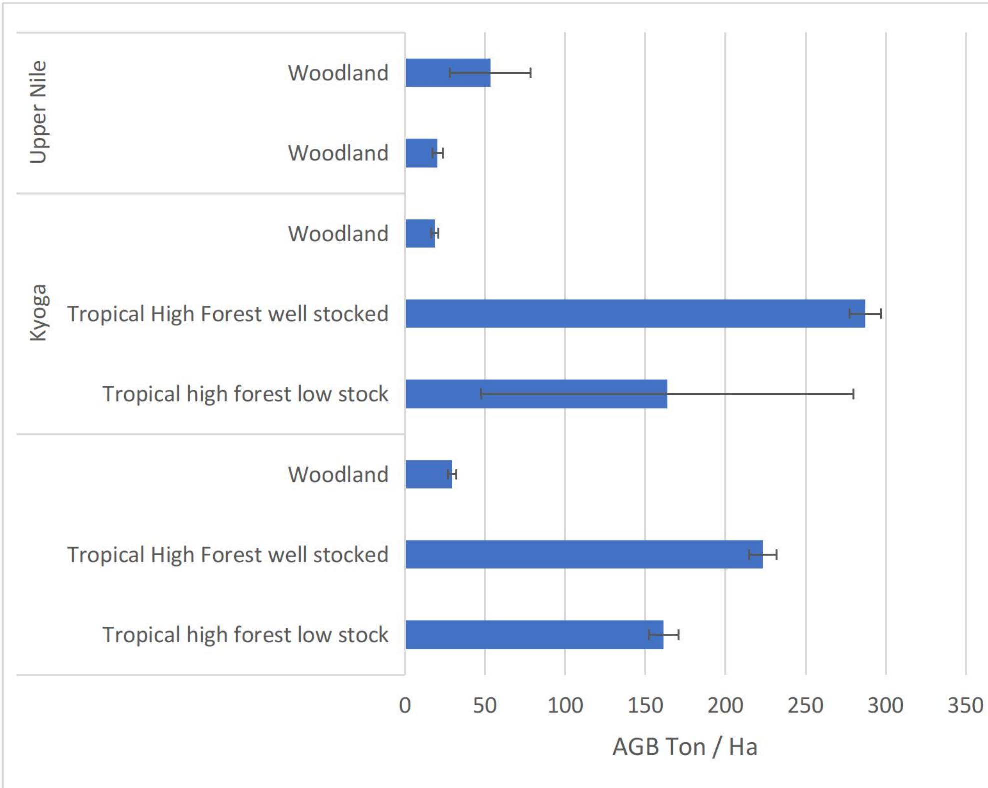


Figure 7- 7. Above ground biomass in forest by WMZs

In the Albert WMZ, non – forest vegetation has almost the equal biomass stock. Subsistence farmland has slightly higher biomass of 16 tonnes per hectare. Above ground biomass in both bush and grassland is estimated at 15 tonnes per hectare (Figure 7-8).

In the Kyoga, Upper Nile and Victoria WMZs, bush has the highest biomass stock ranging from 12 in Upper Nile to 22 tons per hectare in the Victoria WMZ. Biomass stock in grassland ranges from 10 tons in the Upper Nile WMZ to 14 tons per hectare in the Victoria WMZ (figure 7-8).

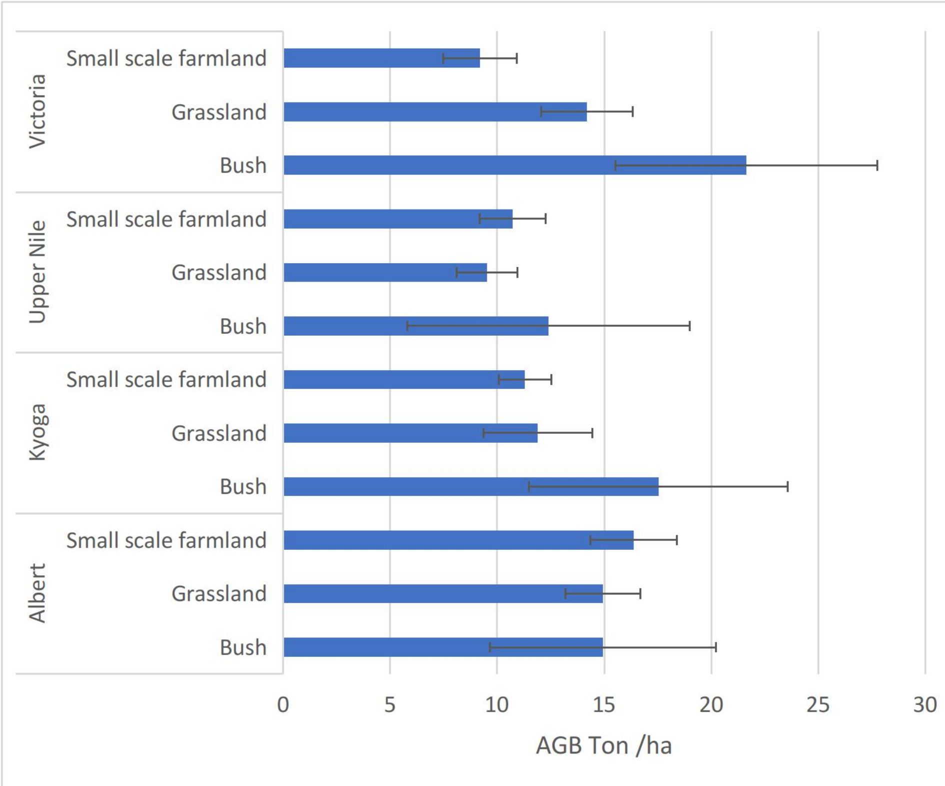


Figure 7- 8. Above ground biomass in non-forest by WMZs

7.4.1 Tree Species Diversity by WMZ

In Table 7-1 is a list of species categorized under as Red list that were enumerated in various WMZs of Uganda. Interpretation of the results should however bear in mind that this report and sampling strategy was never intended for evaluation of species diversity both at national level nor at WMZ level.

Table 7- 1. Abundancy of Red List species by WMZs

Species	Albert	Kyoga	Upper Nile	Victoria
Albizia ferruginea	99	17	117	8
Antrocaryon micraster	1	2		
Beilschmiedia ugandensis	8	4	1	
Chrysophyllum albidum	939	291		
Chrysophyllum muerense	12	25		
Chrysophyllum perpulchrum	72	7		
Dalbergia melanoxylon	3	48	136	
Erythrophleum suaveolens	5	6		
Irvingia gabonensis	1			

Khaya senegalensis	13			
Lovoa swynnertonii	5			7
Lovoa trichilioides	35	17		6
Milicia excelsa	89	126	4	
Olea welwitschii	169	13		
Prunus africana	33	34		1
Tamarindus indica	42	105	63	
Vitellaria paradoxa	11	27	479	
Warburgia ugandensis	162	4		

Interpretation of Simpon's (Figure 7-9) which indicates that the Upper Nile WMZ ranks highest in species abundancy (at 0.71) and the Victoria WMZ ranks low (at 0.61) has the same limitations as the Red list species in table 7-1.

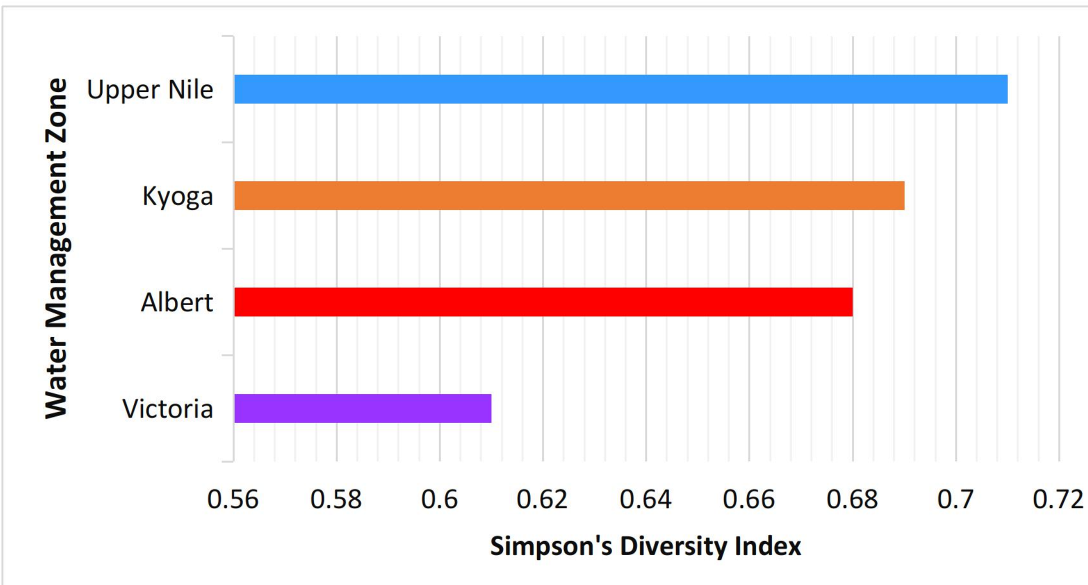


Figure 7- 9: Species diversity by water management zone

8 Conclusion and Way forward

8.1 Interpretation of the results

Tree volume and biomass stocks in well stocked THF is more than tenfold that of woodland and many non-forest land cover types which makes it a major reserve of carbon stock. On the other hand, THF are potential major sources of emissions if they are not protected and are destroyed.

Tree density in terms of stems per ha (see section 6.1) shows that there is generally many stems in the smaller diameter classes for both forest and non-forest classes. Stem volume (see section 6.5) is however concentrated in the big trees in all the three forest strata. In non-forests classes, stem volume is generally higher in small diameter classes apart from the occasional very large trees that may be scattered in subsistence farmland.

High tree density (stems per hectare) is important for end uses such as firewood in rural areas that heavily rely on small trees and twigs. However, for other end uses such as timber, tree size (volume) and species is a determinant factor. The unique requirements need to be considered when giving concessions and when modelling biomass supply and demand.

The existence of very high trees stock in the small diameter classes especially in woodlands and the majority of non- forest land (bush, grassland and cropland) is important for Uganda given that the largest end use of wood is fuelwood in rural areas which largely depends on trees and bushes typically less than 5cm diameter. This implies that if well managed, fuelwood use in rural areas has the potential to be more sustainable than commercial extraction which utilises relatively larger diameters.

Table 6-5 in section 6.6.1, Table 6-6 and Table 6-7 in section 6.6.2 and Table 6-8 in in section 6.6.3 tend to confirm that biomass use or extraction by local communities from within the immediate neighbourhoods such as subsistence farmland is more or less sustainable. The same data tend to indicate extraction of biomass from woodlands is unsustainable and is thus degrading the biomass stocks. Several studies show that these woodlands (mainly in central Uganda) are the major charcoal sources for the three urban centres of Entebbe, Jinja and Kampala metropolitan.

Tree species diversity is not confined to natural forests even though they have the highest numbers of tree species count (including count of herbaceous plants).

8.2 Improvements to NFI during REDD+ Readiness Phase

Improvements in NFI during the REDD+ readiness has targeted institutionalization and better coordination of the NFI, improved data collection protocols and procedures, improved data analysis tools and improved data sharing protocols.

For the first time, community level sensitization and involvement of a wide range of partners is now part of the NFI process. Joint NFA \ UWA field inventories have been carried out in Elgon forest, Kibale forest, Semiliki NP, Queen Elizabeth NP and Bokora

Wildlife reserve. District leadership both administrative (CAO, RDC, LC5) and Technical (e.g., District Forestry Services, District production officers) jointly plan NFI operations and are active front line officers for NFI operations.

Several technical improvements have been achieved. In previous inventories, information on socio-economic, deadwood and stumps were not collected. The need for the estimation of a variety of carbon pools (living and dead organic matter) has necessitated including extra parameters into Uganda's NFI surveys. Estimation of soil carbon pools has been done in collaboration with NARO, Soils Labs, Kawanda.

Identifying and minimizing sources of errors is an important aspect for Uganda's NFI integrity both as critical input for strategic planning while at the same time it enhances the trust the credibility of Uganda's reporting requirement under several UNFCC protocols and other international obligations. Quality Control / Quality Assurance (QC /QA) process have been embedded in NFI include re-measurement of a sub sample of sample plots measured by NFI.

Improvement in data analysis include introduction of digital data collection tools using tablets, transmission of data to a central database while teams are still in the field and introduction of several open source data analysis, presentation and sharing tools. These include Open Foris suite, R scripts and data mashup.

During the REDD+ readiness phase, NFI data infrastructure for easy updating and retrieval of forest statistics has been put in place. The infrastructure hosts a series of data checking and data cleansing processes along with the entire data transmission, collation, analysis, presentation and data sharing processes.

8.3 Future areas of Improvements

Historical land use/land cover stratification is based on the 13 classes that were developed by the NBS in the early 1990s. Due to time and resource constraints, during the REDD+ readiness phase (2016 to 2019) sampling focused on the three forest strata of THF well stocked, THF low stoked and woodlands. Some NBS plots were located in forest plantations but were too few and thus considered not representative.

Given that forest plantations are included in Uganda's forest definition, it is important that a fair assessment of carbon stocks in forest plantations be conducted. In the short term this could be done by integrating data collected by other government programmes and even the private forest companies. There is a need to rejuvenate efforts that were initiated by the Ministry of Water and Environment (MWE) where all the forestry sector institutions e.g., NFA and SPGS and private sector e.g., UTGA work together.

The results from the accuracy assessment on 2005 and 2010 land cover maps show that area under forest plantations (small woodlots in particular) had been grossly underestimated. There is need to utilize emerging technologies in mapping. There is also need for a robust spatial database infrastructure for more streamlined GIS / remote sensing analysis and updates.

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Appendix I, Forest Inventories in Uganda

From the early 1990s forest inventories in Uganda have had significant changes. The Norwegian Agency for International Development (NORAD), supported a landscape inventory approach called the National Biomass Study (NBS). European Union (EU) supported Forest Resources Management and Conservation Programme (FRMCP) that targeted inventories in Tropical High Forest under the management of NFA. These were Exploratory Inventory (EI) and Integrated Stock Survey and Management Inventory (ISSMI). Also with support FRCPM, Uganda conducted biodiversity surveys in 12 THF CFR. Three of these reserves were found to be of high conservation values and were later put the management of Uganda Wildlife Authority (UWA) so that they are according high protection. Here below is a brief description of key forest inventories in Uganda.

Integrated Stock Survey and Management Inventory (ISSMI) - is 5% assessment of a forest and is primarily a planning, control and monitoring tool at compartment level. When a compartment is identified for harvesting within a 5-year coupe, ISSMI is carried out before the start of that period.

Permanent Sample Plot – is carried out in both natural high forests and plantations to provide information on Annual Allowable Cut (AAC), forest growth and yield information, potential productivity of the site, effects of silvicultural treatment on growth and yield, data on the effect of management of stands on physical, chemical and biological properties of the site and changes in site productivity over successive rotations of tree crops under management.

Biodiversity Inventory – In early 1990s Forest Department (FD) carried out biodiversity in some selected (65) CFRs across the country. The inventory looked at five taxa and these were plants, birds, moths, butterflies and small mammals. From this inventory report, a nature conservation master plan was developed leading to about 50% of Uganda's forests being marked for conservation as strict nature reserve and buffer.

Appendix IIa, Biomass Inventory data form

The form below was used to collect data in the biomass inventory survey before the introduction of digital data collection. The same parameters are still collected by use of electronic devices and installed with a mobile application called Open Foris.

Biomass Monitoring Sample Plot Enumeration Form, NFI REDD+

Date	Time start	Time End	Sheet		of		Plot Coordinates(WGS84) X-coordinates	Y-Coordinates

Team Leader	Enumerator	GPS No	Altitude (m)	Slope Degree 0-5	6-15	>15

Plot ID (No)	Plot Polygon	Surrounding Polygon	Plot Corner	Slope Orientation N	NE	E	SE	S	SW	W	NW

Accessibility (good/medium/poor)	Plot size (m)	Strip Width	Complexity (LO/ME/HI)	Canopy %

Land Use (Others Specify)	NHF Medium Altitude	NHF Montane	Woodland	Plantation Coniferous	Plantation Deciduous	Non Forest

Major Land Cover Types

Cover type	Percentage	General Comment(Unique futures that can help future identification)
Trees		
Bush		
Grassland		
Crops (Name the type)		
Bare Soil		

SITE CHARACTERISTICS		LOCAL ATTITUDE
Fire Evidence		
Grazing Intensity		
Local Economy		
Distance to the road		

S/ No	Tree(T) /Recruit(R)/ Dead wood(D)	Stump(Mark X if stump)	Height of POM (m)	Stump/D W Age (years)	Common (Local) Name	Scientific Name	DBH (cm)	Bole Hgt. (m)	Hgt (m)	Tree Quality	Crown Diam.	Tree Condition	Crown Condition	Causative agents	Tree Status

TREE QUALITY CODES

1= Unusable

2 = Usable (0.5 log)

3 = Fair (1.5 logs)

4 = Good (2 logs)

5 = Very good (2+ logs)

TREE CONDITION

1 = Alive

2 = Declining

3 = Unhealthy

4 = Dying

5 = Dead

CROWN CONDITION

1 = Healthy

2 = Declining health

3 = Unhealthy

4 = Dying

5 = Dead

FIRE EVIDENCE

1 = No evidence

2 = Old

3 = Recent

GRAZING INTENSITY

1 = No grazing

2 = Grazing

3 = Grazing and Browsing

4 = Intensive grazing and browsing

STUMP AGE

1 = Recent

2 = Old

3 = Very old

LOCAL ATTITUDE

1 = Good

2 = Normal

3 = Poor

4 = Hostile

LOCAL ECONOMY

1 = Crop production

2 = Livestock/Herding

3 = Timber harvesting

4 = Charcoal production

5 = Fishery

6 = Tourism

9 = Handcraft

10 = Mining/Extraction

11 = Hunting

12 = Gathering

99 = Others

DISTANCE TO THE ROAD

1 = Good

2 = Normal

3 = Poor

4 = Hostile

CAUSATIVE AGENTS

0 = N/A

1 = Insects

2 = Diseases/Fungi

3 = Fires

4 = Animals

5 = Humans

6 = Climate

99 = Other

The form below was used to collect EI data before the introduction of digital data collection. The same parameters are still collected by use of electronic devices and installed with a mobile application called Open Foris.

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Appendix IIb, EI data collection form

Exploratory Inventory Sample Plot Enumeration Form, NFI REDD+							Block Coordinates	
Date	Time start	Time End		Sheet		of	X-coordinates	Y-Coordinates
Forest Inventory Area	Reserve	Cpt. No	Block No	Transect No			Plot Coordinates	
							X-Coordinates	Y-Coordinates
Plot ID (No)	Team Leader	GPS No		Altitude (m)				
Photo ID- N	Photo-E		Photo-S				Photo-W	Canopy %
Land Use (Others Specify)	NHF Montane		NHF Dense		Woodland		Bamboo	
Notes of Site (site Codes)		*Observations e.g. Logging, Fires, Agriculture, open rock etc.*						

Forest flow wood information status					
Log No	DBH (cm)	Length (m)	Decomposition status		
			1	2	3

Decomposition status description		
1	2	3
Recent	Initial	Advanced

S/ No	Tree/Recruit/Stump N	Stump (Mark X if stump)	Height of POM (m)	Stump Age (years)	Common (Local) Name	Scientific Name	DBH (cm)	Azimuth (dg)	Dist. (m)	Tree Qlty	No of Logs	Tree Condition	Crown condition	Causative Agent	Tree Spp. Code	Tree condition codes
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																

Tree Quality		
1	*2*	*3*
Unusable	*Usable ½ log*	*Fair 1- ½ logs*
4	*5*	
Good (2 logs)	*Very good (2 logs +)*	

Tree Condition		
1	*2*	*3*
Alive	*Declining*	*Unhealthy*
4	*5*	
Dying	*Dead*	

Crown Condition		
1	*2*	*3*
Alive	*Declining*	*Unhealthy*
4	*5*	
Dying	*Dead*	

Causative Agents			
0	*1*	*2*	*3*
N/A	*Insects*	*Dieses/fungi*	*Fires*
4	*5*	*6*	*99*
Animals	*Humans*	*Climate*	*Others*