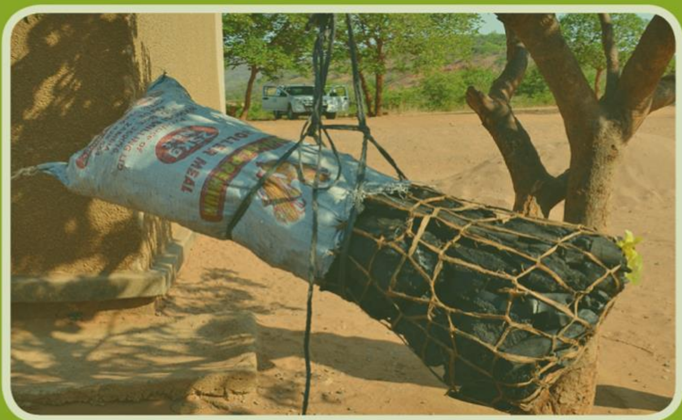
Republic of Zambia

# Integrated Land Use Assessment Phase II (2011-2016)

# FINAL REPORT

DECEMBER 2016



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Forestry Department

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# Integrated Land Use Assessment II – Report for Zambia

**Final Report prepared by the Forestry Department, the Ministry of Lands and Natural Resources and the Food and Agriculture Organization of the United Nations**

**Implementing Agencies**
Forestry Department, Ministry of Lands and Natural Resources

*In collaboration with:*

- Center for International Forestry Research (CIFOR)
- Central Statistical Office (CSO)
- Copperbelt University (CBU)
- Department of National Parks and Wildlife
- Food and Agricultural Organization (FAO)
- Ministry of Agriculture and Livestock (MAL)
- Ministry of Finance and National Planning (MOFNP)
- National Institute for Scientific and Industrial Research (NISIR)
- National Remote Sensing Centre (NRSC)
- Non-Governmental Organisations and Community Based Organisations (NGOs, CBOs)
- Survey Department (SD)
- University of Zambia (UNZA)
- Zambia Agriculture Research Institute (ZARI)
- Zambian Environmental Management Agency (ZEMA)
- Zambia Forestry College (ZFC)
- Zambia Forestry and Forest Industries Corporation (ZAFFICO)

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**About the report**
The report covers biophysical and forest livelihood information collected from Zambia's ten provinces between 2010 and 2015.

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**DISCLAIMER**

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**FOREWORD**

The Forestry Department under the Ministry of Lands and Natural Resources is responsible for the rationalization of the exploitation of forest resources and the promotion of sustainable forest management through the implementation of the Forests Act No. 4 of 2015.

Forests and trees occupy a large area of our country and provide the majority of the Zambian population with various products for their livelihoods. Therefore, forests and woodlands are of significant importance to Zambia's social economic and cultural development. They have a number of ecological functions including providing habitat for wildlife, organic matter to fertilize and nurture the soil, protecting the soil from erosion and cleaning the air of greenhouse gases. Economic value of forests is also achieved through eco-tourism, timber and various wood based products including source of fuel, medicines, fruits, honey and mushroom. The uses and functions of the forests in Zambia underscore the need to take care of them in such a manner that they would continue to provide the benefits in a sustainable way. Unfortunately, assessments of the state of our forests indicate that there is a decline in forest resources due to degradation and deforestation which consequently worsen soil erosion and siltation to water bodies.

This Report provides the findings of the Integrated Land-Use Assessment Project Phase Two (ILUA-II) which was conducted from 2010 to 2016 and was the largest forest inventory ever undertaken in Zambia. The report provides some critical bio-physical statistics of forest cover, volume of the growing stock, the tons of biomass and carbon, tree species abundance and regeneration. In addition, through the Forest Livelihood and Economic Survey (FLES) which was jointly conducted with the Central Statistics Office of Zambia, the report provides some statistics of household dependency on forests for various forest products. ILUA II also carried out some land cover change analysis for the period 2000 and 2014 which shows that the deforestation rate has increased due to unsustainable forest resource use.

It is our sincerely hope, that the ILUA-II Protocols and Systems will be fully institutionalized in order to continue in the collection of data for forest management activities in Zambia. In particular, the National REDD+ Strategy requires that Zambia continues to monitor its forests through Monitoring, Reporting, and Verification activities.

Trevor Kaunda
Permanent Secretary
**Ministry of Lands and Natural Resources**

**ACKNOWLEDGEMENT**

The Integrated Land-use Assessment Report Phase II is the result of collaborated effort of a spirited team who planned the inventory and survey through refined methodologies to meet acceptable standards. The team went further to conduct field assessment and household surveys across the country without any eventualities. The data collected was efficiently analysed and packaged for dissemination to various stakeholders.

Let me therefore take this opportunity to thank the following organization who participated in the implementation of this momentous work:

- Centre for International Research (CIFOR)
- Central Statistics Office (CSO)
- Copperbelt University (CBU)
- Department of National Parks and Wildlife (DNPW)
- Ministry of Agriculture (MoA)
- Ministry of Finance
- National Institute of Scientific and Industrial Research (NISIR)
- National Remote Sensing Centre (NRSC)
- Non-Governmental Organizations and Community Based organizations (NGOs & CBOs)
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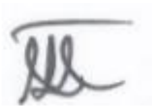
- Zambia Environmental Management Agency (ZEMA)
- Zambia Forestry and Forest Industries Corporation (ZAFFICO)

The Ministry of Lands and Natural Resources would like to express the heartfelt gratitude and appreciation to the Government of the Republic of Finland for the financial assistance and to the Food and Agriculture Organization of the United Nations (FAO) for the technical assistance. Sincere gratitude is also extended to all the consultants, technicians and field crew listed in appendix 1 for their various expertise and valuable contributions.



**Ignatius N. Makumba**
**DIRECTOR OF FORESTRY**

**ACRONYMS**

| | | |
|---|---|---|
| AGB | - | Above Ground Biomass |
| BA | - | Basal Area |
| BCEF | - | Biomass Conversion and Expansion Factor |
| BEF | - | Biomass Expansion Factor |
| BGB | - | Below Ground Biomass |
| CBNRM | - | Community Based Natural Resources Management |
| CBO | - | Community Based Organization |
| CBU | - | Copperbelt University |
| CSI | - | Cluster Sampling Intensity |
| CSO | - | Central Statistics Office |
| CSS | - | Cluster Sampling System |
| DBH | - | Diameter at Breast Height |
| ETM | - | Enhanced Thematic Mapper |
| FAO | - | Food and Agriculture Organization |
| FD | - | Forestry Department |
| FDHQs | - | Forestry Department Headquarters |
| FMU | - | Forest Management Unit |
| FRA | - | Forest Resource Assessment |
| FREL | - | Forest Reference Emission Level |
| FRL | - | Forest Reference Level |
| FT | - | Field Team |
| GHG | - | Green House Gas |
| GIS | - | Geographical Information System |
| GPS | - | Global Positioning System |
| GRZ | - | Government of Republic of Zambia |
| ILUA | - | Integrated Land use Assessment |
| IPCC | - | Intergovernmental Panel on Climate Change |
| LANDSAT | - | Land Remote Sensing Satellite |
| LCM | - | Land Cover Maps |
| LULUCF | - | Land use, Land-use Change and Forestry |
| MLNR | - | Ministry of Lands and Natural Resources |
| MRV | - | Monitoring Reporting and verification |
| NFI | - | National Forest Inventory |
| NFMA | - | National Forest Monitoring and Assessments |
| NFORMA | - | National Forest Resource Monitoring and Assessments |
| NFMS | - | National Forest Monitoring System |
| NGO | - | Non-governmental Organization |
| NLCD | - | National Land-cover Datasets |
| NRA | - | National Resource Assessment |

| | | |
|---|---|---|
| NRSC | - | National Remote Sensing Centre |
| NWFP | - | Non-wood Forest Products |
| OWL | - | Other Wooded Land |
| PCI | - | Plot Sampling Intensity |
| PFA | - | Protected Forest Area |
| PFAP | - | Provincial Forestry Action Program |
| PMU | - | Project Management Unit |
| QA | - | Quality Assurance |
| QC | - | Quality Control |
| RCMRD | - | Regional Centre for Mapping of Resources for Development |
| REDD | - | Reduced Emissions from Deforestation and Forest Degradation |
| SD | - | Survey Department |
| SFM | - | Sustainable Forest Management |
| SRS | - | Simple Random System |
| TOF | | Trees Outside Forests |
| TORs | - | Terms of Reference |
| UNDP | - | United Nations Development Programme |
| UNFCC | - | United Nations Framework Convention on Climate Change |
| UTM | - | Universal Transverse Mercator |
| WD | - | Wood Density |
| ZARI | - | Zambia Agriculture Research Institute |
| ZAWA | - | Zambia Wildlife Authority |
| ZEMA | - | Zambia Environmental Management Agency |

**EXECUTIVE SUMMARY**

Substantial biophysical and socio-economic data related to forests and land-use was collected through the Integrated Land Use Assessment project in Zambia (ILUA II, 2010 - 2016). The overall objective of ILUA II was to "*strengthen forest resources management and enhance its contribution to sustainable development, land use and livelihoods*" in the country. It is the second comprehensive forest resources assessment conducted in the country. The first assessment (ILUA I, 2005 - 2008) generated baseline data, while ILUA II was designed to enhance the use and development of that data towards sustainable forest management (SFM), the Reduction of Emissions from Deforestation and Degradation (REDD+) and the provision of additional information on trends in forest cover change through enhanced and refined methodologies.

The methodological design and approach of ILUA II was based on the Global FAO National Forest Monitoring and Assessment (NFMA) framework and aimed at gathering accurate biophysical and socio economic data. A two-stage stratified sampling was used to establish 1,093 clusters and 4,372 sample plots across the country. In each province, FAO Forest Resource Assessment (FRA) land cover classes (i.e. Forest, Other Wooded Land and Other Land) were used as strata for data collection and analyses. Area estimates for vegetation types in each stratum were then computed, weighted and aggregated to the national level. Field data were stored and managed in an *Open Foris Collect* database, while the data were analysed using *Open Foris Calc*.

In order to produce forest cover maps, the Landsat 5, 7 and 8 images with a 30 m spatial resolution were acquired and used to generate land cover maps for the years 2000, 2010 and 2014. These maps were used to determine the forest cover between time intervals (years of interest). As a part of ILUA II, social economic data related to forests were also collected through the Forest Livelihood and Economic Survey (FLES) using a stratified two-stage cluster sampling procedure. The current report reveals major biophysical and socio-economic findings of the assessments conducted during ILUA II. The following are the key findings for the biophysical and socio-economic assessments:

1) **Tree species (density) abundance**: More than 2,500 different tree species were found during the assessment mainly identified in local languages and diatribes across the country. The 2 most dominant species were the *Entandrophragma delevoyi* (Mofu) and *Brachystegia longifolia* (Mubombo) while *Julbernardia paniculata* (Mutondo) and *Brachystegia speciformis* (Kaputu) were the most abundant species recorded. There are about 11.4 *billion trees* (trees measuring ≥ 10cm diameter at breast height) and an estimated 10.9 *billion saplings* (trees measuring ≥ 5cm and < 10cm diameter at breast height across the country for different tree species. On average there are 154 *tree stems/ha* and 148 *stems* for saplings per hectare in forested areas.

2) **Tree species regeneration:** Seedlings with a height of less than 1.3m represented 80% of seedlings counted during the assessment. The highest density of seedlings in the country was found in Muchinga Province and the lowest in Southern and Copperbelt Provinces. This suggests

that forests in Muchinga have higher regeneration potential than forests in Southern and Copperbelt Provinces.

3) **The commercial timber species:** These prime commercial timber species filtered from the list of all tree species accounts for 6.4 *billion stems* representing 29% of the total tree count in this assessment. Based on the national frequency of valuable species used for saw-log production only, *Colophospermum mopane* (Mupani) is the most abundant (though lesser-used) species accounting for 10.57%, followed by the most commonly processed *Pterocarpu angolensis* (Mukwa) which is estimated at 8.74%, *Guilbortia coloesperma* (Rose-wood) is at 2.7%, *Afzelia quanzensis* (Mupapa) 1.3%, *Baikiaea pulrijuga* (Mukusi) 2.1%, and *Pterocarpus chrysothrix* (Mukula). Meanwhile, *mukwa* is more abundant in Western Province representing 2.01% and in North-western Province it is estimated at 1.84%, while in Northern and Luapula provinces it is estimated at 1.62% and 1.53% respectively. Traditionally *Baikiaea plurijuga* which is the most sought after for durable sawn timber production is only available in Western and Southern provinces estimated at 1.62% and 0.47% respectively.

4) **Tree volumes**: The total tree (for trees measuring ≥ 10 cm *dbh*) volume for the growing stock was estimated at 3,178 *million* $m^3$ the majority of this volume, 2,602 *million* $m^3$, is contained in forest woodlands, while the saplings (for trees measuring ≥ 5 and < 10 cm *dbh*) volume is estimated to be 154.4 *million* $m^3$ of which forest land returned 124.6 *million* $m^3$; other wooded-land returned 20.6 *million* $m^3$; and other land 9.1 *million* $m^3$ (Table X). The actual distribution of total growing stock (volume) for saplings inside forests (by major vegetation types) shows that forest woodlands which accounts for the highest has a total of 117.5 *million* $m^3$, and the lowest is in forest plantations which has 0.05 *million* $m^3$.

5) **Biomass stock**: Total biomass in the standing trees (*dbh* ≥ 10 cm) was estimated at 2.74 *billion tons*, while for the saplings (*dbh* 5 - 9.9 cm) it was estimated at 220.9 *million tons*. Biomass from the stumps and lying dead wood was estimated at 68.4 *million tons* and 107.4 *million tons* respectively. Biomass in standing trees varied across provinces: North-western province recorded the highest (113.2 *tons/ha*) while the lowest biomass was recorded in Lusaka Province (55.9 *tons/ha*). Standard error of mean forest biomass (above-ground biomass) was 2.4 *tons/ha* representing a 6.9% sampling error at the 95% confidence level.

6) **Carbon stock**: Total carbon from standing trees (*dbh* ≥ 10 cm) was estimated at 1.34 *billion tons* compared to 108.3 *million tons* from saplings, 33.5 *million tons* from stumps and 52.6 *million tons* from dead wood. Carbon content was highest in North-western province (55.5 *tons/ha*) and the lowest was recorded in Lusaka province (27.4 *tons/ha*).

7) **Forest cover**: The total forest cover from wall-to-wall (based on the 2014 remote sensing data) computation is estimated to be 45.9 *million ha* and represents 61.04% of the country's land surface area. Meanwhile, the estimated forest land (under vegetation types) extrapolated from sample plot is 44.17 *million hectares* (±1.2 *million ha*) evaluated at 95% confidence interval, representing 58.7% of the country land surface area. The remote sensing based forest cover

estimates are more reliable than sample plot based extrapolation which in this case slightly under estimates the forest cover by 1.77 *million hectares* accurately and spatially accounted for by the land cover maps.

8) **Deforestation rate**: The land cover map data for the years 2000, 2010 and 2014, shows that human activities related to land use and land-use change in forests (LULUCF) reduced the forest cover from 47.07 *million* hectares (*ha*) in 2000 to 45.94 *million* hectares (*ha*) in 2014. Therefore, the total forest cover lost is estimated to be 1.1 *million ha* (1,110 $km^2$) representing an annualized minimum of forest cover loss (deforestation) of 79,345 *ha per annum* (0.17%) based on an arithmetic mean analysis, with the weighted annualized loss indicating a maximum of 149,876 *ha per annum* (0.32%) over the period of 14 years. Therefore, Zambia's current official deforestation rate is estimated to be between 79,000 and 150,000 *ha per year*.

9) **Drivers of deforestation**: The direct drivers of forest cover loss based on the land cover maps (*changes in the land cover classes*) are mainly attributed to agriculture which increased by 0.95% from 47.05 *million ha* in the year 2000 to 45.94 *million ha* in the year 2014 and settlement expansion which increased by 0.48% from 137,245 ha in the year 2000 to 501,658 ha in the year 2014. Conversion of land to other-land increased by 0.04% from 135,643 *ha* in the year 2000 to 165,721 *ha* in the year 2014; and Wetland (*especially water development*) increased by and 0.05% from 5.04 *million ha* in the year 2000 to 5.08 *million ha* in the year 2014 respectively. Other-land and wetland (water development) was mainly attributed to the opening up of new mines and related infrastructure development.

10) **Forests and livelihood**: Overall, 21% of households in Zambia depend on crop production as the main livelihood activity, followed by fuelwood collection (16%). Non-wood forest products such as edible wild foods (i.e. fruits, roots, tubers and bulbs), plant medicines and mushrooms were among the top ten forest products contributing to household incomes observed during the assessment. Among forest products, charcoal and fuelwood contributed more to income at household level across provinces. However, unlike charcoal, a large proportion of fuelwood produced was used for consumption as the main source of energy. This suggests that forests continue to play a significant role in people's livelihoods. The national average of forest area cleared was estimated at 0.73 *ha per* household in 2015. Forest clearing for agriculture was highest in Lusaka Province (1.38 *ha per* household) and lowest in Luapula Province (0.25 *ha per* household) suggesting that high income provinces clear more forests than low income provinces.

In view of the fact that the data is of high quality and is thus reliable, it is suitable to be used as the country's latest baseline and reference for future assessments. The project has also enhanced the capacity of the Forestry Department to conduct future assessments. It is therefore recommended that Zambia should mainstream regular National Forest Inventories (NFIs) into the Forestry Department's mandate for effective forest resources monitoring.

In order to better understand the drivers of deforestation and to inform policy interventions that support sustainable forest management (SFM), this assessment has addressed forest socio-economic information needs through the Forest Livelihoods and Economic Survey (FLES). The increasing population and growing demand for forest goods and services, as well as the demand for agriculture and settlement, will continue to put more pressure on forests. The Provincial Forest Reports and the Forest Management Books (Plans) to be formulated later from this data will thus be fundamental to sustainable forest management at the provincial level and will eventually lead to more effective management of forests in Zambia.

It is recommended that NFIs framework be mainstreamed into basic and tertiary education curricula. It is also recommended that a forest management code and the Provincial Forest Management books are put in place. The forest management code will set standards for all forest management planning, forest inventories and other technical requirements, and will also set a standard format for plans that take into consideration the needs of forest users.

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# 1.0 INTRODUCTION

Zambia's forests provide a wealth of socio-economic and environmental services. However, they face immense pressure arising from various forms of land use change and anthropogenic activities such as extensive practices of agricultural expansion, increasing demand for fuelwood, overgrazing, late season forest fires and infrastructure development (roads and urban expansion), to mention but a few (UN-REDD, 2012). To address these challenges, the Government of the Republic of Zambia (GRZ) had put in place a multi-sectoral Integrated Land Use Assessment (ILUA) project supported by appropriate revised laws[4]. The main stakeholders of this project include the Ministry of Lands, Natural Resources and Environmental Protection (MLNEP), Ministry of Finance (MOF), Ministry of Agriculture and Livestock (MAL), Central Statistical Office (CSO), University of Zambia (UNZA), Copperbelt University (CBU), National Institute for Scientific and Industrial Research (NISIR), smallholder farmers, Non-Governmental Organisations (NGOs), Civil society and international institutions including the Center for International Forestry Research (CIFOR), Food and Agriculture Organization (FAO) of the United Nations and Cooperating Partners (CPs) (Forestry Department, 2010).

The overall objective of ILUA was to *"strengthen forest resources management and enhance its contribution to sustainable development, land use and livelihoods"* (Forestry Department, 2010). The project was funded by the Government of the Republic of Finland with technical support from the FAO. It has been implemented in the country by the Forestry Department in two phases: ILUA I (2005–2008) and ILUA II (2010–2016). While ILUA I provided a baseline for the national level information, ILUA II was designed to provide information at the provincial level that supports sustainable forest management (SFM), REDD+ initiatives and Green-House Gas (GHG) inventories (GRZ, 2010a). Therefore, this report collates and compiles the data produced by ILUA II into a succinct document that captures the project activities over the past 6 years.

## 1.1 Background information

### 1.1.1 Location and administration of Zambia

Zambia is located in sub-Saharan Africa and lies between latitudes 8°–18° S and longitudes 22°–34° E, and covers a total surface area of approximately 75.3 million hectares. The country is landlocked and shares borders with 8 countries: the Democratic Republic of Congo (DRC) and Tanzania in the north, Malawi in the east, Angola in the west, and Botswana, Namibia, Mozambique and Zimbabwe in the south. Zambia, whose capital city is Lusaka, is administered through 10 provinces, namely; Central, Copperbelt, Eastern, Luapula, Lusaka, Muchinga, Northern, North-Western, Southern and Western. The provinces vary widely in size, from Western Province which covers nearly 16% of the country's land area, to Lusaka Province which takes up merely 3.3%.

[4] Before 2015, the Forest Act of 1973 was used. This was revised to the Forest Act No.4 of 2015 supported by the Forest Policy of 2014. The Zambia Forest Action Plan was the link document to various processes and programs including ILUA.

### 1.1.2 Population

The Population and Housing Census of 2010 estimated the population of Zambia at 13.1 million with a 2.8% growth rate per annum, representing a 0.4% increase from the previous census of 2000 (CSO, 2012). The population is projected to be 17.9 million by 2020 (CSO, 2013). Interestingly, the population in rural areas is expected to grow at a relatively stable average rate of 2.4% per annum while the urban population is expected to grow at a declining average rate of about 3.5% per annum during the same period. The projected change in population is likely to increase pressure on the existing forest resources, especially in rural areas. (CSO, 2013).

### 1.1.3 Land use and forest planning

Land use planning has been practiced in Zambia since the 1950s. In 1964, the country inherited a system that categorised land into state land, reserves and trust land from the colonial government. In 1968, the Government of Zambia commenced enacting laws that provided for state control of land. In 1995, the Lands Act was enacted, which provided for the conversion of land holding from customary to leasehold tenure (GRZ, 1995). Regarding forest planning, District Forest Management Books (DFMB) were produced up to the 1970s. These books contained detailed forest inventory information which was used as baseline data for subsequent forest resource assessments in the country. Using previous forest management books, the Zambia Forest Action Plan (ZFAP) in 1997 prepared the 20-year forest management plan for the country (Forestry Department, 1997). ZFAP led to the development of several other programmes such as the Provincial Forest Action Plan (PFAP), Forest Support Programme (FSP) and Forest Resource Management Programme (FRMP), and linked them to the national development plans. Currently, ILUA projects have been implemented in Zambia to strengthen forest resource assessments.

### 1.1.4 Vegetation and land classification

Since the 1930s, at least 10 vegetation surveys have been conducted in Zambia to cover either parts of or the entire country. The first extensive vegetation surveys in Zambia were conducted between 1932 and 1942 (Trapnell, 1953). Three main vegetation classes were derived, namely; (i) Forests, (ii) Woodland, and (iii) Grassland. Soil types were also included in these surveys in order to derive vegetation floristic associations and produce a vegetation-soil map (Trapnell and Clothier, 1957). The limitation of these surveys is that they only covered central and western Zambia and thus could not be applied countrywide (Lees, 1962). The vegetation survey that was conducted from 1958 to 1960 focused on the exploitable volume of trees with 14 cm *dbh* or more (Lees, 1962). The main drawback of this survey was that it was restricted only to the Copperbelt Province. By 1969, surveys conducted by Fanshawe (1969) resulted in the classification of vegetation into four classes: (i) Closed forests, (ii) Open forests, (iii) Termitaria, and (iv) Grasslands. This survey was based on the global vegetation system and it was more comprehensive than any other previous vegetation survey conducted in Zambia (Fanshawe, 1969).

Another vegetation survey was conducted which classified all forests as woodlands because the focus of this survey was on land use categories rather than vegetation classes (Schultz 1974). Six years later, during the reconnaissance assessment of land resources in Zambia, the 5th vegetation survey was conducted by Lawton (Mansfield *et al*. 1976). In this survey, tree canopy cover, fire damage and cultivation were among the most important characteristics of vegetation. However, results of this vegetation survey could not be used countrywide because the assessment was only restricted to Northern and Luapula provinces (Mansfield *et al*., 1976).

In the 1980s, the Southern African Development Coordination Conference (SADCC) classified vegetation based on total biomass for fuelwood using remote sensing data (Millington *et al.*, 1986, Chidumayo, 1987a). The study divided Zambia into nine biomass classes, arranged in the order of magnitude based on area: (i) Wet *Miombo* Woodland, which covers 30.8% of the country's total surface area, (ii) Seasonal *Miombo* Woodland, (iii) Degraded *Miombo* Woodland, (iv) Kalahari Woodland, (v) *Mopane* Woodland, (vi) Dry *Miombo* and *Munga* Woodland, (vii) Swamp and Lake Vegetation, (viii) Scrub Woodland, and (ix) Dry Evergreen Forest, which covers only 1.3% of Zambia's surface area (Forestry Department, 2016b).

In the same period, 1982–1985, Chidumayo (1987a) used topographic and soil data to divide *miombo* forests into five subtypes. Ten years later, the ninth vegetation survey was conducted from 1996 to 1998 through the Provincial Forestry Action Programme (PFAP) implemented under the Forestry Department. This programme developed a land cover classification system based on Landsat MSS images of 1993. As a result, four vegetation classifications were produced: (i) forest, (ii) grassland, (iii) non-vegetated (bare), and (iv) agricultural land (cultivated).

Current surveys conducted during ILUA I (2005–2008) and ILUA II (2010–2016) were the most comprehensive natural resource surveys in Zambia. These surveys used the global FAO Forest Resource Assessment (FRA) classification system as well as national requirements to produce a new vegetation classification for the country. Thus, vegetation was recently classified into three broad categories, (i) Forest, which covers an area of 0.5 ha or more with trees of 10% or more canopy cover and at least 5 m height at maturity *in situ*, (ii) Other Wooded Land (OWL), i.e. area occupying 0.5 ha or more with trees of 5–10% canopy cover or shrubs/bushes with at least 10% canopy cover, and (iii) Other Land, which include trees with less than 5% canopy cover or shrubs/bushes with less than 10% canopy cover. The forest inventory results presented in the current report were based on FRA classification as well as the country level requirement (Table 1).

**Table 1: Land categories and vegetation classification**

| FRA (land) class | Major vegetation and other land | Forests and land use classes |
|---|---|---|
| **Forest land** | Dry evergreen forest | *Parinari* forest and Copperbelt chipya |
| | | *Marquesia* forest |

| FRA (land) class | Major vegetation and other land | Forests and land use classes |
|---|---|---|
| | | Lake basin chipya |
| | | *Chryptosepalum* forest |
| | | Kalahari sand forest |
| | Dry deciduous forest | *Baikiaea* forest and deciduous thicket |
| | | *Itigi* forest |
| | Moist evergreen forest | Montane forest |
| | | Swamp forest |
| | | Riparian forest |
| | Forest woodlands | *Miombo* woodland on plateau |
| | | *Miombo* woodland on hills |
| | | Kalahari woodland on sands |
| | | *Mopane* woodland on clay |
| | | *Munga* woodland on heavy soils |
| | Forest plantations | Broad leaved forest plantation (*Eucalyptus*) |
| | | Coniferous forest plantation (*Pine*) |
| **Other wooded land** | Wooded grasslands (including pans and shrubs with some trees) | Termitary vegetation and bush groups |
| | | Shrubs / thickets |
| **Other land** | Grasslands | Dambos and flood plains |
| | | Marshland and Swamps |
| | Bare land | Barren land |
| | | Sandy dune |
| | | Bare rock / outcrop |
| | Cultivated and managed land | Annual crop |
| | | Perennial crop |
| | | Pasture land |
| | | Fallow |
| | Built-up areas | Urban |
| | | Rural |
| **Water bodies** | Inland water | Lakes, Rivers, Dams |

## 1.2 Historical Forest Assessments

### 1.2.1 National forest inventories

The first national forest inventory (NFI) in Zambia was carried out between 1932 and 1936 in the *Miombo* woodland (Forestry Department, 2008). The second inventory commenced in 1942 and lasted for two years. The main purpose of these inventories was to generate information on the availability of timber and poles for the mining industry. As such, these inventories were restricted to Copperbelt Province, the heart of mining activities. By 1949, the third forest inventory aimed at estimating the volume of timber for concessions was initiated (Forestry Department, 2016c), although it was restricted to Western Province. As such, the findings of this inventory could not be generated countrywide.

A few years later, a large-scale forest inventory, covering priorities beyond Copperbelt and Western provinces, was carried out during 1952–1967 (Pohjonen, 2004). District Management Books were prepared countrywide and were used for subsequent forest assessments (Chakanga and de Backer, 1986, Alajarvi, 1996). For example, Chakanga *et al.* (1986) used 61.2 million hectares from the DMBs as a reference to estimate the total wood biomass for Zambia. Similarly, Alajarvi (1996) also used the DMBs to quantify Zambia's forest cover which was reported to be 59.5 *million hectares* with the standing volume estimated at 4.2 *billion* $m^3$.

In 1997, during the Zambia Forest Action Plan process, several forest resource assessments were carried out. One of these assessments was conducted in 1999 covering three provinces only, i.e. Luapula, Copperbelt and Southern provinces under PFAP (Forestry Department, 1999). In the FAO FRA 2000, the total forest area for Zambia was estimated at 31.2 *million hectares*. In addition, the European Forest Support Programme (EU-FSP, 2001–2003) also carried a number of assessments in 8 provinces and estimated the total forest area to be 30.8 *million hectares*. Furthermore, other studies estimated the total forest area to be 41.2 *million hectares* (Pohjonen, 2004). Inconsistencies observed during these assessments suggested that there was need to carry out a country wide comprehensive forest resource assessment in order to accurately estimate the forest quantities of the country.

### 1.2.2 Fuelwood Surveys

The first rigorous assessment of the total woody volume in Zambia was done in 1986 as part of the National Wood Energy Consumption and Resource Survey (Forestry Department, 2016c). This survey estimated the total wood volume to range from 3.0 to 4.1 *billion* $m^3$ (i.e. average 3.*55 billion* $m^3$) in the total forest area ranging from 41.2 to 55.2 *million hectares* (i.e. average 48.2 *million ha*). In 1987, the second wood fuel assessment was completed as part of the Southern Africa Development Community (SADC) wood energy study. In this assessment, total available wood volume was estimated to be 3.64 *billion* $m^3$.

### 1.2.3 Timber Concession Inventory

The history of timber harvesting in the country dates as far back as 1917 in the Zambezi teak forests of Western Province. The timber concessions were originally intended to promote and stabilise investment in the forestry sector (Piearce, 1986). However, this harvesting of timber by various concession holders was carried out without inventories of concession areas. In later years, the sawmilling companies that operated in the *Baikiaea* (Zambezi Teak) forests were required by the Government to determine the volume of exploitable timber stock in any given concession area. Hence, in the 1940s, a large scale forest inventory was carried out to estimate the volume of timber for concession harvesting in Western Province. Some of the data from these inventories was used by concessionaires in respective areas for their preparation of harvesting plans. In Zambia, a concession area may contain between 4 and 12 commercial trees per hectare and that the appropriate cutting cycle may be between 40 to 80 years depending on the tree species (Forestry Department, 1986).

### 1.2.4 Integrated Land Use Assessment Phase One (ILUA I)

Phase one of ILUA commenced in 2005, 8 years after the formulation of ZFAP. The main purpose of ILUA I was to *"build up forest related land use resource inventories, support national planning capacity and contribute to formulating development policies"*. This project was initiated mainly to address increasing deforestation, the loss of biological diversity and the overexploitation of natural resources (Forestry Department, 2004). While it was recognized that natural resources continued to decline over the years, the extent of depletion was unknown (Forestry Department, 2004). Therefore, Government, in collaboration with the FAO, agreed to undertake a National Forest Assessment (NFA) in 2005 in view of updating information on the state of forests and land use in Zambia. ILUA I was designed as a multi-sectoral project aimed at providing information relevant to national level decision-making, policy formulation and monitoring of forestry and related sectors such as agriculture, wildlife, fisheries, land use and natural resources at national, provincial, district and sub district levels. The capacity of institutions to plan and implement land use assessments, monitor the resources, manage the related information and continue to enhance sustainable natural resource management was improved in ILUA I. There were 884 accessible plots in ILUA I with a total cumulative plot area of 433.1 hectares (Table 2).

**Table 2: Cumulative sample plot size in ILUA I**

| Province | Land area (000 ha) | Forest area (000 ha) | Number of accessible plots | Cumulative plot area (ha) |
|---|---|---|---|---|
| 1. Central | 9,439 | 7,910 | 120 | 59 |
| 2. Copperbelt | 3,133 | 1,609 | 36 | 18 |
| 3. Eastern | 6,911 | 5,152 | 84 | 42 |
| 4. Luapula | 5,057 | 3,465 | 56 | 26 |
| 5. Lusaka | 2,190 | 1,651 | 20 | 10 |
| 6. Northern | 14,782 | 7212 | 172 | 84.4 |
| 7. North-Western | 12,583 | 10,041 | 148 | 70 |
| 8. Southern | 8,528 | 4,672 | 92 | 46 |
| 9. Western | 12,639 | 8,254 | 156 | 77.8 |
| Total | 75,261 | 49,966 | 884 | 433 |

Tables 2 and 3 show that the total plot extrapolated forest area estimated in 2008 for ILUA I forest resource assessment (FRA) was 50.0 *million* hectares (*ha*) representing 66% of the total land area, holding over 2.9 *billion* $m^3$ of growing stock, 5.5 *billion tons* of biomass and storing over 2.8 *billion tons* of carbon.

**Table 3: Area, biomass and carbon of major land categories reported in ILUA I**

| FRA class | Volume (billion $m^3$) | Biomass (billion tons) | Carbon (billion tons) | Total land area (000 ha) | % of country land area |
|---|---|---|---|---|---|
| 1. Forest | 2,785 | 5.1 | 2.4 | 49,968 | 66.4 |
| 2. Other wooded land | 58 | 0.18 | 0.1 | 6,055 | 8.0 |
| 3. Other land | 97 | 0.29 | 0.2 | 15,771 | 21 |
| 4. Water | 1 | 0 | 0 | 3,467 | 4.6 |
| Zambia | 2,941 | 5.6 | 2.6 | 75,261 | 100 |

### 1.2.5 Soil Surveys

Soil surveys in Zambia were conducted in the 1980s and the first comprehensive soils map that correlated with the Soil Taxonomy of 1975 (Soil Survey Staff, 2010) was produced in 1983. The characteristics and distribution of the soils are largely influenced by the climate, particularly rainfall, in different ecological zones. Soils (Acrisols and Ferralsols) that are highly weathered and strongly leached are found in Region III which receives the highest rainfall in the country (for agro-ecological zones see Forestry Department, 2008).

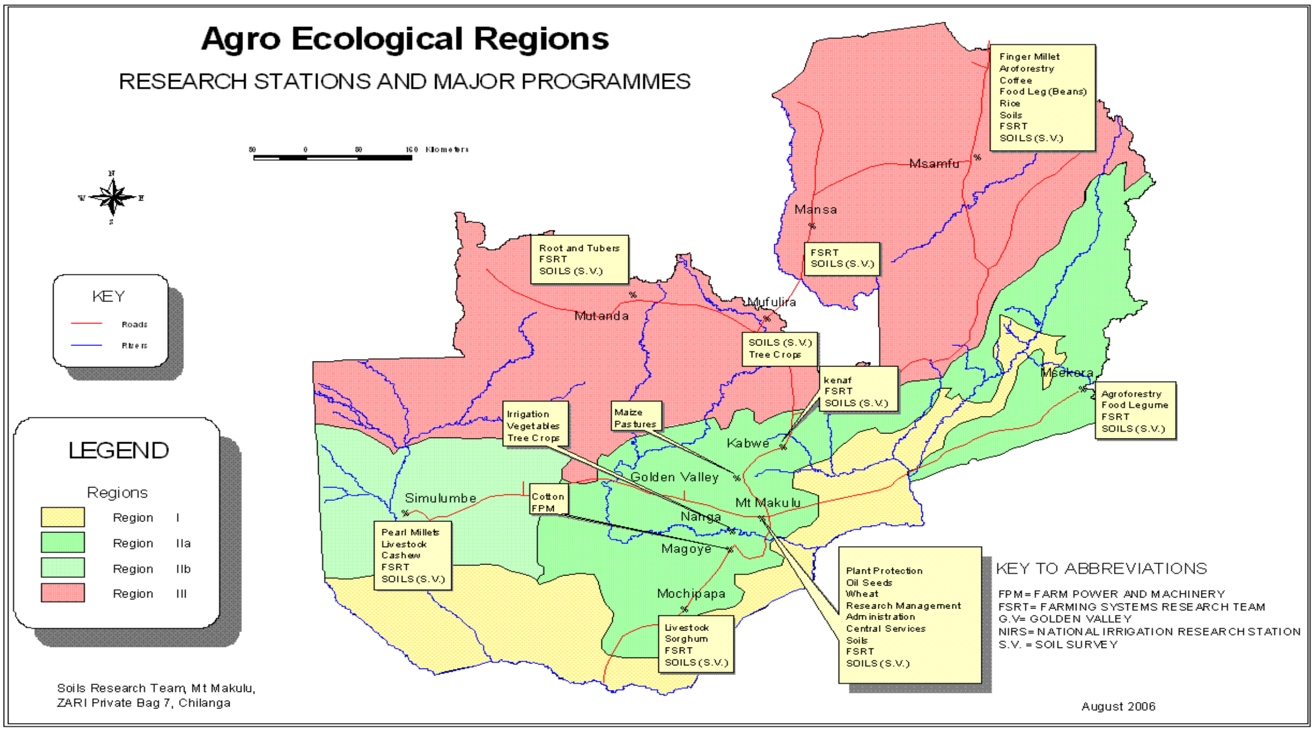



**Figure 1: Zambia Agro Ecological Regions**

Soils in Region III are moderately to strongly acidic with a pH range of 4–5.5. Fertile soils dominated by Luvisols, Acrisols and Vertisols are found in the central and eastern parts of the medium rainfall area, Region II, while in the western parts infertile Arenosols and seasonally waterlogged Gleysols are common. Soil pH ranging between 3.5 and 4.5 characterises this region (Brammer, 1976). Generally, the influence of rainfall on soil formation becomes less in Region I where Arenosols and Podozols are found. These tend to be associated with the Kalahari sands, unconsolidated sandstones or limestone and cover a large proportion of Western Province. These soils are strongly leached, acidic with soil pH of less than 4.0 and are less developed.

# 2.0 INTEGRATED LAND USE ASSESSMENT PHASE TWO (ILUA II)

## 2.1 Project background

In March 2009, a second phase of the Integrated Land Use Assessment was proposed and implemented between 2010 and 2016 by the Ministry of Lands Natural Resources and Environmental Protection (MLNREP). It was financed by the Government of the Republic of Finland (GRZ, 2010a). While ILUA I generated baseline data (Forestry Department, 2008), ILUA II was designed to enhance the use and development of that data towards sustainable forest management, the Reduction of Emissions from Deforestation and Forest Degradation and the provision of additional information on trends in forest change through enhanced and refined methodologies. In addition, phase 2 of this project addressed gaps identified in during phase 1 that included the provision of better information, capacity building, dissemination of information, enhancing the capacity of related institutions in the collection of quality data, adhering to international reporting and improving multi-sectoral dialogue (GRZ, 2010a). In order to better understand the drivers of deforestation and to inform policy interventions that support sustainable forest management, the project also addressed socio-economic related information needs through the Forest Livelihoods and Economic Survey (FLES). Thus, the principle objectives of the project were to (i) Strengthen forest and land use inventories at national and sub national levels, and (ii) Support the implementation of sustainable forest management and initiatives to reduce emissions from deforestation and forest degradation.

### 2.1.1 Intended impacts in the forestry Sector

In line with the Forest Policy, the impacts of ILUA II project are that the benefits of sustainable forest management are increased and mainstreamed into the national economy and policies, supporting the sustainable development of environment and rural livelihoods, and meeting the Millennium Development Goals (MGD) in a changing climate. The project has produced a remarkable set of information not only on forest resources but also on the livelihoods of local communities that directly depend on forests. In fact, communities living in rural areas are closely involved in the use of forest resources; hence forest policies and decisions made at community or national level affect people’s livelihoods. It is generally accepted that improved information guides policy makers towards making better decisions. The ILUA II project has therefore provided stakeholders with the information necessary to make informed decisions regarding the management of forest resources. For example, the analyses of the data with a particular focus on socio-economic, agricultural and climate change issues are expected to facilitate the monitoring and evaluation of policy impacts in Zambia. Consequently, information needs that impact on (i) REDD monitoring and GHG reporting, (ii) information dissemination, and (iii) information use are significantly improved.

### 2.1.2 Outcomes and Outputs

The overall output of ILUA II includes strengthened capacity in planning and implementation of SFM and REDD through better information, capacity building in dissemination of information, and improved multi-sectoral dialogue. Three specific outputs which are realized from the overall output include:

(i) Effective means of dissemination and utilization of the information for multi-sectoral dialogue;
(ii) Improved methodological and human capacity in collecting and analysing forest resource information for SFM, REDD monitoring and carbon inventory; and
(iii) Comprehensive mapping and field survey of both biophysical and socioeconomic components of Forests.

ILUA II also aimed at facilitating the availability of information and linking this to large-scale environmental reporting activities carried out by several stakeholders such as CSO, ZEMA, FAO and Cooperating partners.

#### 2.1.3 Implementation Structure

The ILUA II project was coordinated by a Joint Steering Committee (JSC) within the Environmental and Natural Resource Management and Mainstreaming Program (ENRMMP), with Technical Assistance from FAO. The JSC was made up of representatives from the MLNREP, Ministry of Agriculture and Livestock (MAL), Ministry of Finance and National Planning (MOFNP), National Remote Sensing Centre (NRSC), ZEMA, Zambia Wildlife Authority (Department National parks and wildlife), Cooperating partners, FAO, CSO, Copperbelt University (CBU) and the University of Zambia (UNZA). This committee provided guidance on the overall implementation of the project, which was based on the principles, priorities and objectives of Zambia's Fifth National Development Plan (FNDP).

The JSC was the highest responsible body for monitoring the project's progress; making major and overall policy and strategic decisions for project delivery in conformity with prevailing relevant national policies. The MOFNP was the lead government ministry responsible for creating a conducive and enabling environment for international cooperation to take place, particularly between the private sector and multilateral and bilateral partners. MOFNP also ensured that the line ministries were cooperating with international development partners. The Director of Forestry and the National Project Coordinator (NPC) within the Forestry Department reported the project's progress to the JSC.

The Project Technical Committee (PTC) comprised experts from different sectors who were grouped into 3 thematic areas: (i) Dissemination of information, (ii) Soil carbon assessment, and (iii) Remote Sensing and mapping. The PTC was composed of representatives from MLNREP (Forestry Department, Planning and Information Department-PID, Environment and Natural Resources Department, Zambia Forestry College) and other relevant stakeholders such as UNZA (School of Geography, School of Natural Sciences, School of Agricultural Sciences), CBU (School of Natural Resources), Ministry of Agriculture and Cooperatives (MACO), Survey Department (SD), Zambia Agricultural Research Institute (ZARI), National Institute for Scientific and Industrial Research (NISIR), ZEMA, Zambia Forestry and Forest Industries Cooperation (ZAFFICO), Department of

National Parks and Wildlife (DPNW), CIFOR-Zambia, NGOs, the FAO Representative in Zambia and the CSO. The responsibility of the PTC was to oversee and provide technical input for the implementation of project activities in all phases. In addition, the project established the ILUA information portal which is hosted and maintained by the Forestry Department in conjunction with the PTC. This unit was responsible for delivering the project information to the CSO as provided by the Forestry Department, Survey Department, National Remote Sensing Centre, and the consultants. The portal followed the standards set by FAO's statistical framework 'Country STAT'[5] for data management, archiving, retrieval and dissemination.

The Project Management Unit was responsible for on-the-ground implementation of the project and was composed of project officers, a technical advisor, a systems development specialist, a data processing expert, consultants for remote sensing and web design, a biometrician and experts on special surveys and technical support services.

### 2.1.4 Funding and Technical Assistance

The ILUA II project was implemented by the Government of the Republic of Zambia through the Forestry Department in the Ministry of Lands, Natural Resources and Environmental Protection from 2010 to 2016. Technical assistance was provided by the FAO. The total cost of the project was approximately 5 million Euros provided as a component of the GCP/GLO/194/MUL "*Strengthening forest resources management and enhancing its contribution to sustainable land use and livelihoods with funding from the Government of the Republic of Finland*". The project's cooperating partners provided funds for engaging national and international experts, as well as for vehicles, tools, equipment and other materials. The same funds supported staff from the forestry management unit to carry out mapping, data collection, data entry and processing. In addition, FAO Headquarters provided technical backstopping and assistance by carbon assessment, forest inventory and remote sensing experts.

The Government of the Republic of Zambia provided some counterpart funding (both financial and in-kind) through national budget provisions in order to support the ILUA II project. The Forestry Department provided an office for the project Technical Adviser and communication systems for the field work. The Department also provided offices for the provincial inventory teams, as well as national counterpart staff at secretarial and professional levels.

### 2.1.5 Technical studies (pre-forest resource assessments)

Technical studies were undertaken during the first two years and these provided critical input into the design of the overall assessments. The following papers were prepared:

(i) *Zambia Forest Action Plan Preparatory Review* (by Matakala, 2012): This provided a framework for a full review of ZFAP supporting a strengthened statistical forest database at the

[5] http://www.countrystat.org/

Forestry Department. In addition, this study reinforced the necessity of the inclusion of a number of emerging issues such as climate change and REDD+ in the assessment.

(ii) *Biophysical Information Needs Assessment* (by Lungu & Siampale, 2012): This provided for the information needs of the forestry sector based on the needs assessment. The study recommended biophysical data attributes necessary for inclusion in ILUA II and how such data is to be disseminated among different data users nationally and globally.

(iii) *Classification of Forests in Zambia* (by Chidumayo, 2012): This study provided a methodology for biophysical data collection in ILUA II and included a review of the different attempts at classifying Zambian vegetation in the past.

(iv) *Biodiversity study* (by Chidumayo, 2012)*:* This study was commissioned during the planning phase, and provided guidelines on improvements in the quality and scope of biodiversity data and information to be collected within ILUA II as well as to better serve the forest-related biodiversity information needs for national and international decision making and reporting.

(v) *Assessment of Existing Models for Biomass and Volume Calculations* (by Chidumayo, 2012): This study provided an assessment and review of existing models for tree biomass and volume calculations. It also explored and provided options of relevant allometric models to ILUA II data analysis.

(vi) *Measuring the Informal Forest-based Economy as Part of the National Forest Monitoring and Assessment* (by Lwaile and Gumbo, 2012). This study identified and recommended parameters that would help bring out the forest livelihood and economic aspects in Zambia as a reference material for socio-economic surveys in the forestry sector.

(vii) *Data sharing guidelines* (by Mulongwe, Makumba and Vinya, 2012). In Zambia, forest data is not readily available to key stakeholders and decision makers for a number of reasons, such as the data being outdated or held in an inaccessible format. This paper provides sharing mechanisms and guidelines for the effective use of the biophysical and socio-economic information collected in both ILUA I and ILUA II.

In addition, FAO experts (Tomppo & Tavani, 2012) conducted a study to analyse the new field plot size and shape using data from ILUA I. The consultants' report highlighted the way in which spatial correlation changes when the distance between observations changes. Based on this study, the field plot size was reduced to 20 m x 50 m, compared to the 20 m x 250 m plot applied in ILUA I. The methodological design and approach was based on the FAO National Forest Monitoring and Assessment framework (NFMA) (GRZ, 2010a) and the technical reports presented above.

# 3.0 METHODOLOGY

## 3.1 Biophysical assessments

Besides capturing the current state of the forest, one of the main aims of the project was also to capture the variation in Zambian forests caused by disturbances, degradation, and ecological conditions, assuming that this variation is reflected within forest coverage and between forest types. A two-stage stratified sampling approach was applied during the biophysical assessment.

In the first stage, 6,283 spatially referenced grid observations were distributed systematically across Zambia and overlaid on high-resolution satellite images using an FAO-developed tool called *Collect Earth*. The distance between the two observations was 0.1 degree. At each observation point, a 1 hectare square containing 25 tree canopy observation points was set. Since plot 1 in each cluster fell into the first stage sample sites, the dominant FRA class in plot 1 was later compared with field-based classifications on the corresponding sites. The method cannot give a direct accuracy estimate due to differences in reference areas (i.e. plot being 0.1 ha compared to 1-ha square) but it could be used as an indicative result.

For each observation, variables such as percentage of tree cover, main land use/cover type, and vegetation cover type were evaluated. Each primary observation was classified into one of the 8 classes as follows:

- Class 1: Grassland, Other Wooded Land, Forest with crown cover <10%;
- Class 2: Forest with crown cover ≥80%;
- Class 3: Forest with crown cover ≥50% and <80%;
- Class 4: Forest with crown cover ≥10% and <50%;
- Class 5: Forest, Dry / Moist evergreen;
- Class 6: Forest, Dry deciduous;
- Class 7: Forest, Plantations;
- Class 8: Cultivated land.

The second stage in the sampling design process involved classifying each grid observation and selecting a subset of samples to be enumerated in the field. Bare land, built-up land, and water bodies were excluded from the second phase sampling. The main three targets at the second stage were 1) to cover the previous ILUA I sampling sites, 2) to be able to report results at province level, and 3) to cover different forests types and sites (i.e. above classes[6]) representatively. Thus at the second stage, all ILUA I samples were selected first, and then the rest of the samples were selected randomly using a simulation approach. The simulated option (plus the addition of ILUA I sites) resulted in a set of sampling locations that returned the smallest variance within each target class and province. See Figure 2 for the final sample plot locations.

[6] It was assumed that variation in crown cover density can represent also different forest degradation stages. Thus field samples allocated according crown cover density classes could provide information about forest degradation and its causes.

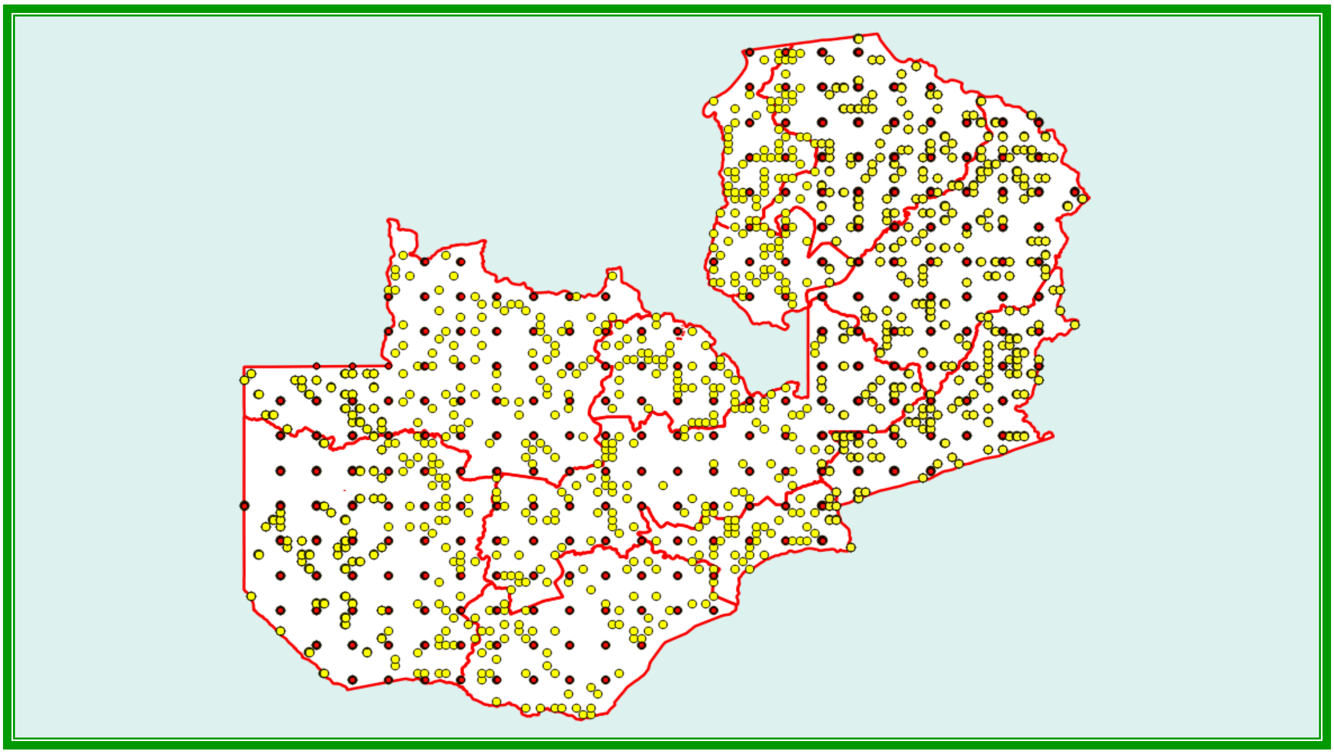


**Figure 2: Location of clusters in ILUA II and revisited ILUA I sites**

The clusters were stratified and distributed to be sampled in forested areas across the country. This was to ensure that the forest variation was targeted for sampling unlike the clusters for ILUA I (red dots) that were systematically distributed at an equidistance of 50 kilometers across the country regardless of their geographical location. The final selection for a total of 1,084 *clusters*, 4,348 *main sample plots* and 13,044 *sub-plots* targeted for assessment across the country (Table 4) was based on the number of field teams recruited for the assignment, average time allocated to complete the biophysical assessments and the available budget provisions.

**Table 4: Number of clusters and sample plots planned for assessment**

| Provinces | Clusters | Main sample plots | Sub-plots |
|---|---|---|---|
| 1. Central | 125 | 500 | 1500 |
| 2. Copperbelt | 56 | 224 | 672 |
| 3. Eastern | 98 | 392 | 1,176 |
| 4. Luapula | 106 | 424 | 1,272 |
| 5. Lusaka | 50 | 200 | 600 |
| 6. Muchinga | 133 | 532 | 1,596 |
| 7. Northern | 119 | 476 | 1,428 |
| 8. Northwestern | 157 | 628 | 1,884 |
| 9. Southern | 98 | 392 | 1,176 |
| 10. Western | 145 | 580 | 1,740 |
| Total | 1087 | 4,348 | 13,044 |

### 3.1.1 Sampling frame

In order to sample biophysical data, the sampling frame consisted of 5 levels: (i) cluster level, (ii) plot level (iii) regeneration sub-plot (iv) soil pit and (v) litter quadrant for the soil cluster, while a cluster where soil was not collected only had three (Levels i – iii). In each cluster, there were 4 plots measuring 0.1 hectares each where data on trees, stumps, and fallen dead wood were recorded. In each plot, a subplot (0.02 hectares) was established where saplings of more than 5 cm but less than 10 cm in diameter were measured. In order to assess regeneration (i.e. trees with less than 5 cm diameter), a circular plot with a radius of 3.99 m within each subplot was established. A soil pit (0.3 $m^2$) was made only in the first plot of the subsets of clusters where soil composite samples were collected and within the subplot, a quadrat (0.25 $m^2$) for litter sampling was installed (see Figure 3 for details). ILUA I plots were also resampled during this assessment but because of the new plot design, each resampled plot covered only 20% of the ILUA I plot area. These revisited plots were designated and treated as permanent sample plots which will be used as benchmarks for future assessments.

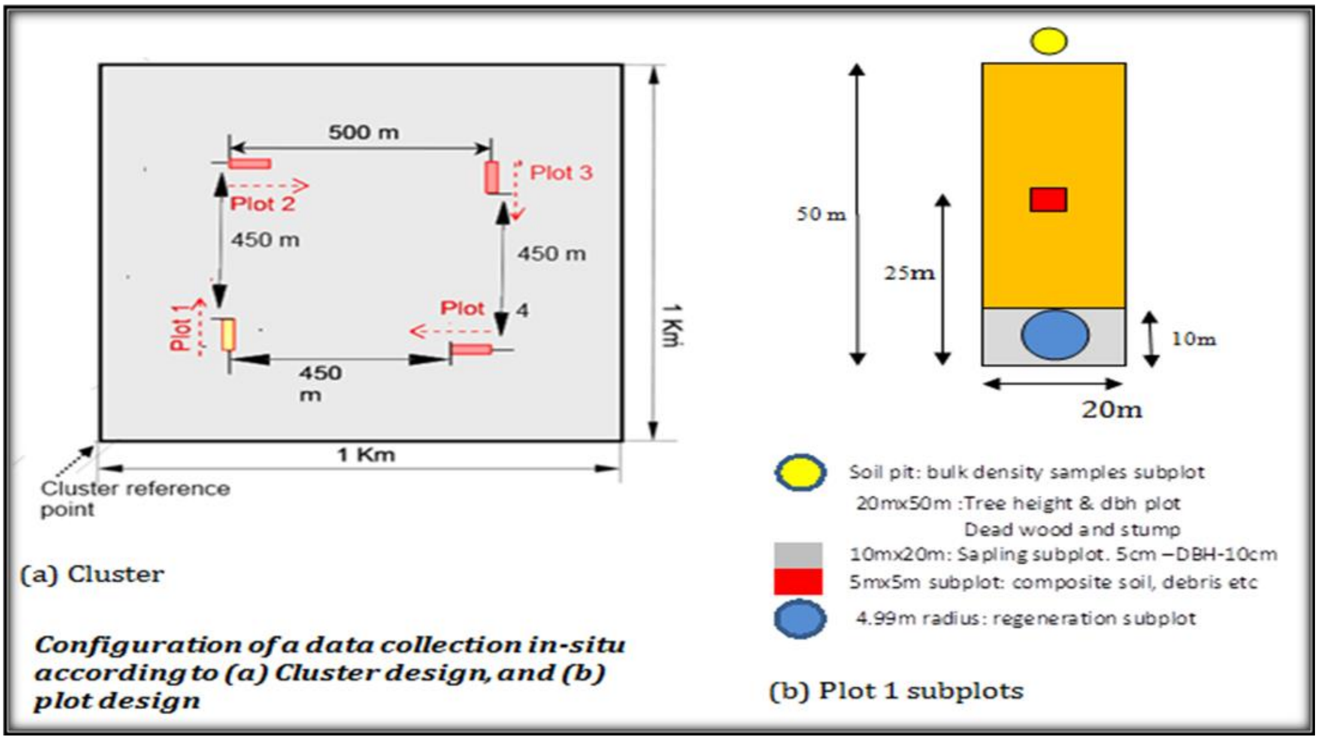



**Figure 3: Configuration of data collection sites (a) cluster design, and (b) plot design**

### 3.1.2 Data collection

The data collection protocols for both biophysical and socio-economic surveys were preceded with intensive training of field teams and enumerators over a period of 2 weeks after which they were ushered in the field to collect the data. The teams were introduced to specialized forest inventory tools and equipment, interpretations of the manuals and field booklets (data entry forms). They were practically trained on the correct use of the tools and equipment, in-situ data quality controls and enumeration of the field data. Team members were also vigorously trained in undertaking long walking and navigation trails to invigorate their energies for the demands of the field excursions under the motto "*endure the terrain, reach the cluster and enjoy the field work*".

Overall data collection was supervised by the quality assurance teams that followed all the teams at different times of the field work. The major variables collected were on the land use and vegetation assessments; soil surveys; litter data (grass, leaves and twigs); and several field qualitative observations made around clusters and sample plots including collection of data regarding extraction of forest products and services from the forests, proposed management actions obtained through field surveillances and semi-interviews.

### 3.1.2.1 Land use and vegetation assessments

Land use and vegetation type section (LUVS) was recorded for each plot regardless of whether the plot was accessible or not (where possible). The classification system used to define each land use/vegetation type section was based on a dichotomous approach. The first level comprised of classes that were based on the framework of the FAO FRA (i.e., Forest, Other wooded Land, Other Land and Water)[7]. The second level was country specific and included additional vegetation sub-classes that were integrated in the first level to take into account Zambia's information needs. Data related to trees, stumps, fallen dead wood, tree uses, forest products and forest services were obtained on the plots. These are described by entity types in Table 5.

**Table 5: Field data assessments by entity types**

| Entity | Criteria* | Main attributes |
|---|---|---|
| 1. Stand | within plot locations | land use/vegetation type, stand origin and canopy structure, forest products and forest services |
| 2. Tree | *dbh*≥ 10 cm | species name, *dbh*, top height, bole height, stem quality, health status, location within plot, main use of tree (as sawlog/timber/pole, fuelwood/ charcoal, medicinal use, fruits or other uses) |
| 3. Sapling | *5cm* ≤*dbh*< 10cm | species name, *dbh*, top height |
| 4. Regeneration | *dbh*<5 cm | species name, count by 1-cm *dbh* classes |
| 5. Stump | diameters ≥10cm at the cutting level | species, diameter, stump height, approximate year when the tree was cut, location within plot |
| 6. Fallen dead wood | diameter ≥ 10cm, length ≥ 1 m | diameters (2), length, number of pieces, decay status |
| 7. Bamboo | within plot locations | species name, mean *dbh*, height of a clump, number of bamboo stems in clump |
| 8. Soil | Soils samples (500–700 g per sample) | soil physical characteristics (e.g. colour, texture, structure and bulk density) and organic soil carbon and soil chemical attributes (e.g. pH) in the laboratory |
| 9. Litter | in a square/quadrant | Weight and laboratory analysis |

* *dbh*: diameter at the breast height (1.3m)

[7] Furthermore, in order to align ILUA II data collection to the IPCC land cover/use classification system, the following classes were incorporated in the data analysis phase: Forest land, Cropland, Grassland, Wetlands, Settlements and Other lands. This was necessary for Measuring, Reporting and Verifying (MRV) Greenhouse Gas emissions from Deforestation and Degradation in line with the UN-REDD Programme.

#### 3.1.2.2 Soil assessments

Soil samples were collected from a predefined subset of sampling clusters and were only collected from Plot 1. At the soil pit study site, three types of soil samples were taken. First, an undisturbed core ring sample was collected at a 0–10 cm, 10–20 cm and the 20–30 cm layer each (Figure 3). Secondly, from the same layers in the soil pit, disturbed soil samples were collected for the measurement of soil organic carbon. Thirdly, composite soil samples were collected using a soil auger targeting the topsoil (0–10 cm), and subsoil (10–20–30 cm depths) from within the sampling plot; Five (5) soil samples were obtained from the centre of the sampling plot, five meters to the north, east, west and south as well as the centre. For bulk density determination, undisturbed mineral soil samples were taken from the vertical side face of the pit using soil core rings for three depths; 0-10cm; 10-20cm; 20-30cm.

#### 3.1.2.3 Litter data (grass, leaves and twigs)

Litter data particularly the lying biomass on the forest floor which include grasses, leaves and twigs were randomly collected in a quadrant only in soil clusters. The quadrant was thrown over the forest floor within plot 1 of the designated soil cluster and the dry litter samples were collected, packed in a plastic bag whose weight was known and the sample weighed on a scale in-situ. The litter samples were supplemented by additional 10 disc pasture samples for the forest undergrowth (i.e. standing grasses) collected from all the sample plots during the survey. The type of disc pasture meters were calibrated for the Kruger National Park fire racemes and are useful for GHG emission related to fires that consume grass biomass during forest or wild fires.

#### 3.1.2.4 Other assessments

General information about vegetation, forest services and the legal status of the area were obtained. The protection status and legal designation of the area (e.g. national forest, plantation or national park) were also assessed. Data regarding forest products and services provided by the forests were obtained through observations and interviews. Information on proposed management action (e.g. early burning, selective cutting, thinning, pruning or coppicing) was recorded based on expert knowledge. For additional details see the biophysical manual (Forestry Department, 2016).

### 3.1.3 Processing of biophysical data

Biophysical data was captured, cleaned and processed in *Open Foris Collect* and partially using MS Excel. Data quality was managed through an integrated data entry and data cleansing workflow before making calculations using R scripts in *Open Foris Calc* (see section 4).

#### 3.1.3.1 Area estimates

The dominant FRA class was determined visually for each plot using high resolution satellite data, a Zambia Vegetation Map (1975) and the *Open Foris Collect Earth* tool during the 1st stage sampling. In addition, a canopy cover estimate was determined with the help of 25 systematically located points inside the sampling squares in order to separate Other Woodland from Forest Land. Using this method, the square observation was regarded as a point. Proportions of points falling within each FRA class in each province were computed and this analysis gave the areas of FRA classes by provinces. Forest plantation area on the Copperbelt Province (ca. 55,000 ha) was obtained from ZAFFICO (2014). An area estimate for each vegetation/land cover type in the FRA class in provinces was computed using area-based methods where recorded plot section areas were summed up and the proportion of each class in a FRA category was computed. Major vegetation type areas were computed as totals of the corresponding vegetation/land cover type area.

### 3.13.2 Tree heights

In the North-Western Province tree top heights were recorded only from a subset of enumerated trees. In the rest of the provinces, heights were captured for all trees located within the plot. A height curve was used to calculate tree height for missing tree heights as well as stumps recorded in the plot. The height model parameters were estimated using data from the North-Western Province and only living healthy trees were used in the analysis. Later in the calculation of results, missing tree heights were computed with the help of the model otherwise recorded tree heights were always used. The heights used in data processing were derived using the model of Näslund (1937) as indicated below. This model is a generic approach for tree height estimation based on diameter at breast height and was only applied in the North-Western Province.

$$h = 1.3 + \frac{dbh^2}{(a + b \times dbh)^2}$$ Equation 1

Where *h* = estimated top height [m],

*dbh* = breast height diameter [cm],

*a, b* a = 2.28355; b = 0.22373

### 3.1.3.3 Tree volume and bole volume

The volume of a tree was computed using the following equation (Chidumayo, 2012):

$$vol = 0.67 \times \pi \times \left(0.01 \times \frac{dbh}{2}\right)^2 \times h$$ Equation 2

Where *π* = Pi (3.14159),

*dbh* = breast height diameter [cm],

*h* = Measured tree top height [m].

The bole volume of a tree was computed using the following equation (Chidumayo, 2012):

$$vol_{bole} = 0.81 \times \pi \times \left(0.01 \times \frac{dbh}{2}\right)^2 \times h_{bole}$$ Equation 3

Where *π* = Pi (3.14159),

*dbh* = breast height diameter [cm],

$H_{bole}$ Measured bole height [m].

#### 3.1.3.4 Dbh before felling the stumps

For stumps the estimate for *dbh* before felling was needed to estimate the tree's above-ground biomass (AGB) before felling in order to estimate below-ground biomass (BGB). Because there was no empirical data about the relationship between *dbh* and stump diameter at different heights, a model from Tanzania NFI was applied[8]. The model used was as follows:

$$dbh_{est} = d_{stump} + 0.38524 \times (1.3 - h_{stump}) - 0.20325 \times (1.3 - h_{stump}) \times d_{stump} \quad \text{Equation 4}$$

Where $dbh_{est}$ = estimated *dbh* [cm],
$d_{stump}$ = recorded stump diameter [cm],
$h_{stump}$ = recorded stump height [m].

#### 3.1.3.5 Tree biomass and carbon

Calculation of tree *AGB* was undertaken using equation of Chidumayo (2012), as follows:

$$\ln AGB = 2.342 \times \ln(dbh) - 2.059 \quad \text{Equation 5}$$

Where *ln* = Natural logarithm

The *BGB* was computed with the help of root-shoot factor of 0.28 as follows:

$$BGB = 0.28 \times AGB \quad \text{Equation 6}$$

The applied default carbon fraction to convert biomass into carbon was 0.49.

#### 3.1.3.6 Stump volume and biomass

The stump above-ground volume was computed as a frustum based on the recorded stump's diameter, estimated diameter at the ground level and height. The stump's AGB (i.e. biomass remaining on the land) in tons was computed with the help of a default dry wood density (*WD*) factor of 619 kg/m$^3$ and the volume (Chidumayo, 2012).

$$AGB_{stump} = vol_{stump} \times WD \quad \text{Equation 7}$$

Where $vol_{stump}$ = Volume of stump,
*WD* = Wood density (kg/m$^3$).

#### 3.1.3.7 Dead wood volume and biomass

The dead wood (DW) volume was computed as a frustum based on two recorded diameters and the length of the dead wood log. Dead wood biomass in tons was computed with the help of a default wood density factor and the volume, as follows:

$$Biomass_{DW} = vol_{DW} \times WD \quad \text{Equation 8}$$

Where $Vol_{DW}$ = Volume of dead wood,
*WD* = Wood density (kg/m$^3$).

The decomposition status was recorded for dead wood particles in two classes: sound and rotten. Because rotten wood is lighter than sound wood, the wood density of rotten dead wood was scaled

[8] The model is based on 32,000 live tree data collected in NAFORMA Project in Tanzania supported by FAO. The model developed by L. Vesa (2013). Unpublished.

down using a 50% lower wood density than for solid wood. If the decay class was missing in the data, it is assumed that the dead wood log was sound.

### 3.1.3.8 Calculation of results for the stratum level

The primary calculation unit was plot section because it was the smallest homogenous land unit in terms of land cover/land use, so all results were computed by plot section level first. Following this, the sums of the result variables and cumulative plot section areas were computed for the domain of interest (as vegetation type) in stratum. Thus, the analysis followed an area-based approach, although only accessible plot sections were used,

### 3.1.3.9 Variance and reliability of the mean biomass

Variance of the mean biomass on land estimate was obtained with the following formula (Korhonen and Scott, 2016):

$$v(\bar{x}_d) = \frac{n}{n-1} \frac{\sum_{ij}^{n}(x_{id} - a_i \bar{x}_d)^2}{\left(\sum_{ij}^{n} a_i\right)^2}$$ Equation 9

Where $x_{id}$ = mean of the biomass in the plot in domain of interest *d*,

$\bar{x}_d$ = mean of the biomass in domain of interest *d*,

$a_{ijk}$ = the area of plot *j* in cluster *i* that is in condition *k* that is of known area, such as total land. If the entire plot is in a single condition, the area is equal to the whole plot area. If the condition is not measured due to being out of population or inaccessible, then the area *a* is 0,

*n* = number of clusters that fell (even partially) in the population.

Variance for total biomass (for any category of interest) was calculated as follows:

$$v(X_d) = A^2 \cdot v(\bar{x}_d)$$ Equation 10

Where $\bar{x}_d$ = mean of the biomass in domain of interest *d*,

*A* = Area of interest *d.*

The variance of the mean biomass over strata was computed based on the following equation (Särndal *et al*., 1992):

$$v(\bar{x}_{st}) = \frac{v(X_{st}) + \bar{x}_{st}^{\,2} v(A_{st}) - 2\bar{x}_{st}\,\mathrm{cov}(X_{st}, A_{st})}{A_{st}^{\,2}}$$ Equation 11

Where $A_{st}$ = Area in stratum.

The standard error ($s_{\bar{st}}$) of the mean biomass in stratum is square root of the variance (Freese, 1962):

$$s_{\bar{st}} = \sqrt{v(\bar{x}_{st})}$$ Equation 12

The sampling error (*SE*) was computed as follows:

$$SE_{st} = t * s_{\overline{st}}$$ Equation 13

Where t= Student's t-value at 0.05 probability level.

The relative sampling error was computed as follows:

$$relative\ SE_{st} = \frac{100 * SE_{st}}{\bar{x}_{st}}$$ Equation 14

## 3.2 The Land-cover Mapping and Change Detection Method

The forest cover mapping has two main components; the first is the initial classification of the 1990, 2000 and 2010 epochs, undertaken jointly by the Regional Centre for the Mapping of Resources for Development (RCMRD) of Nairobi, Kenya and the Zambian Forestry Department with inputs from technical partners such as the National Remote Sensing Centre (NRSC); Survey Department, Zambia Environmental Management Agency (ZEMA); Centre for Energy, Environment and Engineering in Zambia (CEEEZ) and the Food and Agriculture Organization (FAO) of the United Nations (UN). The second component of the work sought to derive accurate estimates of forest cover estimates for the year 2000 and subsequently for 2014 (in response to needs from the UN REDD program). The process involved the rectification of erroneous results identified in the initial land cover maps especially for the year 2000, but provided an opportunity to generate an additional land cover map for the year 2014 which increased the earth observation periods (epochs) to 4 with a total of 24 years. However, for the purpose of constructing the forest reference emission level (FREL) the dataset for 1990 was dropped from the overall epochs used for this reporting, though it is very useful for understanding the activities and trends in forest cover change (i.e. deforestation and or forest degradation).

### 3.2.1 The land-cover map production and quality controls

The 2010 land cover map served as the input dataset from which the 2000 and 2014 land cover maps were labelled and generated. This means that the 2010 land cover map was upheld as a better reference from which forest and non-forest pixels on the land-sat images for the "*year-before*" (2000) and "*year-after*" (2014) were identified and pre-marked. Change pixels (e.g. *pixels exhibiting deforestation between the years 2000 and 2010 and between the years 2010 and 2014, respectively*) which were detected as non-forest pixels between 2000 and 2010 were labelled as forest in the year 2000 map, and pixels detected as non-forest between 2010 and 2014 were labelled and added as non-forest in the year 2014 map.

Landsat images covering the entire national territory of Zambia for years 2000, 2010 and 2014 were accessed and processed via the Google Earth Engine (GEE). National mosaics and change detection for Zambia were carried out using a GEE javascript processing chain. In the case of Zambia, the script was run once to produce a result for years 2000 and 2010 and a second time to produce a result for years 2010 and 2014. Each mosaic was created from pixels derived from the full Landsat archive filtered using user-supplied parameters for date range, days of year, cloud cover and geographic extent. Each pixel was corrected for the latitudinal component of sun-sensor-target geometry and a 'weight' parameter was created that allowed the automatic selection of the single 'best' pixel available to be used in the final mosaics.

Direct change detection approaches were used to characterize forest cover loss between time periods. Supervised classification for non-forest areas was performed on the best-pixel composites, and relied upon inputs from expert image interpreters during the initial phases of analysis. These experts were composed of stakeholders from partner institutions who were familiar with image analysis and land cover characteristics in Zambia. Experts identified known areas of stable forest and stable non-forest in between each of the time periods. The spectral information from the imagery was collected at each of the identified sites, relating the known classes with a uniquely identifiable spectral signature. This input data was known as 'training data' because it is used to construct or 'train' models for classifying the unknown pixels in the national mosaics.

### 3.2.2 The use of random forest algorithms

Training inputs were used in conjunction with Random Forest (RF) algorithms to create a final model for detecting deforestation. The RF algorithm is a classification technique employed in machine learning applications, and is an ensemble learning technique. During the training phase of the process, a large number of decision trees are generated using randomly sampled (with replacement) training data. Approximately 30% of the training data (out-of-bag) is retained and not used for building the decision trees; this data is used to test the error of the decision tree and is also used to determine the variable importance. In the present analyses, the RF algorithm was trained using user-defined training data for the three classes of interest; namely, stable forest, stable non-forest and change (forest to non-forest). The training data was made up of spectral inputs to the RF classifier which included Landsat red, near-infrared and infrared bands (*Landsat 7 bands 3, 4 and 5 and Landsat 8 bands 4, 5 and 6*) as well as all possible, two-band simple ratios of these bands. The model developed using the training data was applied to the base data set and all pixels within that data were assigned to one of the three classes depending on which terminal node they fell into. The maps were then assessed for logical consistence, map positional, thematic, temporal, and completeness accuracies both for the year 2000 to 2010 and for the year 2010 to 2014 time periods. Outputs from these analyses were used to update the 2000 forest layer as well as to create a new 2014 land cover map.

### 3.2.3 The land cover classification scheme

The classification scheme for the national land cover datasets (NLCD) was intentionally developed for green-house gas (GHG) inventory and to provide baseline data for the land use, land-use change and forestry (LULUCF). However, the data-sets have multi-disciplinary applications such as providing a basis for accurately reporting on the annualized deforestation rate for the country, updating the vegetation maps, forest estate maps, deriving and formulating land use plans amongst others. The land cover classification made use of Landsat 5 thematic mapper (TM), Landsat 7 enhanced thematic mapper (ETM) and Landsat 8 operational land imager (OLI) satellite images with a spatial resolution of 30m and augmented by a suite of other geospatial ancillary datasets. The land cover maps were developed using the pixel based supervised classification methods; images used for the classification were selected based on seasonality, with dry season (*i.e. July to October*) images being preferred. The maximum likelihood classification algorithm was used where pixels of an image were clustered to a (relatively small) set of classes. Pixels with similar properties were placed in the same class. Multispectral data from the pixels in the sample area, or spectral signatures from the spectral library, were used to train a classification algorithm in order to obtain a final classification image. The classification scheme used was based on the Inter-governmental Panel on Climate Change (IPCC) as shown in Table 6.

**Table 6: The land cover classification scheme**

| Land cover categories | National land cover descriptions |
|---|---|
| 1. Settlements | Land covered mainly by densely populated and organized or irregular settlement patterns surrounding cities, towns, chiefdoms and rural centres commonly referred to as urban and rural built-up areas. |
| 2. Cropland | Land actively used to grow agriculture (annual and perennial) crops which may be irrigated or rain feed for commercial, peasant and small scale farms around urban and rural settlements |
| 3. Grassland | Land that includes wooded rangeland that may be covered mainly by grasslands, plains, dambos, pans found along major river basins and water channels. |
| 4. Forests | This is land covered both by natural and planted forest meeting the threshold of 10% canopy cover growing over a minimum area of 0.5 ha with trees growing above 5m height. |
| 5. Wetlands | Land which is waterlogged, may be wooded such as marshland, perennial flooded plains and swampy areas (*surface water bodies included*). |
| 6. Other land | Barren land covered by natural bare earth / soil such as sandy dunes, beach sand, rocky outcrops and may include old open quarry sites for mines and related infrastructure outside settlements. |

### 3.2.4 Land cover mapping work-flow

The workflow used to produce the land cover maps is summarized in Figure 4. It describes the iterative approach used to undertake the land cover classifications specifically for the time series of 1990, 2000 and 2010. The 2014 land cover map used a similar work-flow; however, it was mainly processed using a javascript processing chain via the Google Earth Engine (GEE). The workflow in Figure 4 includes collection of ancillary and primary data, and an independent assessment of the input (landsat) data. A thorough assessment of the imagery (including preliminary image classification using the un-supervised ISODATA) to select the best quality images was done before image interpretation, selecting of image legend for training areas and classifying the images.

The mapping team collected the required training sample sets and ground reference data based on the initial image classifications and later used it to generate the final classified images (maps). The ground referencing data collected from the field (i.e. for the year 2010) was used to assess the overall accuracy, the user and producer accuracies including the performance of the Kappa coefficient. A comprehensive reference dataset for the years 2000 and 2014 were randomly generated using ERDAS IMAGINE version 2016 software. Therefore, the total reference datasets for the year 2000 were 1,470, for the year 2010 they were 2,700 and for the year 2014 they were 3,529 geo-coded against 6 land cover classes at a minimum of 200 reference points per class. The ground reference point data was overlaid on the classification dataset of the maps and assigned a land cover attribute by the reviewer based on automatic interpretation and comparison. This was necessary in order to remove bias and systematic errors inherent in maps, as well as to ensure that the generated maps could provide acceptable accuracies from which to base the forest cover change analyses and interpretations.

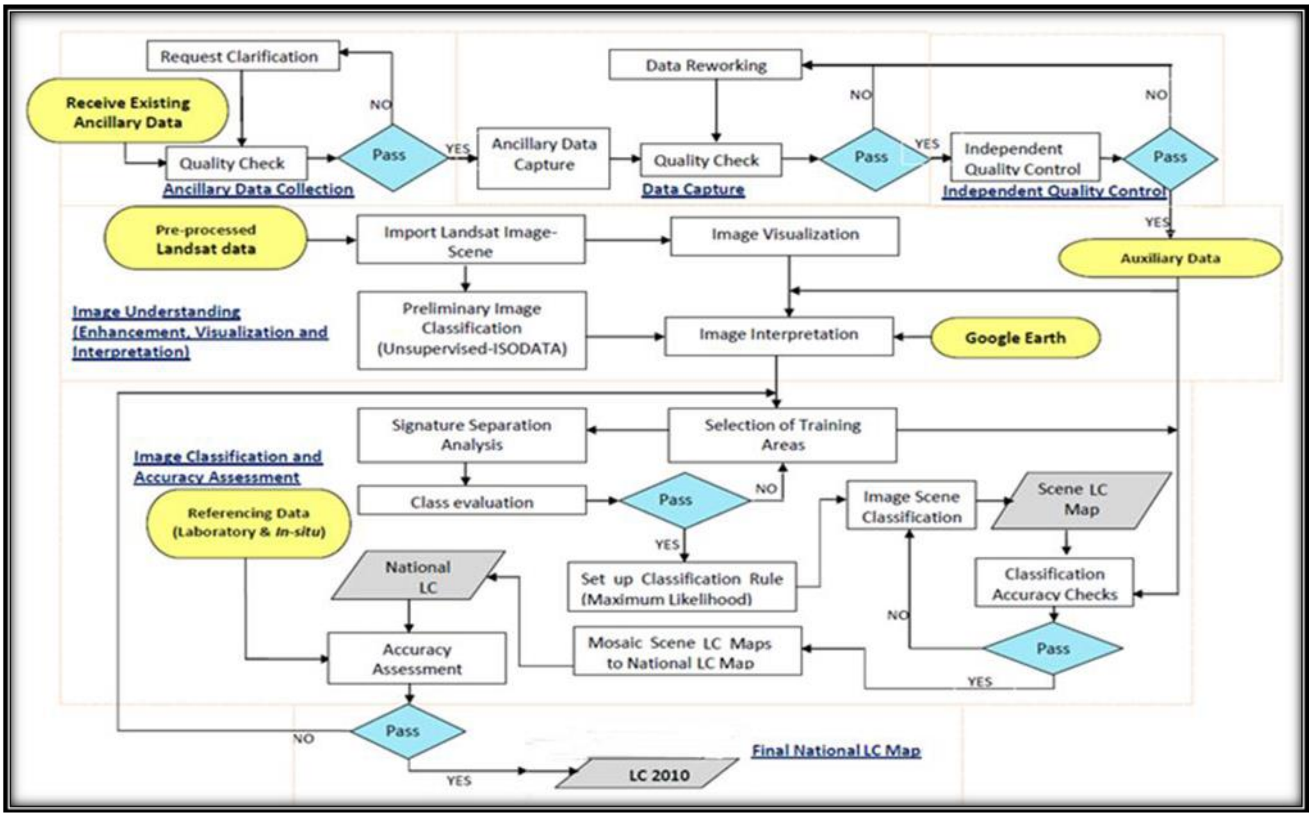



**Figure 4: Land cover mapping workflow**

### 3.2.5 Land-cover map accuracies

The expected overall accuracy for all national land cover maps (based on the IPCC classification scheme) was set to be at-least 85%. Therefore, any land cover map whose overall accuracy was less than 85% could NOT be accepted for use as a useful baseline or input dataset for GHG inventory.

This means that after running the accuracy assessment, if the overall accuracy was less than 85%, the classified image was subjected to a thorough technical review (*including performing the class separability analysis, verifying the spectral classifications in the feature space and checking for the quality of the reference point data*) following the standard work-flow illustrated in Figure 4 and described in Chapter 3.2.4 of this report.

*The minimum acceptable overall accuracy for a national land cover map with 6 major land cover classes (i.e. IPCC schema I) in Zambia is 85 to 90%, while similar land cover maps at provincial, district and local levels that can be used for GHG inventory and related land cover mapping is expected to be between 90% and 95%. However, all land cover maps should generate and report on the user and producer accuracies including the kappa coefficient. The land cover map statistics and results should thoroughly provide a clear and concise narrative of the methodology used, quality of input datasets including all pre- and post-processing steps undertaken. All land cover maps should have a nationally applicable and internationally recognised metadata that clearly outlines the date of production, purpose of the map, author/owner, what it should or NOT be used for amongst other metadata descriptions. This is the nationally set mapping standard for land cover maps that shall be acceptable and officially recognized in forestry mapping including for all REDD+ processes in Zambia.*

The extracted land cover map statistics used in this report are purely based on the mapped pixels for 2000, 2010 and 2014 land cover maps. The map estimates are useful as official baseline (reference) data for green-house gas (GHG) inventory, and sustainable forest management (SFM) at National, Provincial, District and Local levels. No adjusted area estimates were applied on the land cover maps to warrant conservative estimates for constructing the forest reference emission levels (FREL). The map results are basically used for national reporting and can further be used as input (reference) data for advanced processing by individuals, mapping institutions and any other parties with varying interests and expectations to generate derived products for various applications including the production of adjusted area estimates to support the FREL.

## 3.3 Forest Livelihood and Economic Survey (FLES)

### 3.3.1 Survey design and data collection

Forest Livelihood and Economic Survey (FLES) methodology was designed to collect data used to monitor the socio-economic importance of forests, forest governance and the informal forest-based economy. The objectives of FLES were to (i) assess the importance of forest products and services to livelihoods, food security and energy, (ii) assess accessibility to user rights and management of forest resources, and (iii) assess the contributions of forests to meeting REDD+ needs on monitoring safeguards and governance (Forestry Department, 2016a).

A stratified two-stage cluster sampling procedure was used. In the first stage, 252 standard enumeration areas (SEAs) were selected (Figure 5) and stratified according to the forest cover based on the 2010 land cover map. SEAs falling within exclusively protected areas e.g. national parks were excluded from this exercise as there are no consumptive activities allowed in these areas.

- Stratum 1: high forest cover which was 70% of total area or more;
- Stratum 2: medium forest cover which was more than 30 % but less than 70% of the total area;
- Stratum 3: low forest cover which is 30% or less of the total area.

At the second stage, 20 households from each of 252 selected SEAs were sampled resulting in 5,040 households. Households (HH) were stratified into four categories, depending on their involvement in the utilization of forest products:

- Category 1: Households collecting forest products for sale;
- Category 2: Households collecting forest products only for own consumption but not for sale;
- Category 3: Households not collecting forest products but buying or acquiring them through bartering;
- Category 4: Other Households.
-

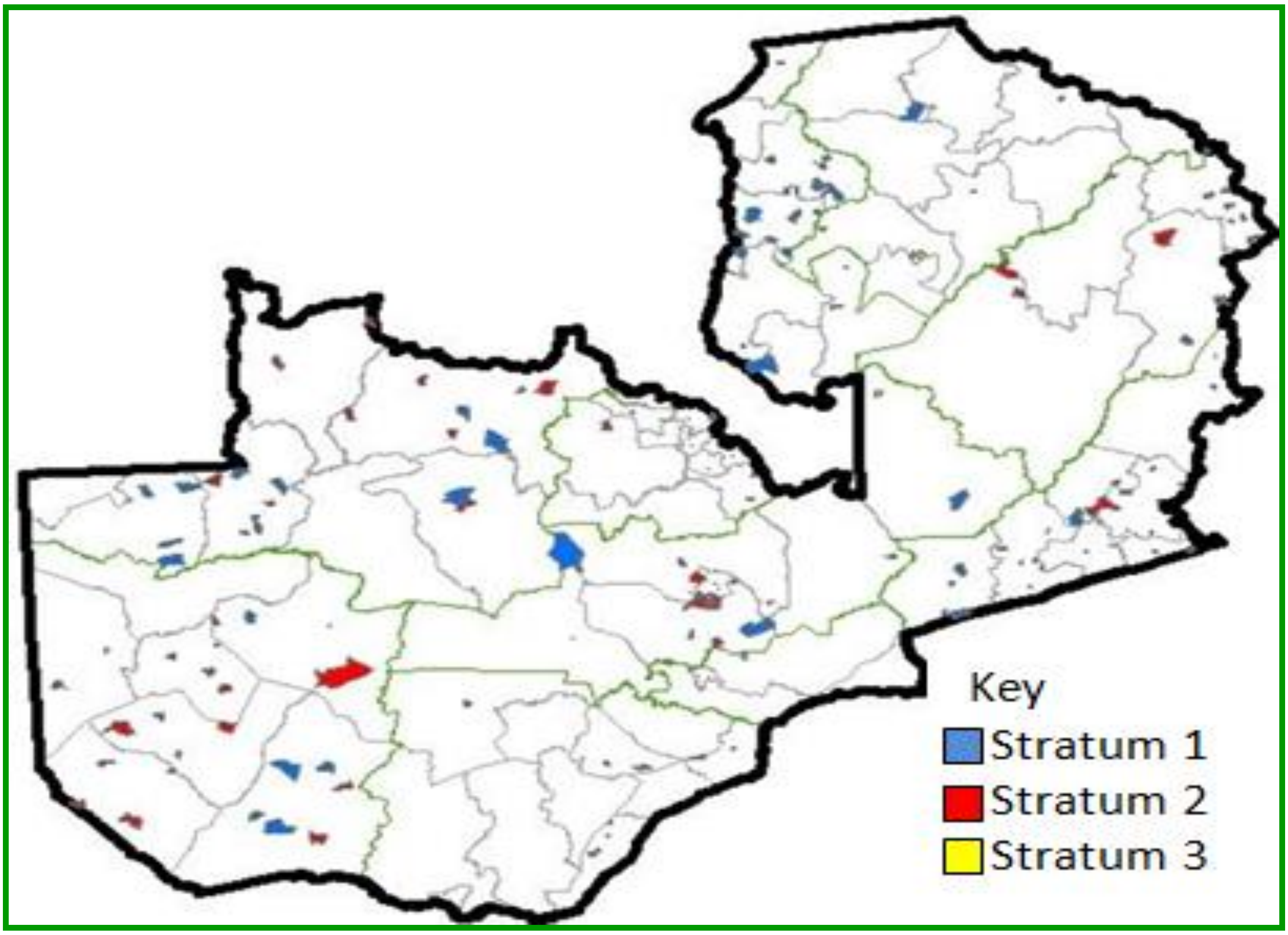



**Figure 5: Map of selected standard enumeration areas in Zambia**

In addition, within each SEA, between one and three key informants were also selected for interviews, following which two focus group discussions were undertaken (one with a male group and another one with a female group). Focus group discussions provided statistics related to forest resource use at community level.

It also helped to triangulate information received from the household survey. Samples were allocated proportionately in the rural and urban areas in each province. Data collection consisted of undertaking four types of interviews, each with separate questionnaires for key informants, focus groups (male and female groups), households, and individuals at household level.

- *Background information of Household*: Households involved in forest-based livelihood activities and gender distribution collecting forest products from different strata.
- *Land tenure and use*: The size of land owned per household was obtained. Each household further provided information on the proportion of land used for agriculture, tree growing and land in fallow. They also reported their sources of forest products and use rights (i.e. either from own land, customary land, state land, or private/leased land).
- *Access to and availability of forest products*: The number of people collecting forest products was obtained by gender in each stratum. Distance and time to the source of the forest products were also estimated. Households also provided information on forest products' availability and trends.
- *Forest clearing and regeneration*: The number of households cutting trees from the forests and woodland and the size of area cleared and regenerated per year were obtained.
- *Overall livelihood*: The number of households involved in livelihood activities including forestry, agriculture, mining, employment and entrepreneurship among others was obtained. Additionally, the top ten livelihood activities were also ascertained.
- *Forest products and services*: Data on the number of households utilizing forest products as the main source of income and their rank of importance was also collected.

### 3.3.2 Data processing and analysis

FLES data was captured in the Statistical Package for Social Sciences (SPSS version 22) software and was then cleaned and weighted using the 2010 census as the baseline to generate national statistics. Sampling weights were needed to convert the data to national level statistics. Cross-tabulation of variables and frequencies was used to analyse data in SPSS and tables were exported to MS Excel for further processing and graphics. All FLES-related work was conducted and supervised by Central Statistical Office (CSO) in collaboration with the Forestry Department.

Statistics from domains on the background factors, including gender disaggregation into males and females, were generated wherever possible. Furthermore, subsequent breakdowns and analyses were also processed at household level and cross-tabulated with factors such as land tenure, access and availability to forest products, forest clearing and management, livelihood activities dependent on forests such as forest product collection, and various land use activities.

# 4.0 THE ASSESSMENT RESULTS

## 4.1 Forest inventory measured data and sampling intensity

There are 1,016 *clusters* reached and assessed during the forest resource assessment against a target of 1,087 *clusters*, representing 93.5% record of success in terms reaching the clusters. However, the biophysical data captured in the database is from 986 *clusters* with 3,892 *main sample plots* and 7,784 *sub-plots* where at-least 60 variables were assessed in different land categories (Table 7). A total of 11 clusters were not entered because they did not have biophysical records captured from the field due to their geographical locations (*i.e. bare-land and or water bodies*). The measured data include 4,156 segments of plot sections with key variables of the biophysical data that generated results for the forest growing stock (*i.e. tree species density/number of stems, commercial timber species distribution and tree and saplings volumes*), biomass and carbon stocks for both live and dead-wood.

**Table 7: Measured data and records of success for the national forest inventory (NFI)**

| Provinces | Accessed against targeted clusters | | | | Biophysical data captured into the database | | |
|---|---|---|---|---|---|---|---|
| | Targeted clusters | Accessed clusters | % Record success | | Clusters registered in the *dbse* | Number of plots | Number of sub-plots |
| 1. Central | 125 | 122 | 97.6 | | 122 | 478 | 956 |
| 2. Copperbelt | 56 | 51 | 91.1 | | 51 | 197 | 394 |
| 3. Eastern | 98 | 92 | 93.9 | | 91 | 363 | 726 |
| 4. Luapula | 106 | 98 | 92.5 | | 98 | 387 | 774 |
| 5. Lusaka | 50 | 41 | 82.0 | | 41 | 162 | 324 |
| 6. Muchinga | 133 | 122 | 91.7 | | 122 | 483 | 966 |
| 7. Northern | 119 | 107 | 89.9 | | 104 | 408 | 816 |
| 8. North-western | 157 | 143 | 91.1 | | 138 | 547 | 1,094 |
| 9. Southern | 98 | 95 | 96.9 | | 75 | 292 | 584 |
| 10. Western | 145 | 145 | 100.0 | | 144 | 575 | 1,150 |
| Total | 1,087 | 1,016 | 93.5 | | 986 | 3,892 | 7,784 |

The record of success in table 7 translates to a sampling intensity estimated at 0.0005% based on the country's land area, compared to 0.0006% for ILUA I (*largely because of larger sampling plots)* forest resource assessment (FRA). The sampling intensity is calculated based on the total land area surface for the country which includes its water bodies.

However, the overall sample size which technically refers to the number of sampling units (*986 clusters with 11,676 observations*) that are selected from the targeted population is considered spatially to be more representative than in the ILUA I, as it covered only the forested land as on the 2010 land cover map for the country (Forestry Department, 2016). It is important to realize that the standard error depends on the sample size and not on the sampling intensity. Table 8 shows the area sampled and its related sampling intensity in each province.

**Table 8: The sampling intensity against total land area by province**

| Province | Total land area | Total plot area (ha) | Sampling intensity (%) |
|---|---|---|---|
| 1. Central | 11,002.94 | 47.50 | 0.0004 |
| 2. Copperbelt | 3132.84 | 19.50 | 0.0006 |
| 3. Eastern | 5,097.59 | 36.40 | 0.0007 |
| 4. Luapula | 5056.91 | 37.70 | 0.0008 |
| 5. Lusaka | 2550.74 | 16.00 | 0.0006 |
| 6. Muchinga | 8,680.60 | 47.60 | 0.0006 |
| 7. Northern | 7,692.75 | 40.90 | 0.0006 |
| 8. North-Western | 12,582.64 | 53.80 | 0.0004 |
| 9. Southern | 6,825.82 | 28.50 | 0.0004 |
| 10. Western | 12,638.58 | 57.01 | 0.0005 |
| **Zambia** | **75,261.40** | **385.10** | **0.0005** |

*The results for the soils and litter samples (including grass biomass) are not reported because they were not processed and analysed at the time of reporting. However, the raw data was entered and cleansed into Open-Foris the forest database and is readily available for statistical analysis. It is also anticipated that the FLES and all results for soils and litter samples shall be published in detailed and independent technical reports.*

## 4.2 The Tree Growing Stock

### 4.2.1 Tree species abundancy and distribution

There are 2,597 different tree species that include trees, saplings and seedlings mainly identified in local languages and diatribes from different parts of the country during the national forest inventories (NFI), and over 1,000 tree species were recorded as unknown (not identified). The 2 most dominant species were the *Entandrophragma delevoyi* (Mofu) and *Brachystegia longifolia* (Mubombo) while *Julbernardia paniculata* (Mutondo) and *Brachystegia speciformis* (Kaputu) were the most abundant species recorded with relative abundance of 9.1% and 7.8% respectively. Amongst the commercial (timber) species *Guibourtia coleosperma* (Muzauli or rose wood), *Pterocarpus angolensis* (Mukwa), were found to be one of the 10 most abundant tree species (Table 9).

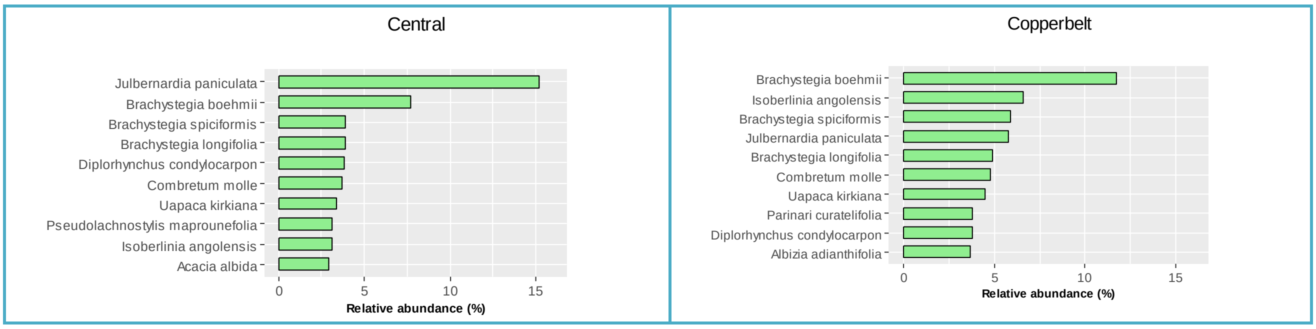
The largest vegetation (tree species composition) cover is typically the forest woodlands which comprises of the *kahari*, *miombo*, *mopane* and *munga* wood lands, of which the *miombo* woodlands alone covers over 60% of all the forest types in Zambia. The *miombo* woodland is dominated by *Brachystegia* (*B. spiciformis* and *B. boemmii*) and *Julbernadia* (*J. globiflora*) *genuses*. Other species include *Diplorinchus condilocarpon*, *Terminalia sericea*, *Acacia polyacantha*, *A. gerrardii*, *Albizia antunesiana*, *Faurea rochetiana*, *Combretum molle*, *C. imberbe*, *Bauhinia thonningii*, *B. petersiana*, *Flacourtia indica*, *Launea edulis*, *Strychnos spinosa* and *Vanguerina infausta*.

**Table 9: Top twenty (20) abundant tree species**

| Rank | Species | Relative abundance (%) |
|---|---|---|
| 1 | *Julbernardia paniculata* | 9.1 |
| 2 | *Brachystegia spiciformis* | 7.8 |
| 3 | *Brachystegia boehmii* | 7.1 |
| 4 | *Brachystegia longifolia* | 5.7 |
| 5 | *Colophospermum mopane* | 4.9 |
| 6 | *Parinari curatelifolia* | 3.2 |
| 7 | *Isoberlinia angolensis* | 3.0 |
| 8 | *Cryptosepalum exfoliatum* | 2.7 |
| 9 | *Guibourtia coleosperma* | 2.5 |
| 10 | *Diplorhynchus condylocarpon* | 2.2 |
| 11 | *Pterocarpus angolensis* | 2.2 |
| 12 | *Marquesia macroura* | 2.2 |
| 13 | *Julbernardia globiflora* | 2.0 |
| 14 | *Erythrophleum africanum* | 1.9 |
| 15 | *Pseudolachnostylis maprounefolia* | 1.7 |
| 16 | *Pericopsis angolensis* | 1.7 |
| 17 | *Brachystegia floribunda* | 1.5 |
| 18 | *Burkea africana* | 1.3 |
| 19 | *Combretum molle* | 1.3 |
| 20 | *Uapaca kirkiana* | 1.2 |

### 4.2.2 Top ten (10) common tree species in the provinces

The top ten most common species by provinces are presented in the following charts. The frequencies are computed from the total number of trees in the provinces. *Brachystergia boehmii* (Musamba) is abundant in Copperbelt, Muchinga and Lusaka provinces. *Julbernadia paniculata* (Mutondo) is abundant in Central, North-western and Western provinces. *Colophorspermum mopane* (Mupani) is common in Eastern and Southern provinces while in Northern Province, *Brachystegia speciformis* (Kaputu) is the most abundant tree species. *Pterocarpus angolensis* (Mukwa) was found to be the most abundant tree in Luapula province (Figure 6).



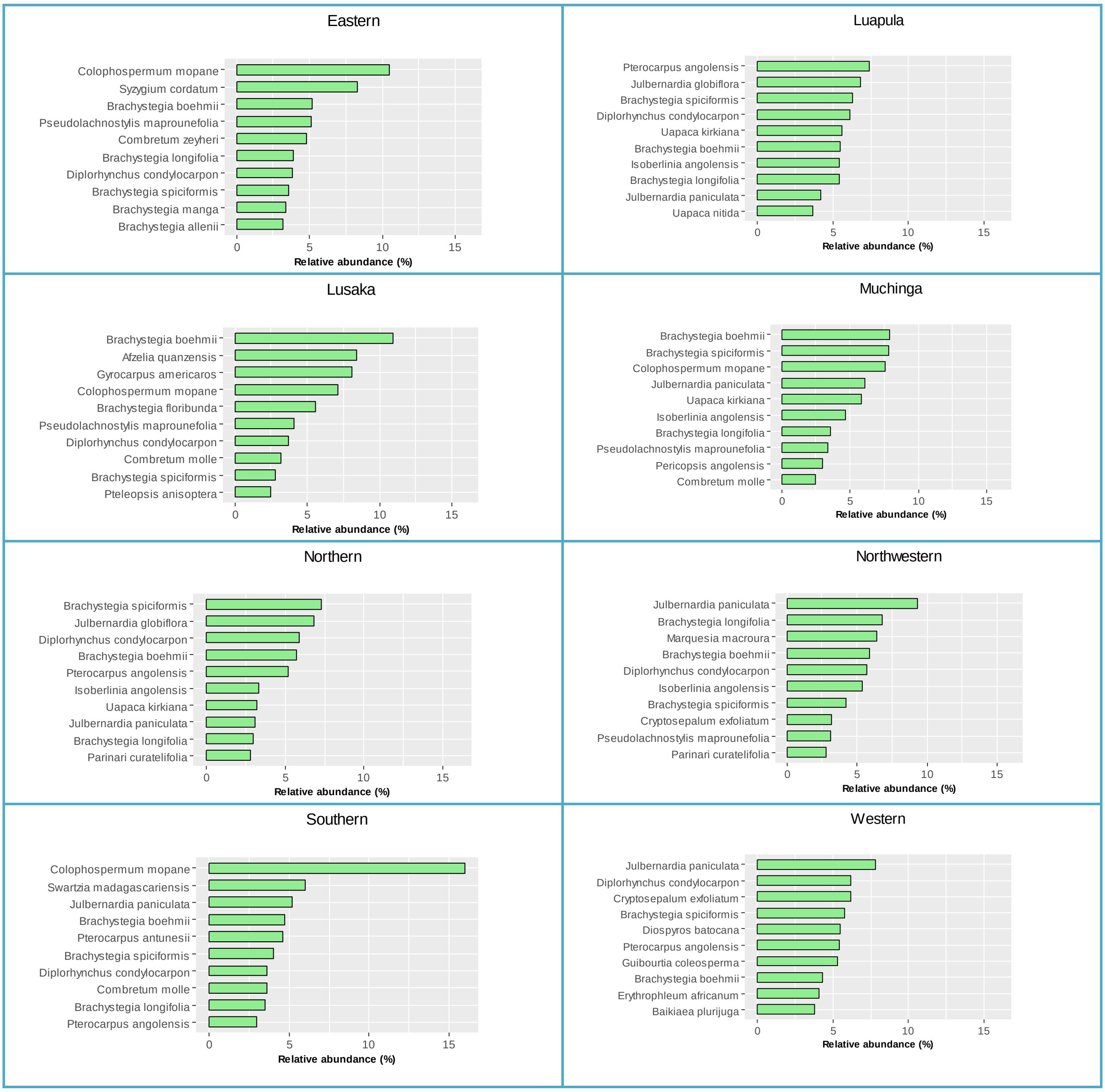



**Figure 6: Top ten most abundant tree species across provinces**

### 4.2.3 Trees and saplings density

There are 11.4 *billion tree stems* (trees measuring ≥ 10cm diameter at breast height) and an estimated 10.9 *billion saplings* (trees measuring ≥ 5cm and < 10cm diameter at breast height across the country for different tree species. On average there are 154 *tree stems/ha* and 148 stems for saplings per hectare in forested areas (Table 10).

The actual distribution of trees by major land categories shows that forest land has 230 *stems/ha*, other wooded land has *51 stems/ha* and other land has 35 *stems/ha*, while there are 189 *saplings per hectare* in forest land, 189 *saplings per hectare* in other wooded land and 46 *saplings per hectare* in other land.

**Table 10: Trees and saplings density by major land categories**

| Variables | Forests | Other wooded land | Other land | Total stems |
|---|---|---|---|---|
| 1. Total number of stems (*million*) | 8,651 | 1,935 | 797 | **11,383** |
| 2. Number of stems/ha | 230 | 51 | 35 | **154** |
| | | | | |
| 3. Total number of saplings (*million*) | 8,349 | 1,826 | 765 | **10,940** |
| 4. Number of saplings/ha | 189 | 138 | 46 | **148** |

Meanwhile, bigger trees measuring ≥ 10cm diameter at breast height accounts for 276 *stems/ha* in the dry evergreen forest, the forest woodlands has 231 *stems/ha*, moist evergreen forest has 169 *stems/ha*, exotic forest plantations has 168 *stems/ha* and the dry deciduous forest has 164 *stems/ha*. There are stems located outside forests distributed as follows: built-up (within settlements) areas have an estimated 62 *stems/ha*, other wooded land having 51 *stems/ha*, some grass-lands have 38 stems/ha, cultivated land has 32 *stems/ha*, the barren land has 18 *stems/ha* and other-land has 9 *stems/ha*.

There are 196 *stems/ha* of saplings (smaller trees) measuring ≥ 5cm and < 10cm diameter at breast height in the forest woodlands, 148 *stems/ha* in the dry deciduous forest, 108 *stems/ha* in the dry evergreen forest, while the moist evergreen forest has 77 *stems/ha* and exotic forest plantations has 23 *stems/ha*. Saplings located outside forests are distributed as follows: other wooded land having 108 *stems/ha*, cultivated land has 66 *stems/ha*, built-up (within settlements) areas have an estimated 65 *stems/ha*, some grass-lands have 23 *stems/ha*, the barren land has 14 *stems/ha* and other-land has 1 *stem/ha*.

The average number of stems for saplings across all the provinces is estimated to be 237 *stems/ha* of which Luapula Province has the highest number estimated at 348 *stems/ha* and the lowest being in Western Province which returned 128 *stems/ha*. The second highest number of saplings is in the Copperbelt Province which has 294 *stems/ha*, while Central Province returned 254 *stems/ha*, Muchinga Province has 312 *stems/ha*, Eastern Province has 306 *stems/ha*, North-western Province has 235 *stems/ha*, Northern Province has 232 *stems/ha*, Lusaka Province has 202 *stems/ha* and Southern Province has 134 *stems/ha*.

### 4.2.4 Tree seedlings (regeneration potential)

The regeneration data consist of undergrowth trees with diameter at breast height (*dbh)* less than 5 cm. In this data, a large proportion of seedlings were less than 1.3 m in height and these represented approximately 80% of the total seedlings counted.

The seedlings with *dbh* less than 1 cm and height more than 1.3 cm constituted just over 10% of the total regeneration across all the provinces. The smallest proportion of the total regeneration consisted of seedlings with *dbh* between 2 cm and 4.9 cm (Figure 7).

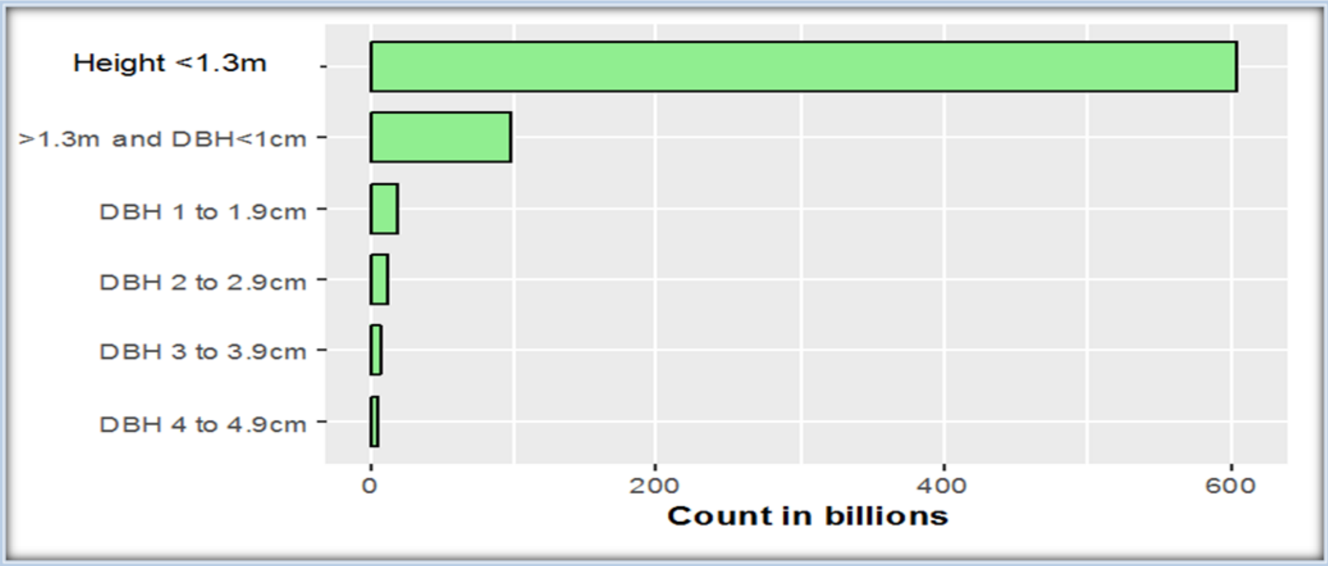



**Figure 7: Number of seedlings by diameter classes regenerating in forest land**

Tree seedlings were the majority in terms of vegetation assemblage in all the ten (10) provinces where Muchinga Province returned over 35,000 *seedlings/ha* and the lowest seedlings are in Southern and Copperbelt provinces where they each returned just slightly above 5,000 *seedlings/ha* (Figure 8). This suggests that forests in Muchinga have a higher natural regeneration potential than forests in Southern and Copperbelt provinces where extensive agriculture (*land tillage and uprooting*) practices are more pronounced.

Meanwhile, tree seedlings with a diameter less than 1 cm and a height above 1.3 m were more abundant in Northern Province compared to other provinces in the country. The second highest density of tree seedlings in the country were found in Luapula Province which recorded over 25,000 *seedlings/ha*, followed by Northern Province which has 22,000 *seedlings/ha* (Figure 8).

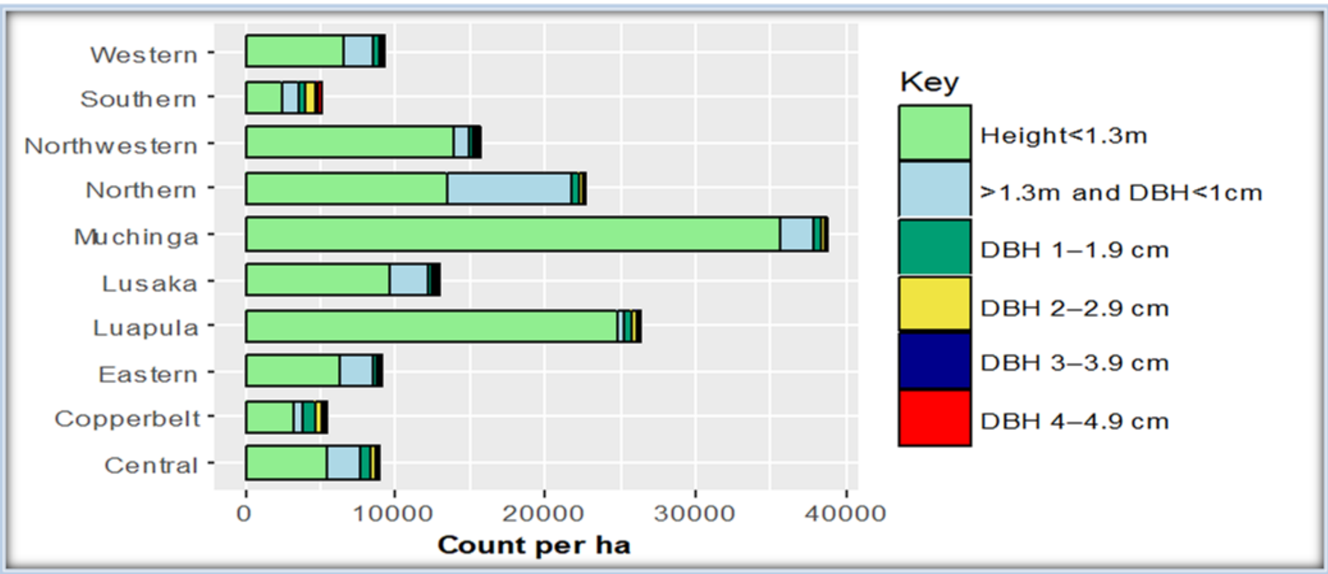


**Figure 8: Number of seedlings and small saplings per ha across provinces**

### 4.2.5 Tree species health

It is estimated that 91.7% of the trees assessed across the country are regarded as healthy (or are growing in normal condition). Only 7.2% of the trees were considered unhealthy (injured or diseased) but they are determinant and living, and they are likely to recover. Meanwhile, the largest proportion (13.0%) of health trees was recorded in Muchinga Province. Dead trees were estimated to be 1.1% of the total number of standing trees, and these included those burnt, die-backs and unlikely to recover (Table 11).

**Table 11: Tree species health status**

| Province | (%) of Health trees | (%) of Other living trees | (%) of Dead |
|---|---|---|---|
| 1. Central | 92.0 | 6.6 | 1.4 |
| 2. Copperbelt | 95.0 | 4.9 | 0.1 |
| 3. Eastern | 95.9 | 3.9 | 0.2 |
| 4. Luapula | 93.6 | 5.0 | 1.4 |
| 5. Lusaka | 92.1 | 6.5 | 1.4 |
| 6. Muchinga | 86.6 | 13.0 | 0.4 |
| 7. Northern | 91.3 | 8.6 | 0.1 |
| 8. North-Western | 90.3 | 7.1 | 2.6 |
| 9. Southern | 93.6 | 6.2 | 0.2 |
| 10. Western | 95.0 | 4.9 | 0.1 |
| **Zambia** | **91.7** | **7.2** | **1.1** |

## 4.3 Commercial Timber Species Results

There are 6 timber species considered by the wood industry to be of high value and price listed by the Forest Department as the commercial trees particularly for saw-log and poles production and these are: *Alfzelia quanzensis* (Mupapa), *Baikiaea plurijuga* (Mukusi), *Colophospermum mopane* (Mupani), *Guibortia coleosperma* (Muzauli or rose wood), *Pterocarpus angolensis* (Mukwa) and *Pterocarpus chrysophrix* (Mukula). These prime commercial timber species were filtered from the list of all tree species reported earlier and accounts for 6.4 *billion stems* representing 29% of the total tree count in this assessment.

Based on the national frequency of valuable species used for saw-log production only, these commercial species varied from province to province, with *Colophospermum mopane* being the most abundant lesser-used species accounting for 10.57%, followed by the most commonly processed *Pterocarpu angolensis* which is estimated at 8.74%. Mukwa is abundant in Western province representing 2.01% and in North-western province it is estimated at 1.84%, while in Northern and Luapula provinces it is estimated at 1.62% and 1.53% respectively. Traditionally *Baikiaea plurijuga* which is the most sought after for durable sawn timber production is only available in Western and Southern provinces estimated at 1.62% and 0.47% respectively.

In recent years, the demand for *Pterocarpus chrisothrix* for saw-log production, a previously lesser known and used timber species in Zambia was mostly found in Luapula province at 0.46%, Eastern province at 0.18% and Northern province at 0.12%. In the recent past, *Ptercocarpus chrisothrix* has exceeded the demand for the traditional frequently used species. It has become the most sought out and highly valued commercial timber species for the international market. Overall, the top six (6) most sought after species for saw-log and sawn timber production, by applicants for concession licences, include *A. quanzensis*, *B. plurijuga, C. mopane, G. coleosperma, P. angolensis, and P. chrysophrix* (Table 12). Some provinces did not have all of the top six (6) species available for timber production. These include Copperbelt province, with only *P. angolensis*, and Lusaka province with *A. quanzensis* (0.9%), *C. mopane (0.72%)* and *P. angolensis* (0.09%).

**Table 12: Top six (6) commercial timber species distribution by provinces**

| Province | Species Relative Abundance (%) | | | | | |
|---|---|---|---|---|---|---|
| | AQ | BP | CM | GC | PA | PC |
| 1. Central | 0.08 | - | 1.10 | 0.03 | | 0.01 |
| 2. Copperbelt | - | - | - | - | 0.17 | - |
| 3. Eastern | 0.01 | - | 2.47 | - | 0.24 | 0.18 |
| 4. Luapula | 0.07 | - | - | - | 1.53 | 0.46 |
| 5. Lusaka | 0.90 | - | 0.72 | - | 0.09 | - |
| 6. Muchinga | 0.03 | - | 3.40 | - | 0.74 | 0.02 |
| 7. Northern | 0.01 | - | 0.12 | - | 1.62 | 0.12 |
| 8. North-Western | 0.13 | - | - | 0.71 | 1.84 | 0.01 |
| 9. Southern | 0.05 | 0.47 | 2.75 | 0.02 | 0.49 | - |
| 10. Western | 0.04 | 1.62 | - | 2.01 | 2.02 | - |
| Zambia | 1.31 | 2.09 | 10.57 | 2.77 | 8.74 | 0.80 |

**Note:** AQ is *Afzelia quanzensis*, BP is *Baikiaea plurijuga*, CM is *Colophospermum mopane*, GC is *Guibourtia coleosperma*, PA is *Pterocarpus angolensis*, and PC is *Pterocarpus chrysothrix*

### 4.3.1 Commercial timber species density

The actual distribution of the top six (6) commercial tree species densities for saw-logs and poles inside forests across the country is estimated to be 23 and 36 *stems per ha* (*sph*) respectively. On a provincial level and across the 3 major land categories (forest land, other wooded land and other land), the highest tree densities for saw-logs is found in North-western estimated at 32 *sph*, Eastern province has 29 *sph* and Muchinga province has 28 *sph*, while the lowest was observed in Lusaka province with only 15 *sph*. Regarding trees for poles, North-western Province recorded the highest densities with 71 *sph* and the lowest density was found in the Copperbelt province estimated at 7 *sph* (Table 13).

Inside forests there are 34 and 53 *sph* for saw-logs and poles respectively, while in other wooded land there are 6 and 9 *sph*, and other land has 9 and 14 *sph* for saw-logs and poles respectively (Table 13).

**Table 13: Commercial timber tree density and volumes distribution by provinces**

| Province | Saw-Logs | | | Poles | |
|---|---|---|---|---|---|
| | Trees (/ha) | Bole ($m^3$/ha) | Volume ($m^3$/ha) | Trees (/ha) | Volume ($m^3$/ha) |
| 1. Central | 21 | 5.1 | 8.5 | 23 | 4.4 |
| 2. Copperbelt | 27 | 8.9 | 13.3 | 7 | 0.9 |
| 3. Eastern | 29 | 4.5 | 8.2 | 64 | 15.9 |
| 4. Luapula | 18 | 2.9 | 4.7 | 13 | 2.7 |
| 5. Lusaka | 15 | 1.9 | 3.9 | 51 | 11.8 |
| 6. Muchinga | 28 | 3.8 | 7.3 | 45 | 12.0 |
| 7. Northern | 15 | 1.7 | 3.5 | 12 | 2.6 |
| 8. North-Western | 32 | 7.0 | 18.5 | 71 | 18.3 |
| 9. Southern | 17 | 5.1 | 7.6 | 51 | 10.7 |
| 10. Western | 22 | 4.0 | 8.4 | 14 | 2.7 |
| Zambia | 23 | 4.6 | 9.3 | 36 | 8.5 |
| | | | | | |
| Zambia (Inside Forests) | 34 | 7.0 | 14.3 | 53 | 13.1 |
| Zambia (OWL) | 9 | 1.3 | 2.0 | 14 | 1.8 |
| Zambia (OL) | 6 | 0.9 | 1.7 | 9 | 1.8 |

The distribution of commercial timber species density (number of stems) and volumes for saw-logs and poles production inside forests where concession licenses can be applied for and considered for issuance varied from one province to the other (Table 14).

**Table 14: Commercial timber bole density and volumes distribution by provinces**

| Province | Saw-Logs (Timber) | | | Poles | |
|---|---|---|---|---|---|
| | *sph* | Bole ($m^3$/ha) | Volume ($m^3$/ha) | *sph* | Volume ($m^3$/ha) |
| 1. Central | 37.5 | 9.5 | 15.8 | 38.4 | 7.6 |
| 2. Copperbelt | 43.3 | 14.5 | 21.6 | 11.1 | 1.5 |
| 3. Eastern | 42.3 | 6.4 | 12.3 | 100.8 | 25.0 |
| 4. Luapula | 27.9 | 4.6 | 7.3 | 19.7 | 3.8 |
| 5. Lusaka | 19.8 | 2.6 | 5.4 | 76.5 | 17.8 |
| 6. Muchinga | 36.2 | 5.2 | 9.8 | 58.2 | 16.2 |
| 7. Northern | 22.8 | 2.6 | 5.4 | 15.6 | 4.0 |
| 8. North-Western | 42.1 | 9.3 | 24.7 | 91.4 | 24.6 |
| 9. Southern | 21.6 | 8.6 | 12.7 | 89.6 | 19.4 |
| 10. Western | 32.0 | 6.2 | 13.4 | 19.2 | 4.3 |
| Zambia | 34.1 | 7.0 | 14.3 | 52.8 | 13.1 |

### 4.4 Tree Volumes, Biomass and Carbon Stocks

The total volume over-bark for all trees measuring ≥ 10cm diameter at breast height (*dbh*) is estimated to be 3,178 *million* $m^3$ of which forest land returned 2,923 *million* $m^3$; other wooded-land returned 101.5 *million* $m^3$; and other land has 153.3 *million* $m^3$. The forest land returned a total merchantable bole volume of 1,520 *million* $m^3$ (at 34.4 $m^3$/ha) which represented 52% of the total growing stock in forest land.

The total tree biomass were estimated at 2,743.9 *million tons* (above-ground biomass is 2,143.6 *million tons* and below ground biomass is 600.3 *million tons*) and total carbon is estimated to be 1,344.5 *million tons* (above-ground carbon is 1,050.4 *million tons* and below ground carbon is 294.1 *million tons*) in all land respectively (Table 15). Further, the Forest land returned total biomass stock of 2,486.3 *million tons*, other wooded land has 111.5 *million tons*, and other land has 146.0 *million tons*. The total carbon stock in Forest land is estimated to be 1,218.3 *million tons*, other wooded land has 54.7 *million tons*, and other land has 71.5 *million tons* (Table 15).

**Table 15: Total volume, biomass and carbon stocks distribution by land categories**

| Variable | Forest Land | Other Wooded Land | Other Land | Total |
|---|---|---|---|---|
| 1. Branch-wood (other) volume (*million* $m^3$) | 1,403.6 | 43.6 | 79.4 | 1,526.6 |
| 2. Merchantable (bole) volume (*million* $m^3$) | 1,519.7 | 57.9 | 73.9 | 1,651.5 |
| Total growing stock (*million* $m^3$) | 2,923.3 | 101.5 | 153.3 | 3,178.1 |
| | | | | |
| 3. Above-ground biomass (*million tons*) | 1,942.5 | 87.1 | 114.0 | 2,143.6 |
| 4. Below-ground biomass (*million tons*) | 543.8 | 24.4 | 32.0 | 600.3 |
| Total biomass stock (*million tons*) | 2,486.3 | 111.5 | 146.0 | 2,743.9 |
| | | | | |
| 5. Above-ground carbon (*million tons*) | 951.8 | 42.7 | 55.9 | 1,050.4 |
| 6. Below-ground carbon (*million tons*) | 266.5 | 12.0 | 15.6 | 294.1 |
| Total carbon (*million tons)* | 1,218.3 | 54.7 | 71.5 | 1,344.5 |

### 4.4.1 Mean volumes, biomass and carbon stocks

The mean volumes over all land (where trees are growing) is estimated to be 43.0 $m^3/ha$. The growing stock volume is highest in forest land (*66.2* $m^3/ha$) and lowest in other wooded land (*7.7* $m^3/ha$) (Table 16). The mean biomass stock over all land is estimated to be 37.1 *tons/ha* (where 29.0 *tons/ha* is for ABG and 8.1 *tons/ha* is for BGB) and the mean carbon stock is estimated to be 18.2 *tons/ha* (where 14.2 *tons/ha* is for ABC and 4.0 *tons/ha* is for BGC).

**Table 16: Mean volumes, biomass and carbon stocks distribution by land categories**

| Variable | Forest Land | Other Wooded Land | Other Land | All Lands |
|---|---|---|---|---|
| 1. Branch-wood (other) volume ($m^3/ha$) | 31.8 | 3.3 | 4.8 | 20.7 |
| 2. Merchantable (bole) volume ($m^3/ha$) | 34.4 | 4.4 | 4.5 | 22.3 |
| Growing stock volume ($m^3/ha$) | 66.2 | 7.7 | 9.3 | 43.0 |
| | | | | |
| 3. Above-ground biomass (*tons/ha*) | 44.0 | 6.6 | 6.9 | 29.0 |
| 4. Below-ground biomass (*tons/ha*) | 12.3 | 1.8 | 1.9 | 8.1 |
| Tree biomass (*tons/ha*) | 56.3 | 8.4 | 8.8 | 37.1 |
| | | | | |

| Variable | Forest Land | Other Wooded Land | Other Land | All Lands |
|---|---|---|---|---|
| 5. Above-ground carbon (*tons/ha*) | 21.5 | 3.2 | 3.4 | 14.2 |
| 6. Below-ground carbon (*tons/ha*) | 06.1 | 0.9 | 0.9 | 04.0 |
| Tree carbon (*tons/ha)* | 27.6 | 4.1 | 4.3 | 18.2 |

Further, the Forest land returned mean biomass stock of 56.3 *tons/ha*, other wooded land has 8.4 *tons/ha*, and other land has 8.8 *tons/ha*. The mean carbon stock in Forest land is estimated to be 27.6 *tons/ha*, other wooded land has 4.1 *tons/ha*, and other land has 4.3 *tons/ha* (Table 16). However, at the country level, the standard error of mean forest biomass (AGB) is estimated to be 2.4 tons/ha, equal to a sampling error of 6.9% at the 95% confidence interval. For other wooded land and other land, the relative sampling errors of mean AGB estimates is 64.7% and 71.3% respectively.

### 4.4.2 Total trees volume in vegetation types and other areas

The largest growing stock (volume) for all trees measuring ≥ 10cm diameter at breast height is found in forest woodlands and is estimated at 2,601.7 *million* $m^3$ representing 88.9% of the volume for trees inside forests and it represents 81.6% of the total volume for all trees under this category. The second largest volume (217.1 *million* $m^3$) is found under the dry evergreen forests which are the *Cryptosepalum* (mavunda) *forests* located mainly in the North-western Province (Table 17).

**Table 17: Total volume distribution by vegetation types and other areas**

| Vegetation types and other areas | Merchantable (bole) volume (million $m^3$) | Branch wood (other) volume (million $m^3$) | Total gross volume (million $m^3$) |
|---|---|---|---|
| 1. Dry evergreen forest | 79.3 | 137.8 | 217.1 |
| 2. Dry deciduous forest | 29.0 | 39.7 | 68.7 |
| 3. Moist evergreen forest | 12.1 | 14.4 | 26.5 |
| 4. Forest woodland | 1,391.2 | 1210.5 | 2,601.7 |
| 5. Forest plantation | 8.1 | 1.2 | 9.3 |
| Subtotal (inside forests) | 1,519.7 | 1403.6 | 2,923.3 |
| | | | |
| 6. Other wooded land | 57.9 | 43.6 | 101.5 |
| 7. Grassland | 32.4 | 38.6 | 71.0 |
| 8. Bare land | 0.4 | 0.3 | 0.7 |
| 9. Cultivated land | 33.1 | 32.6 | 65.7 |
| 10. Build up | 5.1 | 5.5 | 10.6 |
| 11. Other land | 2.9 | 2.4 | 5.3 |
| Subtotal (outside forests) | 73.9 | 79.4 | 153.3 |
| Grand total | 1,651.5 | 1,526.60 | 3,178.1 |

The other growing stock volume estimates for similar tree dimensions is found in land categories for trees outside forests (TOF) where the other wooded land returned a total of 101.5 *million* $m^3$, some trees growing in grass-lands have a total of 71 *million* $m^3$, isolated trees growing in bare land returned a total of 0.7 *million* $m^3$, trees growing in cultivated land have 65.7 *million* $m^3$, trees inside settlements (built-up land) yielded a total of 10.6 *million* $m^3$ and those trees captured in other land returned a total volume of 5.3 *million* $m^3$ (Table 17).

### 4.4.3 Mean volume in vegetation types and other areas

Comparatively, the mean volume estimates is highest in Forest plantations (169.2 $m^3/ha$) as compared to overall volume estimates earlier reported to be highest in forest woodlands. This is because the number of stems per hectare basis is higher in Forest plantations as compared to tree densities in the indigenous forests. Similarly, the dry evergreen forest returned the second highest mean volume estimated at 105.5 $m^3/ha$ as compared to forest woodlands which have 64.7 $m^3/ha$. The dry deciduous forest has a mean volume of 52.4 $m^3/ha$ followed by the moist evergreen forest which returned a mean volume of 47.2 $m^3/ha$ (Table 18).

**Table 18: Mean volume distribution by vegetation types and other areas**

| Vegetation types and other areas | Merchantable (bole) volume ($m^3$/ha) | Branch wood (other) volume ($m^3$/ha) | Growing stock volume ($m^3$/ha) |
|---|---|---|---|
| 1. Dry evergreen forest | 38.5 | 67 | 105.5 |
| 2. Dry deciduous forest | 22.1 | 30.3 | 52.4 |
| 3. Moist evergreen forest | 21.6 | 25.6 | 47.2 |
| 4. Forest woodland | 34.6 | 30.1 | 64.7 |
| 5. Forest plantation | 147.8 | 21.7 | 169.5 |
| Inside forests | 34.4 | 31.8 | 66.2 |
| | | | |
| 6. Other Wooded Land | 4.4 | 3.3 | 7.7 |
| 7. Grassland | 4.7 | 5.6 | 10.3 |
| 8. Bare land | 1.2 | 1.2 | 2.4 |
| 9. Cultivated land | 4.0 | 3.9 | 7.9 |
| 10. Build up | 8.6 | 9.3 | 17.9 |
| 11. Other land | 8.2 | 6.6 | 14.8 |
| Outside forests | 4.5 | 4.8 | 9.3 |

Mean volume for areas outside forests is estimated at 9.3 $m^3/ha$. However, other wooded land returned a mean volume of 7.7 $m^3/ha$, while trees growing in grass-lands have a total of 10.3 $m^3/ha$, isolated trees growing in bare land returned a mean volume of 2.4 $m^3/ha$, trees growing in cultivated land have a mean volume of 7.9 $m^3/ha$, trees inside settlements (built-up land) yielded a mean volume of 17.9 $m^3/ha$ and those trees captured in other land returned a mean volume of 14.8 $m^3/ha$ (Table 18).

Generally, bole (*merchantable*) volume accounts for the largest volume of the tree resource than the branch wood (other) due to the larger basal area for tree stems which are normally bigger than the branches combined. However, some umbrella shaped trees with huge branch wood may sometime have larger volumes than in the tree stems or merchantable bole.

### 4.4.4 Total biomass and carbon stocks in vegetation types and other areas

Total biomass stocks inside forests (major vegetation types) are highest in forest woodlands (2,215.8 *million tons*) and lowest in Forest plantations (5.0 *million tons*). Dry evergreen forest has 178.5 *million tons* of biomass, dry deciduous forest has 62.4 *million tons* and the moist evergreen forest has 24.6 *million tons* (Table 19). The total biomass stock for the trees found in areas outside forests are highest in other wooded land which returned 111.5 *million tons* and lowest in isolated trees sampled under bare-land which has 0.8 *million tons*. The tree biomass captured from cultivated land has a total share of 66.0 *million tons*, the grass-lands have 61.1 *million tons*, tree biomass within settlements (built-up areas) have 12.4 *million tons* and the other land has 5.6 *million tons*.

**Table 19: Total biomass and carbon stocks distribution by vegetation and other areas**

| Vegetation | Above ground biomass (million tons) | Below ground biomass (million tons) | Total biomass (million tons) | Above ground carbon (million tons) | Below ground carbon (million tons) | Total carbon (million tons) |
|---|---|---|---|---|---|---|
| 1. Dry evergreen forest | 139.5 | 39 | 178.5 | 68.3 | 19.2 | 87.5 |
| 2. Dry deciduous forest | 48.8 | 13.6 | 62.4 | 23.9 | 6.7 | 30.6 |
| 3. Moist evergreen forest | 19.2 | 5.4 | 24.6 | 9.4 | 2.7 | 12.1 |
| 4. Forest woodland | 1,731.1 | 484.7 | 2,215.8 | 848.3 | 237.5 | 1,085.8 |
| 5. Forest plantation | 3.9 | 1.1 | 5.0 | 1.9 | 0.5 | 2.4 |
| Sub-total (inside forests) | 1,942.5 | 543.9 | 2,486.4 | 951.8 | 266.5 | 1,218.3 |
| | | | | | | |
| 6. Other wooded land | 87.1 | 24.4 | 111.5 | 42.7 | 12 | 54.7 |
| 7. Grassland | 47.7 | 13.4 | 61.1 | 23.4 | 6.5 | 29.9 |
| 8. Bare land | 0.7 | 0.1 | 0.8 | 0.3 | 0.1 | 0.4 |
| 9. Cultivated land | 51.6 | 14.4 | 66.0 | 25.3 | 7 | 32.3 |
| 10. Build up | 9.7 | 2.7 | 12.4 | 4.7 | 1.4 | 6.1 |
| 11. Other land | 4.4 | 1.2 | 5.6 | 2.2 | 0.6 | 2.8 |
| Sub-total (outside forests) | 201.2 | 56.2 | 257.4 | 98.6 | 27.6 | 126.2 |
| | | | | | | |
| Grand total | 2,143.7 | 600.2 | 2,743.9 | 1,050.4 | 294.1 | 1,344.5 |

Total carbon stocks inside forests (major vegetation types) are highest in forest woodlands (1,085.8 *million tons*) and lowest in Forest plantations (2.4 *million tons*). Dry evergreen forest has 87.5 *million tons* of carbon, dry deciduous forest has 30.6 *million tons* and the moist evergreen forest has 12.1 *million tons* (Table 19).

The carbon content for the tree biomass found in areas outside forests are highest in other wooded land which returned 54.7 *million tons* and lowest in isolated trees sampled under bare-land which has 0.4 *million tons*. The tree biomass captured from cultivated land has a total share of carbon stock amounting to 32.3 *million tons*, the grass-lands has 29.9 *million tons*, tree biomass within settlements (built-up areas) have 6.1 *million tons* and the other land has 2.8 *million tons*.

### 4.4.5 Mean biomass and carbon stocks in vegetation and other areas

The mean biomass stock inside forests (major vegetation types) is highest in forest plantations (90.6 *tons/ha*) and lowest in Moist evergreen forest (43.8 *tons/ha*). Dry evergreen forest has 86.8 *tons/ha* of biomass stock, forest woodlands have 55.1 *tons/ha*, and dry deciduous forest has 47.6 *tons/ha* (Table 20). The mean biomass stock for the trees found in areas outside forests are highest in settlements (built-up areas) which returned 20.8 *tons/ha* and lowest in isolated trees sampled under bare-land which has 0.6 *tons/ha*. The mean biomass captured from cultivated land has a total share of 7.9 *tons/ha*, the grass-lands have 8.8 *tons/ha*, other wooded land has 8.4 *tons/ha* and the other land has 8.8 *tons/ha*.

**Table 20: Mean biomass and carbon stocks distribution by vegetation and other areas**

| Vegetation | Above ground biomass (tons/ha) | Below ground biomass (tons/ha) | Total biomass (tons/ha) | Above ground carbon (tons/ha) | Below ground carbon (tons/ha) | Total carbon (tons/ha) |
|---|---|---|---|---|---|---|
| 1. Dry evergreen forest | 67.8 | 19 | 86.8 | 33.2 | 9.3 | 42.5 |
| 2. Dry deciduous forest | 37.2 | 10.4 | 47.6 | 18.2 | 5.1 | 23.3 |
| 3. Moist evergreen forest | 34.2 | 9.6 | 43.8 | 16.8 | 4.7 | 21.5 |
| 4. Forest woodland | 43.1 | 12 | 55.1 | 21.1 | 5.9 | 27.0 |
| 5. Forest plantation | 70.8 | 19.8 | 90.6 | 34.7 | 9.7 | 44.4 |
| Inside forests | 44.0 | 12.3 | 56.3 | 21.5 | 6.1 | 27.6 |
| | | | | | | |
| 6. Other wooded land | 6.6 | 1.8 | 8.4 | 3.2 | 0.9 | 4.1 |
| 7. Grassland | 6.9 | 1.9 | 8.8 | 3.4 | 0.9 | 4.3 |
| 8. Bare land | 2.1 | 0.6 | 2.7 | 1.0 | 0.3 | 1.3 |
| 9. Cultivated land | 6.2 | 1.7 | 7.9 | 3.0 | 0.9 | 3.9 |
| 10. Build up | 16.3 | 4.5 | 20.8 | 8.0 | 2.2 | 10.2 |
| 11. Other land | 6.9 | 1.9 | 8.8 | 3.4 | 0.9 | 4.3 |
| Outside forests | 12.4 | 3.5 | 15.9 | 6.1 | 1.7 | 7.8 |

The mean carbon stocks inside forests (major vegetation types) are highest in forest plantations (44.4 *tons/ha*) and lowest in Moist evergreen forest (21.5 *tons/ha*). Dry evergreen forest has 42.5 *tons/ha* of carbon, forest woodlands have 27.0 *tons/ha* and dry deciduous forest has 23.3 *tons/ha* (Table 20). The mean carbon content for the tree biomass found in areas outside forests are highest in settlements (built-up areas) which returned 10.2 *tons/ha* and lowest in isolated trees sampled under bare-land which has 1.3 *ton/has*. The mean carbon from other wooded land is 4.1 *tons/ha*, cultivated land returned 3.9 *tons/ha*, the grass-lands have 4.3 *tons/ha*, and the other land has 4.3 *tons/ha*.

### 4.4.6 Total biomass and carbon stocks by provinces

Total biomass stock distribution by provinces shows that North-western Province has the largest share of 831.2 *million tons* representing 30.3% of the total biomass. The lowest biomass stock is under Lusaka Province which has 80.9 *million tons* representing 2.9% of the total biomass. The second highest biomass stock is found in Western Province which returned 358.9 *million tons*, followed by

Central Province which has 323.4 *million tons*. Muchinga Province has the fourth largest share of 313.9 *million tons*, Northern Province has 243.6 *million tons*, Luapula Province has 160.5 *million tons*, Eastern Province has 153.8 *million tons*, Southern Province has 146.1 *million tons*, and Copperbelt Province has 131.8 *million tons* (Table 21).

The average biomass stock across all the provinces is 38.3 *tons/ha*. However, the highest mean biomass stock is in North-western Province which has 67.4 *tons/ha*, and the lowest is in Southern Province with 29.7 *tons/ha*. The Copperbelt Province has 51.2 *tons/ha*, Luapula Province has 41 *tons/ha*, Northern Province has 40 *tons/ha*, Central Province has 38.3 *tons/ha*, Eastern Province has 37.6 *tons/ha*, Muchinga Province has 37.2 *tons/ha*, Lusaka Province has 36.2 *tons/ha*, and Western Province has 36.1 *tons/ha* (Table 21).

**Table 21: Total biomass and carbon stocks distribution by provinces**

| Provinces | Biomass stock (*million tons*) | | Biomass stock (*million tons*) | |
|---|---|---|---|---|
| | AG Biomass | Total biomass | AG carbon | Total carbon |
| 1. Central | 252.6 | 323.4 | 123.8 | 158.4 |
| 2. Copperbelt | 102.9 | 131.8 | 50.4 | 64.6 |
| 3. Eastern | 120.1 | 153.8 | 58.9 | 75.3 |
| 4. Luapula | 125.4 | 160.5 | 61.5 | 78.7 |
| 5. Lusaka | 63.2 | 80.9 | 31 | 39.6 |
| 6. Muchinga | 245.2 | 313.9 | 120.2 | 153.8 |
| 7. Northern | 190.3 | 243.6 | 93.2 | 119.4 |
| 8. North-Western | 649.3 | 831.2 | 318.2 | 407.3 |
| 9. Southern | 114.1 | 146.1 | 55.9 | 71.6 |
| 10. Western | 280.4 | 358.9 | 137.4 | 175.8 |
| Zambia | 2,143.70 | 2,743.90 | 1,050.40 | 1,344.50 |

Meanwhile, total carbon stock distribution by provinces relates directly to the biomass stock where North-western province has the largest share of 407.3 *million tons* representing 30.3% of the total biomass. The lowest biomass stock is under Lusaka province which has 39.6 *million tons* representing 2.9% of the total biomass.

The second highest biomass stock is found in Western province which returned 175.8 *million tons*, followed by Central province which has 158.4 *million tons*. Muchinga province has the fourth largest share of 153.8 *million tons*, Northern Province has 119.4 *million tons*, Luapula Province has 78.7 *million tons*, Eastern Province has 75.3 *million tons*, Southern Province has 71.6 *million tons*, and Copperbelt province has 64.6 *million tons*.

### 4.4.7 Total biomass stocks in major land categories by province

The highest biomass stock both for above and below ground, including total biomass distribution in major land categories by province is undoubtedly found in forest land and the second highest biomass stock is found in other land across all provinces except for Muchinga province where its total biomass is apparently higher in other wooded land (12.6 *million tons*) as compared to other land (7.2 *million tons*) (Table 22). Comparatively, number of trees and area extent (total coverage) in other wooded land is less than other land which has several land sub-categories with a lot of trees growing in such areas and these include: some grass-lands, bare-land, land under settlements (built-up areas) and other areas.

However, the overall biomass distribution by province is no different from what has been discussed in the previous chapters where North-western province accounts for highest share, while the lowest biomass stock is found in Lusaka province.

**Table 22: Distribution of biomass stocks in major land categories by province**

| Province | AG biomass (million tons) | | | Total biomass (million tons) | | |
|---|---|---|---|---|---|---|
| | Forest Land | Other Wooded Land | Other Land | Forest Land | Other Wooded Land | Other Land |
| 1. Central | 216.0 | 13.8 | 22.8 | 276.4 | 17.7 | 29.2 |
| 2. Copperbelt | 95.9 | 1.7 | 5.3 | 122.8 | 2.2 | 6.8 |
| 3. Eastern | 99.3 | 8.5 | 12.4 | 127.0 | 10.9 | 15.9 |
| 4. Luapula | 117.0 | 4.2 | 4.3 | 149.7 | 5.3 | 5.5 |
| 5. Lusaka | 59.8 | 1.1 | 2.3 | 76.5 | 1.4 | 2.9 |
| 6. Muchinga | 229.8 | 9.8 | 5.6 | 294.2 | 12.6 | 7.2 |
| 7. Northern | 177.5 | 4.0 | 8.8 | 227.2 | 5.1 | 11.2 |
| 8. North-Western | 609.9 | 9.7 | 29.8 | 780.6 | 12.4 | 38.2 |
| 9. Southern | 85.2 | 17.1 | 11.8 | 109.1 | 21.9 | 15.1 |
| 10. Western | 252.2 | 17.2 | 10.9 | 322.9 | 22.0 | 14.0 |
| Zambia | 1,942.5 | 87.1 | 114.0 | 2,486.4 | 111.5 | 146.0 |

### 4.4.8 Total carbon stocks by major land categories in province

The trend in the distribution of total carbon stock both for above and below ground, including total biomass distribution in major land categories by province is very similar to the total biomass stock as outlined in chapter 4.3.7. This is because the carbon stock estimates are based on the ratio of 0.49% of the total biomass stock and this is why trees and woody biomass play an important role in the natural carbon cycle. For instance, forest biomass accounts for over 45% of terrestrial carbon stocks, with approximately 70% and 30% contained within the above and below ground biomass, respectively.

Not all trees exist inside of forests (IOF); however, trees feature prominently in other land across each province including in settlements and agricultural landscapes (Table 23). Almost half of all agricultural (cropland) land maintains at least 10% tree cover. Despite widespread distribution, tree outside forests (TOF) are an often neglected carbon pool and very little or no information is available on carbon stocks in these systems or their carbon sequestration potential. However, this report provides that there is a lot of information both on biomass and carbon stocks in other land besides forests (Table 23).

**Table 23: Distribution of carbon stocks in major land categories by province**

| Province | AG carbon (million tons) | | | Total carbon (million tons) | | |
|---|---|---|---|---|---|---|
| | Forest Land | Other Wooded Land | Other Land | Forest Land | Other Wooded Land | Other Land |
| 1. Central | 105.8 | 6.8 | 11.2 | 135.5 | 8.7 | 14.3 |
| 2. Copperbelt | 47.0 | 0.8 | 2.6 | 60.1 | 1.1 | 3.3 |
| 3. Eastern | 48.6 | 4.2 | 6.1 | 62.3 | 5.3 | 7.8 |
| 4. Luapula | 57.3 | 2.0 | 2.1 | 73.4 | 2.6 | 2.7 |
| 5. Lusaka | 29.3 | 0.5 | 1.1 | 37.5 | 0.7 | 1.4 |
| 6. Muchinga | 112.6 | 4.8 | 2.7 | 144.1 | 6.2 | 3.5 |
| 7. Northern | 87.0 | 2.0 | 4.3 | 111.3 | 2.5 | 5.5 |
| 8. North-Western | 298.8 | 4.7 | 14.6 | 382.5 | 6.1 | 18.7 |
| 9. Southern | 41.7 | 8.4 | 5.8 | 53.4 | 10.7 | 7.4 |
| 10. Western | 123.6 | 8.4 | 5.4 | 158.2 | 10.8 | 6.9 |
| Zambia | 951.8 | 42.7 | 55.9 | 1,218.3 | 54.7 | 71.5 |

### 4.5 Saplings volume, biomass and carbon stocks

The total volume over-bark for all saplings (trees measuring ≥ 5 and < 10 cm diameter at breast height) is estimated to be 154.4 *million* $m^3$ of which forest land returned 124.6 *million* $m^3$; other wooded-land returned 20.6 *million* $m^3$; and other land 9.1 *million* $m^3$ (Table 24).

**Table 24: Sapling biomass and carbon in major land categories**

| Variable | Forest land | Other wooded land | Other land | All land |
|---|---|---|---|---|
| 1. Above-ground biomass *(million tons)* | 108.8 | 21.3 | 9.3 | 139.5 |
| 2. Below-ground biomass *(million tons)* | 30.5 | 6 | 2.7 | 39.1 |
| Total biomass *(million tons)* | 139.3 | 27.3 | 12.0 | 178.6 |
| | | | | |
| 3. Above-ground carbon *(million tons)* | 53.3 | 10.5 | 4.6 | 68.4 |
| 4. Below-ground carbon *(million tons)* | 15 | 2.9 | 1.3 | 19.1 |
| Total carbon *(million tons)* | 68.3 | 13.4 | 5.9 | 87.5 |

The total saplings biomass is estimated at 178.9 *million tons* (above-ground biomass is 139.5 *million tons* and below ground biomass is 39.1 *million tons*) across all land categories. Further, the saplings biomass stock in the Forest land is estimated to be 139.3 *million tons*, other wooded land has 27.3 *million tons*, and other land has 12 *million tons*. The total saplings carbon stock is estimated at 87.5 *million tons* (above-ground carbon is 68.4 *million tons* and below ground biomass is 19.1 *million tons*) in all land categories. However, the saplings carbon stock in the Forest land is estimated to be 68.3 *million tons*, other wooded land has 13.4 *million tons*, and other land has 5.9 *million tons* (Table 24).

### 4.5.1 Mean volume, biomass and carbon stocks for saplings

The mean (average) volume for sapling across all land categories is estimated to be 2.1 $m^3$/ha, of which forest land returned 2.8 $m^3/ha$; other wooded-land returned 1.6 $m^3/ha$; and other land 0.5 $m^3/ha$. The mean saplings biomass is estimated at 2.4 *tons/ha* (above-ground biomass is 1.9 *tons/ha* and below ground biomass is 0.5 *tons/ha*) across all land categories. Further, the saplings biomass stock in the Forest land is estimated to be 3.2 *tons/ha*, other wooded land has 2.1 *tons/ha*, and other land has 0.7 *tons/ha* (Table 25).

**Table 25: Mean sapling biomass and carbon stocks in major land categories**

| Variable | Forest land | Other Wooded Land | Other Land | All Land |
|---|---|---|---|---|
| 1. Above-ground biomass *(tons/ha)* | 2.5 | 1.6 | 0.6 | 1.9 |
| 2. Below-ground biomass *(tons/ha)* | 0.7 | 0.5 | 0.1 | 0.5 |
| Mean biomass stock *(tons/ha)* | 3.2 | 2.1 | 0.7 | 2.4 |
| | | | | |
| 3. Above-ground carbon *(tons/ha)* | 1.2 | 0.8 | 0.3 | 0.9 |
| 4. Below-ground carbon *(tons/ha)* | 0.0 | 0.0 | 0.0 | 0.3 |
| Mean carbon stock *(tons/ha)* | 1.2 | 0.8 | 0.3 | 1.2 |

The mean saplings carbon stock is estimated at 1.2 *tons/ha* (above-ground carbon is 0.9 *tons/ha* and below ground carbon is 0.3 *tons/ha*) across all land categories. Further, the saplings carbon stock in the Forest land is estimated to be 1.2 *tons/ha*, other wooded land has 0.8 *tons/ha*, and other land has 0.3 *tons/ha* (Table 25).

### 4.5.2 Biomass and carbon stocks for saplings in vegetation types and other areas

In tree-saplings inside forests and or according to major vegetation types, the forest woodlands accounts for more biomass (131.4 *million tons*) and carbon (64.4 *million tons*) stocks and the lowest biomass (0.*04 million tons*) and carbon (0.02 *million tons*) stocks are in forest plantations. The second highest biomass and carbon stocks are in the dry evergreen forest which has 3.7 *million tons* and 1.8 *million tons* respectively. The dry deciduous forest has 3.4 *million tons* of biomass and 1.7 *million tons* of carbon stock, while the moist evergreen forest has 0.7 *million tons* and 0.3 *million tons* of biomass and carbon stocks respectively (Table 26).

For tree-saplings outside forests, the biomass and carbon stocks are more in the other wooded land which returned 27.3 *million tons* and 13.4 *million tons* respectively, and the lowest is found in other area which has 0.007 *million tons* of biomass and 0.003 *million tons* of carbon. The second highest biomass and carbon stocks are for saplings located under cultivated land which has 8.7 *million tons* and 4.2 *million tons* respectively. The grasslands have 2.7 *million tons* of biomass and 1.3 *million tons* of carbon stock, saplings under the settlements (built-up area) have 0.5 *million tons* of biomass and 0.3 *million tons* of carbon stocks, while isolated saplings sampled from bare land returned 0.5 *million tons* of biomass and 0.3 *million tons* of carbon (Table 26).

**Table 26: Biomass and carbon stocks distribution for saplings by vegetation types**

| Major vegetation type | Biomass and carbon (million tons) | | | |
|---|---|---|---|---|
| | AG biomass | Total biomass | AG carbon | Total carbon |
| 1. Dry evergreen forest | 2.9 | 3.7 | 1.4 | 1.8 |
| 2. Dry deciduous forest | 2.7 | 3.4 | 1.3 | 1.7 |
| 3. Moist evergreen forest | 0.6 | 0.7 | 0.3 | 0.3 |
| 4. Forest woodland | 102.6 | 131.4 | 50.3 | 64.4 |
| 5. Forest plantation | 0.03 | 0.04 | 0.01 | 0.02 |
| Inside forests | 108.8 | 139.3 | 53.3 | 68.3 |
| | | | | |
| 6. Other Wooded Land | 21.3 | 27.3 | 10.5 | 13.4 |
| 7. Grassland | 2.1 | 2.7 | 1.0 | 1.3 |
| 8. Bare land | 0.05 | 0.07 | 0.03 | 0.03 |
| 9. Cultivated land | 6.8 | 8.7 | 3.3 | 4.2 |
| 10. Build up | 0.4 | 0.5 | 0.2 | 0.3 |
| 11. Other areas | 0.005 | 0.007 | 0.003 | 0.003 |
| Outside forests | 9.3 | 12.0 | 4.6 | 5.9 |
| | | | | |
| Zambia | 139.5 | 178.6 | 68.4 | 87.5 |

Comparatively, there are more biomass and carbon stocks for saplings located under other wooded land than in the dry evergreen forest, dry deciduous forest, moist evergreen forest and forest plantations combined. This is because there more undergrowth trees sprouting in areas where tree canopy is less than in over grown trees with dense over-storey crowns that supresses saplings and tree seedlings.

### 4.5.3 Biomass and carbon stocks for saplings in provinces

The sapling biomass and carbon stock distribution by provinces shows that North-western Province has the largest share of 36.7 *tons/ha* of biomass and 18.0 tons/ha of carbon. The lowest biomass stock is under Lusaka Province which has 5.4 *tons/ha* and 2.6 *tons* of carbon stock. The second highest biomass stock is found in Muchinga Province which returned 32.2 *tons/ha* and 15.8 *tons/ha* of carbon stock, followed by Central Province which has 23.5 *tons/ha* of biomass and 11.5 *tons/ha* of carbon. Luapula Province has 15.7 *tons/ha* of biomass and 7.7 *tons/ha* of carbon, Western Province has the fourth largest share of 15.3 *tons/ha* of biomass and 7.5 *tons/ha* of carbon, Eastern Province has 14.2 *tons/ha* of biomass and 6.9 *tons/ha* of carbon, Copperbelt Province has 9.3 *tons/ha* of biomass and 4.6

*tons/ha* of carbon, Southern Province has 6.2 *tons/ha* of biomass and *3.1 tons/ha* of carbon, and Lusaka Province has 5.4 *tons/ha* of biomass and 2.6 *tons/ha* of carbon (Table 28).

**Table 28: Total biomass and carbon for saplings distribution by province**

| Province | Biomass stock (million tons) | | Carbon stock (million tons) | |
|---|---|---|---|---|
| | AG biomass | Total biomass | AG carbon | Total carbon |
| 1. Central | 18.4 | 23.5 | 9.0 | 11.5 |
| 2. Copperbelt | 7.3 | 9.3 | 3.6 | 4.6 |
| 3. Eastern | 11.1 | 14.2 | 5.4 | 6.9 |
| 4. Luapula | 12.3 | 15.7 | 6.0 | 7.7 |
| 5. Lusaka | 4.2 | 5.4 | 2.1 | 2.6 |
| 6. Muchinga | 25.1 | 32.2 | 12.3 | 15.8 |
| 7. Northern | 13.6 | 17.5 | 6.7 | 8.6 |
| 8. North-Western | 28.7 | 36.7 | 14.1 | 18.0 |
| 9. Southern | 4.9 | 6.2 | 2.4 | 3.1 |
| 10. Western | 12.0 | 15.3 | 5.9 | 7.5 |
| Total | 137.5 | 176.0 | 67.4 | 86.2 |

## 4.6 Stumps and wood removals

The total number of stumps estimated countrywide was 1,126 *million*, containing 68.4 *million tons* of total biomass where above ground biomass is 23.9 *million tons* and below ground biomass is 47.5 *million tons*, and 33.5 *million tons* of total carbon where above ground carbon is 11.7 *million tons* and below ground carbon is 21.8 *million tons*.

Approximately 55% stumps were found in forest land, 31% in other wooded land and 14% in the other land category. Both below ground biomass and carbon stocks for stumps is relatively higher than above ground biomass and carbon stock because the larger proportion of the wood materials which grows above these stumps constitute the wood removals from the area. Meanwhile, there are 14 *stumps/ha* in forest land, 26 *stumps/ha* in other wooded land and 9.7 *stumps/ha* in other land.

**Table 29: Biomass and carbon stock for stumps in FRA classes**

| Variable | Forest land | Other wooded land | Other land | All land |
|---|---|---|---|---|
| 1. Above-ground biomass (*million tons*) | 14.1 | 6.5 | 3.3 | 23.9 |
| 2. Below-ground biomass (*million tons*) | 26.2 | 10.7 | 7.6 | 47.5 |
| Total biomass (*million tons*) | 40.3 | 17.2 | 10.9 | 68.4 |
| | | | | |
| 3. Above-ground carbon (*million tons*) | 6.9 | 3.2 | 1.6 | 11.7 |
| 4. Below-ground carbon (*million tons*) | 12.8 | 5.2 | 3.8 | 21.8 |
| Total carbon (*million tons*) | 19.7 | 8.4 | 5.4 | 33.5 |

The total number of stumps in the land categories varied among provinces, with Muchinga province recording the highest number (above 400 *million stumps*) and Southern Province the lowest (about 20 *million stumps*). The second highest number of stumps is in Northern Province which returned above 230 million stumps, followed by North-western province which has a record of 160 *million stumps* (Figure 9).

Coincidentally, Muchinga and Northern provinces have a high number of stumps and wood removals due to the practice of chitemene system which involves pollarding of trees leaving stumps to regenerate and elsewhere, the agriculture practice is for complete removal of stumps and their root system through ring-barking and burning of stumps with roots.

Removals were estimated based on stump data and its biomass and carbon were estimated to be removed from all land categories between different year intervals, particularly more from the Forest land category. Most of these removals for both biomass and carbon occurred within 2 to 4 years before the assessment. A similar trend for stump biomass and carbon stock was observed across the provinces.

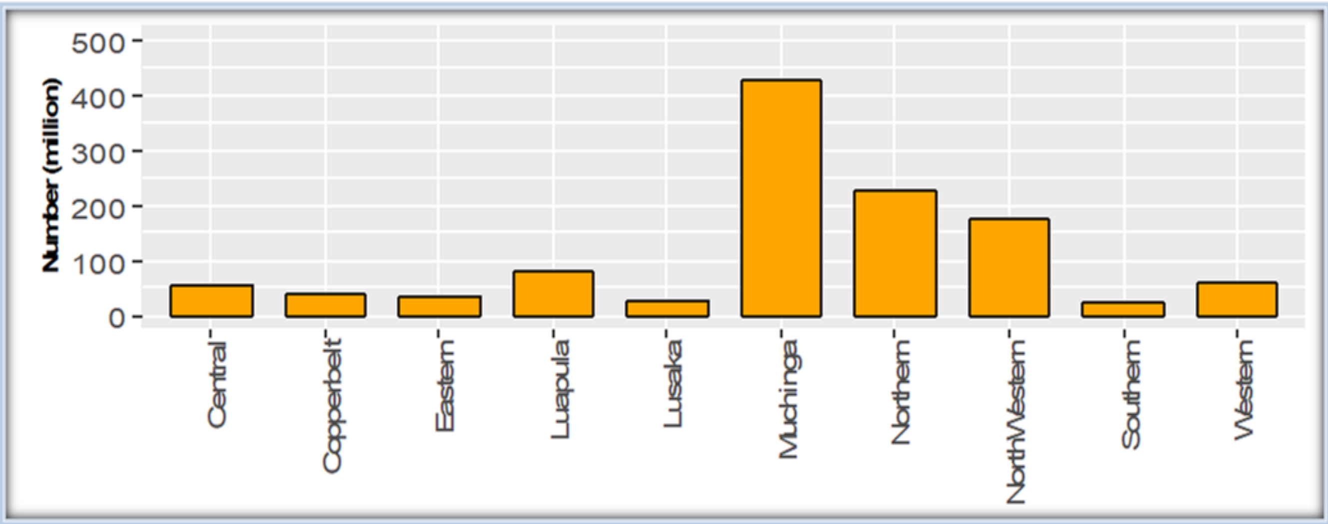



**Figure 9: Number of stumps in the provinces**

### 4.7 Dead wood biomass and carbon stock

Lying dead wood was estimated to contain 107.4 *million tons* of biomass and 52.6 *million tons* of carbon, of which more than 75% were found in Forest land. The major vegetation types (inside forests) contained varying quantities of dead wood. For example, forest plantations were found to have the highest number (density) of dead wood, biomass and carbon stocks, and the lowest was found in the moist evergreen forest class.

However, forest woodland contained by far the highest total biomass (70.1 *million tons*) and carbon (34.4 *million tons*) stocks among all major vegetation types in the country (Table 30).

**Table 30: Biomass and carbon in dead wood by major vegetation types**

| Major vegetation types | Dead wood biomass | | Dead wood carbon | |
|---|---|---|---|---|
| | Tons/ha | Total biomass million tons | Tons/ha | Total carbon million tons |
| 1. Dry evergreen forest | 4.8 | 9.9 | 2.3 | 4.8 |
| 2. Dry deciduous forest | 1.6 | 2.1 | 0.8 | 1.0 |
| 3. Moist evergreen forest | 0.8 | 0.5 | 0.48 | 0.2 |
| 4. Forest woodland | 1.7 | 70.1 | 0.9 | 34.4 |
| 5. Forest plantation | 6.3 | 0.3 | 3.19 | 0.2 |
| Inside forests | 1.9 | 83.0 | 0.99 | 40.6 |
| | | | | |
| 6. Other wooded land | 1.1 | 14.9 | 0.6 | 7.3 |
| 7. Grassland | 0.2 | 0.2 | 0.2 | 0.1 |
| 8. Bare land | 0.3 | 1.4 | 0.1 | 0.7 |
| 9. Cultivated land | 1.0 | 7.9 | 0.5 | 3.9 |
| 10. Build up | 0.3 | 0.1 | 0.1 | 0.0 |
| 11. Other land | - | - | - | - |
| Outside forests | 0.6 | 9.5 | 0.3 | 4.7 |

### 4.8 Extrapolated land area results from sample plots

Land area estimates generated from sample plot extrapolation analysis reviews that 59% of the country is covered by Forest land, 18% is covered by Other wooded-land and 22% is covered by Other land as major forest resource assessment land classes, while surface water is estimated to be 1% (Table 31). These results are an extrapolation and inference of field classifications as observed from the sampled areas and not a holistic aerial view land categorisation.

Therefore, the reported land category area estimates may be hypothetical and concluded to account for areas outside the observations made from the plot locations. The conclusions are purely a logical judgement on the basis of circumstantial evidence from the number of sample plots assessed rather than on the basis of direct observations. It means that these estimates may be subject to greater uncertainty as compared to estimates from wall-to-wall (land-cover mapping) results.

**Table 31: Land areas of major FRA categories**

| FRA class | Area (000 ha) | % of country land area |
|---|---|---|
| 1. Forest land | 44,170 | 59 |
| 2. Other wooded land | 13,219 | 18 |
| 3. Other land | 16,533 | 22 |
| 4. Water | 1,339 | 1 |
| **Zambia** | **75,261** | **100** |

These estimates are dependent on the sample size which has a strong relationship with the sampling error expected in the results. For instance, the overall indicative accuracy for forest land alone is 82% with a standard error estimated to be 1.4% (606,812ha). The sampling error at 95% confidence level is 1.19 *million ha*. The forest inventory sampling errors for all major land area estimates according to provinces are presented in Table 32. The area estimation computations were based on the method by Tomppo and Andersson, FAO, 2008 and Olofsson *et al.* 2014.

**Table 32: Sampling error of major land area estimates at 95% confidence level**

| Province | Forest Land (%) | OWL (%) | Other Land (%) | Water (%) |
|---|---|---|---|---|
| 1. Central | 3.5 | 2.8 | 3.1 | 0.4 |
| 2. Copperbelt | 6.0 | 4.2 | 5.4 | - |
| 3. Eastern | 4.7 | 3.8 | 4.3 | 0.6 |
| 4. Luapula | 4.8 | 4.1 | 3.3 | 2.6 |
| 5. Lusaka | 6.8 | 5.3 | 5.5 | 1.0 |
| 6. Muchinga | 3.4 | 2.8 | 2.4 | 0.5 |
| 7. Northern | 3.7 | 2.9 | 2.9 | 1.7 |
| 8. North-Western | 2.7 | 1.8 | 2.3 | 0.4 |
| 9. Southern | 3.6 | 2.9 | 3.5 | 1.5 |
| 10. Western | 3.0 | 2.4 | 2.6 | 0.4 |
| Zambia | 1.2 | 0.9 | 1.0 | 0.3 |

Sampling error is the difference that arises when using a sample to estimate an unknown population characteristic. There are several factors that determine the amount of error present in a sample and one of the factors is the amount of variation (or differences in magnitudes) in the population. A second factor is the size of the sample which can be adjusted to reduce sampling error and obtain a desired level of precision. Therefore, one method of evaluating the extrapolation precision is to use these estimates in comparison with the mapping results which are expected to be closer to the true value for land areas. This is useful because when we know what the true value is, the extrapolated land area estimates can be compared to it in order to cross check any discrepancies associated. Therefore, extrapolation land area results normally overestimates the true value because of the sampling error reflected in the discrepancy between the sample and population mean.

## 4.9 Other results based on Qualitative analyses

### 4.9.1 Livestock management and grazing in forested land

Domestic animal grazing inside forests is not very common in Zambia as compared to areas outside forests (i.e. other wooded land and other land), with only 4.5% of the Forest area reported as extensively grazed, 21.1% occasionally grazed, 10.5% as frequently grazed and 67.5% of the Forest land reported to have no grazing at all. Similar grazing patterns were observed in all the provinces, with no grazing reported from almost the entire Luapula Province.

Extensive grazing was mainly reported in Southern and Western provinces where there are more stocks of cattle. For instance, communal grazing land was more prevalent in Southern, Western and Central provinces. Fenced, unimproved pastures were more common in Western and Copperbelt provinces, while fenced improved pastures were observed mainly in Central, Southern and Lusaka provinces (Table 33).

**Table 33: Proportion of Forest area used for livestock management**

| Province | Total area (000 ha) | Not applicable (%) | Communal grazing (%) | Fenced unimproved pastures (%) | Fenced Improved pastures (%) | Not Known (%) |
|---|---|---|---|---|---|---|
| 1. Central | 5,641.5 | 57.7 | 35.9 | 0.3 | 2.7 | 3.4 |
| 2. Copperbelt | 1,872.5 | 76.2 | 19.6 | 3.3 | 0.0 | 0.8 |
| 3. Eastern | 2,638.3 | 78.8 | 19.0 | 1.4 | 0.0 | 0.9 |
| 4. Luapula | 2,849.1 | 94.6 | 5.0 | 0.0 | 0.0 | 0.4 |
| 5. Lusaka | 1,651.3 | 82.6 | 15.3 | 1.0 | 1.0 | 0.0 |
| 6. Muchinga | 6,176.6 | 80.8 | 3.6 | 1.0 | 0.0 | 14.7 |
| 7. Northern | 4,440.7 | 75.7 | 6.1 | 0.0 | 0.0 | 18.2 |
| 8. North-Western* | 9,050.2 | - | - | - | - | - |
| 9. Southern | 2,864.6 | 52.8 | 42.5 | 0.0 | 1.8 | 3.0 |
| 10. Western | 6,985.4 | 52.5 | 42.0 | 4.8 | 0.0 | 0.7 |
| Zambia | 44,170.2 | 69.3 | 22.5 | 0.6 | 0.3 | 5.7 |

*Data was not collected for North-western province (*i.e. the protocol was still under review at the time and it was tested there-in*)

### 4.9.2 Forest fires, types and occurrence

Ground (surface) fire was observed as the most common type of fire, burning 84% of total forest area in the country. The proportion of forest area burnt by this type of fire varied from the largest in Muchinga Province to the smallest in Southern Province. Crown fire was rare, burning less than 3% of the forest area and mainly observed in the Baikiaea forests of Western Province. Although sub-terrain fire occurred in all the provinces, it was most common in Lusaka Province. Bush fires range across most of the country in the later dry season, escaping from “cultivated areas” and caused by the local people burning off crop residue or hunting, as well as by lightning strikes. However, the vegetation is adapted to it, particularly the grasses.

### 4.9.3 Stand structure

Forty-five (45%) percent of the vegetation types in Zambia has a two-storey layer of canopy cover, i.e. *miombo* woodland which is characterized by two distinct canopy layers. Only 25% of the Forest land had a stand structure of three layers, while 18% had a single layer. The Forest land in Lusaka Province had more than three-layer vegetation compared to other provinces attributed mainly to high levels of disturbances which trigger spontaneous vegetation succession building multi-storeys of tree canopies. The highest proportion of Forest land (more than 30%) with single-layer vegetation was observed in

Southern province due to extensive and intensive clearing of undergrowth vegetation for Agriculture purposes. Data was not collected in North-Western Province.

### 4.9.4 Shrubs and undergrowth

Undergrowth in the Forest areas across the country was mainly characterized by mixed type of shrubs and different types of grass. Dominant grasses recorded are *Hyperrhenia filipendula*, *H. dissoluta*, *Hyperthelia dissolute*, *Brachiaria brizantha*, *Pogonathria squarrosa*, *Craspedorachis rhodesiana* and *Eragrostis* species.

It was estimated that more than 60% of the forest undergrowth in Copperbelt and Eastern provinces was mainly bushes or shrubs, while in Muchinga, Northern and Central provinces the undergrowth was dominated by grass (at least 30%). New tree shoots (regeneration) was more common in Luapula and Western provinces as compared to other provinces (Table 34).

**Table 34: Proportion of forest areas with shrubs and undergrowth**

| Province | Proportion of forest area (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | No undergrowth | Bushes | Grass | Elephant grass | New tree generation | Mixed | Other vegetation |
| 1. Central | 16 | 6 | 30 | 2 | 7 | 40 | 0 |
| 2. Copperbelt | 14 | 0 | 17 | 1 | 3 | 65 | 0 |
| 3. Eastern | 2 | 1 | 29 | 4 | 2 | 62 | 0 |
| 4. Luapula | 1 | 5 | 28 | 0 | 36 | 30 | 0 |
| 5. Lusaka | 6 | 22 | 25 | 0 | 0 | 45 | 2 |
| 6. Muchinga | 6 | 4 | 37 | 1 | 1 | 50 | 0 |
| 7. Northern | 29 | 4 | 35 | 0 | 0 | 29 | 2 |
| 8. North-Western | 4 | 14 | 9 | 0 | 13 | 20 | 0 |
| 9. Southern | 32 | 7 | 31 | 0 | 6 | 22 | 3 |
| 10. Western | 12 | 10 | 19 | 1 | 36 | 42 | 0 |
| Zambia | 11.6 | 7.9 | 24.6 | 0.9 | 12.3 | 42.1 | 0.6 |

### 4.9.5 Ownership and administration

The forest land/areas in Zambia are either under customary or state land tenure system. This is where all protected areas (i.e. forest reserves, game management areas, national parks, bird sanctuaries, conservancies, and heritage sites) are located. However, some non-protected forest land may be owned under title by individuals, companies, other institutions and local councils though all trees (forests) on such land according to the Forest Act No.4 of 2015, are vested in the hands of the President on behalf of the general public.

Compared to other provinces, a considerable proportion of the Forest land in Central (16%) and Lusaka (10%) provinces were under private ownership. A large proportion of Forest areas in Muchinga, Western and North-western provinces are owned by the State (Table 35).

**Table 35: Forest land ownership**

| Provinces | % of forest area proportion | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No data | Private individuals | Private industries | Other private | Public state | Local government | Communal land | Other |
| 1. Central | 1 | 16 | 0 | 4 | 4 | 3 | 41 | 0 |
| 2. Copperbelt | 2 | 8 | 0 | 2 | 1 | 0 | 54 | 2 |
| 3. Eastern | 0 | 3 | 0 | 0 | 22 | 9 | 65 | 0 |
| 4. Luapula | 0 | 6 | 0 | 3 | 9 | 0 | 79 | 2 |
| 5. Lusaka | 2 | 10 | 0 | 0 | 13 | 4 | 70 | 0 |
| 6. Muchinga | 1 | 4 | 0 | 0 | 30 | 0 | 64 | 0 |
| 7. Northern | 0 | 8 | 0 | 0 | 18 | 0 | 65 | 8 |
| 8. North-western | 6 | 1 | 1 | 1 | 24 | 1 | 66 | 0 |
| 9. Southern | 5 | 3 | 2 | 2 | 16 | 7 | 66 | 0 |
| 10. Western | 0 | 0 | 0 | 0 | 29 | 4 | 67 | 0 |
| Zambia | 1.9 | 5.4 | 0.3 | 0.9 | 24 | 3.1 | 63.3 | 1.1 |

## 4.10 The Land-Cover Mapping Results (2014, 2010 and 2000)

The targeted deliverables for the land cover maps include the spatial analyses by zonal tabular statistics of each land cover class for the respective years; the map accuracies (i.e. overall, user and producer accuracies); errors of ommission and commission; the kappa coefficient, and distribution of forest cover by provinces.

Other results are land cover changes (i.e. using the change matrix) for three epochs: between 2000 and 2010; 2010 and 2014; and finally between 2000 and 2014. The land cover change matrix results provides details on deforestation estimates, associated causes of forest cover changes and the major drivers of deforestation.

### 4.10.1 The 2014 land cover results

The calculated land cover results for the year 2014 shows that: the current forest cover for Zambia is estimated to be 45.94 *million ha* representing 61.04% of the total land area (Table 38). Grasslands is the second largest and covers approximately 16.39 *million ha* (21.78%); followed by Agriculture (cropland) land which is approximately 7.18 *million ha* (9.54%).

Land under wetlands (including water bodies) is approximately 5.08 *million ha* (6.75%), while land under Settlements (rural and urban built-up areas) is approximately 0.50 *million ha* (0.67%), and other land is 0.17 *million ha* (0.22%) respectively (Table 38).

These are the latest and official land cover area estimates for the country generated from remote sensing imagery data for landsat 7. The results are fully supported by the 2014 land cover map for Zambia officially published by Government through the Forestry Department (Figure 10).

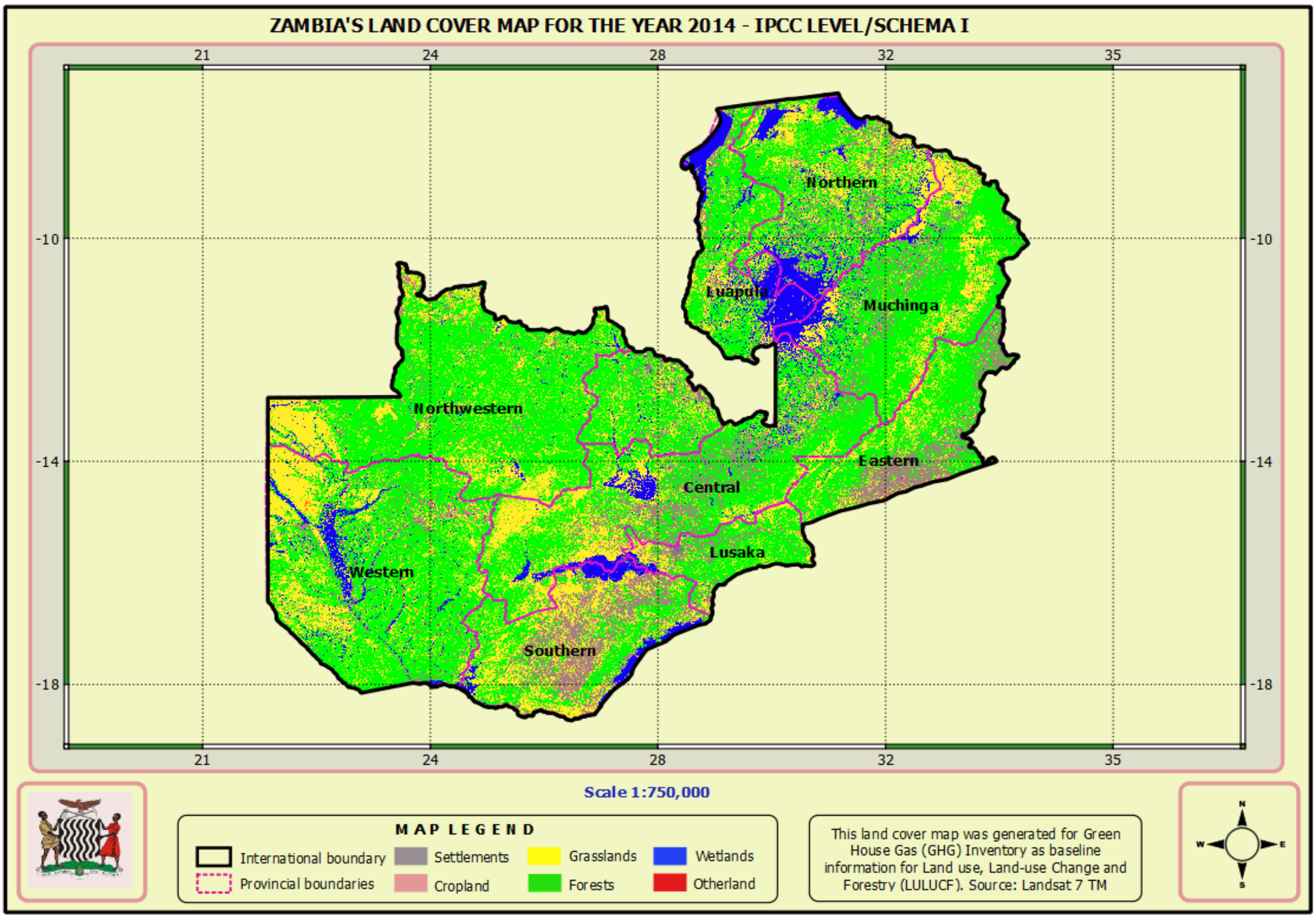



**Figure 10: The 2014 land cover map**

The 2014 land cover map returned an overall accuracy of 87.7%. However, the wetland and cropland classes were problematic due to mixed pixels (*inadequate pixel hygiene*), hence they returned lower producer and user accuracies respectively (Table 36). For instance, the total land area under wetland had 78.5% *producer accuracy* which means that the probability of what was classified as this class had 25% error of omission, while the cropland has an error of commission estimated to be 25.3% against its user accuracy of 74.7% (Table 36).

**Table 36: Accuracy assessment results for the 2014 land cover map**

| 2014 Land Cover Acc. Assessment | | Reference Data | | | | | | Row Total | User Accuracy | Error of Com. % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Settlement | Cropland | Grasslands | Forests | Wetland | Other-land | | | |
| Classified Data | Settlements | 94 | 23 | 0 | 0 | 0 | 3 | 120 | 78.3% | 21.7 |
| | Cropland | 15 | 435 | 90 | 32 | 0 | 10 | 582 | 74.7% | 25.3 |
| | Grasslands | 0 | 0 | 582 | 106 | 25 | 0 | 713 | 81.6% | 18.4 |
| | Forests | 0 | 0 | 11 | 1674 | 39 | 0 | 1724 | 97.1% | 2.9 |
| | Wetland | 0 | 11 | 40 | 11 | 234 | 0 | 296 | 79.1% | 20.9 |
| | Other-land | 7 | 11 | 0 | 0 | 0 | 76 | 94 | 80.9% | 19.1 |
| Column Total | | 116 | 480 | 723 | 1823 | 298 | 89 | 3529 | - | |
| Producer Accuracy | | 81.0% | 90.6% | 80.5% | 91.8% | 78.5% | 85.4% | - | Overall accuracy (87.7%) | |
| Error of Omi. % | | 19.0 | 9.4 | 19.5 | 8.2 | 21.5 | 14.6 | | | |

However, all the classes had better overall Kappa coefficient of 0.85 way above the minimum (*acceptable moderate agreement*) threshold of 0.5. Kappa measures the percentage of data values in the main diagonals in the accuracy assessment table and then adjusts these values for the amount of agreement that could be expected due to chance. The numerator (*produced data*) represents the discrepancy between the observed probability of success and the probability of success under the assumption of an extremely bad case.

**Table 37: Conditional kappa coefficient for each of the 2014 land cover classes**

| Land Class Names | Reference Totals | Classified Totals | Number Correctly classified | Overall Kappa statistics | Interpretations / remarks for Kappa |
|---|---|---|---|---|---|
| 1. Settlements | 116 | 120 | 94 | 0.8097 | very good agreement |
| 2. Agriculture | 480 | 582 | 435 | 0.8714 | very good agreement |
| 3. Grasslands | 723 | 713 | 582 | 0.8231 | very good agreement |
| 4. Forests | 1,823 | 1,724 | 1,674 | 0.8675 | very good agreement |
| 5. Water | 298 | 296 | 234 | 0.8989 | very good agreement |
| 6. Other-land | 89 | 94 | 76 | 0.8019 | very good agreement |
| Column Total | 3,529 | 3,529 | 3,095 | 0.8454 | very good agreement |

The comparative independence for kappa coefficient implies that: if a pair of ratings agrees by 100%, the maximum value for kappa occurs when the observed level of agreement is equal to 1, which makes the produced data (*enumerator*) to be as good as the reference data (*denominator*). Therefore, the 2014 land cover map is a nationally acceptable dataset to be used for GHG inventroy, sustainable forest management (SFM) application and as the latest land cover baseline data for the country. The following land cover class areas were calculated from ArcMap 10.5 using spatial zonal statistics (Table 38).

**Table 38: Land cover area distribution in the year 2014 by province**

| Name of Province | Settlements (Built-up) | Cropland Area (Ha) | Grassland Area (Ha) | Forest land Area (Ha) | Wetland Area (Ha) | Other land Area (Ha) | Total land Area (Ha) |
|---|---|---|---|---|---|---|---|
| 1. Central | 54,642 | 1,922,366 | 2,366,248 | 5,701,471 | 954,208 | 4,009 | 11,002,944 |
| 2. Copperbelt | 44,720 | 534,864 | 573,383 | 1,896,348 | 77,208 | 6,316 | 3,132,839 |
| 3. Eastern | 43,343 | 1,058,636 | 363,508 | 3,599,412 | 24,559 | 8,129 | 5,097,587 |
| 4. Luapula | 46,231 | 461,644 | 838,800 | 3,269,517 | 434,426 | 6,290 | 5,056,908 |
| 5. Lusaka | 44,651 | 459,080 | 611,473 | 1,409,189 | 21,023 | 5,329 | 2,550,745 |
| 6. Muchinga | 44,098 | 592,434 | 970,021 | 6,359,200 | 704378 | 10,465 | 8,680,596 |
| 7. Northern | 43,955 | 748,691 | 1,848,767 | 4,277,891 | 756,745 | 6,699 | 7,682,748 |
| 8. Northwestern | 54,701 | 283,015 | 2,788,981 | 8,833,712 | 589,098 | 33,130 | 12,582,637 |
| 9. Southern | 85,464 | 930,931 | 1,423,026 | 3,756,345 | 635,322 | 4,728 | 6,835,816 |
| 10. Western | 39,853 | 191,235 | 4,605,976 | 6,840,231 | 880,659 | 80,626 | 12,638,580 |
| TOTAL | 501,658 | 7,182,896 | 16,390,183 | 45,943,316 | 5,077,626 | 165,721 | 75,261,400 |

Meanwhile, the largest forest cover is located in North-western province which represents 19.23% of total forest cover for the year under review and the lowest is located under Lusaka province which represents 3.07%. The second largest forest cover is located in Western province estimated at 14.89%, followed by Muchinga Province which returned 13.84%, Central 12.41%, Northern 9.31%, Southern 8.18%, Eastern 7.83%, Luapula 7.12%, and the Copperbelt province has 4.13% of the total forest cover (Table 39).

**Table 39: Forest cover distribution by province based on 2014 land cover map**

| Name of Province | Total land area (ha) | Forest cover (ha) | % Proportion of forest cover | |
|---|---|---|---|---|
| | | | of country forest cover | of provincial area |
| 1. Central | 11,002,944 | 5,701,471 | 12.41 | 51.82 |
| 2. Copperbelt | 3,132,839 | 1,896,348 | 4.13 | 60.53 |
| 3. Eastern | 5,097,587 | 3,599,412 | 7.83 | 70.61 |
| 4. Luapula | 5,056,908 | 3,269,517 | 7.12 | 64.65 |
| 5. Lusaka | 2,550,745 | 1,409,189 | 3.07 | 55.25 |
| 6. Muchinga | 8,680,596 | 6,359,200 | 13.84 | 73.26 |
| 7. Northern | 7,682,748 | 4,277,891 | 9.31 | 55.68 |
| 8. Northwestern | 12,582,637 | 8,833,712 | 19.23 | 70.21 |
| 9. Southern | 6,835,816 | 3,756,345 | 8.18 | 54.95 |
| 10. Western | 12,638,580 | 6,840,231 | 14.89 | 54.12 |
| TOTAL | 75,261,400 | 45,943,316 | 100.0 | - |

However, Muchinga Province still has the largest forest cover extent representing 73.26% of its total land area as compared to Central province which has the least forest cover estimated at 51.82% of its total land area. This is true for Central Province because of national circumstances related to extensive agriculture activities which have over the years converted large tracts of forests into permanent agriculture land. Coincidentally, Central Province which is currently the biggest province in Zambia has the largest established farming blocks with regular commercial and relatively larger peasant farms that are almost inter-connecting its districts from Itezhi-tezhi up to Serenje. The farming blocks are located in Mumbwa, Mkushi and Serenje districts.

### 4.10.2 The 2010 land cover results

The 2010 land cover results shows that total forest cover was the largest and estimated to be 46.69 *million ha* representing 62.05% of the total land area of Zambia (Table 42). The land cover under Grasslands was the second largest and covers approximately 16.37 *million ha* (21.76%); followed by Agriculture (cropland) land which was approximately 6.75 *million ha* (8.96%); land under wetlands (including water bodies) was approximately 5.09 *million ha* (6.77%), while land under Settlements (rural and urban built-up areas) was approximately 0.21 *million ha* (0.28%), and other land was 0.14 *million ha* (0.19%). The data was processed and generated from land remote sensing satellite (landsat) data for 2010, and the results are supported by the 2010 land cover map for Zambia officially published by Government through the Forestry Department (Figure 11).

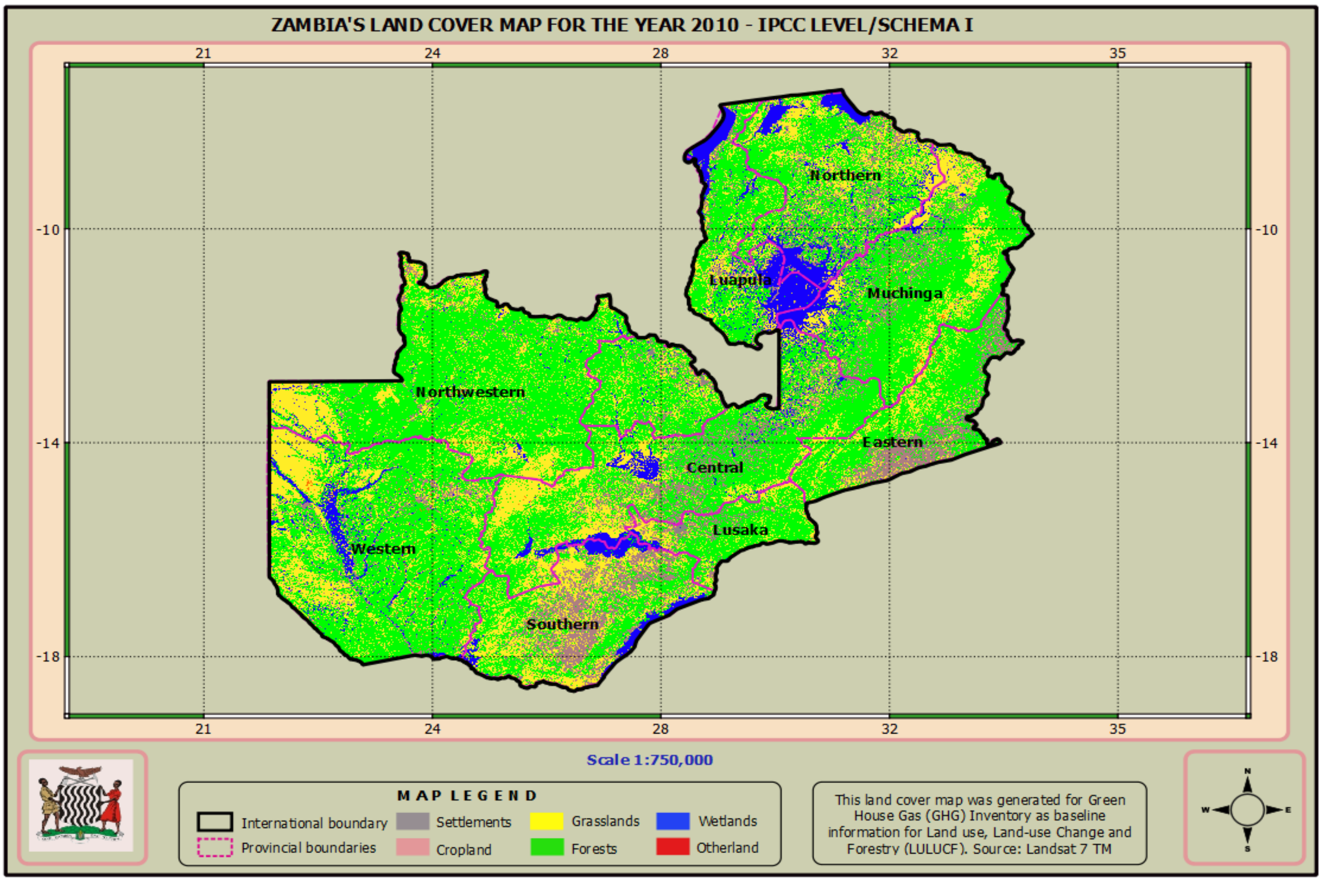



**Figure 11: The 2010 land cover map**

The 2010 land cover map returned an overall accuracy of 85.6%. However, the cropland cover returned a relatively lower producer and user accuracies (Table 40). For instance, its producer accuracy was estimated to be 79.1% which means that the probability of what was classified as this class had approximately 21% error of omission, while the error of commission is estimated to be 25.9% against its user accuracy of 74.1% (Table 40). Overall, the 2010 land cover map was better than for the other years because the collection of data for ground truthing and the reference data was done within 2 years of the satellite data acquisition.

**Table 40: Accuracy Assessment Results for 2010 land cover map**

| 2010 Land cover Acc. Assessment | | Reference Data | | | | | | Row Total | User Accuracy | Error of Com. % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Settlement | Cropland | Grasslands | Forests | Wetland | Other land | | | |
| Classified Data | Settlements | 56 | 1 | 0 | 0 | 1 | 0 | 58 | 96.6% | 3.4 |
| | Cropland | 5 | 337 | 45 | 67 | 0 | 1 | 455 | 74.1% | 25.9 |
| | Grasslands | 0 | 34 | 480 | 63 | 20 | 0 | 597 | 80.4% | 19.6 |
| | Forests | 0 | 52 | 72 | 1099 | 13 | 0 | 1236 | 88.9% | 11.1 |
| | Wetland | 0 | 2 | 4 | 6 | 327 | 0 | 339 | 96.5% | 3.5 |
| | Other-land | 0 | 0 | 2 | 0 | 0 | 13 | 15 | 86.7% | 13.3 |
| Column Total | | 61 | 426 | 603 | 1235 | 361 | 14 | 2700 | - | |
| Producer Accuracy | | 91.8% | 79.1% | 79.6% | 89.0% | 90.6% | 92.9% | - | Overall accuracy (85.6%) | |
| Error of Omi. % | | 8.2 | 20.9 | 20.4 | 11.0 | 9.4 | 7.1 | | | |

Generally, all the land cover classes had better overall Kappa coefficient of 0.83 way above the minimum (*acceptable moderate agreement*) threshold of 0.5. However, the kappa coefficient for other land was relative lower (0.79) as compared to the rest of the land cover classes, but still has good chance of statistical agreement.

**Table 41: Conditional kappa coefficient for each of the 2010 land cover classes**

| Land Class Names | Reference Totals | Classified Totals | Number Correctly classified | Overall Kappa statistics | Interpretations / remarks for Kappa |
|---|---|---|---|---|---|
| 7. Settlements | 61 | 58 | 56 | 0.8397 | very good agreement |
| 8. Agriculture | 426 | 455 | 337 | 0.8182 | very good agreement |
| 9. Grasslands | 603 | 597 | 480 | 0.8231 | very good agreement |
| 10. Forests | 1,235 | 1,236 | 1,099 | 0.8095 | very good agreement |
| 11. Water | 361 | 339 | 327 | 0.8721 | very good agreement |
| 12. Other-land | 14 | 15 | 13 | 0.7983 | good agreement |
| Column total | 2,700 | 2,700 | 2,312 | 0.8268 | very good agreement |

Based on map accuracies in Table 40, the 2010 land cover map was upheld as a good product acceptable to be used as a national reference dataset for GHG inventroy, sustainable forest management (SFM) application and to guide the implementation of REDD+ related activities because it returned a relatively higher level of classification confidence. The 2010 land cover map was the input map dataset used to develop and plan for the national sampling frame for the biophysical assessment and for the forest livelihood and economic survey (FLES) during the planning phase of the integrated land use assessment (ILUAII) project. It was also the quality control dataset that supported the final production of the 2000 and 2014 land cover maps. The following land cover areas were calculated from ArcMap 10.5 using spatial zonal statistics (Table 42).

**Table 42: Land cover area distribution in the year 2010 by province**

| Name of Province | Settlements (Built-up) | Cropland Area (Ha) | Grassland Area (Ha) | Forest land Area (Ha) | Wetland Area (Ha) | Other land Area (Ha) | Total land Area (Ha) |
|---|---|---|---|---|---|---|---|
| 1. Central | 25,435 | 1,891,666 | 2,351,527 | 5,959,915 | 772,565 | 1,836 | 11,002,944 |
| 2. Copperbelt | 15,291 | 491,939 | 571,108 | 1,949,123 | 101,234 | 4,144 | 3,132,839 |
| 3. Eastern | 12,823 | 1,024,085 | 397,293 | 3,614,115 | 43,314 | 5,956 | 5,097,586 |
| 4. Luapula | 15,049 | 411,971 | 845,027 | 3,286,495 | 494,249 | 4,117 | 5,056,908 |
| 5. Lusaka | 15,211 | 486,921 | 612,201 | 1,412,234 | 21,023 | 3,155 | 2,550,745 |
| 6. Muchinga | 13,946 | 544,621 | 973,358 | 6,383,372 | 757,007 | 8,292 | 8,680,596 |
| 7. Northern | 13,784 | 701,041 | 1,851,960 | 4,289,187 | 832,250 | 4,526 | 7,692,748 |
| 8. Northwestern | 27,691 | 232,291 | 2,792,084 | 9,052,223 | 447,388 | 30,960 | 12,582,637 |
| 9. Southern | 58,907 | 823,943 | 1,364,844 | 3,770,178 | 805,391 | 2,553 | 6,825,816 |
| 10. Western | 10,209 | 136,602 | 4,615,624 | 6,979,332 | 818,360 | 78,453 | 12,638,580 |
| Total | 208,346 | 6,745,080 | 16,375,028 | 46,696,174 | 5,092,781 | 143,991 | 75,261,400 |

Meanwhile, the largest forest cover was in North-western Province which represents 19.4% of total forest cover and the lowest was under Lusaka Province which represents 3.0%. The second largest forest cover was located in Western Province estimated at 15.0%, followed by Muchinga Province at 13.7%, Central 12.8%, Northern 9.2%, Southern 8.1%, Eastern 7.7%, Luapula 7.0%, and the Copperbelt Province had 3.0% of the total forest cover (Table 43).

**Table 43: Forest cover distribution by province based on 2010 land cover map**

| Name of Province | Total land area (ha) | Forest cover (ha) | % Proportion of forest cover | |
|---|---|---|---|---|
| | | | of country forest cover | of provincial area |
| 1. Central | 11,002,944 | 5,959,915 | 12.76 | 54.17 |
| 2. Copperbelt | 3,132,839 | 1,949,123 | 4.17 | 62.22 |
| 3. Eastern | 5,097,587 | 3,614,115 | 7.74 | 70.90 |
| 4. Luapula | 5,056,908 | 3,286,495 | 7.04 | 64.99 |
| 5. Lusaka | 2,550,745 | 1,412,234 | 3.02 | 55.37 |
| 6. Muchinga | 8,680,596 | 6,383,372 | 13.67 | 73.54 |
| 7. Northern | 7,682,748 | 4,289,187 | 9.19 | 55.83 |
| 8. Northwestern | 12,582,637 | 9,052,223 | 19.39 | 71.94 |
| 9. Southern | 6,835,816 | 3,770,178 | 8.07 | 55.15 |
| 10. Western | 12,638,580 | 6,979,332 | 14.95 | 55.22 |
| Total | 75,261,400 | 46,696,174 | 100.0 | - |

However, Muchinga Province had the largest forest cover extent representing 73.54% of its total land area as compared to Central Province which had the least estimated at 54.17% of its total land area. Northern Province had 71.94% of forest cover against its total land area, followed by Eastern Province which had 70.90%, Luapula 64.99%, Copperbelt 62.22%, Northern 55.83%, Lusaka 55.37%, Western 55.22% and Southern Province had 55.15% of forest cover against its total land area (Table 43).

### 4.10.3 The 2000 land cover results

The 2000 land cover results shows that total forest cover was the largest and estimated to be 47.05 *million ha* representing 62.52% of the total land area of Zambia (Table 46). The land cover under Grasslands was the second largest covering approximately 16.43 *million ha* (21.8%); followed by Agriculture (cropland) land which was approximately 6.47 *million ha* (8.59%); land under wetlands (including water bodies) was approximately 5.04 *million ha* (6.70%), while land under Settlements (rural and urban built-up areas) was approximately 0.14 *million ha* (0.18%), and other land was 0.14 *million ha* (0.18%).

The data was generated from remote sensing (landsat) products for the year 2000 and and the results are supported by the 2000 land cover map for Zambia officially published by Government through the Forestry Department (Figure 12). Meanwhile, all land cover maps used in this report are avaliable on the national forestry monitoring system (NFMS) web-portal ([www.zmb-nfms.org/portal](www.zmb-nfms.org/portal)) for download as *pdf* map files and for online viewing by interested parties.

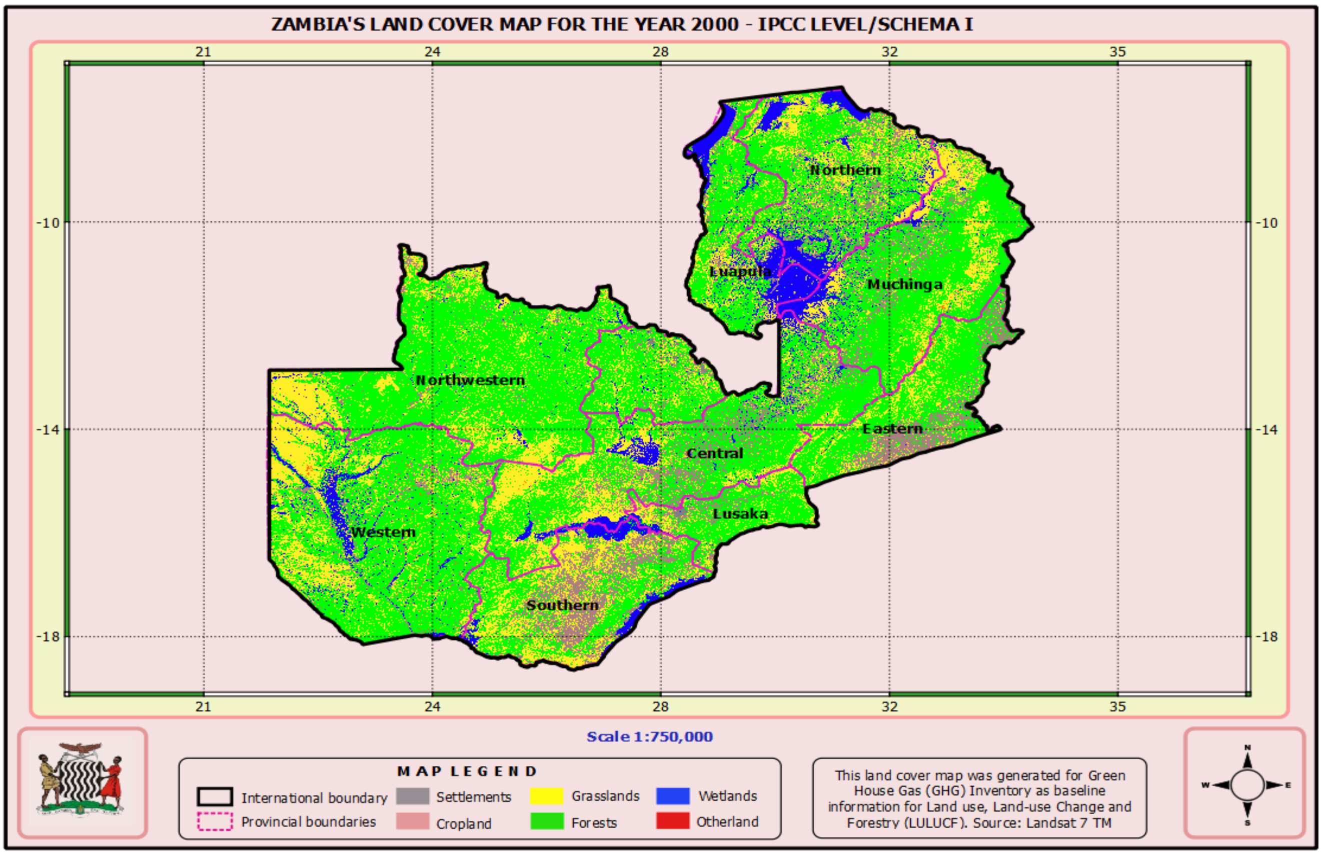



**Figure 12: The 2000 land cover map**

The 2000 land cover map returned an overall accuracy of 89.05%. However, the cropland cover returned a lower producer accuracies (Table 44). Its producer accuracy was estimated to be 73.4% which means that the probability of what was classified as this class had approximately 26.6% error of omission. Overall, the user accuracy for all classes was far much better because it confirms the likelihood that a pixel classified as a certain class actually represents that same class in the map.

**Table 44: Accuracy assessment results for 2000 land cover map**

| 2000 Land Cover Acc. Assessment | | Reference Data | | | | | | Row Total | User Accuracy | Error of Com. % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Settlement | Cropland | Grasslands | Forests | Wetland | Other land | | | |
| Classified Data | Settlements | 5 | 0 | 0 | 0 | 0 | 0 | 5 | 100.0% | 0.0 |
| | Cropland | 0 | 105 | 8 | 0 | 0 | 1 | 114 | 92.1% | 7.9 |
| | Grasslands | 0 | 21 | 482 | 23 | 5 | 0 | 531 | 90.8% | 9.2 |
| | Forests | 0 | 15 | 70 | 626 | 8 | 0 | 719 | 87.1% | 12.9 |
| | Wetland | 0 | 2 | 7 | 1 | 87 | 0 | 97 | 89.7% | 10.3 |
| | Other-land | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 100.0% | 0.0 |
| Column Total | | 5 | 143 | 567 | 650 | 100 | 5 | 1470 | - | |
| Producer Accuracy | | 100.0% | 73.4% | 85.0% | 96.3% | 87.0% | 80.0% | - | Overall accuracy (89.05%) | |
| Error of Omi. % | | 0.0 | 26.6 | 15.0 | 3.7 | 13.0 | 20.0 | | | |

However, almost all the classes had better overall Kappa coefficient of 0.83 way above the minimum (*acceptable moderate agreement*) threshold of 0.5. Comparatively, the other-land class was slightly weaker than the rest of the land cover classes though it had a good chance of statistical agreement rate at 0.75 (Table 45).

**Table 45: Conditional kappa coefficient for each of the 2000 land cover classes**

| Land Class Names | Reference Totals | Classified Totals | Number Correct | Overall Kappa statistics | Possible Interpretation / Remarks of Kappa |
|---|---|---|---|---|---|
| 1. Settlements | 5 | 5 | 5 | 0.8061 | very good agreement |
| 2. Agriculture | 143 | 114 | 105 | 0.8126 | very good agreement |
| 3. Grasslands | 567 | 531 | 482 | 0.8368 | very good agreement |
| 4. Forests | 650 | 719 | 626 | 0.8488 | very good agreement |
| 5. Water | 100 | 97 | 87 | 0.8972 | very good agreement |
| 6. Other-land | 5 | 4 | 4 | 0.7556 | good agreement |
| Column Total | 1470 | 1470 | 1309 | 0.8262 | very good agreement |

Based on map accuracies above, the 2000 land cover map is a good and nationally acceptable product to be used for GHG inventroy, sustainable forest management (SFM) and for REDD+ related activities because it returned a reasonably higher level of classification confidence. The following land cover class areas were calculated from ArcMap 10.5 using spatial zonal statistics (Table 46).

**Table 46: Land cover area distribution in the year 2000 by province**

| Name of Province | Settlements (Built-up) | Cropland Area (Ha) | Grassland Area (Ha) | Forest land Area (Ha) | Wetland Area (Ha) | Other land Area (Ha) | Total land Area (Ha) |
|---|---|---|---|---|---|---|---|
| 1. Central | 18,201 | 1,849,733 | 2,237,988 | 6,123,456 | 772,565 | 1,001 | 11,002,944 |
| 2. Copperbelt | 8,278 | 462,230 | 538,826 | 2,018,962 | 101,234 | 3,309 | 3,132,839 |
| 3. Eastern | 6,902 | 986,001 | 443,028 | 3,613,221 | 43,314 | 5,121 | 5,097,587 |
| 4. Luapula | 9,790 | 389,010 | 854,906 | 3,305,671 | 494,249 | 3,282 | 5,056,908 |
| 5. Lusaka | 8,210 | 460,202 | 643,077 | 1,415,912 | 21,023 | 2,321 | 2,550,745 |
| 6. Muchinga | 7,657 | 519,800 | 999,027 | 6,389,648 | 757,007 | 7,457 | 8,680,596 |
| 7. Northern | 7,513 | 676,057 | 1,895,048 | 4,298,113 | 802,325 | 3,692 | 7,682,748 |
| 8. Northwestern | 18,259 | 210,381 | 2,760,652 | 9,115,834 | 447,388 | 30,123 | 12,582,637 |
| 9. Southern | 49,023 | 794,541 | 1,403,843 | 3,781,349 | 805,341 | 1,719 | 6,835,816 |
| 10. Western | 3,412 | 118,600 | 4,649,942 | 6,991,982 | 797,026 | 77,618 | 12,638,580 |
| Total | 137,245 | 6,466,555 | 16,426,337 | 47,054,148 | 5,041,472 | 135,643 | 75,261,400 |

Meanwhile, the largest forest cover was in North-western province which represents 19.37% of total forest cover and the lowest is under Lusaka province which represents 3.01%. The second largest forest cover is located in Western province estimated at 14.86%, followed by Muchinga province at 13.58%, Central 13.01%, Northern 9.13%, Southern 8.04%, Eastern 7.68%, Luapula 7.03%, and the Copperbelt province has 4.29% of forest cover against the total land area of the country (Table 47).

**Table 47: Forest cover distribution by province based on 2000 land cover map**

| Name of Province | Total land area (ha) | Forest cover (ha) | % Proportion of forest cover | |
|---|---|---|---|---|
| | | | of country forest cover | of provincial area |
| 1. Central | 11,002,944 | 6,123,456 | 13.01 | 55.65 |
| 2. Copperbelt | 3,132,839 | 2,018,962 | 4.29 | 64.45 |
| 3. Eastern | 5,097,587 | 3,613,221 | 7.68 | 70.88 |
| 4. Luapula | 5,056,908 | 3,305,671 | 7.03 | 65.37 |
| 5. Lusaka | 2,550,745 | 1,415,912 | 3.01 | 55.51 |
| 6. Muchinga | 8,680,596 | 6,389,648 | 13.58 | 73.61 |
| 7. Northern | 7,682,748 | 4,298,113 | 9.13 | 55.94 |
| 8. Northwestern | 12,582,637 | 9,115,834 | 19.37 | 72.45 |
| 9. Southern | 6,835,816 | 3,781,349 | 8.04 | 55.32 |
| 10. Western | 12,638,580 | 6,991,982 | 14.86 | 55.32 |
| Total | 75,261,400 | 47,054,148 | 100.0 | - |

However, Muchinga province had the largest forest cover extent representing 73.61% of its total land area as compared to Southern and Western provinces each have the least forest cover extents estimated at 55.32% of their respective total land areas. North-western province had 72.45% of forest cover against its total land area, followed by Eastern province which had 70.88%, Luapula 65.37%, Copperbelt 64.45%, Northern 55.94%, Central 55.65%, and Lusaka has 55.51% of forest cover against its total land area.

**Table 48: The land cover map area and percentage estimates for 2000, 2010 and 2014**

| Land cover Classes | Land area in ,000 ha | | | Land area in % | | |
|---|---|---|---|---|---|---|
| | Yr. 2000 | Yr. 2010 | Yr. 2014 | Yr. 2000 | Yr. 2010 | Yr. 2014 |
| 1. Settlement | 137 | 208 | 502 | 0.18 | 0.28 | 0.67 |
| 2. Cropland | 6,467 | 6,745 | 7,183 | 8.59 | 8.96 | 9.54 |
| 3. Grassland | 16,426 | 16,375 | 16,390 | 21.83 | 21.76 | 21.78 |
| 4. Forests | 47,054 | 46,696 | 45,943 | 62.52 | 62.05 | 61.04 |
| 5. Wetlands | 5,041 | 5,093 | 5,078 | 6.70 | 6.77 | 6.75 |
| 6. Other land | 136 | 144 | 166 | 0.18 | 0.19 | 0.22 |
| Total | 75,261 | 75,261 | 75,261 | 100.00 | 100.00 | 100.00 |

### 4.10.4 Land cover changes between 2000 and 2014

The land cover results between 2000 and 2014 indicates some significant changes though the major proportion of the land is still under forests. The analysis reveals that the total forest cover and the area under grasslands decreased by -1.48% (from 47,054 *million ha* in 2000 to 45,943 *million ha* in 2014) and it decreased by -0.05% (from 16,426 *million ha* in 2000 to 16,390 *million ha* in 2014) respectively (Figure 13). The decrease in these land cover classes is attributed mainly to human encroachments related to different livelihood (anthropogenic) activities. For instance, Agriculture (cropland) land which is the main stay increased by 0.95% from 6,467 *million ha* in 2000 to 7,183 *million ha* in 2014, land under Settlements increased by 0.48% from 0.137 *million ha* in 2000 to 0.502 *million ha* in 2014, while the Wetlands and Otherland which include major economic activities such as water developments and open pit quarries for the mines increased by 0.05% from 5,041 *million ha* in 2000 to 5,078 *million ha* in 2014 and 0.04% from 0.136 *million ha* in 2000 to 0.144 *million ha* in 2014 respectively (Figure 13).

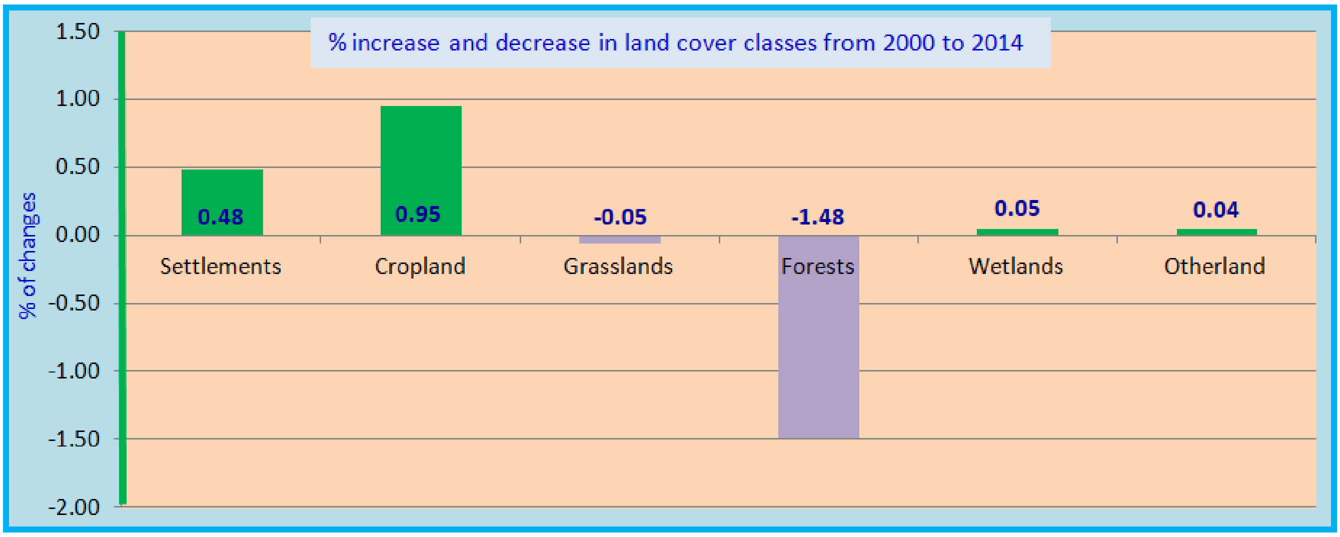



**Figure 13: Percentage wise area increase/decrease between 2000 and 2014**

The area increase in some land cover extents is mainly attributed to additions from land conversion practices into settlements and agriculture land, including the increased demand for land to be used for other social developmental activities. In order to spatially track and identify the drivers of all land cover changes (i.e. decrease and increase), a change matrix analysis was performed. Therefore, the change matrix information in Tabe 49 clearly shows where the physical changes may have occured within the land cover classes, thereby, indicating the potential drivers of deforestation and other land encraochments, and to what magnitude each driver is responsible for the observed changes.

The change matrix shows that only land under forests and grasslands negatively (reduced) changed to either agriculture, settlements, wetlands and otherland in different proportions. The opening and closing stocks is an account of how much land cover was generated in 2000 and 2014 respectively, while the grand total which is exactly the same as the opening stock is the sum of the correctly classified classes and observed changes attributed to other class in a row (Table 49).

Unlike in the accuracy assessment tables, the diagnals are for values of the land cover classes that remained unchanged as classified in the opening stock (*i.e. the land cover classes for 2000*). However, the values for in the diagnals are affected by any conversions corresponding to the values for the closing stock (*i.e. the land cover area estimates for 2014*), to which all possible changes detected over the years are added in order to generate the current (closing stock) land cover area estimates (Table 49). The change matrix outputs (statistics) are an automated products from a GIS software and helps to track all changes over the years.

**Table 49: Land cover change matrix between 2000 and 2014**

| Land cover categories | Opening stock (ha) | Settlements 2014 (ha) | Cropland 2014 (ha) | Grasslands 2014 (ha) | Forests 2014 (ha) | Wetlands 2014 (ha) | Other land 2014 (ha) | Closing stock (ha) | Grand total (ha) |
|---|---|---|---|---|---|---|---|---|---|
| 1. Settlements (2000) | 137 | 137 | - | - | - | - | - | 502 | 137 |
| 2. Cropland (2000) | 6,467 | - | 6,467 | - | - | - | - | 7,183 | 6,467 |
| 3. Grasslands (2000) | 16,426 | - | 2 | 16,390 | - | 27 | 7 | 16,390 | 16,426 |
| 4. Forests (2000) | 47,054 | 364 | 714 | - | 45,943 | 9 | 23 | 45,943 | 47,054 |
| 5. Wetlands (2000) | 5,041 | - | - | - | - | 5,041 | - | 5,078 | 5,041 |
| 6. Otherland (2000) | 136 | - | - | - | - | - | 136 | 166 | 136 |
| Grand Total | 75,261 | 502 | 7,183 | 16,390 | 45,943 | 5,078 | 166 | 75,261 | 75,261 |
| **Note:** the land cover area estimates are expressed in thousand (,000) hectares | | | | | | | | | |

### 4.10.5 Direct drivers of deforestation based on the land cover maps

The land conversion statistics from these land cover maps points to potential drivers of deforestation which are best explained by a combination of factors rather than by single causation. Therefore, the act of clearing forest land and, later converting it to other land use, is rooted in a set of complex social economic, cultural and enviromental realities.

However, the observed land cover changes between 2000 to 2014 are considered as the proximate (direct) drivers of deforestation and these are: Agriculture expansion which accounts for 60.78% of forest cover loss, Settlement expansion accounts for 36.05% of forest cover loss, Otherland expansion accounts for 2.28% of forest cover loss, while the increase in wetland (water developments) accounts for 0.89% of forest cover loss (Table 50).

Similarly, these drivers are also responsible for land encroachments in grasslands where Agriculture land growth accounts for 5.47%, Otherland expansion accounts for 19.31% of the Grassland encroachment, while the increase in Wetland (water developments) area accounts for 75.21% of the Grassland reduction (Table 50). Generally, grasslands are more prone to encroachment especially for agriculture due to soil fertility, though the biggest proportion is related to water development for irrigation and other purposes.

**Table 50: Proximate drivers of deforestation and their related land conversions**

| Proximate (direct) drivers of deforestation | Land conversion from forests | | Land conversion from grasslands | | Total converted land area in ha |
|---|---|---|---|---|---|
| | land area in ha | % | land area in ha | % | |
| 1. Agriculture expansion | 714,363 | 60.78 | 1,978 | 5.47 | 716,341 |
| 2. Settlements expansion | 364,413 | 36.05 | - | - | 364,413 |
| 3. Other-land expansion | 23,095 | 2.28 | 6,983 | 19.31 | 30,078 |
| 4. Wetland (water development) | 8,961 | 0.89 | 27,193 | 75.21 | 36,154 |
| Total | 1,110,832 | 100.0 | 34,176 | 100.00 | 1,146,986 |

The land cover maps for the years 2000, 2010 and 2014, shows that human activities related to land use, land-use change and forests (LULUCF) reduced the forest cover from 47.07 *million* hectares (*ha*) in 2000 to 45.94 *million* hectares (*ha*) in 2014. Therefore, the total forest cover lost is estimated to be 1.11 *million ha* (1,110 $km^2$) representing an annualized forest cover loss (deforestation) of 79,345 *ha per annum* (0.17%) based on a geographic (arithmetic) mean over the period of 14 years (Table 51). However, the weighted annualized loss based on pixel counts indicates a maximum of 149,876 *ha per annum* (0.32%) over the period of 14 years. Therefore, Zambia's current official deforestation rate is estimated to be between 79,000 and 150,000 *ha per year*. This rate of deforestation may be relatively moderate, but shows a sharp rise of forest loss in the recent past and calls for sustainable forest management (SFM) interventions.

**Table 51: Annualized deforestation rate data based on the map statistics**

| Name of province | Forested area (ha) 2000 | Forested area (ha) 2010 | Forested area (ha) 2014 | Total loss (ha for 14 years) | Arithmetic mean (∑X) ha |
|---|---|---|---|---|---|
| 1. Central | 6,123,456 | 5,959,915 | 5,701,471 | 421,985 | 30,142 |
| 2. Copperbelt | 2,018,962 | 1,949,123 | 1,896,348 | 122,614 | 8,758 |
| 3. Eastern | 3,613,221 | 3,614,115 | 3,599,412 | 13,809 | 986 |
| 4. Luapula | 3,305,671 | 3,286,495 | 3,269,517 | 36,154 | 2,582 |
| 5. Lusaka | 1,415,912 | 1,412,234 | 1,409,189 | 6,723 | 480 |
| 6. Muchinga | 6,389,648 | 6,383,372 | 6,359,200 | 30,448 | 2,175 |
| 7. Northern | 4,298,113 | 4,289,187 | 4,277,891 | 20,222 | 1,444 |
| 8. North-western | 9,115,834 | 9,052,223 | 8,833,712 | 282,122 | 20,152 |
| 9. Southern | 3,781,349 | 3,770,178 | 3,756,345 | 25,004 | 1,786 |
| 10. Western | 6,991,982 | 6,979,332 | 6,840,231 | 151,751 | 10,839 |
| Total | 47,054,148 | 46,696,174 | 45,943,316 | 1,110,832 | 79,345 |

The land cover results explained under *Chapter 4.9* of this report provides technical guidance for the status quo on the official forestry statistics to be quoted for national reporting related to area extents for land under settlements, cropland (agriculture), grasslands, forested land, wetland and other areas/land in Zambia.

However, for international reporting (particularly to the UNFCCC) the Forest Reference Emission Level (FREL) report of 2015 for Zambia reported a higher deforestation rate which made the use of the Stratified Area Estimator method and shows that the weighted deforestation rate is averaging 276,021 *ha per annum*. These results were calculated using a method that seeks to correct for bias found in all statistical-based classifications and was recommended as a good practice through the Global Forest Observation Initiatives Methods and Guidance Documentation (GFOI, 2013). In addition, the adjusted area method takes guidance from Olofsson *et al.* (2014) who outline the merits of accuracy-based area corrections.

### 4.11 Forest livelihood and Economic Survey (FLES) Results

These results are based on sample level data which was weighted to a total number of 2,510,713 households (Census 2010 data were used for weighting). It was estimated that out of the total weighted number of households, 88.3 % were carrying out forest-based livelihood activities in low cover forests, followed by 9.1 % in medium cover forests and lastly 2.7% in high cover forest.

Over 1,285,800 (50%) of total households across the country collected forest products for consumption. Meanwhile, 38% acquired these products through bartering or buying, 9% collected forest products for sale, and 1% of the households acquired forest products through other means (Table 52).

**Table 52: Number of households collecting forest products by forest strata**

| Category | Stratum 1 (≥70% forest cover) | | Stratum 2 (30 – 70% forest cover) | | Stratum 3 (≤30% forest cover) | | Total |
|---|---|---|---|---|---|---|---|
| | Number of households | Pro-portion (%) | Number of households | Proportion (%) | Number of households | Proportion (%) | |
| 1. For sale only | 11,354.4 | 5.1 | 32,214.7 | 14.5 | 178,419.2 | 80.4 | 221,988 |
| 2. Consumption | 54,210.4 | 4.2 | 187,438.4 | 14.6 | 1,044,160.4 | 81.2 | 1,285,809 |
| 3. Bartering | 1,530.0 | 0.2 | 7,359.9 | 0.8 | 957,196.3 | 99.1 | 966,086 |
| 4. Other | 24.6 | 0.07 | 233.1 | 0.6 | 36,571.3 | 99.3 | 36,828 |
| Zambia | 67,119.3 | 2.7 | 227,246.1 | 9.1 | 2,216,347.2 | 88.3 | 2,510,712 |

#### 4.11.1 Land holding by households

Table 53 shows the distribution of land holding per province. A total of 5,499,870 hectares of land is held by households and of these, Central Province dominated (33%), followed by Southern Province (14%) and the least was Luapula province (1%). The average land holding area varied across provinces. Central Province recorded the highest average land holding of 7.56 *ha per household*, followed by Lusaka Province with 4.39 *ha per household*. The lowest average land holdings in Zambia were in Luapula Province (1.79 *ha per household*) and Northern Province (1.0 *ha per household*) (Table 53).

**Table 53: Land holding by households across provinces**

| Province | Number of households | Land holding area (ha) | % of total land held | Weighted average land holding per household (ha) |
|---|---|---|---|---|
| 1. Central | 239,318 | 1,808,659 | 33 | 7.56 |
| 2. Copperbelt | 141,195 | 285,600 | 5 | 2.02 |
| 3. Eastern | 382,056 | 920,242 | 17 | 2.41 |
| 4. Luapula | 44,415 | 79,317 | 1 | 1.79 |
| 5. Lusaka | 133,427 | 585,585 | 11 | 4.39 |
| 6. Muchinga | 144,271 | 434,597 | 8 | 3.01 |

| Province | Number of households | Land holding area (ha) | % of total land held | Weighted average land holding per household (ha) |
|---|---|---|---|---|
| 7. Northern | 198,858 | 198,558 | 4 | 1.00 |
| 8. North-Western | 53,077 | 109,394 | 2 | 2.06 |
| 9. Southern | 219,841 | 746,330 | 14 | 3.39 |
| 10. Western | 90,278 | 331,588 | 6 | 3.67 |
| Zambia | 1,646,736 | 5,499,870 | 100 | 3.34 |

There was an inequality in terms of land holding with regards to gender. On national average, males held more land (3.72 *ha per man*) than females (1.99 *ha per female*), and the status was the same across the provinces (Figure 27). Most of such land is located in areas with less than 30% forest cover.

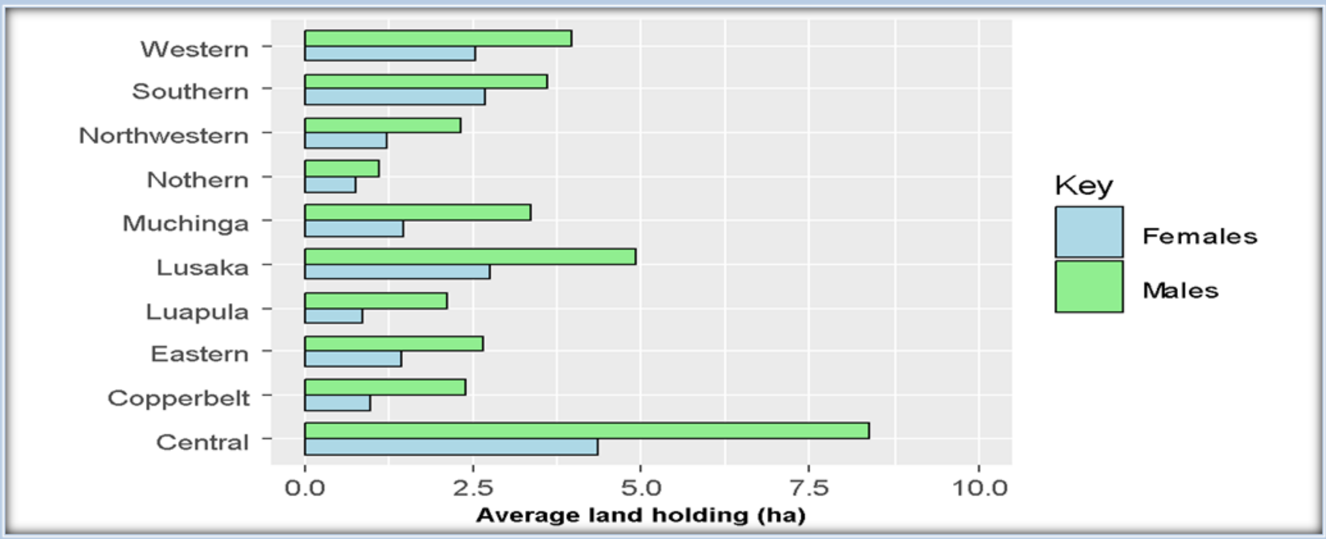
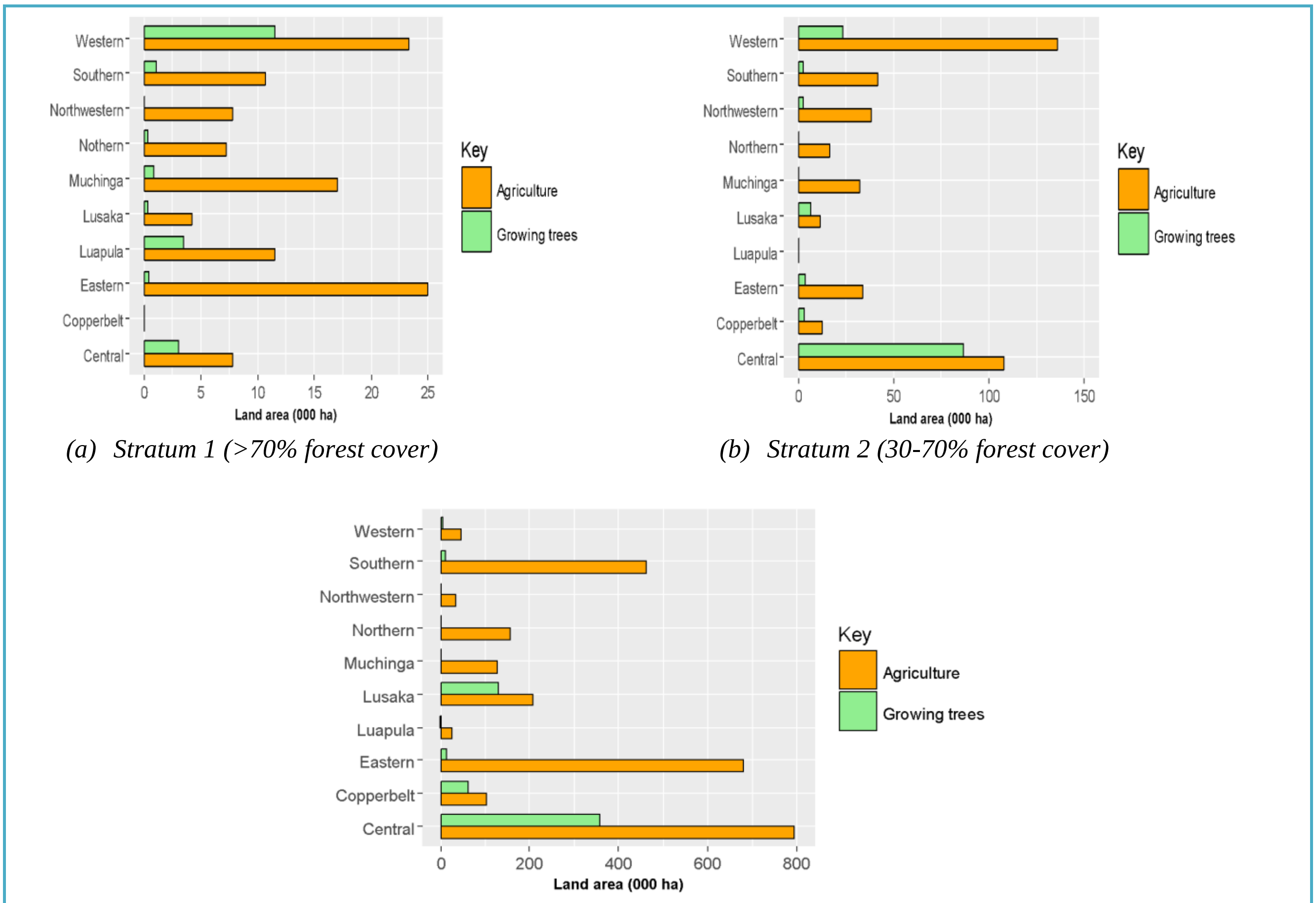



**Figure 14: Average land-holding per household by gender across province**

The number of households reporting land used for growing trees was highest in Central Province (39.6%) and lowest in North-Western Province (0.6%). Land used for growing trees at household level in Zambia was estimated at 729,412 ha.

Land used by households for agriculture cultivation in the country was estimated at 3,176,677 *ha*, out of which Central Province had over 900,000 *ha* (26%), followed by Eastern Province at 737,000 *ha* (23%), then Southern Province at 513,000 *ha* (16%) and the least was Luapula Province with 35,700 ha (1%). The distribution of land used for growing trees and agriculture across the provinces is presented in Figure 15.




(a) *Stratum 1 (>70% forest cover)*

(b) *Stratum 2 (30-70% forest cover)*

(c) *Stratum 3 (<30% forest cover)*

**Figure 15: Land used for growing trees and agriculture across provinces**

### 4.11.2 Land user rights

User rights were quantified using customary and state land tenure categories. There were more men (34%) having land rights in the country compared to women (21%). However, those having joint rights were in the majority (35%). Estimates for different rights held to state land at national level were equally dominated by men (4%) and joint ownership (4%). This inequality was spread across all provinces in Zambia, with Northern Province having the highest number of men with land rights to customary land. The only exception was in Muchinga Province, where the difference was marginal (Table 40).

**Table 54: Land rights by gender across provinces**

| Province | Number of households | Customary Land | | | State land | | |
|---|---|---|---|---|---|---|---|
| | | Men (%) | Women (%) | Joint (%) | Men (%) | Women (%) | Joint (%) |
| 1. Central | 243,727 | 33.5 | 21 | 38 | 3 | 2 | 2 |
| 2. Copperbelt | 134,367 | 16.8 | 18 | 22 | 23 | 10 | 11 |
| 3. Eastern | 379,885 | 47.2 | 17 | 35 | 0 | 0 | 0 |
| 4. Luapula | 43,164 | 21.1 | 33 | 45 | 0 | 0 | 0 |

| Province | Number of households | Customary Land | | | State land | | |
|---|---|---|---|---|---|---|---|
| | | Men (%) | Women (%) | Joint (%) | Men (%) | Women (%) | Joint (%) |
| 5. Lusaka | 110,515 | 30.8 | 11 | 21 | 17 | 6 | 14 |
| 6. Muchinga | 135,906 | 4.1 | 3 | 81 | 2 | 1 | 8 |
| 7. Northern | 200,645 | 59.9 | 35 | 5 | 0 | 0 | 0 |
| 8. North-Western | 56,647 | 15.3 | 19 | 65 | 0 | 0 | 0 |
| 9. Southern | 205,383 | 19.3 | 24 | 45 | 3 | 1 | 8 |
| 10. Western | 106,686 | 44.9 | 31 | 24 | 0 | 0 | 0 |
| Zambia | 1,616,926 | 33.9 | 21 | 35 | 4 | 2 | 4 |

## 4.12 Forest products and services

Focus group interviews during the biophysical assessment revealed that non-wood forest products (NWFP) and wood products constituted a large proportion of area used for the collection of all forest products, accounting for 88% and 63% respectively, regardless of whether the products were from Forest Land, Other Wooded Land or Other Land (Figure 29). Although forests may provide many benefits and services, few such benefits and services were recorded during the current biophysical assessment.

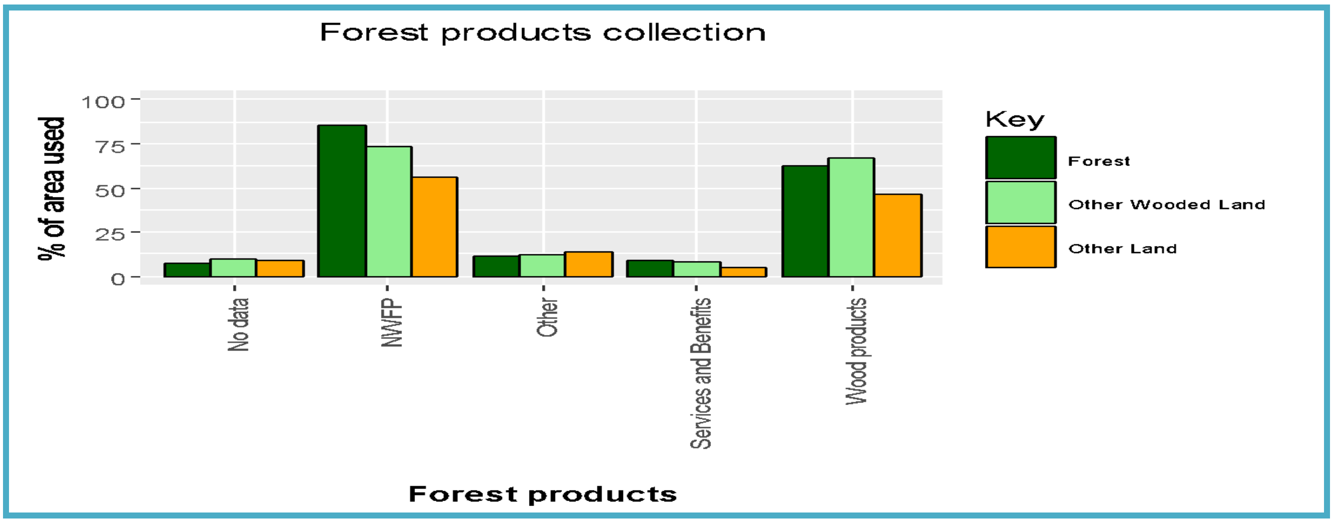



**Figure 16: Proportion of area used for forest products**

### 4.12.1 Wood forest products (WFPs)

Most of the responses obtained from focus group interviews and plot assessments indicated that the perception of forest area used for collection of wood products were mainly from other wooded land as well as Forest area.

The percentage of area used for fuel wood collection was reported to be the highest for all land classes, followed by the area used for industrial wood such as saw-log and pole production. Interestingly, it was established that the proportion of area used for charcoal production constituted less than 5% for across all land classes (Figure 17).

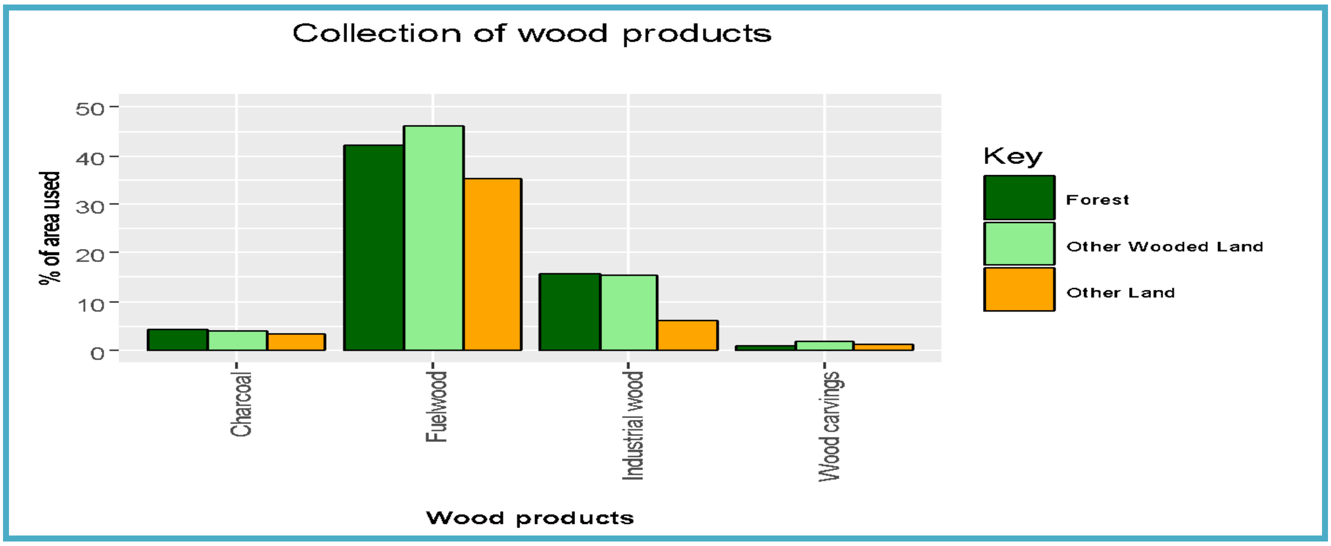



**Figure 17: Proportion of area recorded by wood products**

It was established in the biophysical assessment that Lusaka Province had the highest proportion of area used for industrial wood, followed by Western Province (32.7%). While Southern Province recorded the highest proportion for fuelwood, Muchinga Province recorded the highest for charcoal. Although the land area used for wood carvings was quite insignificant in most provinces, Western Province recorded the highest proportion (Table 55).

**Table 55: Proportion of area used for wood forest products by province**

| Province | Proportion of land used for wood forest products (%) | | | |
|---|---|---|---|---|
| | Industrial wood | Fuelwood | Charcoal | Wood carvings |
| Central | 14.8 | 48.6 | 3.1 | 0.8 |
| Copperbelt | 4.0 | 45.0 | 5.6 | 0.2 |
| Eastern | 15.7 | 44.5 | 3.6 | 0.4 |
| Luapula | 8.8 | 44.8 | 9.7 | 0.0 |
| Lusaka | 47.9 | 28.4 | 5.1 | 0.0 |
| Muchinga | 9.3 | 43.2 | 11.2 | 1.0 |
| Northern | 16.2 | 36.9 | 4.3 | 0.4 |
| North-Western | 4.7 | 39.0 | 0.9 | 0.2 |
| Southern | 23.7 | 57.5 | 1.2 | 0.6 |
| Western | 32.7 | 37.6 | 2.3 | 2.3 |
| Zambia | 13.5 | 41.4 | 4.1 | 1.0 |

### 4.12.2 Industrial round wood

Of the households involved in various economic activities, 39.1% reported collecting industrial round wood from the primary forest, 33% from the secondary forests and 7.3% from cultivated land. It was estimated that 100% of households in Northern and Western provinces obtained industrial round wood from primary forests, while 100% of households in Luapula, Muchinga and Eastern Province obtained the product only from secondary forests (Table 56).

**Table 56: Households collecting industrial round wood by province**

| Province | Number of households | Primary forest (%) | Secondary forest (%) | Cultivated land (%) |
|---|---|---|---|---|
| Central | 10,326 | 48.3 | 36.1 | 15.7 |
| Copperbelt* | - | - | - | - |
| Eastern | 3,339 | 0 | 100.0 | 0 |
| Luapula | 123 | 0 | 100.0 | 0 |
| Lusaka | 664 | 90.4 | 9.6 | 0 |
| Muchinga | 1,560 | 0 | 100.0 | 0 |
| Northern | 2,858 | 100.0 | 0 | 0 |
| North-Western | 69 | 49.6 | 50.4 | 0 |
| Southern | 3,023 | 2.0 | 98.0 | 0 |
| Western | 77 | 100.0 | 0 | 0 |
| Zambia | 22,038 | 39.1 | 53.6 | 7.3 |
| *no data was collected | | | | |

### 4.12.3 Fuelwood

The highest proportions of households collecting fuelwood from primary forests were in Copperbelt (93.9%) and Western (93.7%) provinces, with the lowest being reported in Eastern Province (21.7%). The main source of fuelwood in Muchinga Province was from secondary forests (Table 57).

**Table 57: Households collecting fuelwood by land use across provinces**

| Province | Number of house-holds | Primary forest (%) | Secondary forest (%) | Forest plantation (%) | Grassland (%) | Cultivated land (%) | Village, built-up area (%) |
|---|---|---|---|---|---|---|---|
| 1. Central | 204,019 | 54.4 | 44.3 | 0.1 | 0 | 1.0 | 0.2 |
| 2. Copperbelt | 109,941 | 93.9 | 5.8 | 0.2 | 0 | 0 | 0.1 |
| 3. Eastern | 372,486 | 21.7 | 77.9 | 0.4 | 0 | 0 | 0 |
| 4. Luapula | 22,778 | 95.7 | 4.1 | 0 | 0.2 | 0 | 0 |
| 5. Lusaka | 54,907 | 48.0 | 33.1 | 0.1 | 0 | 14.2 | 4.6 |
| 6. Muchinga | 111,697 | 22.0 | 75.7 | 0.3 | 0 | 2.0 | 0 |
| 7. Northern | 186,443 | 68.2 | 29.0 | 2.9 | 0 | 0 | 0 |
| 8. Northwestern | 49,647 | 69.6 | 21.0 | 9.4 | 0 | 0 | 0 |
| 9. Southern | 168,331 | 80.1 | 5.9 | 4.9 | 9.1 | 0 | 0 |
| 10. Western | 81,792 | 93.7 | 3.3 | 0 | 0.3 | 2.4 | 0.3 |
| Zambia | 1,362,042 | 54.4 | 41.7 | 1.5 | 1.1 | 1.0 | 0.2 |

### 4.12.4 Charcoal

Primary forests are the major source of wood charcoal production and collection. It was estimated that 73% of households in the country produced charcoal from primary forests, while 23% collected or produced this product from secondary forests. Only 2.2% were using forest plantations as a source of charcoal production (Table 47). Estimates also showed that 97.3% of households in Luapula Province produced charcoal from primary forests, thereby constituting the highest in this category, followed by households in Copperbelt Province (95.3%). Households in Muchinga Province produced charcoal mainly from secondary forests (Table 58).

**Table 58: Households collecting or producing charcoal across provinces**

| Province | Number of households | Primary forest (%) | Secondary forest (%) | Forest plantation (%) | Cultivated land (%) | Other (%) |
|---|---|---|---|---|---|---|
| Central | 24,203 | 76.6 | 16.7 | 0.0 | 6.7 | 0 |
| Copperbelt | 37,698 | 95.3 | 2.9 | 1.8 | 0.0 | 0 |
| Eastern | 1,697 | 41.7 | 51.0 | 1.7 | 5.6 | 0 |
| Luapula | 17,271 | 97.3 | 2.7 | 0 | 0 | 0 |
| Lusaka | 7,135 | 73.0 | 24.3 | 0 | 0 | 2.7 |
| Muchinga | 14,791 | 6.2 | 93.8 | 0 | 0 | 0 |
| Northern | 24,124 | 64.3 | 24.8 | 10.9 | 0 | 0 |
| North-Western | 4,093 | 92.8 | 7.2 | 0 | 0 | 0 |
| Southern | 21,982 | 67.4 | 32.6 | 0 | 0 | 0 |
| Western | 225 | 93.3 | 6.7 | 0 | 0 | 0 |
| Zambia | 153,218 | 73.4 | 23.2 | 2.2 | 1.1 | 0.1 |

## 4.13 Non-wood forest products (NWFPs)

More than 11 non-wood forest products (NWFPs) recorded during the biophysical assessment were observed in the Forest and Other Wooded Land classes. Wild fruits were the most dominant NWFP, collected from more than 50% of the Forest area and at least 40% of the area in Other Wooded Land. Mushrooms, plant medicines and wildlife were also among the most important NWFP observed (Figure 18). Others are plant medicines, caterpillars, and bee keeping products and their bye-products, rattan, fibres and some fodder.

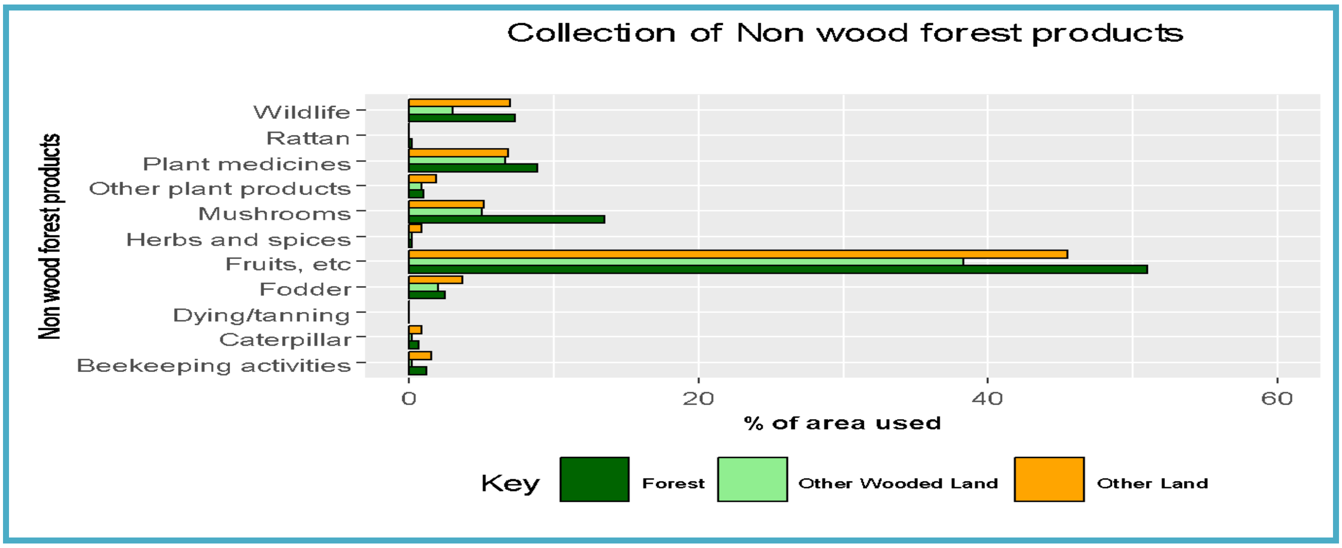



**Figure 18: Proportion of area used for non-wood forest products**

Luapula Province had the largest proportion (67.8%) of Forest area used for wild fruits, nuts and berries, while Northern and North-Western provinces recorded the highest for mushrooms. Fodder for animals, herbs or spices, wildlife and rattan were not commonly observed during the assessment. However, these products were relatively higher in Southern Province compared to other provinces. Lusaka and Copperbelt provinces recorded the highest for beekeeping activities (Table 59).

**Table 59: Proportion of areas used for non-wood forest products by province**

| Province | Proportion of forest areas for non-wood forest products (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fruit, nuts, berries etc. | Mush-room | Fod-der | Rattan | Plant medi-cine | Herbs & spices | Wild-life | Bee keeping | Cater-pillar |
| Central | 63.8 | 9.5 | 0.3 | 0.0 | 6.5 | 0.0 | 2.0 | 0.3 | 0.0 |
| Copperbelt | 23.6 | 15.3 | 2.9 | 0.0 | 6.5 | 0.0 | 2.4 | 4.0 | 1.6 |
| Eastern | 33.4 | 6.4 | 2.5 | 0.0 | 15.1 | 0.0 | 9.8 | 2.2 | 0.0 |
| Luapula | 67.8 | 17.0 | 1.2 | 0.0 | 3.7 | 0.0 | 0.8 | 0.4 | 0.4 |
| Lusaka | 50.1 | 9.0 | 1.0 | 0.0 | 5.1 | 0.0 | 10.2 | 4.1 | 0.0 |
| Muchinga | 40.1 | 19.0 | 4.6 | 0.3 | 5.9 | 0.0 | 12.2 | 0.3 | 1.3 |
| Northern | 55.4 | 24.6 | 0.0 | 0.0 | 2.0 | 0.8 | 7.0 | 0.4 | 0.0 |
| North-Western | 58.8 | 20.7 | 1.9 | 0.0 | 1.9 | 0.3 | 11.2 | 2.3 | 0.0 |
| Southern | 29.8 | 1.2 | 5.9 | 0.5 | 18.0 | 0.6 | 18.3 | 0.0 | 0.0 |
| Western | 52.9 | 2.3 | 4.1 | 0.2 | 23.8 | 0.0 | 0.0 | 0.9 | 1.9 |
| Zambia | 47.1 | 10.1 | 2.6 | 0.1 | 7.9 | 0.3 | 0.0 | 1.1 | 6.2 |

### 4.13.1 Collection of NWFPs by households

There were various NWFPs collected by households from primary, secondary and wooded land in Zambia. These included mushrooms, edible wild fruits, roots, tubers and bulbs, fibre, caterpillars, plant medicines, honey and fodder. Over 42% of households collected mushrooms, which constituted the highest collected NWFPs, followed by 29% of households who collected fruits and other edible wild roots, tubers and bulbs. Households that collected fibre for ropes were at 8% and those collecting caterpillars were at 7% (Figure 19).

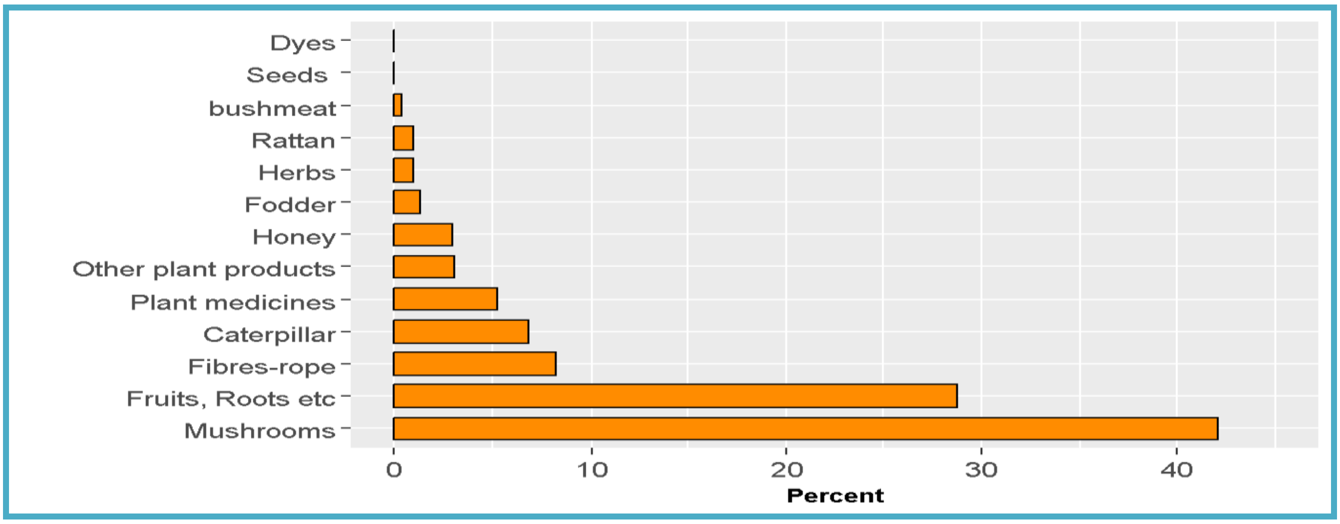
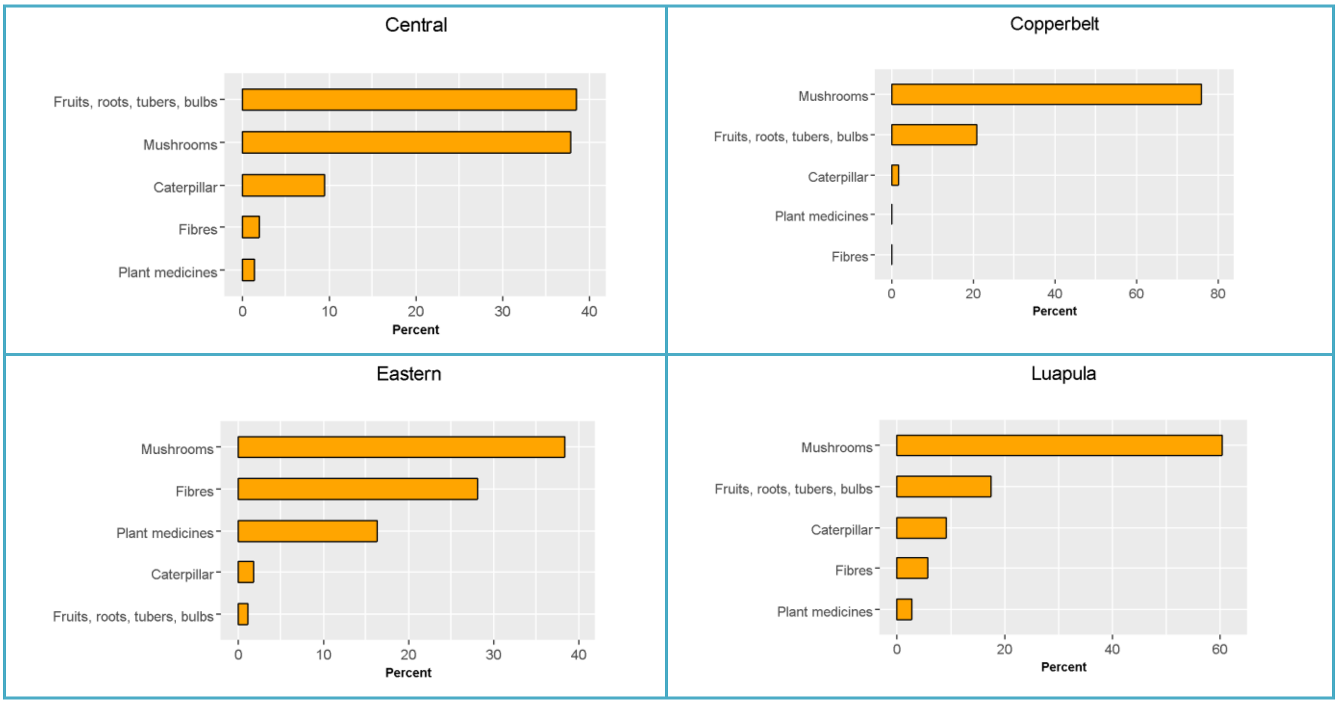



**Figure 19: Ranking of non-wood forest products collected by households**

The top five NWFPs collected in 2015 included mushrooms, fruits, nuts, seeds, berries, roots, tubers, plant medicines, honey and fibre ropes, while their distribution varied across provinces. Fruits, roots, tubers and bulbs were dominant in Central, Northern and Western provinces, while mushrooms were the most abundant NWFP in the other provinces (Figure 20).



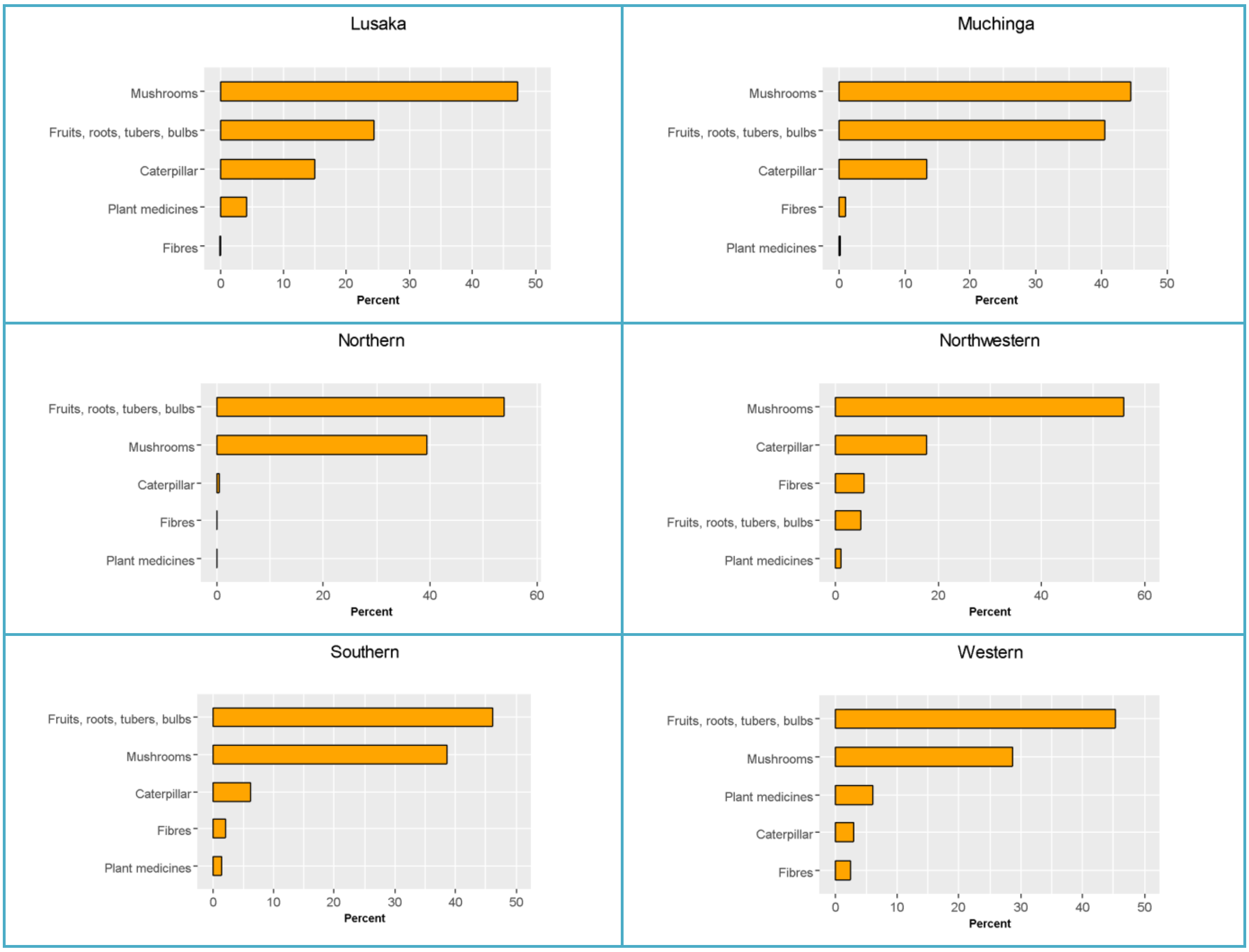



**Figure 20: Ranking of non-wood forest products collected across provinces**

## 4.14 Access to forests and availability of forest products

The link between the biophysical assessment of forest products and services was the household survey under FLES. According to the responses obtained, the number of households collecting forest products from different land categories was highest in Central Province (95%), followed by the number of households in Western Province (82%). The variation across provinces by land categories is shown in Table 60.

**Table 60: Number of households collecting forest products from different land categories**

| Province | Number of households | Family land (%) | Customary land (%) | State Land (%) | Lease land (%) | Other Places (%) |
|---|---|---|---|---|---|---|
| 1. Central | 213,857 | 95 | 5 | 0 | 0 | 0 |
| 2. Copperbelt | 110,322 | 72 | 11 | 10 | 3 | 4 |
| 3. Eastern | 369,128 | 47 | 53 | 0 | 0 | 0 |
| 4. Luapula | 26,817 | 71 | 26 | 3 | 0 | 0 |
| 5. Lusaka | 47,918 | 61 | 31 | 8 | 0 | 0 |
| 6. Muchinga | 107,151 | 50 | 48 | 2 | 0 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7. Northern | 212,311 | 39 | 55 | 5 | 0 | 0 |
| 8. North-Western | 61,978 | 65 | 34 | 1 | 0 | 0 |
| 9. Southern | 197,463 | 50 | 44 | 6 | 0 | 0 |
| 10. Western | 91,945 | 82 | 16 | 2 | 0 | 0 |
| Zambia | 1,438,890 | 59 | 37 | 3 | 0 | 0 |

### 4.14.1 Average distance to collection sites

The average distance to the forest collection areas, reported by households, varied across provinces. Households in Eastern Province covered longer distances (5.7 km) to collect forest products than those in Southern (1.7 km) and North-Western (1.99 km) provinces. This variation may be attributed to the differences in terrain (Figure 21).

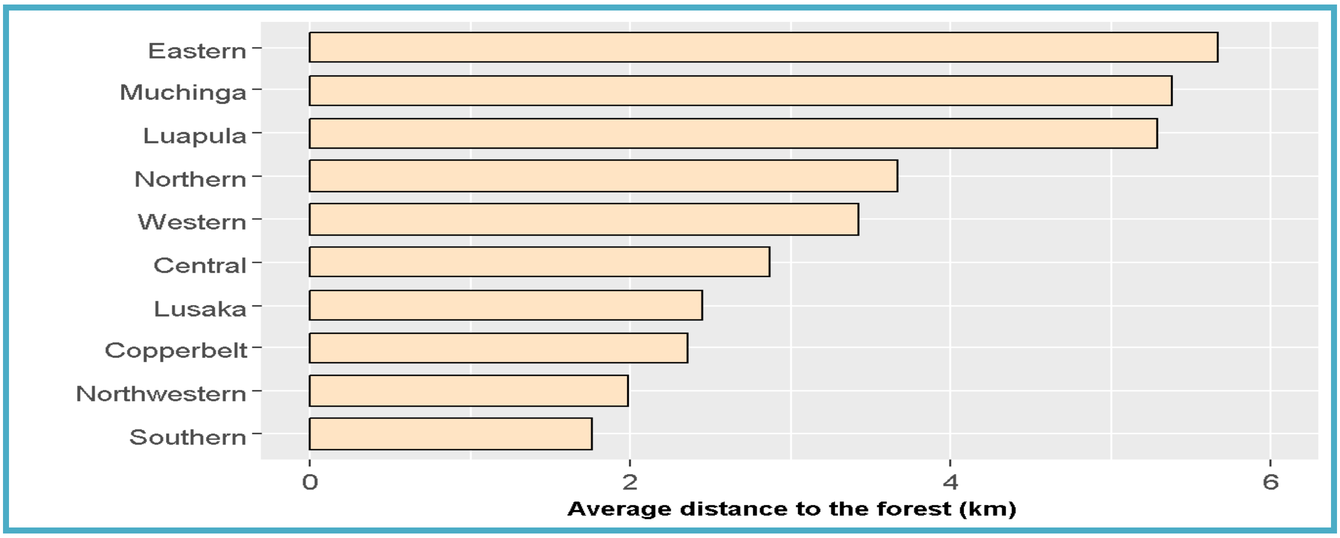



**Figure 21: Average distance to the forest collection area across provinces**

Table 61 shows the distance covered to collect the top ten forest products in Zambia. The longest distance covered (44.5 km) was recorded in Southern Province for the collection of wood poles, followed by Lusaka Province for charcoal and wood carvings, and Eastern Province for industrial round wood. The longest distances reported for the collection of non-wood forest products were in Southern Province for plant medicines (17.1 km), North-Western Province for bush meat (12.0 km), Luapula Province for rattan (6.0 km) and Central Province for honey (10.8 km).

**Table 61: Top ten forest products with longest distance for collection by province**

| Forest product | Average distance (km) | Province |
|---|---|---|
| 1. Wood for poles | 44.5 | Southern |
| 2. Charcoal | 24.5 | Lusaka |
| 3. Wood for wood carvings | 20.5 | Lusaka |
| 4. Plant medicines | 17.1 | Southern |
| 5. Industrial wood | 12.0 | Eastern |
| 6. Wildlife (including bush meat) | 12.0 | North-Western |

| Forest product | Average distance (km) | Province |
|---|---|---|
| 7. Beekeeping activities (e.g. Honey | 10.8 | Central |
| 8. Fuelwood | 8.1 | Copperbelt |
| 9. Caterpillar | 6.5 | Eastern |
| 10. Rattan | 6.0 | Luapula |

### 4.15 Forest clearing by households

Estimates showed that over 6.7% of households reported clearing forests from all forest types. Overall, 28.2% practiced selective tree cutting while 65% did not cut any trees in 2015 (Figure 22). Most tree cutting was recorded in low cover forests. This means that much of the tree regenerations (especially saplings) are highly susceptible to tree cutting by households for various uses that include: poles for building houses, clearance of trees in fallow land for subsistent agriculture.

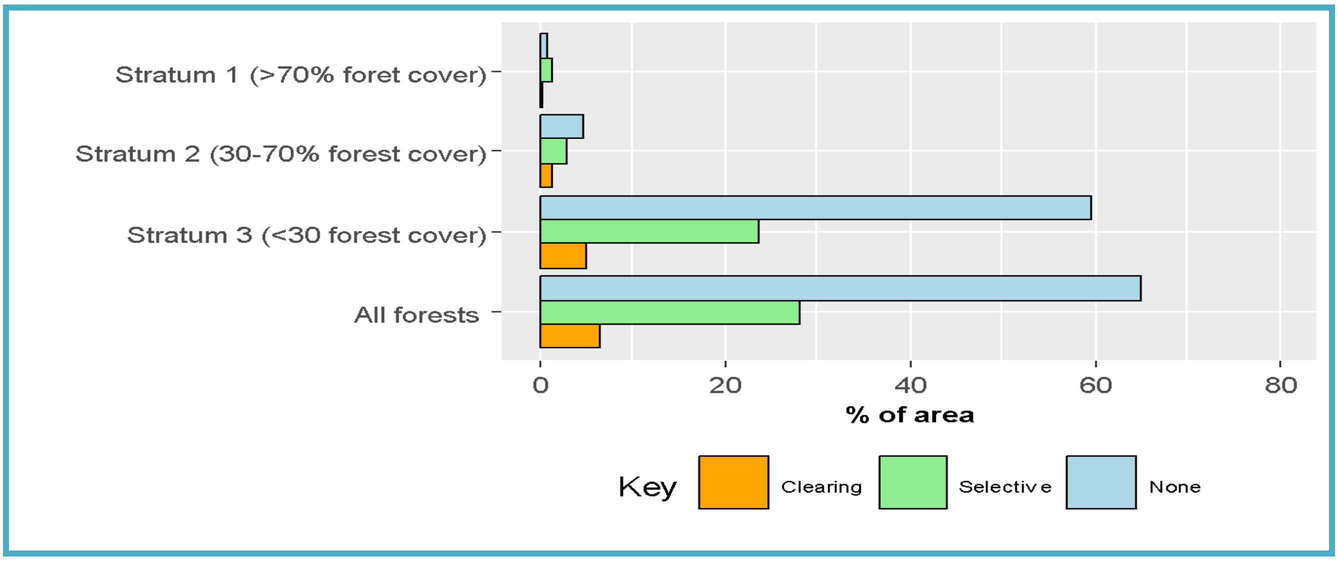



**Figure 22: Forest clearing by forest strata or cover**

The highest proportion of households (23.6%) involved in forest clearing was in Central Province and the lowest in Copperbelt Province (0.8%). The second highest proportion of households involved in forest clearing is in Northwestern Province which recorded 14.1%, Western 12.6%, Muchinga 8.7%, Eastern 6.8%, Luapula 4.5%, Southern 4.2%, Northern 3.4%, and Lusaka 1.6% (Table 62).

**Table 62: Households cutting trees during the last 12 months across provinces**

| Province | Number of households | Forest clearing (%) | Selective cutting (%) | None (%) |
|---|---|---|---|---|
| 1. Central | 294,901 | 23.6 | 18.2 | 58.2 |
| 2. Copperbelt | 372,999 | 0.8 | 16.1 | 83.0 |
| 3. Eastern | 410,741 | 6.4 | 76.2 | 17.4 |
| 4. Luapula | 73,597 | 4.5 | 38.8 | 56.6 |
| 5. Lusaka | 459,116 | 1.6 | 10.8 | 87.6 |

| | | | | | |
|---|---|---|---|---|---|
| 6. | Muchinga | 172,966 | 8.7 | 27.6 | 63.7 |
| 7. | Northern | 225,469 | 3.4 | 38.1 | 58.5 |
| 8. | Northwestern | 63,271 | 14.1 | 53.7 | 32.3 |
| 9. | Southern | 332,807 | 4.2 | 5.5 | 90.4 |
| 10. | Western | 104,844 | 12.6 | 16.9 | 70.4 |
| Zambia | | 2,510,711 | 6.7 | 28.2 | 65.1 |

Forest clearing was highest in Lusaka Province (1.38 *ha per household*) and lowest in Luapula Province (0.25 *ha per household*). The national average of forest area cleared was estimated at 0.73 *ha per household* in 2015. Western has 0.57 *ha per household*, Eastern recorded *0.56 ha per household*, Muchinga 0.51 *ha per household*, Northwestern 0.53 *ha per household*, Central 0.52 *ha per household*, Northern 0.54 *ha per household*, and Copperbelt 0.27 *ha per household* (Figure 23).

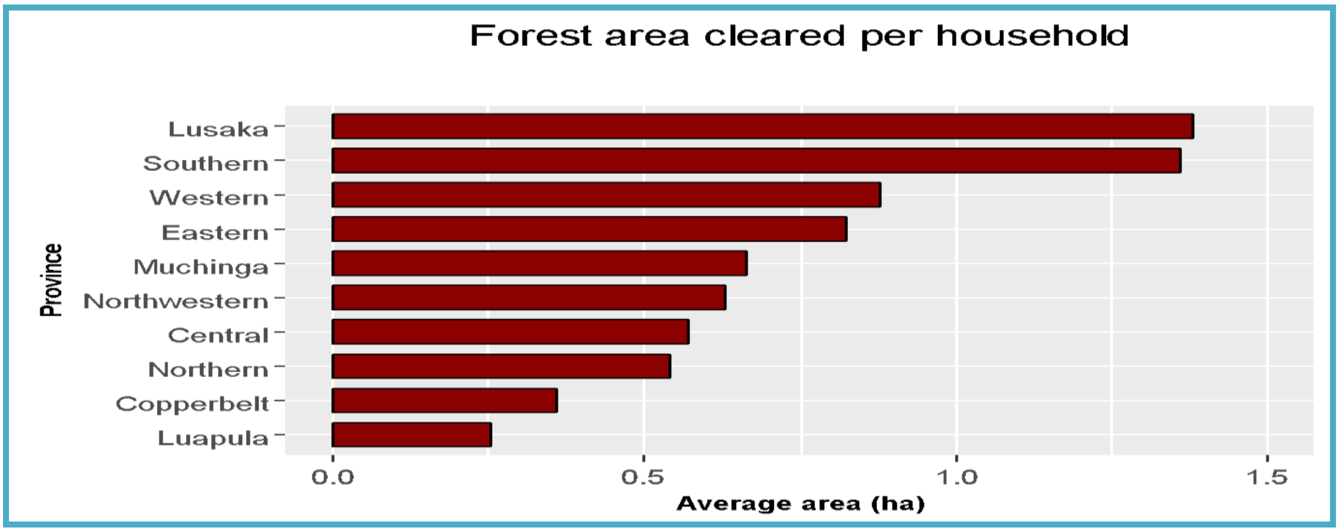



**Figure 23: Average forest area cleared per household across provinces**

### 4.16 Overall livelihood

The 2015 Forest Livelihood and Economics Survey (FLES) revealed that over 21% of households depend on crop production as the main livelihood activity, followed by fuelwood collection (16%). Formal employment and trade in goods-and-services were among the most important livelihood activities observed during the survey. Only 9% of households depended on gathering various NWFPs as the main livelihood activity (Figure 24).

However, the gathering of various NWFPS, harvesting of wood products, charcoal production and collection of some wild fruits amounts to 18.5%.

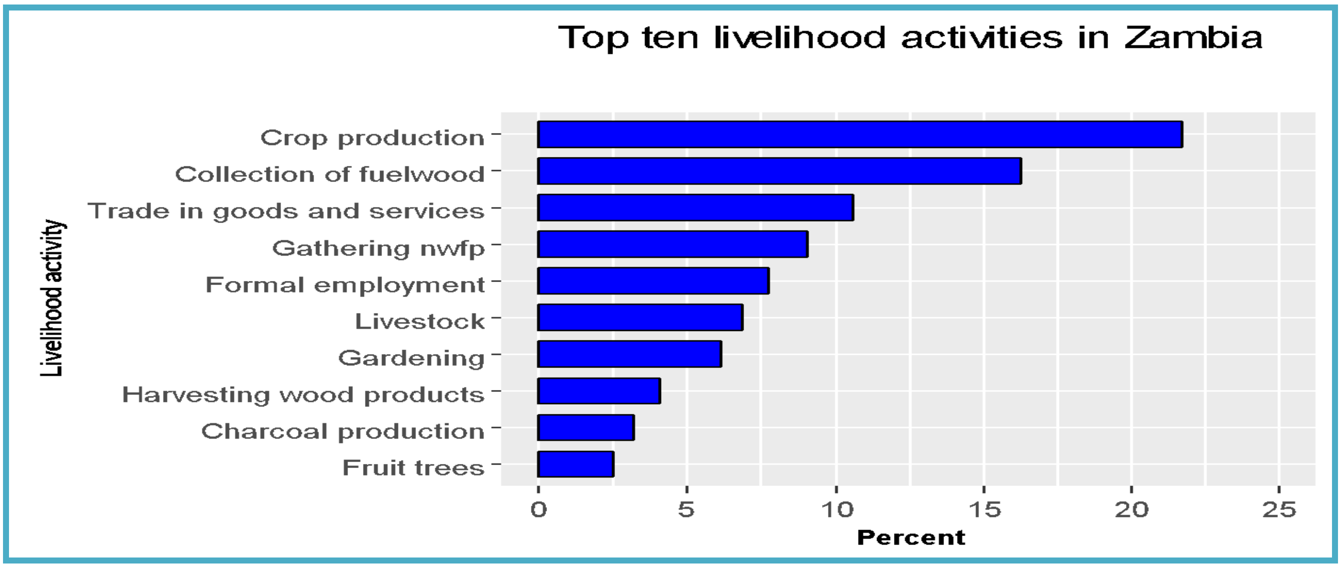
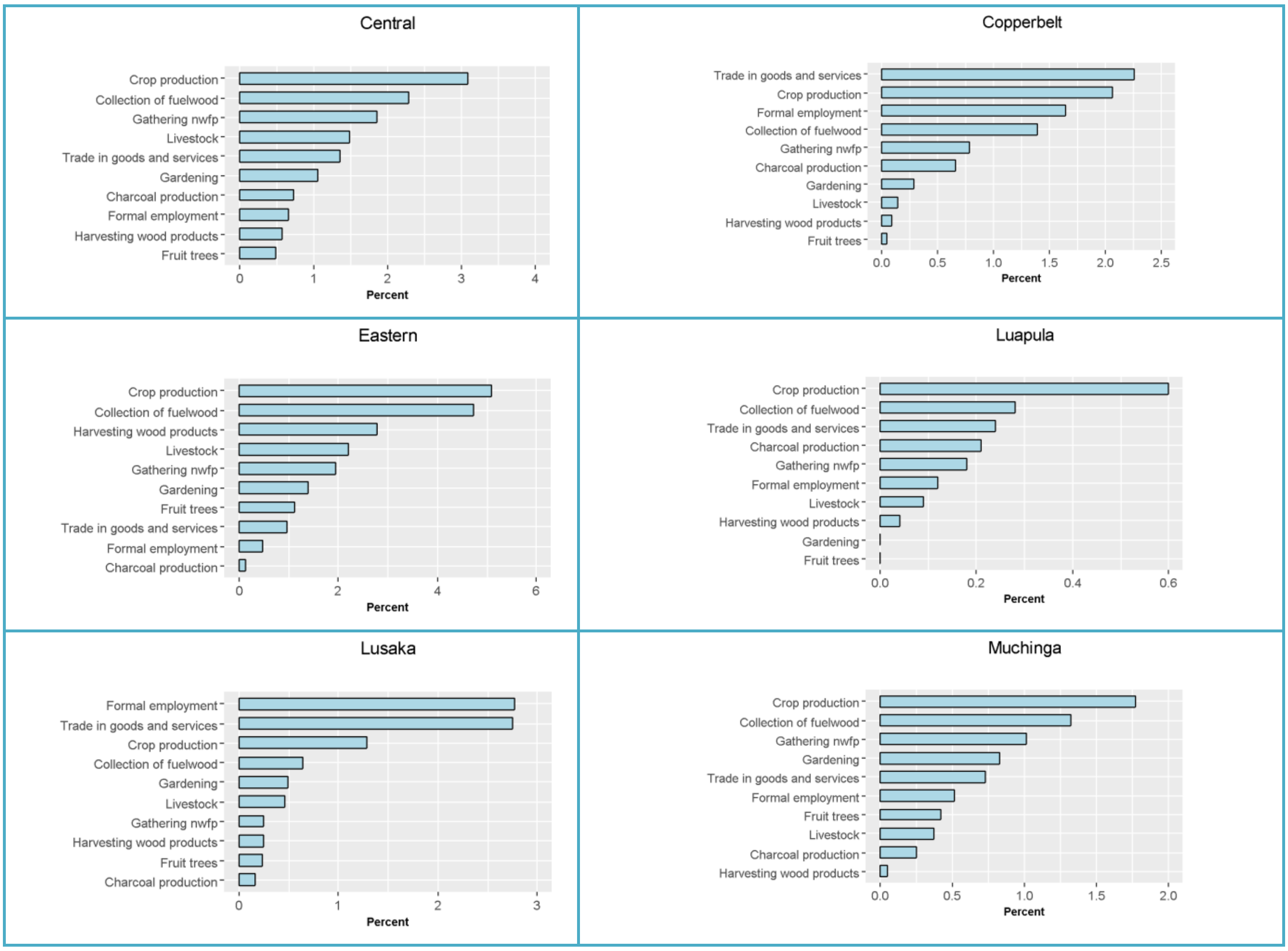



**Figure 24: Top ten livelihood activities**

The distribution of livelihood activities with crop production ranking first and fuelwood ranking second in the country was common across the provinces. However, trade and formal employment were the most important livelihood activities in Copperbelt and Lusaka provinces (Figure 25).



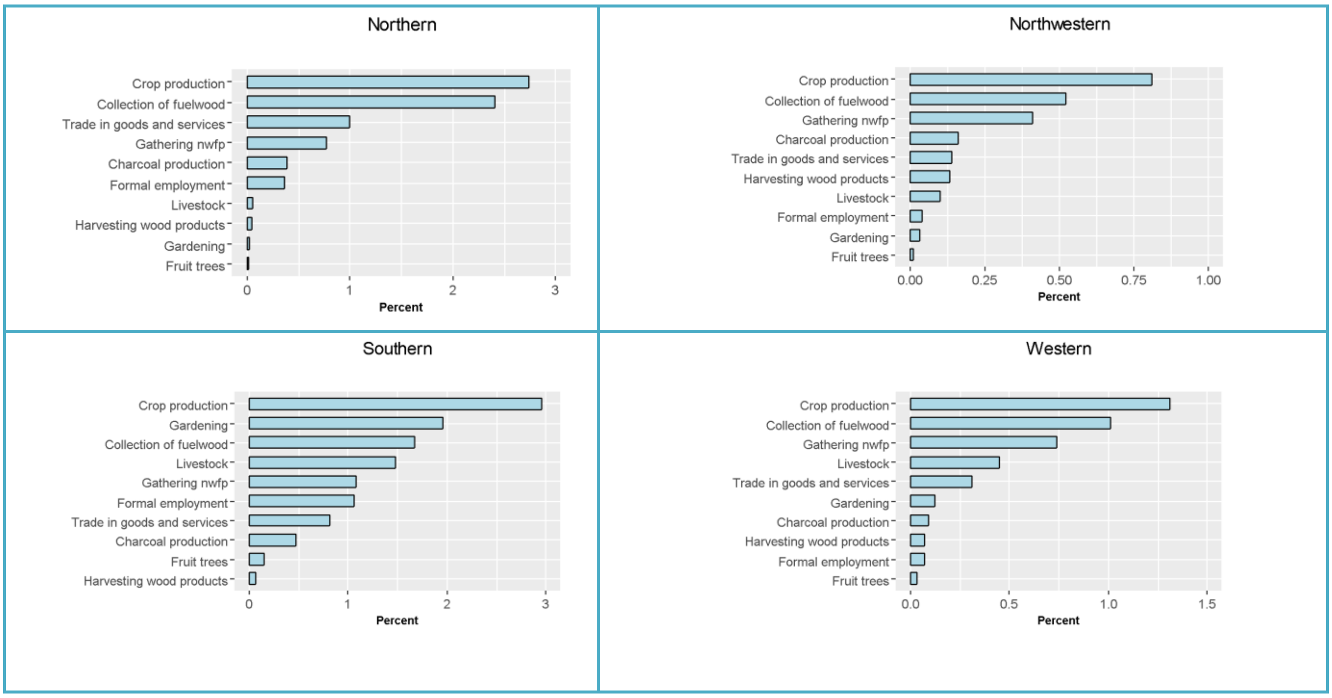



**Figure 25: Top ten livelihood activities across provinces**

Among the main sources of income at the national level, crop production was ranked first, followed by trade in goods and services (own business) and then formal employment (Figure 26). In all cases, gathering of NWFPs ranks the third an indicator that it is an alternative livelihood activity.

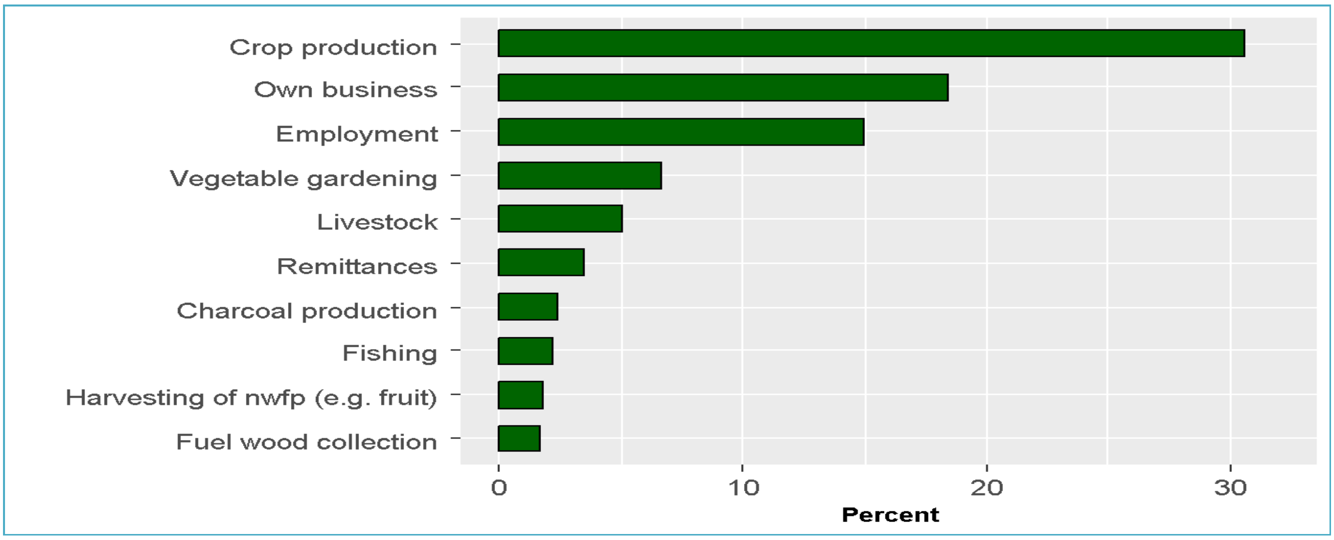



**Figure 26: Top ten household income sources**

However, the main sources of income in provinces varied in importance (Figure 27). For example, own business was the most important source of income in Copperbelt Province, while in Lusaka and Southern provinces, it was employment. Overall, crop production was observed to be the dominant source of income in many provinces (Figure 27).

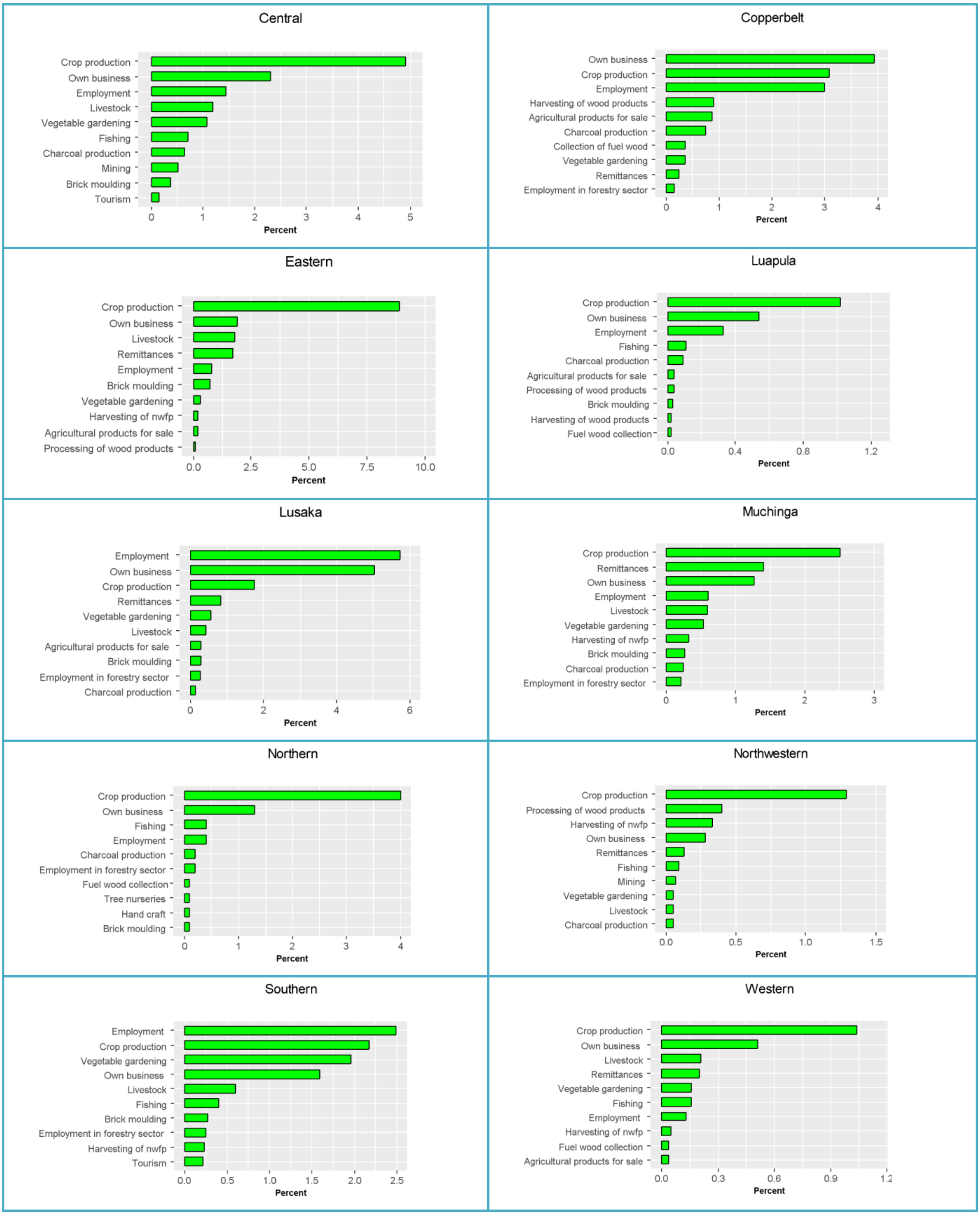



**Figure 27: Top ten important income sources at household across provinces**

The survey established that when forest products are considered separately from other livelihood activities, charcoal production and trade was the main source of forest-based income for over 42% of the households, followed by fuelwood (over 25%) (Figure 28). Although fuelwood collection ranked highest among forest products, its purpose is mainly for consumption and contributes less to household income (Figure 28).

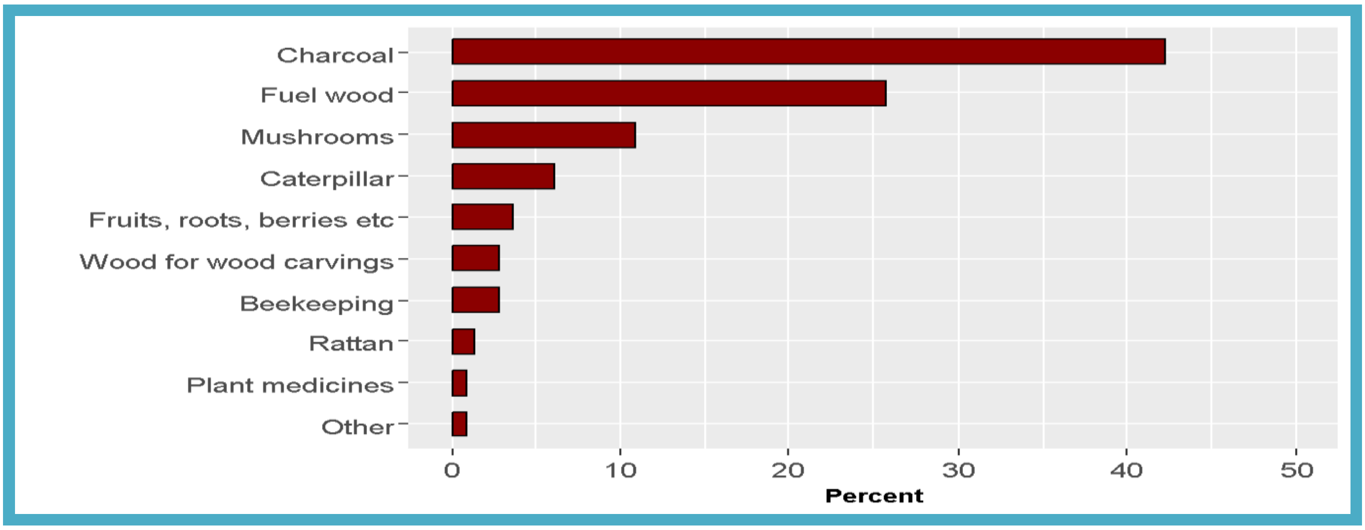



**Figure 28: Contribution of forest products to the household income**

Similar trends were observed for mushrooms, fruits, fibre and poles. Charcoal trade, on the other hand, contributes a significant proportion to the household income (Figure 29), suggesting that charcoal is produced mainly for sale rather than for household use. This is also true for beekeeping, caterpillar collection and wood carvings, where the sale of such products is more than the direct consumption at the household level (Figure 29).

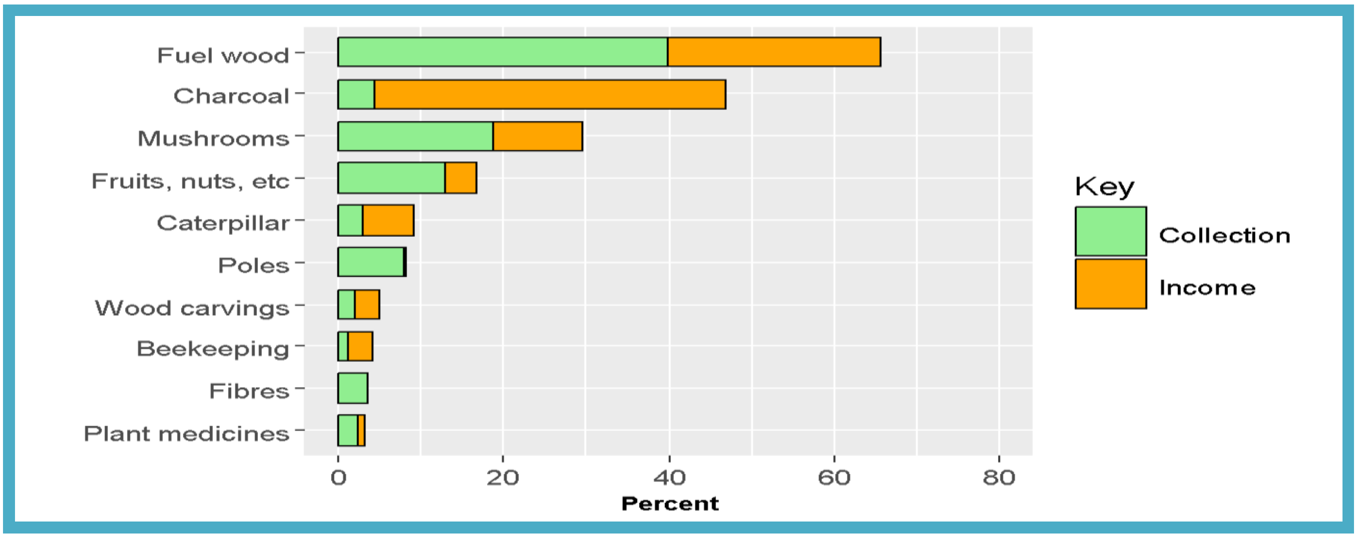



**Figure 29: Perception of contribution of forest products to household income**

### 4.17 Coping strategies

Regarding the top ten coping strategies, results showed that 42% of households turn to families and friends for help during crisis events, compared to only 2.8% of the households harvesting wood and non-wood forest products during the crisis (Figure 30).

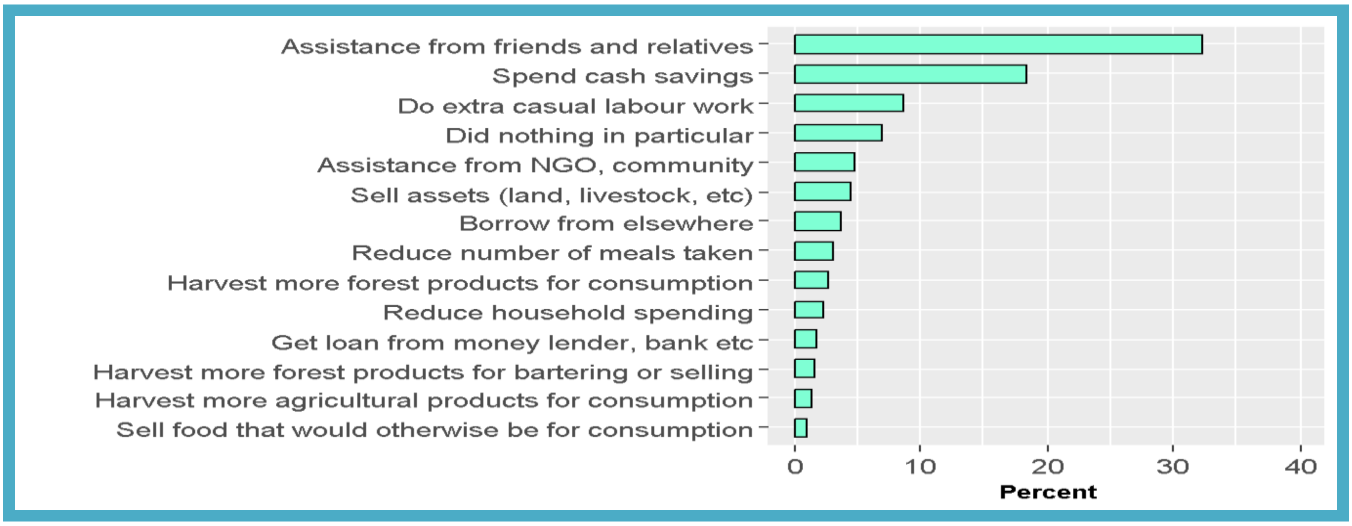



**Figure 30: Top ten household coping strategies during crisis events**

## 5.0 TOWARDS SUSTAINABLE FOREST MANAGEMENT WITH THE ILUAII DATA

The results discussed under *Chapter 4* of this report can be used to effectively manage Zambia's forests on a sustainable basis by putting key interventions in place. The information gathered revealed the overall progress made towards sustainable forest management (SFM) since the ILUA I national forest inventory (NFI), and covered all forest areas in the ten provinces of the country. The purpose of this section is to provide an insight into the complexity and many challenges associated with sustainable forest management (SFM) and how this data could be used to strengthen this initiative. This could also stimulate debate on forestry, hereby fostering policy decision making and actions for further progress in sustainable forest management (SFM).

*Zambia's forests are critically important to the socio-economic development of both the country's rural and urban communities. The success of the country's development strategies will depend to a considerable extent on its forest resources being managed in a sustainable way.*

### 5.1 Productive functions

Forests are subjected to various disturbances such as fires, drought, diseases, and climatic events that influence the composition, structure and functions. Despite these stress factors, the majority (92.7%) of the trees in forests were found to be in good health. This is a positive indicator of the potential for forests to support sustainable development in the country. This status implies that Zambia's forest ecosystem has the potential to continue supplying forest goods and services for now, and should therefore be factored into forestry planning at national and provincial levels notwithstanding the high rates of deforestation.

Forests, and the trees outside the forests, provide a wide range of wood and non-wood forest products to many forest-dependent communities in Zambia. It was found that over 60% of the land area is used for wood products, 76.9% *for non-wood* forest products, 7.8% *for services* and 11.6% *for other* functions. These trees therefore have a significant contribution to make in the future and should be recognised as such and included in future planning activities.

### 5.2 Wood products

The result of this assessment showed that forest woodlands account for over 40 *million ha* (93%) of the total forest area, with over 1.3 *billion* $m^3$ of wood available for commercial purposes. Based on the 1.5 $m^3/ha/annum$ as a mean annual increment (Ngándwe *et al.*, 2015) in forest woodlands, it is estimated that over 33 *million* $m^3$ per annum of wood can potentially be harvested for various uses in Zambia as the annual allowable cut (AAC) from forest woodlands alone. However, the sporadic distribution of prime species, the high cost of production and the unknown technical properties of lesser known species constrain the development of hardwood species for industrial use in the country. ILUA I established that approximately 15% of the forest land was used for industrial wood production in Zambia (Forestry Department 2008). Ngándwe *et al*. (2015) estimated that, on average, over 87% of wood production by volume is used as fuelwood, with only 13% constituting industrial round wood of which approximately 90% is from forest plantations. The area of planted forest and conservation efforts has been declining in the country, particularly the area of primary forests which continues to decline at an alarming rate as the forests are converted to other land uses.

On the other hand, forest plantations for industrial round wood production managed by ZAFFICO is around 55,000+ *ha* all located in Copperbelt Province. However, ZAFFICO has been replanting forest plantation areas where removals have taken place and has also established new plantations in Luapula and Muchinga provinces. It is estimated that over 12,000 ha has been planted with exotic tree species in the country since 2011, of which 10% has been on additional acquired land (ZAFFICO 2011, ZAFFICO 2014). Unfortunately, the rate of forest plantation establishment and replanting is far below the area harvested per annum (ZAFFICO, 2014), thereby creating an expected / potential deficit of industrial round wood in the future.

## 5.3 Wood products and trade

Based on the current assessment, the top five provinces with the greatest potential for forest revenue collection, forest industry development and UN-REDD projects are Western, North-Western, Central, Muchinga and Northern provinces. The potential for forest plantation establishments is greatest in Luapula, Southern, Muchinga, Eastern and Copperbelt provinces. Estimates from the ILUA I data showed that the AAC was about 9.65 *million* $m^3$ per year (Ng'andwe *et al*., 2012, 2015). However, with the more reliable ILUA II data and the adjustment in the stocking density of commercial (bole) and tree volume ratios, the AAC is now more than three times higher than previously reported. Furthermore, removals for trade have increased since 2010. Based on the estimates from FAOSTAT and actual UN Comtrade data, Ng'andwe (2015) estimated primary wood production to have increased from 16 *million* $m^3$ in 2010 to approximately 20 *million* in 2014, representing a 12% increase. Exports of primary wood products have declined from 2.8 *million* $m^3$ in 2010 to 1.4 *million* $m^3$ in 2014[9]. This decrease may be attributed to the current export ban on raw wood materials.

## 5.4 Fuelwood

It was estimated that over 84% of households depend on fuelwood as a source of energy. The over-exploitation of forests for fuelwood has a negative effect on the sustainability of the resource. The assessment has revealed that over 52 trees per ha are available as fuelwood and 10.6 tons per ha as material for charcoal production. Charcoal production ranks as the highest household income generating activity and thus should be managed through appropriate systems, such as the "Coup" system in which land is demarcated specifically for this purpose. Going by the Forest Act No. 4 of 2015, local community members are encouraged to declare some of their forests where sustainable forest management activities can be implemented including sustainable charcoal production with technical assistance from the Forestry Department.

[9] http://comtrade.un.org/

### 5.5 Non-wood forest products

The collection of non-wood forest products demonstrates their importance as commodities for domestic and international markets as well as for livelihoods. Therefore, NWFPs deserve high priority in development and forest conservation strategies. Most of these products collected from the forests are consumed by households or sold in domestic markets and others make their way onto export markets. The most important NWFPs collected include a combination of edible wild foods such as fruit trees, roots, tubers and bulbs as well as plant medicines. Most of the NWFPs have been over-harvested and in some cases depleted.

Bamboo is a major NWFP and wood substitute, but is found in only five of the ten provinces. The highest density of bamboo was found in Copperbelt (135 *stems/ha* in forest land) and Luapula provinces. This is the first assessment of bamboo carried out in Zambia and efforts should be made to manage this resource on a sustainable basis. Using ILUA II biophysical and FLES data, forest management planning should integrate NWFP as a separate section and should involve local communities. This aspect should be included in the Provincial or District Forest Management plans.

### 5.6 Biomass and carbon stocks

The indicators of the productive functions of the forests include the biomass and carbon stocks, as they provide information on the energy potential and capacity to sequester carbon (FAO, 2010, 2015). Globally, and in Zambia, the role of forests as terrestrial sinks and sources of carbon dioxide have received increasing attention. According to the FAO (2015), carbon stocks in the Southern hemisphere, particularly in Africa, are decreasing while in North America and Europe carbon stocks are increasing. Based on the biophysical inventory, Zambia's forest cover is estimated to be 60% of the total land area and forests continue to store large quantities of carbon, estimated at over 1.5 billion tons.

The REDD program, launched in 2009, is expected to contribute to an increased awareness of the role that forests play as terrestrial sinks and sources of carbon dioxide (GRZ, 2010c). In line with the results from the Forest Livelihood and Economic Survey (FLES), the use of woody biomass is likely to increase, as well as the use of improved low-energy-demanding construction materials such as wood and bamboo in green jobs projects. Increased use of improved cook stoves is also expected. According to the FAO (2015), such national interventions will continue to contribute to the reduction of greenhouse gas emissions as opposed to the use of high energy intense materials such as iron and concrete.

### 5.7 Applications of ILUA II data

There are numerous applications for the data collected in both ILUA I and II assessments. In the ZFAP review, it was stated that this information should be used to determine how much area and volume of timber is required for each province to be a concession. For this to be effective, a detailed management plan used for production, conservation and environmental services for each province is required. The sustained supply of goods and services is best achieved through long-term investment and management planning. FLES revealed at household level that trade in fuelwood and crop production are among the top ten livelihood activities in the country. Since wood biomass energy has gained recognition as one of the measures to combat climate change under the Clean Development Mechanism (CDM), project developers can use ILUA II data as a baseline for this purpose. The CDM methodology requires that demonstrable renewable biomass, which is regeneration (seedlings and saplings), and the non-renewable biomass, which is the quantity of biomass removed in excess of regeneration, be determined. The ILUA II data provides this opportunity to industry and meets the following CDM indicators:

- Trend showing increase in time spent or distance travelled by users (or fuel-wood suppliers) for gathering fuelwood or alternatively trend showing increase in transportation distance for the fuelwood transported into the project area. *In the FLES results, the distances and time were captured (e.g. in Eastern Province, the distance to the forest product collection area in this assessment was over 5.5 km);*
- Increasing trends in fuelwood price indicating scarcity; and
- Trends in the type of cooking fuel collected by users, suggesting a scarcity of wood.

*More details on the quantities of timber, NWFP and further application of ILUA II data will be presented in the Saiku reporting system located at the FD server, data dashboard service and the Provincial State of the Forests booklets. Meanwhile, the biophysical data in Zambia has now improved. This will therefore also improve methods for estimating emissions and removals from forest-related activities over time as well as estimates of carbon pools, so that reliable predictions of future emissions can be made. For example, new deforestation data has now been provided, requiring that emission estimates be further adjusted and updated.*

### 5.8 Socio-economic functions (linking forests and livelihood)

There are many livelihood factors affecting the collection or production, marketing and trade of both primary and secondary processed products at household and small and medium enterprise (SME) levels. For example, studies indicate that relatively richer households are engaged in more capital intensive and more profitable forest-based income generating activities such as timber production, as well as large-scale charcoal production and trade (Kalinda *et al*. 2008). Richer households also tend to have higher educational attainment and can afford better health facilities and access to market information compared to the poor (Kalinda *et al*. 2008). It was also reported in ILUA I that increasing levels of income were directly proportional to the overexploitation of forest resources (Forestry Department, 2008, Kalinda *et al*., 2008, Muimba-Kankolongo *et al*., 2015). This is also seen in the top ten forest income sources of households observed in the 2015 FLES survey. In fact, household rankings established in ILUA II reveal that forests are a “food basket” and “drug store” for the rural poor and provide critical safety-nets during stressful environmental conditions such as droughts and floods. For example, charcoal production was among the top ten forests products that contributed to household income in 2015, followed by fuelwood. The FLES survey also established that households cleared forests by cutting trees equivalent to a land area estimated at an average of 0.73 ha per household.

*Gains in settlement area, as well as agriculture area, were found to be associated with forest cover loss. This relationship underscores the need to put in place policies that support the development of management plans at provincial and district levels. Many of the forests in Zambia could be managed as carbon forests under proximate public private partnerships that take advantage of opportunities in the Voluntary Carbon Market as well as other Emissions Reductions programmes. Forest certification is another market-based instrument that Zambia should promote in order to add value to its forests and realize sustainability.*

### 5.9 Contribution to the national economy

There are various wood, non-wood forest products and forest services that were surveyed at household and focus group levels during the FLES and biophysical assessments. There is potential for the CSO to use this data in conjunction with the System of National Accounts to determine the full contribution of the forest sector to the economy. The economic activities can be classified following the International Standard Industry Classification (ISIC) of economic activities (UN, 2006), thereby releasing summaries that could be used in computing the contribution of the sector to the national economy (Ng'andwe *et al*., 2015). For example, Forestry is classified under section "A" of the ISIC which includes Agriculture, Forest and Fishing. Primary forest production is in division 2 of the ISIC under Forest and logging which includes various economic activities taking place in the Forest Land, other wooded land and other lands. Such economic activities are grouped into forest management with classes that include silviculture and other forest activities. The logging group includes logging activities, production of round wood, utility poles as well as activities associated with products that undergo processing such as firewood and charcoal. Gathering or collecting of non-wood forest products is also included under the forest and logging group of the ISIC. The computation of statistics for the forestry sector would raise its profile and would enable the Forestry Department to produce a compendium of forestry statistics on a regular basis for information dissemination and planning purposes.

### 5.10 Legal, policy and institutional framework

In 2015, the Zambian government approved various policies and legislation affecting rights to forest and common lands, as well as rural land use regulations. Earlier, the Zambia Forestry Action Program was the major government forestry initiative (ZFAP, 1997) from which reforms and programs originated to support sustainable forest management. For example, a number of community-based natural resources management programs were also initiated to include PFAP, Environmental Support Program (ESP), the Community Based Natural Resources Management (CBNRM), the Cooperative League of the United States of America (CLUSA), the Administration and Management Design Programme (ADMADE), the Industrial Pollution Prevention Programme (IPPP), the Soil conservation and Agroforestry Extension Programme (SCAFE), and the Zambia Social Investment Fund

(ZAMSIF). Similarly, the government has also, in recent years, undertaken a number of legal reforms in order to bring the forestry sector up to date with on-going governance changes, such as REDD, greenhouse gas reporting and green jobs. Other initiatives include the Decentralization Implementation Plan (2009–2013), Vision 2030 that outlines overall socio–economic goals, and the National policy on the Environment (2007) that provides overall guidance on environmental and natural resources management.

*The government's focus on land use included putting in place an integrated land use assessment system that will improve the management of land resources, subsequently contributing to poverty alleviation, improved food security and sustainable economic growth (GRZ, 2011). Integrated land use assessments will continue to encourage cross-sectoral coordination and collaboration, bringing together stakeholders from diverse disciplines related to land use management (GRZ, 2010b, GRZ, 2010c). The main objective of the new instruments i.e. Forest Policy 2014, Forest Act 2015 and Decentralisation Policy 2013, is to take the power of decision making to lower units such as provinces and districts. These policy and legal initiatives will contribute towards sustainable forest management.*

### 5.11 Forest management certification

According to the FAO (2015), forest management certification is one of the tools used for describing sustainable forest management. In Zambia, most of its forests are not certified, although in the past some companies such as Mangamu Timbers, Muzama Crafts and Wood Processing Industries, and Zambezi Hardwoods trading as Brick-tech Timber Limited at the time attempted to have leased forests certified, although they were later de-registered due to unmanageable circumstances. Still, certification may be the best single means of evaluating progress towards sustainable forest management for Zambia's forest.

# 6.0 CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

The project was aimed at strengthening the information base for sustainable forest management, establishing national forest assessment monitoring systems and implementing best practices in forest management. More than 30 institutions were involved in the process and implementation, including government bodies, academic institutions, research units, international organisations, consultants as well as local communities from across Zambia. There were 1,016 *clusters* successfully assessed against a target of 1,087 *clusters*, representing 93.5% record of success in terms reaching the clusters. However, the biophysical data captured in the database is from 986 *clusters* with 3,892 *main sample plots* and 7,784 *sub-plots* where at-least 60 variables relating to volume, biomass, carbon, forest cover extent and loss, conditions, and the uses and value of forests in different land categories. Socio-economic data was collected from the 2,510,713 national weighted households through the Forest Livelihood and Economic Survey. The outcome of this process is higher quality data on forests and enhanced national capacity in data collection, analysis and reporting. The following are the general conclusions on the process and findings:

- The total forest cover from wall-to-wall (based on the 2014 remote sensing data) mapping is estimated to be 45.9 *million ha* and represents 61.04% of the country's land surface area. Meanwhile, the estimated forest land (under vegetation types) extrapolated from sample plots is 44.17 *million hectares* (±1.2 *million ha*) evaluated at 95% confidence interval, representing 58.7% of the country land surface area.
- The standing trees in these forests, constituting at least 2,500 tree species, contained a total of 3,178 million $m^3$ as growing stock, 2.74 billion tons of biomass and 1.34 billion tons of carbon. These estimates are higher when data from saplings, dead wood and stumps are included.
- The total tree (for trees measuring ≥ 10 cm *dbh*) volume for the growing stock was estimated at 3,178 *million* $m^3$ and for the saplings (for trees measuring ≥ 5 and < 10 cm *dbh*) it is estimated to be 154.4 *million* $m^3$ of which forest land returned 124.6 *million* $m^3$; other wooded-land returned 20.6 *million* $m^3$; and other land 9.1 *million* $m^3$.
- The latest and official deforestation rate for Zambia ranges between 79,000 (0.17%) and 270,000 (0.56%) hectares per annum, calculated as a weighted mean of the full 14-year period. This estimate is based on land cover map data for the years 2000, 2010 and 2014 generated from land-sat imagery. The main drivers are agriculture responsible for 64.3%, settlement expansion 32.8%, other land activities 2.1% and water developments responsible for 1%.
- It is clear from these findings will progress towards sustainable forest management is possible. When interpreting the findings in this report, the scale is crucial. At the national level, the forest resources appear to be decreasing with an annual deforestation rate of 0.17%. While this figure may seem relatively small, when the provincial rates are calculated as part of the ongoing REDD+ initiatives, it will be clear that alarming trends are apparent in certain provinces, especially areas with high forest cover such as North-Western and Muchinga provinces.

- The national average of forest area cleared per household was estimated at 0.73 ha. Forest clearing for agriculture was highest in Lusaka Province and lowest in Luapula Province, suggesting that provinces with a high income cleared more forest area than provinces with a low income.
- The forest woodland vegetation, continue to be the main source of livelihood in all the provinces of Zambia. Overall crop production ranked first as a main livelihood activity. Wood and non-wood forest products collection at household level was among the top ten activities contributing to household income in Zambia, and of these forest products, charcoal and fuelwood contributed more to household income than other products assessed. The distance and time taken to reach forest collection areas varied from province to province, and overall respondents indicated that the time and distance necessary to travel to these sites was increasing.
- The sampling frame used contained more than four times the sites when compared to ILUA I. As such, the sampling errors associated with this inventory are significantly better comparatively. Therefore, the data constitutes a more reliable estimate of forest resources in Zambia and should be used for informed decision making purposes.

### 6.2 Recommendations

Through the ILUA II project, the Forestry Department, in collaboration with development partners, has established a long term national forest monitoring system (NFMS). This system should continue to function and be used to collect data and contribute to forest management activities in Zambia. In particular, the REDD+ program requires that Zambia continues to monitor its forests through Measuring, Reporting and Verification activities. These activities are especially important given the fact that land use changes in the form of conversions from forest to agriculture represent the single largest contributor to emissions in Zambia. The continued monitoring of these changes is crucial to Zambia fulfilling its stipulated mandate of reducing emissions as outlined in the country’s Nationally Determined Contributions recently submitted to the UNFCCC. Consistent monitoring will provide the necessary tools for evaluating decision making and reporting on emissions reductions. Based on the need for continued monitoring and reassessment, the following recommendations are made:

- Institutionalize regular NFIs/ILUAs. NFIs should be mainstreamed and added into FD’s mandate in order to be able to monitor forest resources in Zambia effectively.
- The ILUA database is maintained including the additional data sharing services produced by the project. The sharing of data will facilitate and maintain interest in the activities and progress made by the department. All the results are available via the *Saiku reporting system* for forestry experts and via the data dashboard for public purposes.
- All permanent sample plots that have been established should be used to collect data at regular intervals by the District forest staff (and staff from CSO as appropriate). A simplified standard enumeration form should be prepared from the field manual for this purpose. Future enumeration activities should explore the use of digital data collection devices to streamline the data processing activities.
- Students from higher learning institutions should be employed to undertake additional inventories in partnership with the District forestry staff.

- ILUA data should be mainstreamed into higher education curricula as part of the information sharing, dissemination and sustainability aspect of the land use planning process. This will have long-term benefits for forest management, monitoring and regular and timely reporting in the country.

**Additional information needs:**

- An inventory of wood energy in the country should be done to provide detailed quantitative and qualitative national statistics.
- The status of the Forest Reference Emissions level should be finalized using additional data generated through provincial scale accuracy assessments. Ongoing REDD+ activities are available to support these activities.

**Policy actions:**

- In order to achieve the UN Sustainable Development Goals (SDG), it is recommended that policies that are at odds, such as agriculture and forestry, be harmonized during land use planning and national reporting. The role of CSO in collecting and processing agricultural, environmental and natural resources data from all the standard enumeration areas should be included in policy. The information generated as national statistics should be used in policy formulation to balance land use by agriculture, forestry and other users at national, provincial and district landscapes in an integrated way. Private governance initiatives such as forest certification and voluntary certification schemes should be promoted as they provide appropriate social, economic and environmental safeguards.

**Capacity building:**

- In collaboration with tertiary learning institutions, the raw and processed data should be made available for the purposes of continued analytical studies and development. The identification of new research topics that seek to understand the role forests play in a low carbon development environment is crucial. Post graduate research studies are an effective means of capacity building.
- The need to increase community participation in integrated land use systems is paramount, as supported by the 2014 Forestry Policy. This data can also promote Public Private Partnership (PPP) in forestry using proximate PPP models such as Joint Forest Management and community-based natural resources management. Promoting forest certification, carbon management and trade is an additional application of the generated data.
- While capacitating future generations of foresters in Zambia is crucial, it should also be noted that staff within the Forestry Department will require additional capacity development. The new Forests Act of 2015 calls for increased community-based forest management. These communities will require support from the Forestry Department, and as such, staff members will require training in community-based forest management if they are to provide adequate support to communities.

**International reporting:**

- The FAO (2015) reported that FRA has worked to harmonize procedures with the *International Standard Industrial Classification of All Economic Activities* (ISIC, 2008) since 2010. In line with the ISIC, the boundaries of the forest sector can be summarized as the addition of three categories: forestry and logging (ISIC Rev. 4 Division 02), wood industry (ISIC Rev. 4 Division 16), and the pulp and paper industry (ISIC Rev. 4 Division 17) (FAO, 2010, FAO, 2015). According to a report on *"Guidelines for the Forestry sector data collection and processing*", Ng'andwe *et al*. (2007) revealed that Zambia, through the FAO National Forest Program Facility, has adopted the ISIC and harmonised the definition of the forestry sector in collaboration with CSO National Statistics (CSO, 1997).

*It is highly recommended that, since Zambia is already ahead of the steps the FAO is taking to align reporting to the ISIC, this report should be aligned with the ISIC to enable the CSO to compute the contributions of the forestry sector to the national economy in line with the guidelines and these results. In Zambia, the value added should reflect the performance of the forestry sector as a whole, including the downstream processing activities.*

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## Appendix 1: Forest Inventory Glossary

| TERMINOLOGIES | TECHNICAL DEFINITIONS IN THE REPORT |
|---|---|
| (1.) ***Aboveground biomass*** | Refers to all living biomass of live trees growing above the soil such as the stems, sumps, branches including their barks and foliage. |
| (2.) ***Accuracy*** | Refers to the degree of closeness of a measurement or estimate to the true value of the population. Accuracy may be used in either a qualitative way or as a quantitative summary of total error. (Qualitative: An accurate measurement is one where the total error is small). (Quantitative: $A^2 = B^2 + P^2$, where B denotes a measure of bias and P denotes a measure of precision.) |
| (3.) ***Allometric models*** | Also referred to as allometric equations predict the value of a variable of an object from values of other variables of the same object; a common example is allometric biomass models that predict biomass of an individual tree from "other metrics" (that is the meaning of the term "allometric") such as diameter at breast height (DBH) and tree height. |
| (4.) ***Basal area*** | Basal area is the cross-sectional area of a tree at breast height of all trees per hectare (in $m^2$/ha). Basal area is typically reported in square meters and is calculated for an individual tree using the formula: BA = 0.005454 × DBH2, where DBH is measured in centimetres. |
| (5.) ***Below-ground biomass*** | Refers to all living biomass of live tree roots. However, the fine roots (root hairs) less than 2mm diameter are excluded because often cannot be distinguished empirically from soil organic matter or litter |
| (6.) ***Bias*** | Bias is a systematic error that prevents an accurate estimate of the true value of a variable of interest. A bias can be introduced by a biased selection of population units (selection bias), by biased estimators (estimator bias) or systematic errors in measurements (observer bias). A systematic error cannot be compensated by increasing sample size. |
| (7.) ***Biomass*** | Refers to organic material both above-ground and below ground, and both living and dead, e.g., trees, tree roots and litter, twigs, leaves, grasses, debris, crop residue including any vegetation material either standing, lying on the ground, or buried in the soil. |
| (8.) ***Carbon stock*** | This is the quantity of carbon dioxide in a "pool", meaning reservoir or system which has the capacity to accumulate or release the carbon content. |
| (9.) ***Confidence interval*** | For statistical estimations, the confidence interval defines an upper and lower limit within which the true (population) value is expected to come to lie with a defined probability. |
| (10.) ***Dead wood biomass*** | This is all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood biomass includes wood lying on the surface, dead roots, and stumps larger or equal to 5cm in diameter. |
| (11.) ***Deforestation*** | Refers to a decrease in the area covered by forest or change of land-cover with depletion of tree crown cover to less than 10% from one period to another. It is recognized as the "human induced permanent change of forested (wooded) land to non-forested land (i.e. agricultural land use, settlement or infrastructure |
| (12.) ***Disturbance*** | Refers to an environmental fluctuation and destructive event that disturb forest health, structure, and/or change resources of physical environment at any given spatial or temporal scale, causing forest degradation. Disturbances that affect health and vitality of a forest include biotic agents such as fire, pollution and extreme weather conditions |
| (13.) ***Dominant tree*** | Dominant tree a tree with a crown that receives full light from above and partly from the side: usually larger than the average trees in the stand. Dominant tree crowns usually extend above the general level of the canopy and are well developed but possibly somewhat crowded on the sides |
| (14.) ***Error*** | Error in the forest monitoring context, the term error is used in different meanings: in statistical estimation, the error describes the variability of estimates, usually quantified in terms of root mean square error or error variance or standard error. It describes inherent residual variability and can be used to construct a confidence interval |
| (15.) ***Field protocol*** | Defines in detail which measurements should be taken in which way. As the field protocol also defines which elements are to be included at each sampling location, it is a synonym for the stipulated plot design. The protocol is the detailed and step-by-step description of any empirical study, including national forest monitoring. Also referred to as "*Field manual*" or "*Field protocol*" when referring to field inventories or "classification guide" or "interpretation guide" when referring to image analysis. A field protocol describes in detail sampling design, plot design, all variables including definitions, classifications, measurement devices, and measurement procedures |

| TERMINOLOGIES | TECHNICAL DEFINITIONS IN THE REPORT |
|---|---|
| (16.) ***Forest degradation*** | Forest degradation refers to the changes in forest health and vitality, loss of primary forest (forest of native species) or disturbances in forest ecological processes affecting the species biodiversity composition. This does not involve a reduction of the forest area, but rather a quality decrease in its condition related to one or a number of different forest ecosystem components (vegetation layer, fauna, soil), to the interactions between these components, and more generally to its functioning |
| (17.) ***Forest inventory*** | Forest inventory is the activity of data collection that helps generating the required information base on the forest resource within an area of interest. Forest inventory: is a tool that provides the information about size and shape of the area as well as qualitative and/or quantitative information of the growing stock |
| (18.) ***Forest monitoring*** | The terms “Forest monitoring”, “Forest inventory”, “Forest Assessment” and “Forest Survey” are sometimes used interchangeably, although linguistically they focus on different points: “Forest inventory” focuses on the generation of data on the forests with an emphasis on statistical approaches; “Forest monitoring” has a focus on changes in the forests where such information may come from repeated forest inventories; “Forest assessment” has a focus on the interpretation and evaluation of inventory and monitoring results; and “Forest survey” has a surveying connotation but is frequently used in the same meaning like “Forest inventory” focusing on sampling (survey sampling). |
| ***(19.) Growing stock*** | Refers to volume over bark of all living trees in a given area of forest or wooded land that have more than a certain diameter (≥ 5cm) at breast height. It is usually measured in solid cubic metres ($m^3$). |
| ***(20.) Kappa coefficient*** | Refers to the percentage obtained from a confusion matrix that quantifies the level of agreement between the observed proportion of the correctly classified classes and the correctly classified cases expected by chance. It is normally compared to the overall map accuracy. |
| ***(21.) Land cover*** | Refers to all natural and man-made features that cover the earth’s immediate surface, including vegetation (natural or planted) and human constructions, water, ice, bare rock or sand surfaces. Land-cover uses the floristic type of classification |
| ***(22.) Land use*** | Land use is the human activity associated with a specific land-unit, in terms of utilization, impact or management practice. Land-use derived from a physiognomic classification. |
| ***(23.) Positional accuracy*** | This is the accuracy of coordinate values of the dataset. It gives the level of conformity of data with respect to the nominal terrain (perceived true positions on the ground). It thus defines the deviation in the values of the respective positions between the database data and the nominal terrain. Such information assists in deciding whether datasets are within tolerable accuracy limits of the application. |
| ***(24.) Model*** | A model produces a value of a target variable from a set of values of input variables. In forest monitoring it is mainly two types of models that are used: “allometric models” and “development models”. |
| ***(25.) Parameter*** | In sampling statistics, the term “parameter” is reserved for the true population value of a variable. The parameters of a population remain unknown (unless a full census is done) and are approximated by estimates from sampling studies. |
| ***(26.) Plot design*** | Also referred to as “observation design”, “Response design”: Defines which elements are to be included at each sampling location and how measurements are taken. It is the “field protocol” that is implemented at each sample point. Typical examples are fixed area plots or bitter-lich sampling. |
| ***(27.) Population*** | The population in the sense of sampling is the set of all “elements” for which estimates shall be produced. In forest monitoring, the population is usually defined in terms of area (see sampling frame). In national forest monitoring the population is defined either as the country’s forest area (if the monitoring refers only to forest land). |
| ***(28.) Precision*** | Refers to “reproducibility”, “repeatability”: The precision is the degree to which repeated estimates under unchanged conditions show the same results. A measure of precision of estimates is the standard error. The terms “precision” and “accuracy” are sometimes used interchangeably to characterize the reliability of results from empirical studies; as such they are both used as measures of “uncertainty” and play an important role in reporting results. |
| ***(29.) Producer accuracy*** | Refers to the probability that a reference sample (photo-interpreted land cover class in this project) will be corrected mapped and measures the errors of omission. |
| ***(30.) Sample size*** | Refers to the number of sampling units (observations) that are selected from the targeted population. It is important to realize that the standard error depends on the sample size and not on |

| TERMINOLOGIES | TECHNICAL DEFINITIONS IN THE REPORT |
|---|---|
| | the sampling intensity. |
| ***(31.) Sampling*** | The process of selecting a subset of population elements with the goal to produce estimates for target parameters of the population. A sampling study is technically defined by its sampling design, plot design and estimation design |
| ***(32.) Sampling design*** | Refers to the statistical framework or design that describes how sampling locations are selected (e.g. simple random sampling or systematic sampling). |
| ***(33.) Sampling error*** | Errors associated with the primary measure of the reliability of an estimate. Along with every estimate is an associated sampling error that is typically expressed as a percentage of the estimated value but that can also be expressed in the same units as the estimate or as a confidence interval (the estimated value plus or minus the sampling error). |
| ***(34.) Sampling frame*** | The sampling frame or continuum (area) from which dimensionless samples points are selected based on a statistical sampling design. This is part of the total population (e.g. area of interest) that has a probability (>0) to be selected as sample (observed). |
| ***(35.) Sampling intensity*** | Proportion of the population that is been sampled. In forest inventories the area proportion that was observed in the sampling study (e.g. 3% of the total area). Contrary to sample size, sampling intensity does not have an immediate relationship to precision of estimation. When the sample size is large enough (*although sampling intensity may be relatively small*), one may expect precise results. |
| ***(36.) Standard error*** | Standard error is the standard deviation of all possible sample outcomes. The standard error is estimated based on the sample at hand and is an estimate of precision. |
| ***(37.) Temporal accuracy*** | Temporal accuracy refers to the possible changes detected and mapped. It has to do with the quality of temporal attributes and temporal relationships of features within the timelines (i.e. 2000 to 2010 and 2010 to 2014) under review. |
| ***(38.) Thematic accuracy*** | Thematic accuracy is the closeness of attribute values to their “true” value for quantitative attributes and as correctness of attribute values with respect to “ground truth” for categorical attributes. the measure of thematic accuracy was subjected to the correct identification of respective features according to the feature classes generated and counting how many of all features reflected were correctly classified |
| ***(39.) User accuracy*** | Refers to the probability that a sample from the land cover map actually matches what it is from the reference data (photo-interpreted land cover class in this project) and measures the error of commission. |
| ***(40.) Variable*** | This is a characteristic of the objects of interest that can take on different values and follows a distribution. In statistics also: “random variable”. Examples of variables in forest monitoring are DBH, height, species, development class, forest type, and slope. Variables are either directly measured or observed (such as tree species) or calculated from a set of measured variables. |
| ***(41.) Wood biomass*** | Refers to the natural mass of both living and non-living parts (roots, stumps, stems, and branches including their barks) of a tree that may be ≥ 5cm diameter in a given area of forest or wooded land either standing, lying on the ground, or in the soil. It is usually measured in tonnes of wood fibres. |

## Appendix 2: Experts and Contributors

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## About Integrated Land Use Assessment (ILUA) Phase II

The Integrated Land-Use Assessment project phase two (ILUA II) was launched in November 2010 in the Ministry of Lands and Natural Resources under the Forestry Department. The Project was tasked to develop sound information on forest and tree resources and to continue with the long-term forest and land use monitoring system that was established under the first phase ( ILUA I) in 2008. ILUA II aimed at introducing a policy-relevant, holistic and integrated approach to forestry resources assessment that addresses all domestic information needs as well as international reporting requirements, thereby being able to provide data and information on the forest sector to both national and international users on a regular and timely basis.

While ILUA I generated baseline data, the continuation of ILUA II for six subsequent years from 2010 to 2016 aimed at enhancing the use and development of data and information towards Sustainable Forest Management (SFM). ILUA II also aims to provide information on trends in forest change through refined methodologies, re-assessed field plots and a four-fold intensification of sampling density in order to report at the sub-national level. ILUA II also separately covered socio-economic-related information needs via the Forest Livelihoods and Economic Survey (FLES) which was conducted in collaboration with the Central Statistics Office in order to better understand the pressures on forest resources and to inform policy interventions which support Sustainable Forest Management. Establishing a monitoring system that captures livelihood needs beyond the forests is critical to designing well-targeted and innovative policy solutions that can support and promote sustainable resource management. The principal objectives of the ILUA II project were to build up forest-related land use resource inventories at the sub-national level in Zambia, and to support the implementation of Sustainable Forest Management and the Reduced Emission from Deforestation and Degradation (REDD+) through better information, capacity building, dissemination of information, and improved multi-sectoral dialogue.

The continuation of ILUA in Zambia intends to not only strengthen capacity in planning and implementation of Sustainable Forest Management but also aims to address the emerging issue of implementing emissions reductions activities under the UN REDD+ program. Therefore, data collection needs in ILUA II encompassed more REDD+ pertinent parameters including carbon pools and social safeguards.

Prepared for the Ministry of Lands & Natural Resources
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A cooperation between the governments of Zambia and Finland

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