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Carbon Stock Assessment and Modelling in Zambia A UN-REDD programme study

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country study

UN-REDD PROGRAMME

2009

Food and Agriculture Organization of the United Nations
United Nations Development Programme
United Nations Environment Programme

UN-REDD Programme
MRV Working Paper 4
2009

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The application of UNDP, UNEP and FAO rights-based and participatory approaches will also help ensure the rights of indigenous and forest-dwelling people are protected and the active involvement of local communities and relevant stakeholders and institutions in the design and implementation of REDD plans.

The programme is implemented through the UN Joint Programmes modalities, enabling rapid initiation of programme implementation and channeling of funds for REDD efforts, building on the in-country presence of UN agencies as a crucial support structure for countries. The UN-REDD Programme encourage coordinated and collaborative UN support to countries, thus maximizing efficiencies and effectiveness of the organizations' collective input, consistent with the "One UN" approach advocated by UN members.

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List of acronyms

COP	Conference of the Parties
FAO	Food and Agriculture Organisation of the United Nations
FRA	Forest Resources Assessment
GHG	Green House Gas
ILUA	Integrated Land Use Assessment
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land use, Land-use Change and Forestry
MRV	Measuring, Reporting and Verification
MTENR	Ministry of Tourism, Environment and Natural Resources
NFMA	National Forest Monitoring and Assessment
REDD	Reducing Emissions from Deforestation and Degradation
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
ZFD	Zambian Forestry Department

1. Introduction and background

Reducing Emissions from deforestation and forest degradation (REDD) may play a significant role in climate change mitigation and adaptation. Additionally, it has the potential to yield significant sustainable development benefits and generate a new financing stream for sustainable forest management in developing countries. The Bali Action Plan, adopted by the United Nations Framework Convention on Climate Change (UNFCCC) at the thirteenth session of its Conference of the Parties (COP-13) held in Bali in December 2007, mandates Parties to negotiate a post 2012 instrument, including possible financial incentives for forest-based climate change mitigation actions in developing countries. COP-13 also adopted a decision on “Reducing emissions from deforestation in developing countries: approaches to stimulate action”. This decision encourages parties to explore a range of actions, identify options and undertake efforts to address the drivers of deforestation and forest degradation (UN-REDD Programme 2008). The Bali Action Plan also highlighted the importance of “measurable, reportable and verifiable” (MRV) greenhouse gas mitigation actions and commitments (OECD and IEA 2009).

In response to the COP-13 decision, requests from countries, and encouragement from donors, FAO, UNDP and UNEP developed a collaborative REDD programme. A multi-donor trust fund was established that allows donors to pool resources and provides funding to activities towards this programme. During the pilot phase of this programme, country programmes are being developed under the UN Joint Programme Modality, and with strong linkages to related programmes and activities in the countries. The present study is a component of the UN-REDD country activities for REDD preparations for the Republic of Zambia, which is one among 9 countries selected as pilot countries for the UN-REDD programme.

1.1. Purpose

Developing a Measurement Reporting and Verification (MRV) system will plays a significant role in preparing countries for REDD readiness. The overall purpose of the study has been to establish a starting point for developing the elements of a such a system for the Republic of Zambia. By analysing existing field data generated from the Integrated Land Use Assessment (ILUA) in Zambia, collected in the period from 2005 to 2007 and completed in 2008, in conjunction with ancillary information, the study had the following objectives:

- Provide national level carbon stock assessment by land use category and carbon pool, including statistical precision measures, based on available forest inventory data;
- Compare above findings with previous estimates and reports and analyse the differences;
- Make projections of potential carbon mitigation/sequestration in each land use category under different scenarios of land use developments;
- Evaluate current estimates and reports of emissions from deforestation against the above results;

The study also sought to demonstrate how the selection of methods for estimating forest carbon stock influences the final estimate. In order to structure the report and guide the work, the following working questions were developed:

1. Based on forest inventory data, how can national level carbon stock in Zambia be estimated for various land use categories and carbon pools and within what range are the estimates?
2. What data are available for estimating deforestation in Zambia and what is the estimated annual deforestation rate?
3. Based on historical data and carbon stock estimate derived from ILUA data, what has been the annual decrease in forest carbon stock from deforestation and degradation in Zambia?
4. What are the potential scenarios for REDD in terms of land-use development in Zambia?

Due to limitations in available time and information, most attention has been placed on answering question 1 and 2. Working question 3 and 4 thus remain subjects for further exploration.

The study was carried out in close collaboration with FAO staff members in the National Forest Resources and Assessment (NFMA) programme and the Zambian Forestry Department (ZFD) under Ministry of Tourism, Environment and Natural Resources (MTENR). FAO's Division of Environment, Climate Change and Bio-energy (NRCD) provided supervision along the study course.

1.2. Working process

The study was undertaken during two and a half month in the period from February to July 2009. The working process for the consultancy involved 4 main phases: literature review, data analysis, field work and writing/presentation of results.

To ensure that the study was carried out in concurrence with national research initiatives and other national MRV related activities it was found pertinent to establish collaboration with national stakeholders to the widest extent possible and get their input to the study. In particular the ZFD was planned to have a pivotal role as they tentatively have been assigned as the lead technical governmental entity for implementing a future REDD programme in Zambia. For that reason, UN-REDD focal point in ZFD as well as personnel responsible for the ILUA project were consulted throughout the study period. However, due to the limited experience held at ZFD in conducting studies of this nature, the main work remained in the hands of the FAO consultant.

Literature review

In order to make certain that the report incorporated the optimal methods for estimating carbon stock based on inventory data, a review of state-of-the art studies was carried out. It was found that suitable methods for Africa are not well developed and very few empirically based studies have been made on carbon stock estimation for the region. Furthermore, a considerable amount of time was allocated to the search for ancillary data that could shed light on historical deforestation rates and drivers of carbon emission from forest conversion and degradation. Again, this information was difficult to access within the limited time frame of the consultancy.

Data analysis

The main data source for this study has been the ILUA which was carried out in Zambia during the period from 2005-2008. National wide and systematically sampled field data were analysed by applying methods identified through the literature review. Ancillary data were subsequently used for comparison and further analysis of carbon stock changes over time. An important element in the data analysis was the collaboration with the NFMA technical team, which together with the ZFD has had the main responsibility for collecting the ILUA field data. The NFMA team holds substantial experience in analysing and processing forest inventory data and provided technical input throughout the study process. Results that came out of the ILUA project and were published in the final project report (ZFD/MTENR and FAO 2008a) have been incorporated in the current study where relevant.

Field work

During two weeks from 3- 15 May, fieldwork was undertaken with the purpose of presenting preliminary study findings to national stakeholders, establish collaborative working arrangements and to seek input from national stakeholders for the remaining analysis and writing process. The field work also served as an opportunity for collecting ancillary data.

The mission coincided with at joint UN-REDD scoping mission with members from UNDP, UNEP and FAO. The consultant attended the mission, which served to uncover the various needs for establishing a MRV system in Zambia and how the present report could tap into already existing national MRV related activities.

Annex I presents an outline of the entire mission undertaken for this study.

Writing

Writing was carried out from end May to end June 2009.

1.3. Limitations and assumptions

A number of limitations and assumptions were required to confine the analysis and meet the expected outputs within the allocated time. During the working process it was realised that not all working questions could be evenly well answered. Data base querying and data analysis required substantial time and research, virtually consuming a major part of the available time. At the same time, it was during the field work realised that it was impossible to access all the wanted information. Further, production of scientifically 'bullet proof' results requires large time investment or very narrow study objectives and in depth analyses. This study seeks to explore several elements of MRV for REDD, each of which in principle individually could justify for elaborate and lengthy scientific research. Substantial scientific research in this field of work is currently being undertaken in the academic work and it would be beyond the scope of this study to unveil all elements of carbon stock assessment. Likewise the UN-REDD programme is developing a protocol with the title: Comparison of methods for the measurement and assessment of carbon stocks and carbon stock changes in terrestrial carbon pools, which builds on state-of-the art scientific studies. Consequently, this study should be perceived as but one element of the toolbox for establishing a MRV system for REDD with special focus on the South African region. The current report has striven to provide the best possible results within the allowed time frame and with the available data.

Though it is generally recognised that data obtained with remote sensing methods can play an important role in monitoring green house gases (GHG) emission from forest cover changes this typo of data have only been applied to a minor extent in this study. In the case of Zambia, the available inventory data from the recently completed ILUA was considered the most comprehensive and accurate information source for carbon stock estimation.

It is assumed that the reader of the current report has a general knowledge about the relationship between land use changes and carbon emissions as well as the terrestrial carbon cycle in general. The report does not go into details on these topics. The study follows the widely recognised definitions provided by FAO in the Global Forest Resources Assessment (FAO 2006) and IPCC (IPCC 2006) on land use classification, land use changes and the linkages to carbon emissions. The land use classification applied in the case of Zambia can be viewed in table 7. As for the methods on estimation of carbon stocks changes, the IPCC 2006 guidelines for National Greenhouse Gas Inventories (in the remainder referred to as IPPC 2006 guidelines) as well as the study by S. Brown (1997) have been used as main references. The selection of methods for estimating carbon stock has been drawn from a number of scientific studies.

1.4. Information sources

This study draws on mainly three sources of information:

- Scientific literature, including the IPCC 2006 guidelines. Table 1 provides a list of scientific studies that were relevant when conducting the carbon stock assessment for Zambia. Notice the limited number of studies related to Africa.
- National historical studies providing ancillary information of forest status (table 14)
- The Integrated Land Use Assessment (ILUA) for Zambia (ZFD/MTENR and FAO 2008a).

Table 1 List of main scientific references that were found useful in the study.

Generic studies on carbon estimation in tropical forests
Brown, S. 1997. Estimating biomass and biomass change of tropical forests: a primer. FAO Forestry Paper no. 134 Rome.
Brown, S., Gillespie, A. and Lugo, A.E. 1989. Biomass estimation methods for tropical forests with applications to forest inventory data. Forest Science. 35, 881–902.
Brown, S. and Gaston, G. 1995. Use of forest inventories and geographic information systems to estimate biomass density of tropical forests: applications to tropical Africa. Environmental Monitoring. 38, 157–68.
Brown, S. 2002. Measuring carbon in forests: current status and future challenges. Environmental Pollution. 116, 363–72.

Chave, J., Andalo, C., Brown, S., Cairns, M.A., Chambers. C.Q., Eamus, D. Fölster, -h., Fromard, F., Higuchi, N., Kira, T., Lescure, J-P., Nelson, B.W., Ogawa, H., Puig, H., Riéra, B., Yamakura, T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests Oecologia 145 87–9
Gibbs, H.K., Brown, S., Niles, J.O. and Foley, J.A. 2007. Monitoring and estimating tropical forest carbon stocks: making REDD a reality. Environmental Research Letters (2).
IPCC 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Ed. Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T. and Tanabe, K. (Japan: Institute For Global Environmental Strategies).
Ecosystem and region specific studies related to carbon estimation
Chidumayo, E.N. 1993. Zambian charcoal production: miombo woodland recovery. Energy Policy 12, 586-597.
Chidumayo, E.N. 1994. Inventory of wood used in charcoal production in Zambia. A report for the Biodiversity Support Program, World Wildlife Fund, Washington DC.
Hofstad, O. 2005. Review of biomass and volume functions for individual trees and shrubs in Southeast Africa. Journal of Tropical Forest Science 17 (1): 151-162.

As for the availability of national historical information in Zambia, a number of forest cover surveys have been conducted in the past but in most cases they have been undertaken independently and are not directly comparable. Very few review studies have attempted to provide a thorough analysis of the forest cover trend at national level. In this study, and as a result of this lack of overview in the literature, two references have been used as main information sources: The FRA 2005 country report for Zambia (FAO 2006b) and the 2003 Forestry Support Program Inventory (FSP 2003). While the former provides estimates of forest status trends based on a few historical data sets, the latter gives a short review of past inventories as well as updated and independent inventory data. Table 2 originates from the FSP 2003 report and provides an overview of previous forestry inventories and assessments. No studies, except from that done under the ILUA 2008 project, have attempted to estimate forest cover changes in Zambia based on remote sensing data.

In addition to the forest cover surveys, the National Green House Gas inventory for Zambia from year 2000 (MTENR 2000) and the draft version from 2007 (ECZ 2007) have been used in this study for the purpose of comparison.

Integrated Land Use Assessment (ILUA)

In recognition of the lack of sound and reliable national level forest resource information, the Government of Zambia decided in 2005 to initiate the Integrated Land Use Assessment (ILUA). The ILUA is based on a standard national forest assessment (NFA) approach developed by FAO, which has been applied in several other, mainly developing, countries since 2000 (e.g. Costa Rica, Guatemala, Honduras, Lebanon, Cameroon, The Philippines, Bangladesh and Nicaragua). The NFA design has been developed to ensure collection of a holistic set of data to meet a number of national and international information requirements. Elaborate description of the NFA methodology is available at the webpage of FAO's programme for National Forest Monitoring and Assessment (NFMA) (www.fao.org/forestry/nfma).

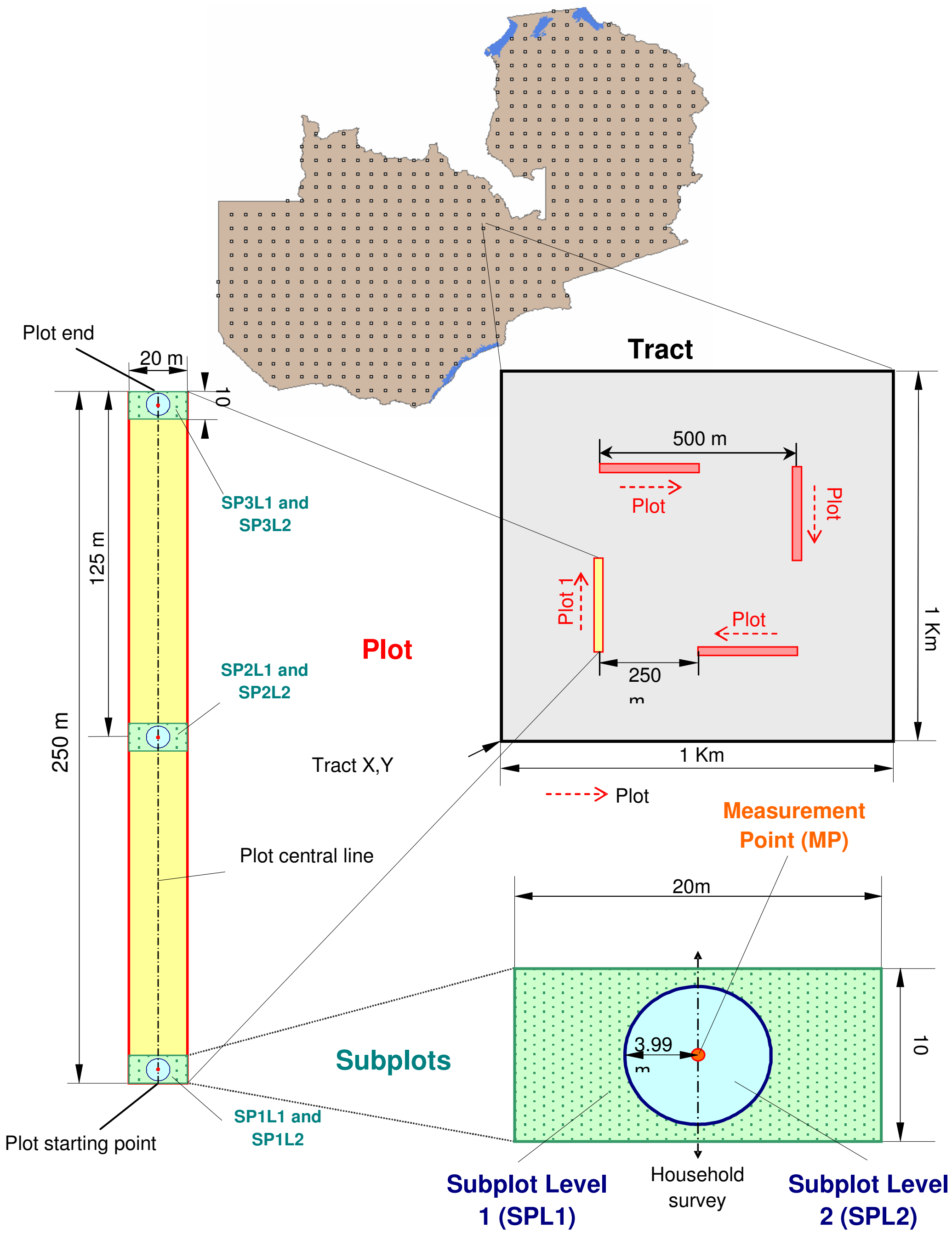

Figure 1 Map showing the distribution of the permanent sample plots and the layout of the field plots (ZFD/MTENR and FAO 2008).

The core set of variables in the standard NFA approach relates only to forest resources. However, in the case of ILUA the assessment was extended to cover also the sectors of agriculture and livestock. The main bulk of data collection for ILUA was conducted in 2006 (consequently, for the remainder of the report, the reference year for the ILUA data will be 2006) while most data processing and analysis for the project report was carried out in 2007.

The data was acquired through field surveys in permanent established sample plots spread across the country and consisted of field measurements, observations and local interviews which captured data related to forestry, livestock and agriculture. In additional, spatial land-cover data was generated from Land-sat Imagery from 2000 and 2005. However, the outputs from the remote sensing study are only used to a minor extent in the current report. Figure 1 depicts the layout of the sample grid and plots for the field inventory. The ILUA data was collected in 248 permanent sample units (often referred to as 'tracts') established systematically throughout the country at the intersections of every 30 minutes on the latitude/longitude grid. Out of the planned 248 sample units, 221 of the sample units were inventoried (the remaining 27 sample units were left out mainly due to inaccessibility). Each sample unit (1 x 1 km) consist of a cluster of 4 sample plots (20 m x 250 m) in which data collection was carried out. Within the sample plots, two levels of subplots were marked out in which, among other things, seedlings and smaller dimension trees were measured. Besides the bio-physical measurements in the plots, socio-economic variables were surveyed in the surrounding area following supplementary sampling procedures. In total 433.1 ha was captured in the sample, translating into a sampling intensity of approximately 0.000006%. The data set contains measurements of diameter at breast height (dbh), total height, commercial height, major branches, species, health state, etc. of 26519 trees, out of which 18420 (29%) belong to the diameter class of dbh $\geq$ 20 cm and 8099 trees (31%) to the diameter class with dbh < 20 cm.

Table 2 Synopsis on the development of Zambian forest inventories 1932-2004 (source: FSP 2003).

Period	Inventory
1932 - 1936	Sample plots established near Ndola to determine the productivity of Miombo woodlands.
1942 - 1944	The first extensive forest inventory identifying and estimating the timber volume availability for Copperbelt Province mines.
1949 - 1951	Small-scale forest inventory identifying and estimating the timber volume for Western Province concession harvesting.
1952 - 1967	Large-scale inventory for District Forest Management Books covering all the Districts in the country.
1972	Timber and woodland survey of East Luangwa, PFA No. 170
1984 - 1986	First estimate of Zambia's woody biomass resource: Wood consumption and supply survey at national level.
1987	Second estimate of Zambia's woody biomass resource: SADC wood energy study based on small-scale satellite imagery.
1994 - 1996	Forest resources management study for Zambezi Teak forests in south-western Zambia in co-operartion with the Japan International Cooperation Agency (JICA).
1996	Forest inventory for Mulungushi West forest reserve, in Central Province and for Mwewa forest reserve, in Luapula Province under the Provincial Forest Action Programme (PFAP).
1996 - 1998	Forest inventories in Copperbelt, Luapula and Southern Provinces under PFAP, Phase I.
1997	SADC estimate of Zambia's forest area: 29.4 million hectares.
1999 - 2001	Forest inventories in Copperbelt, Luapula and Southern Provinces under PFAP, Phase II.
2000	FAO 2000 estimate for Zambia's forest area: 31.2 million hectares.
2001	Local forest inventories in the Central Province under the Environmental Support Programme

	(ESP).
2002 - 2003	Forest inventories in all nine provinces: Central, Copperbelt, Eastern, Luapula, Lusaka, Northern, North-Western, Southern and Western Provinces under the Forestry Support Programme (FSP).
2004	Fourth estimate of Zambia woody biomass resource: FSP
2005 - 2008	Integrated Land Use Assessment (ILUA) covering the whole country

It is important to emphasis that the ILUA only provides data for one-point in time. Obtaining trend data for estimating carbon loss from land use changes is therefore not possible but would require sequential assessments or alternatively, ancillary data from past inventories.

2. Methods for calculating biomass and carbon stock

This chapter covers first part of working question 1:

Based on forest inventory data, how can national level carbon stock in Zambia be estimated for various land use categories and carbon pools and within what range are the estimates?

2.1. Selection of method

Though remote sensing methods are often found advantageous in many circumstances for estimating carbon stock in forests, ground based inventories may be found more feasible in some cases, in particular in developing countries (Gibbs et al. 2008). Furthermore, carbon losses that are not caused directly by deforestation but associated with forest degradation can be difficult to detect with optically based remote sensing methods. In contrary, ground inventory methods are able to capture finer details of change in the sampled area. Additionally, it is possible to incorporate other variables than those needed for pure carbon accounting in the design on ground inventories, such as indicators for the drivers of deforestation and degradation and the environmental impact of REDD related actions. Table 3 originates from Gibbs et al. 2007 and outlines the benefits and limitations of available methods in estimating national-level forest carbon stocks. Their conclusions suggest that field inventories, as for example ILUA, are simple to implement, provides estimates with low uncertainty and a is a good approach in countries with low technical capacity and low labour costs. On the downside, field inventories may be found to be expensive and slow to undertake.

Compared to confined ecological studies that are usually limited in geographical extent and most often not representative to a national scale, national level forest inventory data are preferable (Brown 1997). In that context, the ILUA approach has a number of advantages compared to a conventional forest inventory:

- ILUA contains forest data beyond the mere commercially interesting forest types, species and diameter classes;
- ILUA data contains precise measurements of all trees observed in the field with dbh above or equal to 7 cm, both inside and outside forests;
- All ILUA data are georeferenced and detailed information is stored for all plots and trees;
- Permanent sample plots are established, useful for land use and carbon stock change estimates;
- The ILUA approach follows international agreed definitions and standards;
- ILUA takes a holistic approach capturing many dimensions related to forest management and the multiple functions of forests.

On the less positive side, a recent technical evaluation of the NFMA programme suggested that the inventory design, as also applied in ILUA, has the disadvantage of using a rather sparse sampling design. As a result, change estimates (e.g. in carbon stock or land use areas), which are often small, are difficult to detect or are associated with large sampling errors. However, the evaluation also concludes that the approach suits well the requirements for UNFCCC LULUCF (Land use, Land-Use Change and Forestry) reporting, both in terms of scope and precision (ZFD/MTENR and FAO 2008b).

Table 3 Benefits and limitations of available methods to estimate national-level forest carbon stock (source: Gibbs et al. 2008).

Method	Description	Benefits	Limitations	Uncertainty
Biome averages	Estimates of average forest carbon stocks for broad forest categories based on a variety of input data sources	• Immediately available at no cost • Data refinements could increase accuracy • Globally consistent	• Fairly generalized • Data sources not properly sampled to describe large areas	High
Forest inventory	Relates ground-based measurements of tree diameters or volume to forest carbon stocks using allometric relationships	• Generic relationships readily available • Low-tech method widely understood • Can be relatively inexpensive as field-labor is largest cost	• Generic relationships not appropriate for all regions • Can be expensive and slow • Challenging to produce globally consistent results	Low
Optical remote sensors	• Uses visible and infrared wavelengths to measure spectral indices and correlate to ground-based forest carbon measurements • Ex: Landsat, MODIS	• Satellite data routinely collected and freely available at global scale • Globally consistent	• Limited ability to develop good models for tropical forests • Spectral indices saturate at relatively low C stocks • Can be technically demanding	High
Very high-res. airborne optical remote sensors	• Uses very high-resolution (~10–20 cm) images to measure tree height and crown area and allometry to estimate carbon stocks • Ex: Aerial photos, 3D digital aerial imagery	• Reduces time and cost of collecting forest inventory data • Reasonable accuracy • Excellent ground verification for deforestation baseline	• Only covers small areas (10 000s ha) • Can be expensive and technically demanding • No allometric relations based on crown area are available	Low to medium
Radar remote sensors	• Uses microwave or radar signal to measure forest vertical structure • Ex: ALOS PALSAR, ERS-1, JERS-1, Envisat)	• Satellite data are generally free • New systems launched in 2005 expected to provide improved data • Can be accurate for young or sparse forest	• Less accurate in complex canopies of mature forests because signal saturates • Mountainous terrain also increases errors • Can be expensive and technically demanding	Medium
Laser remote sensors	• LiDAR uses laser light to estimates forest height/vertical structure • Ex: Carbon 3-D satellite system combines Vegetation canopy LiDAR (VCL) with horizontal imager	• Accurately estimates full spatial variability of forest carbon stocks • Potential for satellite-based system to estimate global forest carbon stocks	• Airplane-mounted sensors only option • Satellite system not yet funded • Requires extensive field data for calibration • Can be expensive and technically demanding	Low to medium

Biomass, which is the main source for carbon stock in tropical ecosystems (Gibbs et al. 2008), is here defined as the total amount of aboveground living organic matter in trees (including leaves, twigs, branches, main bole and bark) expressed as oven-dry tons per unit area (tree, hectare, region or country). Biomass density is referred to when expressed as mass per unit whereas total biomass for a region or country is obtained from the product of biomass density and the corresponding area (Brown 1997). Estimation of above ground biomass, which is essentially what ILUA data are able to provide data for, will in most cases be adequate to estimate carbon stock in other pools. The carbon pools and associated methods for estimating carbon stock, as applied in this report, are outlined in table 4. Biomass estimations are in this study not restricted to just forests but to all land uses where trees are observed, including closed forest, open forest, woodlands, woody savannas, woodlots, line tree planting, home gardens, living fences, solitary trees, etc.

Table 4 Carbon pools and associated methods for carbon stock estimation as carried out in this study.

Carbon pools		**Method used for carbon stock estimation with ILUA data**
Biomass	**Above ground**	Methods applied as described in this report section (2.1). Estimates done for all land use categories. Estimates correspond to IPCC 2006 guidelines tier level 2 or 3. Carbon fraction of biomass equal to 0.47.
	Below ground	Look-up tables and correlations with above biomass applied as provided in the IPCC 2006 guidelines for tier level 1 estimations. Below/above ground biomass fraction = 0.28 for tropical dry forest with above ground biomass > 20tonnes/ha. Calculated for all land use categories. Carbon fraction of biomass equal to 0.47.
Dead organic mater	**Dead wood**	Estimated in similar manner as for above ground biomass. Calculated for all land use categories. Carbon in stumps and in dead biomass below ground (roots of dead trees and stumps) have been excluded due to the lack of sufficient data.* Carbon fraction for dead wood has in the estimates been assumed to be equal to that of living biomass (0.47). However, studies suggest a carbon fraction of deadwood to be closer to 0.34 (Pearson & Brown 2005). Thus all deadwood estimates given in this report might need to be adjusted with a factor 0.723 (=0.34/0.47). This adjustment has not been done.
	Litter	Using look-up tables as provided in the IPCC 2006 guidelines for tier level 1 estimates. Evergreen = 5.2 tonnes carbon/ha, deciduous and other natural forest = 2.1 tonnes of carbon/ha. For semi-evergreen forest (miombo), the Frost (1996) litter estimate has been applied (5.48 tonnes of biomass/ha) converted to carbon using 0.47 as carbon fraction. Carbon in the litter pool has only been calculated for forest land use categories.
Soil carbon		Using IPCC look-up tables for tier level 1 estimations. All areas are assumed to contain mineral soils (31 tonnes of carbon/ha). Soil carbon has only been calculated for the land use categories of forest and other wooded land where it is being assumed (following the tier 1 approach) that no change in soil carbon occurs with change of management.

* The number of stumps and their associated diameter were in fact recorded in ILUA. However, the data do not indicate if a dead tree can be associated with any stump or visa versa or if the individual dead trees are still standing or lying on the forest floor. Consequently, in order to avoid double counting, deadwood has only been estimated for the ‘above ground’ fraction.

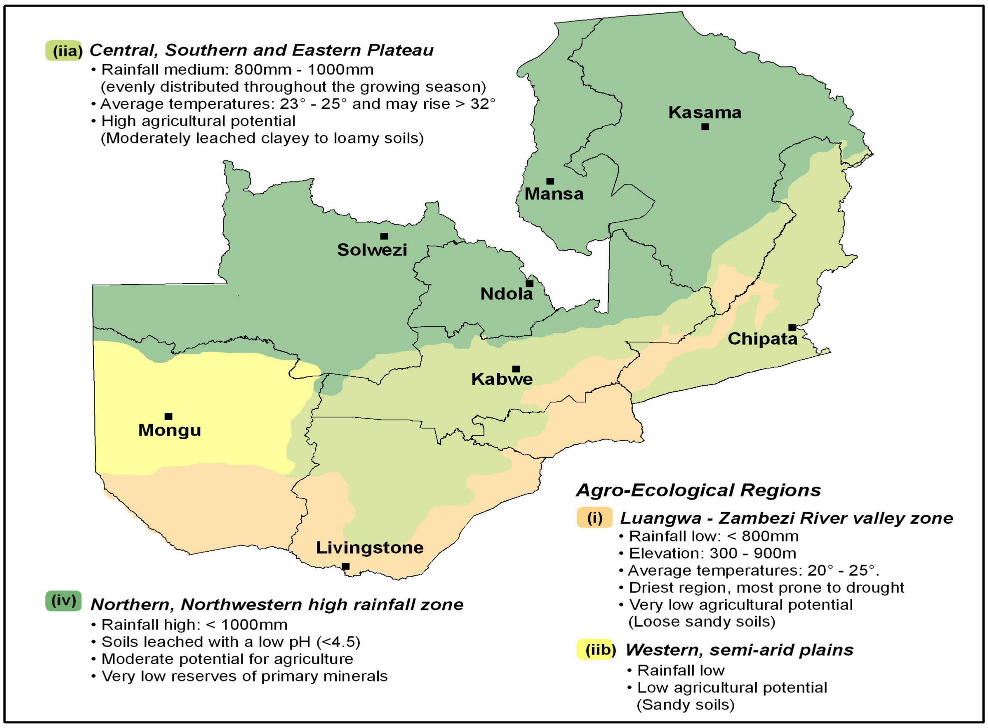

Figure 2 Climatic zones of Zambia (ZFD/MTENR and FAO 2008a).

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Table 5 Models applied in this study for estimation of biomass by Zambian climatic zones (see figure 2 above).

Climatic zone	Description of zone	Models applied
Luangwa Zambezi Rift Valleys	Comprises the low rainfall (semi-arid, < 800mm), low altitude (400-900m), hot and dry areas along the Luangwa and Zambezi Rift Valleys	**i.** $Biomass = (\pi * D^2 * H * 0,74)/4 * BCEF$
		ii. $Biomass = 10^{-0.535 + \log_{10}(pi * D^2/4)}$
		iii. $Biomass = \exp(-2.187 + 0,916 * \ln(\rho D^2 H))$
Central, eastern and Southern Plateau	Consists of a sub-region of the medium rainfall (800-1000mm) plateau including main farming areas on the plateau of Central, Eastern and Southern Provinces. The altitude ranges between 900 and 1300m	**i.** $Biomass = (\pi * D^2 * H * 0,74)/4 * BCEF$
		ii. $Biomass = \exp(-1.996 + 2.32 * \ln(D))$
		iii. $Biomass = \exp(-2.187 + 0,916 * \ln(\rho D^2 H))$
Western Plains	Relate to a sub-region of the medium rainfall (800-1000mm) plateau comprising the Kalahari (Barotse) sand plateau and the Zambezi flood plains. The altitude ranges between 900 and 1200m	**i.** $Biomass = (\pi * D^2 * H * 0,74)/4 * BCEF$
		ii. $Biomass = \exp(-1.996 + 2.32 * \ln(D))$
		iii. $Biomass = \exp(-2.187 + 0,916 * \ln(\rho D^2 H))$
Northern High Rainfall Plateau	High rainfall (>1000mm) area in the north and on the plateau. The altitude ranges between 1100 and 1500m	**i.** $Biomass = (\pi * D^2 * H * 0,74)/4 * BCEF$
		ii. $Biomass = \exp(-2.134 + 2.530 * \ln(D))$
		iii. $Biomass = \exp(-2.977 + \ln(\rho D^2 H))$

i. Volume equation used by ZFD converted to biomass by applying default BCEF (IPCC 2006)
ii. Allometric regression model by Brown (1997)
iii. Allometric regression model by Chave et al. (2005)

In general two methods exist for estimating above ground biomass when using ground based forest inventory data. For the purpose of comparing results of the different methods, it was decided in the study to apply both methods (while recognising that the second method in most cases provides more precise estimates):

A. Converting existing volume density estimates to biomass density;
B. Directly estimating biomass density using biomass regression equations (allometric relationships).

A. Volume function; BCEF

The approach, which is predominantly mentioned in the IPCC 2006 guidelines, is the application of a single discrete transformation factor on available merchantable volume figures to derive at above-ground biomass. The calculation steps involve conversion of volume (m^3) into dry-weight (using the basic wood density (D) (tonnes/m3)) and expansion of merchantable growing stock to account for non-merchantable components of the tree (using the Biomass Expansion Factor (BEF)). Alternatively, a Biomass Conversion and Expansion Factors (BCEF) can be used, which combines the two calculation steps in one factor. BCEF and BEF are mathematically related by: *BCEF=BEF x D*. The IPCC 2006 guidelines provide default range values for BEF and BCEF as well as basic wood density values for some selected species. In this study the BCEF have been applied.

Using volume data to estimate biomass has one main advantage: in many countries the volume data already exists due to the commercial interest in recording stock of wood resources. Such data might even be available for more than one point in time. As outlined earlier in the report, Zambia has had several forest inventories in the past. Of these, the two latest (ILUA 2008 and FSP 2003) both use the same volume function for estimation of growing stock. However, the volume function developed by ZFD was developed based on a sample of trees from only one region of the country, which suggests that it is not representative for the entire country. Making re-estimations of growing stock with alternative volume functions seemed not to be an option as such equations did not exist for all eco-zones found in Zambia. The available volume function takes into account the merchantable part of the tree including branch wood. Having branches already included in the volume function suggests the use of a fairly low BCEF. In order to illustrate the importance of selecting the right BCEF value, estimates have been made for both the low end as well as the average value of the BCEF range (following the default BCEF as provided for tier level 1 estimates in the IPCC 2006 guidelines). It is also worth to keep in mind that the volume function might be biased due to the geographically limited area for which the model was developed.

B. Allometric regressions

An alternative to the conversion of volume data via BCEF is the use of allometric relationships, which allow estimation of biomass directly from the unprocessed ILUA data. This approach is particularly useful in cases, such as ILUA, were detailed information is available capturing for all species and a large proportion of the diameter classes ($\geq$ 7cm). Furthermore, it brings down the calculation process from 2 steps (volume estimation followed by conversion into biomass) to 1 step and decreases the inherent uncertainties within each step.

In general, allometric relationships can be grouped into two sub-categories:

- Generalized allometric models based on a large number of trees and locations and;
- Allometric models based on local ecological studies with a relative small number of sampled trees and/or species.

The literature review revealed that very few studies providing allometric equations have been conducted in Africa. Additionally, the few available are very narrow in geographical coverage and scope: e.g. focus has been on agroforestry systems, include few species or only sample a few trees. Another problem is associated with inconsistencies in study methods and variables causing difficulties when comparing estimates (e.g diameter might be measured at breast height or at stump height and biomass might be presented as dry weight or as fresh weight). This gap in useful generalised allometric models for Africa is also noted by Gibbs et al. 2007 as well as visible in the IPCC 2006 guidelines. While the guidelines suggest the use of allometric equations for reaching tier 3 level accuracy, they only provide study examples for Europe and The Americas.

Irrespectively that the IPCC 2006 guidelines point towards the advantages of using species-specific allometric equations, contemporary research takes a slightly different view. Brown 1997 suggests that in cases where models have to represent forest biomass density for large areas (as when making national level estimates in a country like Zambia), models specifically developed for confined ecological zones are not very suitable. Even though the main bulk of Zambian woody biomass is contained in miombo woodlands, several other ecological zones prevail in Zambia. A number eco-zone specific allometric models would therefore be required to match the variability in tree biomass across all ecological zones and vegetation types. Furthermore, the inherent variability in growing conditions within a single eco-zone such as miombo woodlands will obviously affect how well an allometric model applies to all locations within that zone. For that reason, it was for this study decided to apply generalised allometric models, while at the same time recognising that these were not explicitly developed for the African ecological zones. Along the same line, Gibbs et al. 2007 express the following notion concerning the use of species-specific models versus generalised models:

"Tropical forests often contain 300 or more species, but research has shown that species-specific allometric relationships are not needed to generate reliable estimates of forest carbon stocks. Grouping all species together and using generalized allometric relationships, stratified by broad forest types or ecological zones, is highly effective for the tropics because DBH alone explains more than 95% of the variation in aboveground tropical forest carbon stocks, even in highly diverse regions (Brown 2002). Generalized allometric equations also have the major advantage of being based on larger numbers of trees that span a wider range of diameters (Brown 1997, Chave et al 2005). An extensive review of allometric equations concluded that the pan-tropic models were 'the best available' way to estimate forest biomass and recommended them over local allometric models that may be based on less than 100 destructively sampled trees (Chave et al 2004)."

Two generalized allometric equations were selected with different levels of complexity, which are described in the following:

Allometric regression with one independent variable

Some of the most straight forward allometric regression models are those presented by Brown (1997). The models have the advantage of only having one independent variable (diameter at breast height). The BCEF default values provided by IPCC 2006 guidelines for tropical forests (and as applied in method A) are to a large extent developed based on the allometric models presented by Brown et al. (1989), which are also used in a refined version in Brown (1997). Yet, the use of these simple allometric models implies a few problems. First of all, no data stemming from African location have been included in the regression equations. Secondly, the model's goodness of fit to specific locations will be affected by the high variability of tree biomass with rainfall in dry areas (which apply for most parts of Zambia) (Brown 1997).

Allometric regression with three independent variables

Chave et al. (2005) present a number of allometric regressions, which they tested for their ability to estimate woody biomass in tropical forests. Unfortunately, this study, apart from being one of the most comprehensive studies providing generic allometric model for tropical forest, suffers from the lack of African field sampling sites. Some bias might therefore be expected when applying the models in Zambia. However, based on correspondence with Jerome Chave (Chave 2009, personal comment) and other experts in this field of work, it was decided that no better alternative models were available and that the bias involved by applying the models in an African context would be acceptable. Out of the set of models presented by Chave et al. (2005), two were found useful to the climatic zones of Zambia (dry tropical and moist tropical zones) (table 5 and figure 2). Both models have the independent variables of tree height, dbh and basic wood density and the dependent variable of biomass. While the ILUA data set contains records of both tree height and dbh, data on basic wood density were not directly available. Consequently, it was necessary to establish a data base with basic wood densities for each of the 350 recorded species. Two main sources for wood densities were used: the online data base at World Agroforestry Centre (World Agroforestry Centre 2009) and the downloadable Global Wood Density Database (Zanne et al. 2009). The data base established for the current study is found in Annex II. Both of the mentioned information sources build on an extensive review of scientific studies. As for the Global Wood Density Database, the meta data contains information on geographical location of the original study. For the data base by World Agroforestry Centre, this was not the case. To the widest extend possible basic wood density figures have been used from African tropical or extratropical studies. However, in those cases no data were available from African studies, wood density figures had to be used that potentially could originate from locations outside Africa. Another problem was that, for many of the listed species, there would be more than one record for basic wood density. For those species, a range of basic wood density had to be established, with the result that biomass estimates also had to be presented as ranges. For those species were no value for the basic wood densities was available, a mean value for Africa of 0.58 was applied. The decision path for assigning species with basic wood density values is visualised in figure 3.

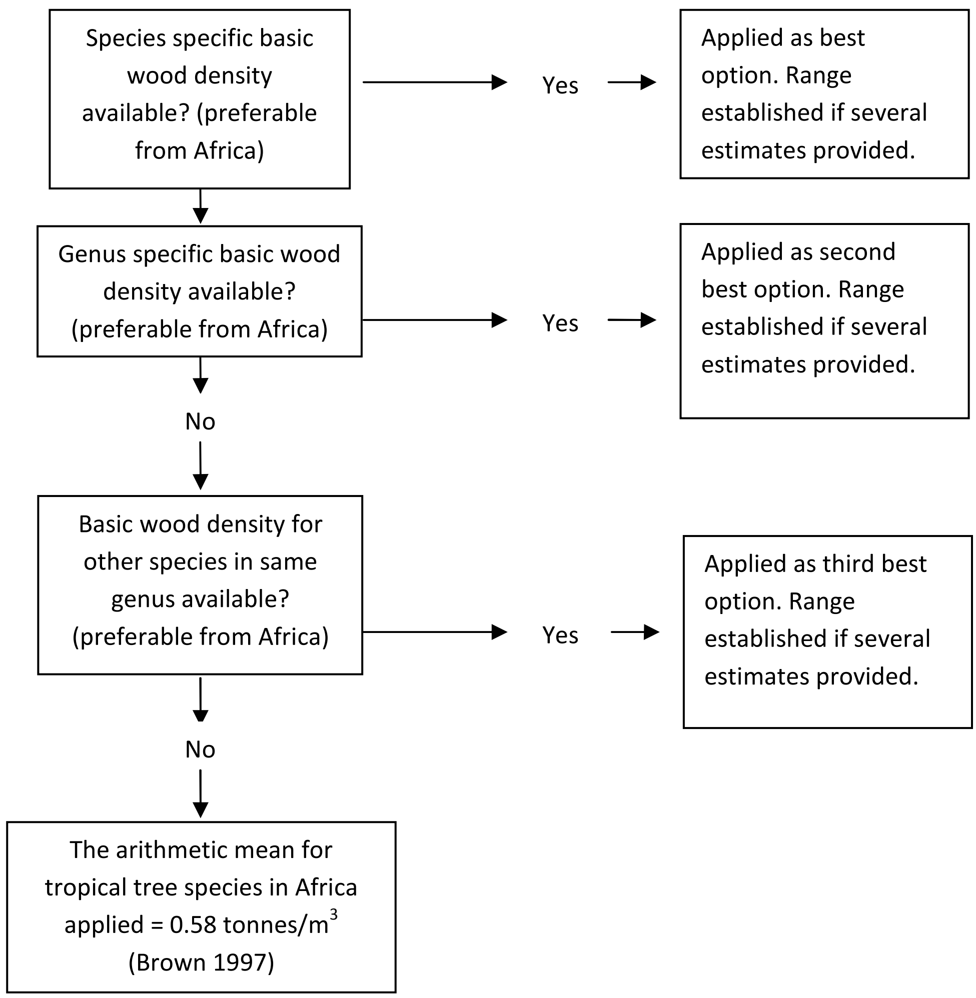

Figure 3 Decision path for assigning basic wood density values to species when calculating biomass.

The effect of using different models and parameters when estimating biomass at tree level is displayed in table 6. It is visible that already at the lowest level of estimation (i.e. tree level), the effect is pronounced. As a means for comparison, an additional volume estimate was included in the table; based on a volume function developed by Malimbwi et al. (1994) (Hofstad 2005) for various Miombo tree species in Tanzania. The comparison with the ILUA volume estimate indicates that the latter are somewhat over estimated. This hypothesis has not been further explored in this study.

Table 6 Example from a randomly selected group of trees from the ILUA data base, which compares biomass and volume estimates at tree level. The ILUA records are displayed in the first three rows (species name, dbh and height). The method denoted 'Volume; BCEF' refers to the conversion of volume estimates to biomass using BCEF. 'Allometric (*variable*)' denotes the use of allometric equations with the in-bracket indicated variables. 'Wd' = basic wood density. Biomass estimates are expressed as dry weight in tonnes.

Scientific name	Dbh	Height	Basic wood density Low	Basic wood density High	Biomass Allometric (dbh)	Biomass Allometric (dbh; height; low wd)	Biomass Allometric (dbh; height; high wd)	Volume (ILUA)	Biomass Volume; BCEF (Low)	Biomass Volume; BCEF (average)	Volume (Malimbwi et al. 1994)*
Julbernadia globiflora	42	17	0,72	1,08	1,51	1,10	1,65	1,74	1,74	2,61	1,29
Combretum molle	20	10	0,76	0,76	0,23	0,15	0,15	0,23	0,23	0,35	0,20
Lannea discolor	29	12	0,46	0,46	0,59	0,23	0,23	0,59	0,59	0,88	0,48
Becium	37	16	0,58	0,58	1,10	0,65	0,65	1,27	1,27	1,91	0,96
Julbernadia globiflora	28	14	0,72	1,08	0,54	0,40	0,60	0,64	0,64	0,96	0,50
Julbernadia globiflora	26	16	0,72	1,08	0,45	0,40	0,59	0,63	0,63	0,94	0,47
Combretum molle	30	16	0,76	0,76	0,65	0,56	0,56	0,84	0,84	1,25	0,62
Erythrophleum africanum	31	15	0,88	1,08	0,70	0,64	0,79	0,84	0,84	1,26	0,64
Pericopsis angolensis	32	11	0,72	0,72	0,76	0,41	0,41	0,65	0,65	0,98	0,56
Maprounea africana	38	10	0,47	0,72	1,18	0,35	0,53	0,84	0,84	1,26	0,74
Pericopsis angolensis	40	18	0,72	0,72	1,34	1,06	1,06	1,67	1,67	2,51	1,21
Lannea discolor	39	17	0,46	0,46	1,25	0,60	0,60	1,50	1,50	2,25	1,11
Diospyros batocana	41	18	0,64	1,25	1,42	0,99	1,93	1,76	1,76	2,64	1,27
Pterocarpus angolensis	30	17	0,52	0,59	0,65	0,40	0,46	0,89	0,89	1,33	0,65
Erythrophleum africanum	43	18	0,88	1,08	1,61	1,49	1,83	1,93	1,93	2,90	1,40
Brachystegia wangermeeana	21	16	0,60	0,71	0,26	0,22	0,26	0,41	0,41	0,61	0,30
Combretum collinum	11	6	0,65	0,65	0,05	0,02	0,02	0,04	0,04	0,06	0,04
Strychnos spinosa	13	5	0,65	0,65	0,08	0,03	0,03	0,05	0,05	0,07	0,05

***** The volume function was developed based on 17 trees of various Miombo tree species in Tanzania and includes stem and branches down to 1 cm diameter.

2.2. Accuracy and uncertainty

The total error in estimating carbon pools consist of sampling error (the variation among sampling units), measurement error (error in measuring the parameter of interest, e.g. dbh) and regression error (in the case of this study, the error inherent in the allometric equations and in the conversion of volume to biomass using BCEF). Brown (2002) refers to work done by Phillips et al. (2000) indicating that sampling error could amount to as much as 90-99% of the total error. Based on that, it was therefore decided for this study only to consider this element of uncertainty.

The ILUA builds on a multistage sampling approach, with three stages of sampling (sampling units, plots and subplots). Each stage of sampling involves measurements of different variables and diameter classes. Hence, in order to make exact estimates of the sampling error, rather complex calculations have to be carried out – a task that would require considerable amount of time. Instead it was found reasonable for the purpose of this study to follow the statistical standards as applied and recommended by FAO's NFMA technical staff. Based on past experiences from other NFMA projects and the basic assumption that variation within the 1x1 km sample units is fairly small, it has been found statistically sound by the NFMA technical staff only to consider one level of sampling; what has previously been denoted the sampling unit (in Figure 1 referred to as "Tract"). Thus, the sampling error is calculated by using the variation in biomass density estimates among the 248 sampling units in the ILUA. This approach also ensures that the sampling error is not underestimated. In the following sections, the sampling error is displayed by the confidence interval for each estimate. For a more thorough discussion of the NFMA sampling design, Tomppo and Anderson have made a technical review of the NFMA approach (FAO 2008).

3. Biomass and carbon stock estimates using ILUA data

This chapter covers second part of working question 1:

Based on forest inventory data, how can national level carbon stock in Zambia be estimated for various land use categories and carbon pools and within what range are the estimates?

The following chapter presents findings from the estimation of carbon stocks. Estimates are in the chapter only provided for the land use categories as applied in FAO's Global Forest Resources Assessment (FRA) (FAO 2006a). Charts are displayed for above ground biomass while tables present carbon stock for the relevant carbon pools. Annex III contains information for the complete set of land use categories following the classification used in ILUA (the classification scheme can be read from table 7). Estimates for above ground biomass, below ground biomass and dead wood have be conducted for all land use categories using the three different methods presented in the previous section. Because the methods for estimating above ground biomass was done with varying magnitude of parameters (basic wood density and BCEF), the result is 5 different estimates for each land use category.

For the land use categories of forest and other wooded land, the estimations are extended to include also the soil carbon pool. While soil carbon estimation models in general are quite complex, the IPCC 2006 guidelines on soil carbon estimation for tier level 1 suggest that soil carbon in forests can be estimated based on a simple model that assumes no effect of management mode. The IPCC land use categories do not specify the land use category of other wooded land and the assumption is here made that areas falling into this land use category can be treated as forest with regard to estimating soil carbon stock. Estimation of carbon stock in litter has only been done for forest. Carbon contained in other vegetation than trees, e.g. grass and herbaceous vegetation found in grass land and wetlands, have not been included in this study as the ILUA do not capture these components. At the end of the section, comparison is made with carbon stock estimates from other carbon stock studies. It should be noted that it is not the intention of this study to provide the "one and only" estimate, but rather to present estimates using various methods. Verification studies might be needed in the future to enable selection of the most valid method.

Table 8 presents the most fundamental result obtained from the ILUA, namely the land uses by area distribution. Following the FAO definition of forest, 66.4% of Zambia's land surface is covered by forest. Added to this comes 8% of Other Wooded Lands, while Other Lands make up 21%. Zambia has 4.6% of its land surface covered by Inland Water.

Table 7 Distribution of land use categories as found in the ILUA (ZFD/MTENR and FAO 2008a) following the ILUA land use classification. Highlighted rows indicate main land use categories as applied in FAO's Global Forest Resources Assessment (FAO 2006a).

Forests (=/> 10% Canopy Cover)	**Area ('000 ha)**	**Proportion of total land area %**
Evergreen Forest	819	1.1%
Semi-evergreen Forest	34,145	45.4%
Deciduous Forest	14,865	19.8%
Other Natural Forests	139	0.2%
Broadleaved forest plantations*	0	0
Coniferous forest plantations*	0	0
Total	**49,968**	**66.4%**
Other Wooded Land (5-10% canopy cover or shrubs/bushes canopy cover >10%	**Area ('000 ha)**	**Proportion %**
Wooded Grasslands	4,897	6.5%
Shrubs/thickets	1,158	1.5%
Total	**6,055**	**8.0**
Other land (<5% canopy cover or shrubs/bushes canopy cover <10%)	**Area ('000ha)**	**Proportion %**
Barren Land	9	0%
Grassland	6,085	8.1%
Marshland	1,332	1.8%
Annual crop	4,700	6.3%
Perennial crop	236	0.3%
Pastures	464	0.6%
Fallow	2,387	3.2%
Urban	7	0%
Rural	551	0.7%
Extraction site/mining area	0	0%
Total	**15,771**	**21.0%**
Inland Water (area occupied by major rivers, lakes and reservoirs)	**Area ('000ha)**	**Proportion %**
Lake	2,693	3.6%
River	774	1.0%
Dam	0	0%
Total	**3,467**	**4.6%**
Total Country Area of Zambia	**75,261**	**100%**

*None of the sample plots in ILUA felt in plantation forests. While plantations exist in Zambia, though with a relatively insignificant area representation, the ILUA data do not allow for estimation of carbon stocks in those areas.

3.1. Forest

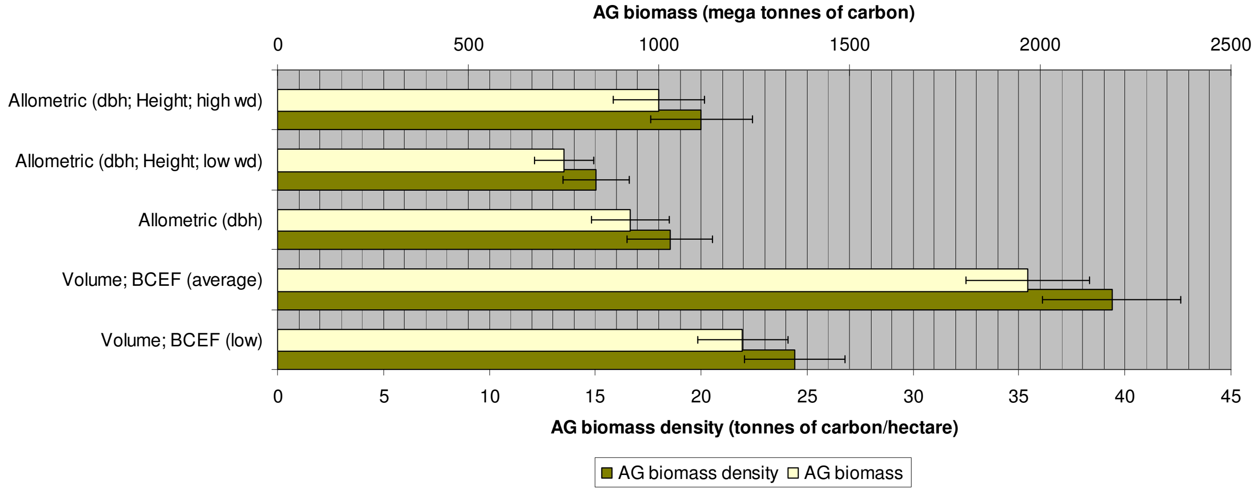

Figure 4 Carbon stock in the above ground biomass pool for forest land across all forest types in Zambia. Estimates are displayed as total amount of carbon (in mega tonnes) and as amount of carbon per hectare (in tonnes). Confidence intervals are indicated with the error bars.

From figure 4 and table 8 it is clear that choice of method has a large effect on the final carbon stock estimate. Depending on method, the above ground estimates span from approximately 15 tonnes of carbon/ha to 39 tonnes/ha. However, because of the estimate derived from applying the average BCEF default values (using IPCC 2006 guidelines) deviates significantly from the estimates using any other method, it was as previously mentioned considered relevant to assume this estimate as valid. Thus, the range is narrowed down to approximately 15 tonnes/ha – 24 tonnes/ha, which in total figures amounts to 750 – 1219 mega tonnes of carbon. Biomass (above and below ground) is estimate to be in the range of 960 and 1561 mega tonnes of carbon (still disregarding the estimate derived from using average level BCEF). The total carbon stock (including biomass, dead wood, litter and soil) amounts to between 2652 mega tonnes of carbon and 3323 mega tonnes of carbon. The ratio between live biomass and dead wood biomass above ground is found to be in the range of 0.02 and 0.057.

Not surprisingly for an African country in dry tropical climatic zone, semi-evergreen forest (which mainly consists of miombo woodlands) makes up the main bulk of the carbon stock (figure 5). Deciduous forest (which includes baikiea forests, kahlari woodlands, mopane woodlands and munga woodlands) also add a significant proportion.

Table 8 Carbon stock in carbon pools for forest land across all forest categories in Zambia. Estimates are displayed as total amount of carbon (in mega tonnes) and as amount of carbon per hectare (in tonnes). Confidence intervals are indicated with "+/-". The method denoted 'Volume; BCEF' refers to the conversion of volume estimates to biomass using BCEF. 'Allometric (*variable*)' denotes the use of allometric equations with the in bracket indicated variables. 'Wd' = basic wood density.

Pool, Scale and confidence interval		Method: Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	24,41	39,37	18,53	15,02	20,01
	+/- per ha	2,35	3,254815	2,025277	1,563811	2,3997847
	Total (mega tonnes of carbon)	1219,56	1967,002	925,8671	750,532	999,46763
	+/- total	117,5462	162,6134	101,1846	78,12935	119,89534
Biomass BG	Density (tonnes of carbon/ha)	6,834882	11,02384	5,188917	4,206271	5,6014022
	+/- per ha	0,658774	0,911348	0,567078	0,437867	0,6719397
	Total (mega tonnes of carbon)	341,4767	550,7605	259,2428	210,149	279,85094
	+/- total	32,91293	45,53176	28,3317	21,87622	33,570694
Dead wood	Density (tonnes of carbon/ha)	1,791342	3,857677	0,677367	0,372375	0,4705143
	+/- per ha	0,433884	0,878666	0,196865	0,090767	0,130117
	Total (mega tonnes of carbon)	89,49702	192,7329	33,84186	18,60419	23,507304
	+/- total	21,6772	43,89891	9,835527	4,534779	6,5007592
Litter	Density (tonnes of carbon/ha)	2,475806	2,475806	2,475806	2,475806	2,4758058
	+/- per ha	na	na	na	na	na
	Total (mega tonnes of carbon)	123,7111	123,7111	123,7111	123,7111	123,71106
	+/- total	na	na	na	na	na
Soil	Density (tonnes of carbon/ha)	31	31	31	31	31
	+/- per ha	na	na	na	na	na
	Total (mega tonnes of carbon)	1549,008	1549,008	1549,008	1549,008	1549,008
	+/- total	na	na	na	na	na

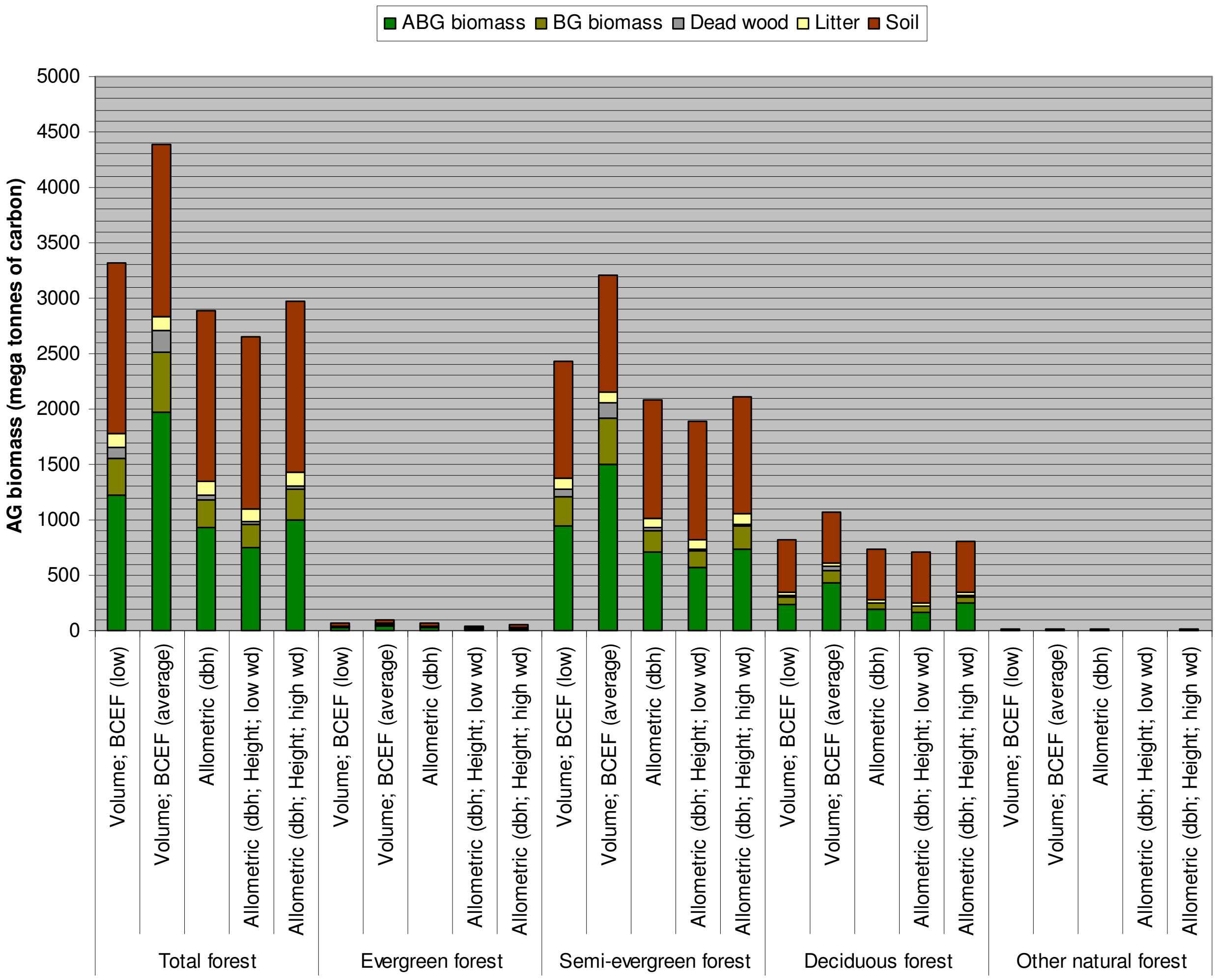

Figure 5 Distribution of carbon stock by carbon pools in the different forest categories in Zambia estimated with different methods (data displayed in table 9).

Table 9 Distribution of carbon stock by carbon pools in the different forest categories in Zambia estimated with different methods (see figure 5).

	Metod	ABG biomass (M tonnes)	BG biomass (M tonnes)	Dead wood (M tonnes)	Litter (M tonnes)	Soil (M tonnes)	Total (M tonnes)
Total forest	Volume; BCEF (low)	1219,56	341,4767	89,49702	123,7111	1549,008	3323,252
	Volume; BCEF (average)	1967,002	550,7605	192,7329	123,7111	1549,008	4383,214
	Allometric (dbh)	925,8671	259,2428	33,84186	123,7111	1549,008	2891,671
	Allometric (dbh; Height; low wd)	750,532	210,149	18,60419	123,7111	1549,008	2652,004
	Allometric (dbh; Height; high wd)	999,4676	279,8509	23,5073	123,7111	1549,008	2975,545
Evergreen	Volume; BCEF (low)	27,71207	7,759378	4,984604	4,2588	25,389	70,10385
	Volume; BCEF (average)	41,6356	11,65797	9,774859	4,2588	25,389	92,71622
	Allometric (dbh)	24,18561	6,77197	2,449497	4,2588	25,389	63,05488
	Allometric (dbh; Height; low wd)	13,04847	3,653571	0,843542	4,2588	25,389	47,19338
	Allometric (dbh; Height; high wd)	14,84218	4,15581	1,078783	4,2588	25,389	49,72457
Semi-evergreen	Volume; BCEF (low)	948,6373	265,6184	70,31401	87,94386	1058,495	2431,009
	Volume; BCEF (average)	1493,452	418,1664	150,0022	87,94386	1058,495	3208,059
	Allometric (dbh)	707,7292	198,1642	24,52055	87,94386	1058,495	2076,853
	Allometric (dbh; Height; low wd)	564,7903	158,1413	13,59523	87,94386	1058,495	1882,966
	Allometric (dbh; Height; high wd)	739,2881	207,0007	17,2906	87,94386	1058,495	2110,018
Deciduous	Volume; BCEF (low)	240,2838	67,27947	13,54902	31,2165	460,815	813,1438
	Volume; BCEF (average)	427,5253	119,7071	31,49477	31,2165	460,815	1070,759
	Allometric (dbh)	190,9087	53,45442	6,654464	31,2165	460,815	743,049
	Allometric (dbh; Height; low wd)	171,1245	47,91486	4,076726	31,2165	460,815	715,1476
	Allometric (dbh; Height; high wd)	243,3827	68,14714	5,028937	31,2165	460,815	808,5902
Other nat. for.	Volume; BCEF (low)	2,92634	0,819375	0,649382	0,2919	4,309	8,995997
	Volume; BCEF (average)	4,38951	1,229063	1,461109	0,2919	4,309	11,68058
	Allometric (dbh)	3,043677	0,852229	0,217348	0,2919	4,309	8,714154
	Allometric (dbh; Height; low wd)	1,568792	0,439262	0,088694	0,2919	4,309	6,697648
	Allometric (dbh; Height; high wd)	1,954739	0,547327	0,108984	0,2919	4,309	7,211951

3.2. Other wooded land

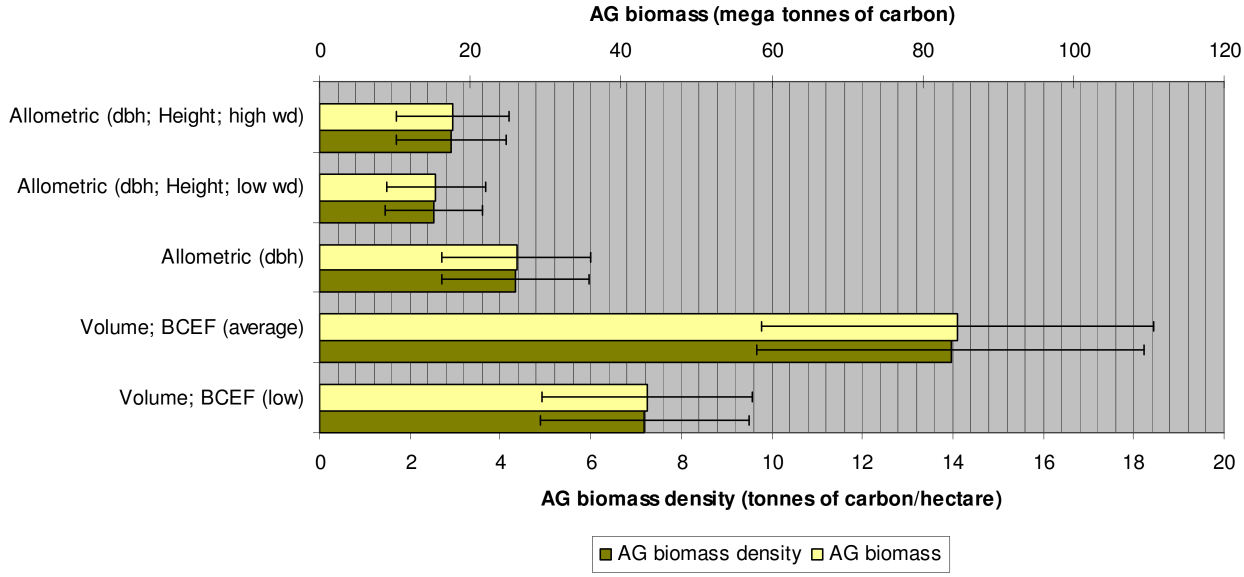

Figure 6 Carbon stock in the above ground biomass pool for other wooded land in Zambia. Estimates are displayed as total amount of carbon (in mega tonnes) and as amount of carbon per hectare (in tonnes). Confidence intervals are indicated with the error bars.

Other wooded lands contain areas of wooded grasslands with tree cover less than 10% and areas with shrubs and bushes. The biomass (above and below ground) is estimated to be in the range of 22-61 mega tonnes of carbon. The total carbon stock (biomass above and below ground, dead wood and soil) is estimated to be between 210 and 250 mega tonnes of carbon. The data are displayed in details in table 10 and show that soil carbon is making up a significant proportion of the total carbon stock (between 75% and 90%). It should be kept in mind that the biomass figures here only include woody biomass while biomass in grass and other vegetation are not accounted for. Above ground biomass in *other wooded lands* is presented in figure 6.

Table 10 Carbon stock in different carbon pools for other wooded land in Zambia. Estimates are displayed as total amount of carbon (in mega tonnes) and as amount of carbon per hectare (in tonnes). Confidence intervals are indicated with "+/-". The method denoted 'Volume; BCEF' refers to the conversion of volume estimates to biomass using BCEF. 'Allometric (*variable*)' denotes the use of allometric equations with the in bracket indicated variables. 'Wd' = basic wood density.

Pool, Scale and confidence interval / Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; eight; high wd)
Biomass AG	Density (tonnes of carbon/ha)	7,178815492	13,96089521	4,318788292	2,544918813	2,911304522
	+/- per ha	2,303426902	4,281903781	1,630347871	1,077135111	1,22437625
	Total (mega tonnes of carbon)	43,51762482	84,63025696	26,18028124	15,4271721	17,64818417
	+/- total	13,96326008	25,95668916	9,883088241	6,529539824	7,422108334
Biomass BG	Density (tonnes of carbon/ha)	2,871526197	5,584358083	1,727515317	1,017967525	1,164521809
	+/- per ha	0,921370761	1,712761513	0,652139148	0,430854044	0,4897505
	Total (mega tonnes of carbon)	17,40704993	33,85210279	10,4721125	6,170868842	7,059273669
	+/- total	5,58530403	10,38267567	3,953235297	2,61181593	2,968843334
Dead wood	Density (tonnes of carbon/ha)	0,248116579	0,547947314	0,142324939	0,062539124	0,068502795
	+/- per ha	0,197844022	0,438602714	0,142633655	0,05474679	0,060984396
	Total (mega tonnes of carbon)	1,504070445	3,321629542	0,862766751	0,379109079	0,415260561
	+/- total	1,199320689	2,658787983	0,86463817	0,331872335	0,369684394
Soil	Density (tonnes of carbon/ha)	31	31	31	31	31
	+/- per ha	na	na	na	na	na
	Total (mega tonnes of carbon)	187,705	187,705	187,705	187,705	187,705
	+/- total	na	na	na	na	na

3.3. Other land

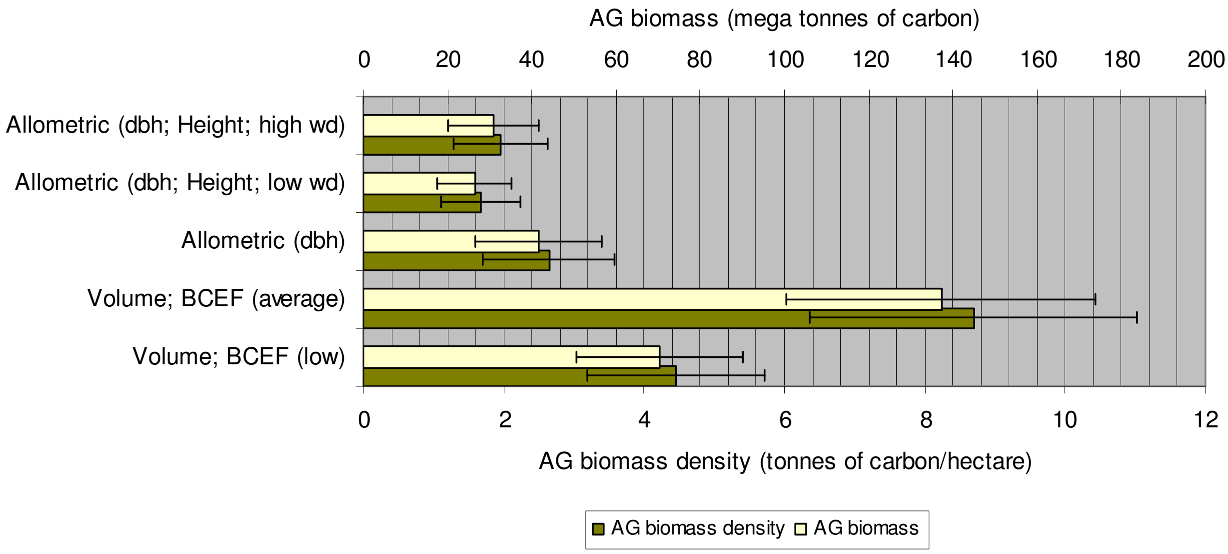

Figure 7 Carbon stock in the above ground biomass pool for the land use category of other land in Zambia. Estimates are displayed as total amount of carbon (in mega tonnes) and as amount of carbon per hectare (in tonnes). Confidence intervals are indicated with the error bars.

Other lands include: grasslands, marshlands, barren lands, annual crop, perennial crop, pastures, fallow, urban and rural areas. As already noted, the ILUA data only give way for estimating carbon stock in woody live and dead biomass, whereas soil and litter has to be estimated based on IPCC default values. Neither does the ILUA record data on biomass contained in non-woody vegetation (e.g. grass and crops). The carbon stock given for the land use category of *other lands* therefore only contains what is being captured from measuring trees (live and dead) larger or equal to 7 cm in dbh. Litter is not considered as a significant carbon pool in land use areas outside *forest*. Due to the complexity in the calculation of soil carbon for areas outside *forest* and *other wooded land* (the amount of soil carbon is heavily influenced by management practices and land use type) soil carbon has not been calculated for the land use category of *other lands*.

The amount of carbon contained in biomass (above and below ground) in *other lands* is estimated to be in the range of 37-98 mega tonnes of carbon (table 11). Above ground biomass is presented in figure 7.

Table 11 Carbon stock in different carbon pools for the land use category of other land in Zambia. Estimates are displayed as total amount of carbon (in mega tonnes) and as amount of carbon per hectare (in tonnes). Confidence intervals are indicated with "+/-". The method denoted 'Volume; BCEF' refers to the conversion of volume estimates to biomass using BCEF. 'Allometric (*variable*)' denotes the use of allometric equations with the in bracket indicated variables. 'Wd' = basic wood density.

Pool, Scale and confidence interval	Method	Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; Height; low wd)	Allometric (dbh; Height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	4,45481052	8,695795469	2,642360895	1,678175459	1,95646122
	+/- per ha	1,251006264	2,323545775	0,947787855	0,56683949	0,672136495
	Total (mega tonnes of carbon)	70,25717734	137,1420943	41,67288758	26,46664102	30,85550828
	+/- total	19,72972106	36,64482852	14,94763898	8,939671487	10,60031908
Biomass BG	Density (tonnes of carbon/ha)	1,781924208	3,478318187	1,056944358	0,671270184	0,782584488
	+/- per ha	0,500402506	0,92941831	0,379115142	0,226735796	0,268854598
	Total (mega tonnes of carbon)	28,10287093	54,85683771	16,66915503	10,58665641	12,34220331
	+/- total	7,891888425	14,65793141	5,979055593	3,575868595	4,24012763
Dead wood	Density (tonnes of carbon/ha)	0,234454756	0,503843767	0,107653265	0,05133616	0,056808851
	+/- per ha	0,154248603	0,322693227	0,066998077	0,036366896	0,04016472
	Total (mega tonnes of carbon)	3,697604935	7,946160832	1,697808359	0,80962673	0,895936994
	+/- total	2,432667212	5,089221006	1,056632097	0,573545266	0,633441056

3.4. Inland water

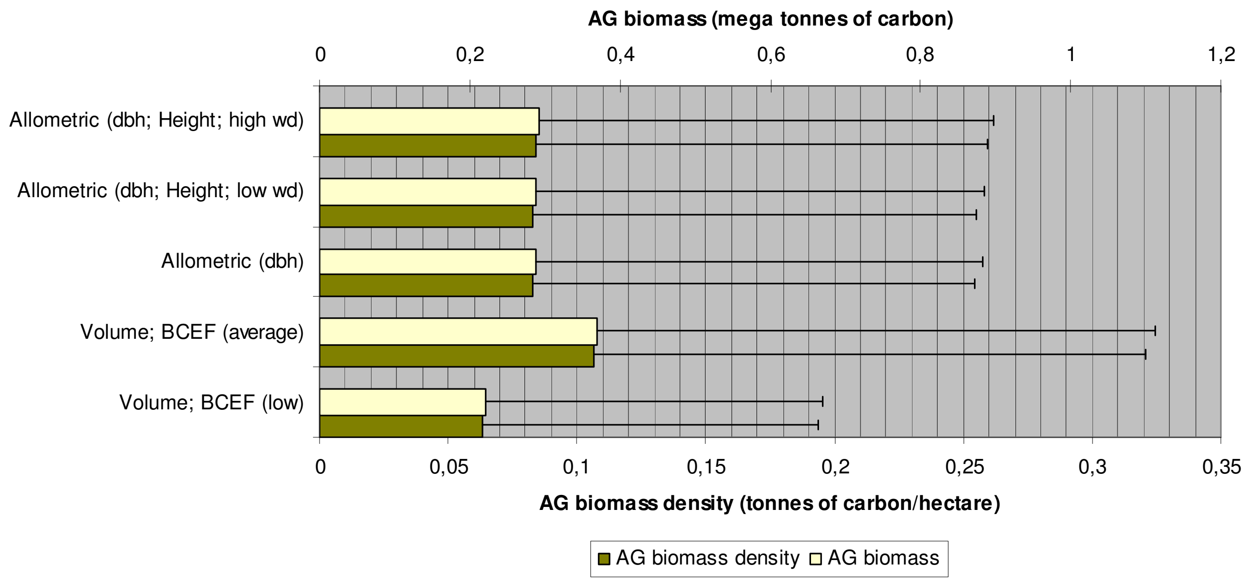

Figure 8 Carbon stock in the above ground biomass pool for the land use category of inland water in Zambia. Estimates are displayed as total amount of carbon (in mega tonnes) and as amount of carbon per hectare (in tonnes). The confidence intervals indicated with the error bars only display the positive side to avoid negative values.

Lastly, *inland water* (lakes, rivers and dams) is estimated to contain 0.26-0.35 mega tonnes of carbon stored in woody biomass (above and below ground) (table 12). Estimates for above ground biomass alone are presented in figure 8. Like for *other land*, soil carbon and litter is excluded from the calculations. Notice the relative large confidence interval caused by the few observations in this land use category.

Table 12 Carbon stock in different carbon pools for the land use category of inland water in Zambia. Estimates are displayed as total amount of carbon (in mega tonnes) and as amount of carbon per hectare (in tonnes). Confidence intervals are indicated with "+/-".The method denoted 'Volume; BCEF' refers to the conversion of volume estimates to biomass using BCEF. 'Allometric (*variable*)' denotes the use of allometric equations with the in bracket indicated variables. 'Wd' = basic wood density.

Pool, Scale and confidence interval		Method: Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; Height; low wd)	Allometric (dbh; Height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	0,06351	0,106354923	0,082806254	0,082907889	0,084188768
	+/- per ha	0,12981	0,214544279	0,171529715	0,172435246	0,174867721
	Total (mega tonnes of carbon)	0,22021	0,368785368	0,28713043	0,287482847	0,291924291
	+/- total	0,45011	0,743931625	0,594778756	0,597918684	0,606353283
Biomass BG	Density (tonnes of carbon/ha)	0,0127	0,021270985	0,016561251	0,016581578	0,016837754
	+/- per ha	0,02596	0,042908856	0,034305943	0,034487049	0,034973544
	Total (mega tonnes of carbon)	0,04404	0,073757074	0,057426086	0,057496569	0,058384858
	+/- total	0,09002	0,148786325	0,118955751	0,119583737	0,121270657
Dead wood	Density (tonnes of carbon/ha)	0	0	0	0	0
	+/- per ha	0	0	0	0	0
	Total (mega tonnes of carbon)	0	0	0	0	0
	+/- total	0	0	0	0	0

3.5. Discussion of estimates

Choice of method for estimating carbon stock strongly affects the magnitude of estimate. It is therefore crucial that verification studies are made prior to embarking any carbon stock assessment to test the fit of available methods and sub-models. This could be done e.g. by conducting destructive sampling of trees to accurately measure biomass, which then should be compared with estimates obtained with different allometric equations. It is important to notice is that in cases where detailed data exist at tree-level on diameter, height and species, as it does in the ILUA data set, the use of allometric equations are preferred. Conversion of volume to biomass via BCEF is the second best option and should only be applied in cases where only volume estimates are available. Thus, improvement of above ground biomass estimates and associated accuracy estimates are best obtained by focusing future work on developing and refining allometric equations applicable to the ecological regions of Zambia. For carbon stock estimates tied to carbon pools in below ground biomass, deadwood, litter and soil, the estimates provided in this study are to varying extent based on assumed correlations with above ground biomass and the use of generic models such as those provided by IPCC 2006 guidelines. While some scientific studies have been done for the miombo woodland ecosystem, further research is needed to cover the remaining Zambian ecosystems, in particular with regard to the improvement of models and accuracy measurements for carbon pools not contained in above ground living biomass.

In order to verify the carbon stock estimates made in this study, comparisons were made with a number of previously completed studies. These are summarised in table 13 and show significant range. The highest and lowest estimates differ with more than a factor of 6. Gibbs et al. (2007) use the IPCC 2006 guidelines default values to come up with their estimate, which in the table is referenced to as IPCC 2006. They assume the ecological zone to be tropical dry forest, in which case the IPCC 2006 guidelines suggest an average of 120 tonnes of carbon/ha. This is significantly higher than the figure found in this study (19 -31 tonnes of carbon/ha). Even if the assumption concerning ecological zone is altered to pure tropical scrubland (which is another vegetation type found in Zambia), the IPCC 2006 guidelines default value for this forest type is still found to be high; namely in the range of 20-200 tonnes/ha and with 70 tonnes/ha as average. Only the estimates provided in FRA 2005 and Gibbs & Brown (2007a, 2007b) are in the proximity of what is being suggested in this study. The latter references incorporate human disturbances in their estimate, while the other studies assume undisturbed forests.

Table 13 Carbon stock estimates made for Zambia in various studies. All estimates are for above and below ground biomass in mega tonnes of carbon/ha.

Original study/data	**Olsen et al. (1983) /Gibbs (2006)**	**Houghton (1999)/ DeFries et al. (2002)**	**IPCC 2006**	**Brown (1997)/ Achard et al. (2004)**	**Gibbs and Brown (2007a, 2007b)**	**FRA 2005**	**This study**
Reference	Gibbs et al. 2007	Gibbs et al. 2007	Gibbs et al. 2007	Gibbs et al. 2007	Gibbs et al. 2007	FAO 2006	
Estimate	4295	3423	6378	3725	1455	1156	960-1561

Compared to FRA 2005 data, the ILUA indicate forest cover to be higher in Zambia (42,452,000 ha versus 49,968,000 ha). In terms of carbon stock, the two set of data show estimates that are very close. While the FRA 2005 reports a total biomass carbon stock in forest of 1156 M tonnes (corresponding to an average biomass density of approximately 27 tonnes of carbon/ha), the present study estimate it to be in the range of 960-1561 M tonnes (with biomass density ranging from 15-24 tonnes of carbon/ha) (exclusive the outlying estimate derived from using average BCEF values). As the FRA 2005 biomass figures are based on an assumption that no change in biomass density has occurred since1969 (1969 is the base year), it indicates that biomass density has decreased with between 3-12 tonnes of carbon/ha since 1969.

The analysis of ILUA data suggests a dead/live ratio in forest to be in the range of 0.02 to 0.057, which is significantly lower than the ratio of 0.14 as applied in the Zambian country report for FRA 2005. This discrepancy is obviously also reflected in the dead wood carbon stock estimates. While FRA 2005 provides an estimate of 161 mega tonnes of carbon in dead wood, this study suggests a range from 18 to 89 mega tonnes. IPCC 2006 guidelines do not provide any default values on dead wood.

4. Estimation of deforestation rates in Zambia

This section covers working questions 2:

What data are available for deforestation in Zambia and what is the estimated annual deforestation rate?

Estimating deforestation rates relies on the availability of historic data sets that can provide information about forest cover changes at different points in time. At national level, very few of such data sets exist for Zambia. Those that actually do exist are in most cases collected independently of each other with the result that surveys in general lack consistency with respect to applied methods and are not directly comparable. Furthermore, the definitions and classification might also differ across surveys (though reclassification was done in FRA 2005 to comply with FAO definitions for the estimates of Millington and Towsend (1989) as well as Chakanga and de Backer (1986)). It should therefore be emphasised that the trend estimation done in this section is tied to a significant degree of inaccuracy. Section 1.4 presents in short the sources of information used in this study and a list of past forest cover surveys completed for Zambia. In total, seven surveys have been included in the following forest cover change analysis. Figure 9 displays forest cover estimates for the different surveys and the applied methods. Table 14 summarizes the meta data for the same surveys.

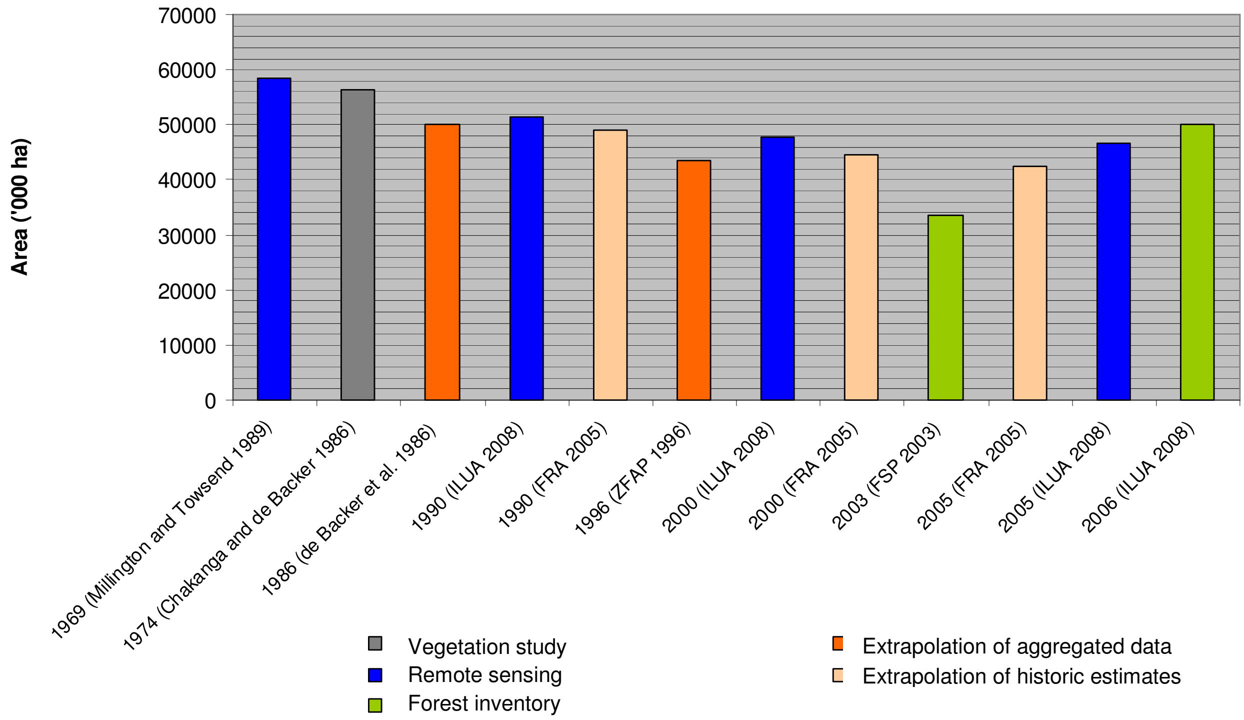

Figure 9 The figure shows past studies quantifying forest extent in Zambia and the associated estimates**.** The methods applied are indicated with colours. The name of the study is provided in parentheses (see table 14 for details).

Table 14 List of historic studies quantifying forest cover in Zambia. The table outlines the publication year, data reference year, methods applied and literature reference.

Author/title of survey and year of publishing	Reference year	Assessment method	Literature reference
Millington and Towsend (1989)	1969	Vegetation maps in conjunction with remote sensing	FAO 2006b
Chakanga and de Backer (1986)	1974	Vegetation maps	FAO 2006b
de Backer et al. (1986)	1986	Extrapolation of aggregated data from forest management plans (dating back to 1965)	FSP 2003
ILUA (2008)	1990	Remote sensing*	ZFD/MTENR and FAO 2008b
FRA 2005 (2006)	1990	Extrapolation of historic estimates (Millington and Towsend (1989) and Chakanga and de Backer (1986))	FAO 2006b
ZFAP (1996)	1996	Extrapolation of aggregated data from forest management plans (dating back to 1965)	FSP 2003
ILUA (2008)	2000	Remotes sensing*	ZFD/MTENR and FAO 2008b
FRA 2005 (2006)	2000	Extrapolation of historic estimates (Millington and Towsend (1989) and Chakanga and de Backer (1986))	FAO 2006b
FSP (2003)	2003	Forest inventory	FSP 2003
FRA 2005 (2006)	2005	Extrapolation of historic estimates (Millington and Towsend (1989) and Chakanga and de Backer (1986))	FAO 2006b
ILUA (2008)	2005	Remote sensing*	ZFD/MTENR and FAO 2008b
ILUA (2008)	2006	Forest inventory	ZFD/MTENR and FAO 2008b

* Remote sensing study performed by A. Siampale (forestry officer at the Zambian Forestry Department) on an ad hoc basis under the ILUA project (ZFD/MTENR and FAO 2008b).

In order to make a rough estimation of the annual deforestation rate in Zambia, the data from figure 9 was analysed across time. The data plots and associated trend lines are shown in figure 10. Because the forest area estimate from FSP inventory from 2003 was found to be considerable lower than estimates made both before and after, it was decided to exclude this estimate from the time series. Likewise, FRA 2005 estimate was excluded as it an extrapolation of the estimates done by Millington and Townsend (1989) and Chakanga and de Backer (1986) and thus is not an independent estimate.

The analysis indicates a forest cover decline in the period from 1969 to 2006. The annual deforestation rate is found to be in the surrounding of 298,000 hectares (the value can be read from the slope parameter in the regression function). Assuming an above ground biomass density between 15 and 24 tonnes of carbon per hectare (as found in this study), the total change of carbon stock due to deforestation is estimated to be in the range of 4.4-7.2 million tonnes of carbon. Again it should be emphasised that these estimates cannot be verified and should be considered only as indications. As comparison, the FRA 2005 report the annual deforestation in Zambia to be in the surroundings of 444,800 ha while the estimation done under the ILUA project suggests deforestation to be in the range of 250,000 and 300,000 hectares.

The existing difficulties in estimating past deforestation rates, seems to suggest a need for more in-dept and scientifically sound analysis of remotely sensed data sets to derive at a deforestation estimate with acceptable accuracy. Though human capacity exists in Zambia to perform such analyses, expert support would probably be needed for advancing on this matter. That would entail support both in terms of training but also in form of software and imageries. The FRA 2010 remote sensing study might serve as a platform for developing this component of Zambian forest inventory. This work should tap into the preparatory work for the ILUA phase-2, which is currently in the pipeline. The next phase of ILUA could also provide opportunity for performing re-measurements in all or selected sample plots to provide for time series data.

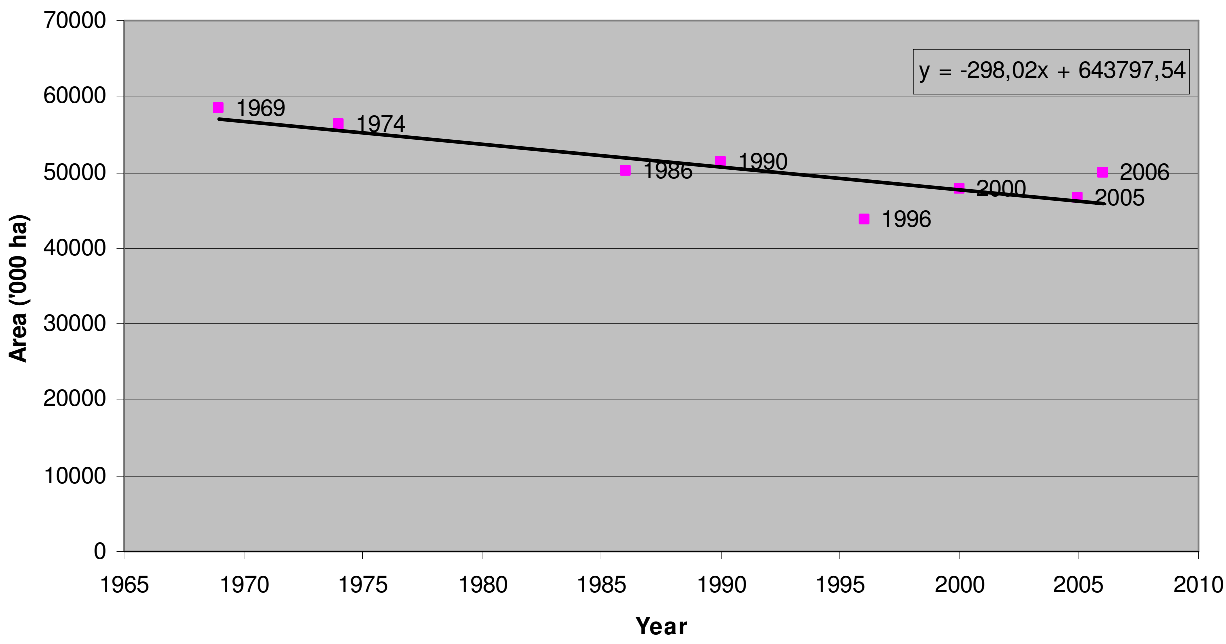

Figure 10 Regression function to estimate the annual change in forest extent in Zambia in the period from 1969 to 2006 (ILUA).

5. Emissions from deforestation and forest degradation

This chapter covers working question 3:

Based on historical data and carbon stock estimate derived from ILUA data, what has been the annual decrease in forest carbon stock from deforestation and degradation in Zambia?

The loss of carbon in Zambia cannot solely be ascribed to deforestation, e.g. due to removal of forest areas for agricultural expansion and human settlements. Forest degradation plays a significant role in carbon stock reduction in Zambia, with demand for wood energy as main cause. The degree to which forest degradation occurs on the ground is extremely difficult to quantify over large areas and conventional monitoring of forest extent will not provide very useful information concerning the degree of forest degradation. Alternatively, with outset in the stock-difference method (as opposed to the gain-loss method), the most precise and at the same time available option is to estimate biomass changes over time (Murdiyarso et al. 2008). By comparing the five different estimates for above ground biomass, as determined in this study, with historical data, an approximated loss of carbon stock is estimated (figure 11). Four historical surveys are included in this regression analysis: de Backer et al. (1986), the ETC study (1986), ZFAP inventory (1996) and FSP inventory (2003) (all estimates found in FSP 2003 report). Though the data sets are not perfectly comparable, they provide the best available information on biomass change over time. Except from the ILUA, the survey information were restricted to growing stock estimates. Thus, to allow comparable estimates, these historical growing stock estimates had to be converted into biomass carbon. This was done by applying an average BCEF, which was determined based on the ILUA data and biomass estimates provided from the current study (average BCEF should in this cse not to be confused with the average BCEF as provided in IPCC 2006 guidelines). The average BCEF values applied in this conversion were calculated by relating the above ground biomass estimates in forest (for each of the five methods) with the volume estimates. Carbon fraction was set to be equal to 0.47. Retrospective conversion of volume to biomass has to be based on the assumption that the average relationship between growing stock and biomass at national level did not change over time. This assumption might not hold as the presumed decrease in growing stock level (m3/ha) most probably would affect the average BCEF value. Usually the growing stock level and BCEF are negatively correlated, i.e. the BCEF value decreases with increasing growing stock level. In turn, the older the data set, the less power the BCEF should have. However, this discrepancy is most probably negligible compared to the general level of uncertainty in the comparison of historical data sets.

The regression analysis estimates an annual decrease in above ground biomass in the range of 12.8 – 20.9 mega tonnes of carbon (again the method of using the 'average IPCC default BCEF 'is disregarded, though it is interesting to observe for the purpose of comparison). The estimated annual carbon loss can be read in the slope parameter in the regression functions in figure 11. Though the R-squared values are low, this it is not an indication for above ground biomass in forest not being correlated with time, but rather it indicates that time alone cannot explain the variation in the sample of biomass estimates.

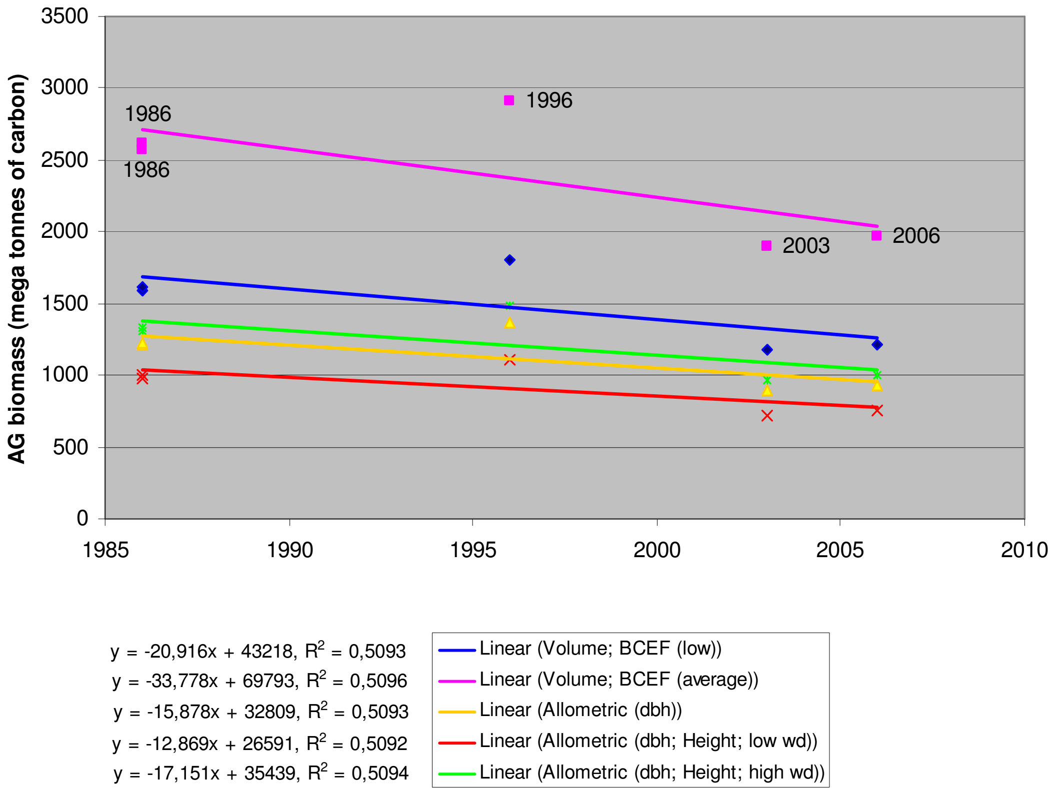

Figure 11 Regression functions to estimate the annual carbon loss from deforestation and forest degradation in the period from 1986 to 2006 (ILUA) with past inventories as data.

Conclusively, analysis of historical data sets provides two estimates of annual carbon stock decline. First, using the change in forest extent and biomass density as variables (as done in chapter 4) gives an annual decrease in above carbon stock in the range of 4.7 – 7.5 mega tonnes of carbon. Alternatively, by using growing stock and biomass estimates as variables we arrive at a loss in carbon stock between 12.8- 20.9 mega tonnes of carbon. The difference between these two estimates (between 5.1 and 16.2 mega tonnes of carbon) could be speculated to stem from forest degradation, which is not captured in the change of forest extent. However, uncertainty associated with the measurements does without doubt explain much of the discrepancy between the estimates.

The draft national communication for 2005, to be submitted to UNFCCC, estimates the annual CO2 emission from forestry and land use change to be 41007 Gg, which correspond to 11 Mega tonnes of carbon. Out of this, roughly half is assessed stemming from charcoal and wood energy production (ECZ 2007). This estimate was based on changes in land use areas and associated emission factors.

The occurring forest degradation can also be observed from the decline in growing stock level over time. Comparing past inventories reveals an altered standing volume per hectare (table 15). Though part of the difference between estimates may stem from varying focus of the inventories as well as methods and definitions, it could also in part reflect the ongoing forest degradation.

Table 15 Changes in growing stock levels over time by comparing different forest inventories.

Inventory	ZFAP (1996)	FSP (2003)	ILUA (2006)
Growing stock level (m3/ha)	94	83	55

6. REDD potentials under different land use development scenarios

This chapter covers working question 4:

What are the potential scenarios for REDD in terms of land-use development in Zambia?

Though this part of the study is the least explored, the assessment of carbon stock trends in Zambia indicates a clear decline in woody biomass. This is caused mainly by two well known sources: deforestation caused by expansion of agricultural areas and human settlements and forest degradation due to the extensive extraction of wood to meet energy demands (firewood and charcoal). For charcoal alone, a study done under the ILUA programme (ZFD/MTENR and FAO 2008b) estimated that in 2008 the extraction of wood would reach 5.8 million tonnes of biomass, equal to approximately 2.7 million tonnes of carbon (table 16). Hence, potentials exist to mitigate the loss of carbon from both deforestation and forest degradation.

Table 16 Estimated charcoal production and associated wood consumption. Adapted from ZFD/MTENR and FAO 2008b.

Year	Charcoal production (million tonnes)	Wood biomass used (million tonnes)
1969	0.33	1.375
1980	0.49	2.042
1990	0.685	2.854
2000	0.905	3.771
2008*	**1.392**	**5.800**

Data sources: Chidumayo (1994); FNDP (2006) and; ILUA (2008). * estimated charcoal consumption for 2008 was based on population data and average charcoal consumption per capita. Furthermore, the estimate includes both urban and rural charcoal consumption (while the other estimates reflect consumption by urban households only). Urban and rural charcoal consumption is 95% and 5% respectively.

By relating rate of deforestation and rate of biomass loss, the analyses elaborated in the previous sections also indicate a general decrease in biomass density, i.e. currently forests seem to contain less woody biomass per hectare compared to previously. This has obvious implications for REDD potentials in Zambia. First of all, the potentials to reduce carbon stock losses are smaller than presumed by other sources (e.g. the IPCC 2006 guidelines, see table 7) as a large proportion of the carbon stock seems already to have been degraded. This historical (and probably also present) pressure on the forest resource should of course influence the establishment of a business as usual baseline for REDD payments. This simply because the historical rate of carbon emission will most probably not continue along the same line but rather slow down together with decreasing biomass density. Furthermore, if past deforestation will be used as variable in forecasting emission levels, default biomass density values (as fore example suggested by IPCC 2006 guidelines) should be revised and down-graded. On the other hand, and maybe relevant under a REDD+ scheme, the gap between the current and historical carbon stock levels leaves room for sequestration of carbon, both through reforestation and afforestation.

In order to explore the potential for carbon sequestration in forests, an analysis was made on the relationship between carbon stock and the level of disturbance. The ILUA data set contains information concerning the level of disturbance detected in each sampled land use section. The difference in carbon stock by carbon pool is presented in figure 12. It is important to note that this analysis was done by using only one biomass estimate (i.e. only one method); conversion of volume to biomass using low IPCC default values. Because the estimates, as it has been seen in chapter 3, so heavily depend on choice of method, the correlation analysis of the carbon stock and disturbance level, therefore should mainly be viewed as an example of the data potential of ILUA. Nevertheless, the estimates provide an indication of the relative differences in carbon stocks in forests subject to different disturbance levels. Not surprisingly, heavily disturbed forests have a lower biomass density than undisturbed forest (though no statistically significant difference can be proven). Surprisingly though, slightly and moderately disturbed forests have a larger biomass density, which is explained by an increased regrowth subsequent to tree clearing. Chidumayo (1993) finds that plant density in first and second regrowth miombo forest after clearing was 3.6 and 5.7 times larger respectively than in old growth. It is therefore not possible firmly to conclude that extraction of wood has a negative impact of the remaining biomass. Whether there is a net loss or gain of carbon over time from the extraction of wood will depend on the level of extraction, the end use of wood and the annual sequestration from tree increment. Though important for analysing the carbon sequestration potentials in Zambia, these issues are not further explored in this study.

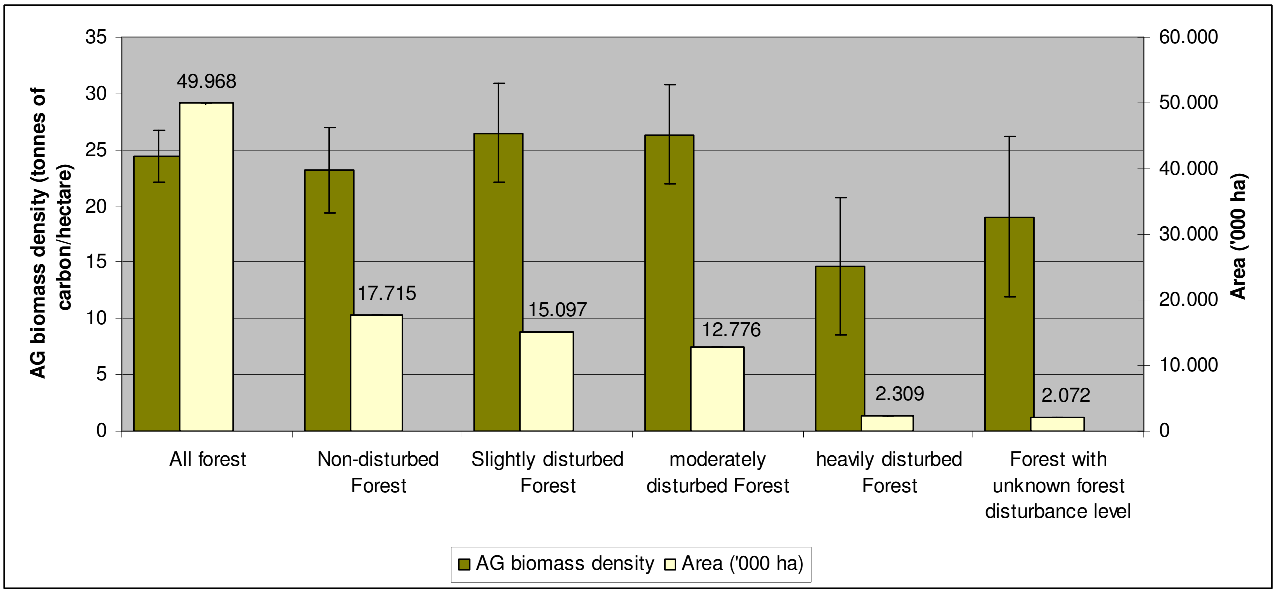

Figure 12 Distribution of forest areas and above ground biomass density subject to different levels of disturbance. Notice that above ground biomass was estimated based on the conversion of growing stock by applying low range BCEF values.

Another matter to consider is the ecological effects of climate change. The Zambian National Adaptation Programme of Action (NAPA) from 2007 found that climate changes seem to jeopardize regeneration of miombo forest (MTENR 2007). Further, The Initial National Communication under UNFCCC from 2000 (MTENR 2000) concludes from its analysis that:

"Projections of future vegetation distribution patterns indicated that under projected climatic variables-1, miombo woodland cover would suffer a 50 percent reduction across the country whereas mopane and munga would predominate. The kalahari and dry evergreen forest (e.g . Cryptosepalum, Parinari and Marquesia) would disappear. For another set of projected climatic variables-2 the country would be predominantly covered by miombo, chipya, kalahari and Cryptosepalum while mopane, munga and Baikiaea species would disappear."

Future ecological changes caused by climate changes have potential implications for the outcome of a REDD agreement in Zambia and should be considered in the design phase of such a scheme.

7. Conclusion and recommendations

Following the four working questions, the following conclusions can be made:

- Different methods for estimating biomass were applied on existing forest inventory data from the Integrated Land Use Assessment to obtain a range for the carbon stock contained in above ground biomass. A comparison of estimates indicates that the use of allometric equations is a promising approach compared to the use of BCEF in cases where detailed data exist at tree level. However, improved above ground biomass estimates and associated accuracy estimates could be obtained by focusing future work on developing and refining allometric equations applicable to Zambian ecological regions. Apart from above ground biomass and dead wood carbon pools, carbon stocks tied to carbon pools of below ground biomass, litter and soil, were estimated based on assumptions about the correlations with above ground biomass and the use of default models such as those provided by IPCC guidelines. The ILUA approach does not provide useful data for estimating carbon stocks in soil and litter pools. While some scientific studies have been done for the miombo woodland ecosystem, further research is needed to cover the remaining ecosystems on improving models and accuracy measurements for all carbon pools but in particular those not contained in above ground living biomass. Lastly, a thorough statistical appraisal of the uncertainty elements in carbon stock estimations would be advantageous for future carbon stock accounting. In particular, as the main part of the total estimation uncertainty in forest inventories usually stems from sampling error, scrutiny of the ILUA multistage sampling approach would be useful in order to develop scientifically sound methods for estimating the error linked to this type of inventory.

- The study shows that choice of method for estimating carbon stock strongly affects the magnitude of estimate. It is therefore crucial that studies are made prior to embarking any carbon stock assessment to verify the applicability of the available methods and sub-models (e.g. by conducting destructive sampling of trees to accurately measure biomass). The study showed that by applying different estimation methods on field inventory data the total carbon stock in Zambian forest amounts to between 2652 and 3323 mega tonnes. Above and below ground biomass in forest is estimated to be in the range of 960 and 1561 mega tonnes of carbon, which translates into between 15 and 24 tonnes of carbon per hectare. Semi-evergreen forest (miombo) makes up the main bulk of woody biomass in Zambia. The carbon pool in soil is also suggested to contribute considerable to the total carbon stock in forest with an estimated quantity of 1549 mega tonnes (based on IPCC default values). Land use categories outside forests have insignificant importance relative to forest in terms of carbon storage in woody biomass. The study provides forest carbon stock estimates in biomass pools that are distinguishable different from previous estimates in the literature, which is here argued to be caused by overestimation in the latter.

- Very few forest cover data are available for Zambia that are consistent and comparable over time. The trend estimations provided in this report are consequently constrained and lack accuracy. However, for the purpose of roughly estimating annual deforestation in Zambia, the historical data set considered the most reliable were collected and a regression was made with time as the independent variable and forest extent as dependent variable. The analysis suggests an annual deforestation of approximately 298,000 hectares. There seems to be a need for more in-dept and scientifically sound analysis of remotely sensed data sets to derive at a deforestation estimate with acceptable accuracy.

- To estimate changes in carbon stock over time, a regression was made with the biomass estimates derived from the current study against past forest inventory data on growing stock. Prior to performing the regression, the growing stock estimates had to be converted to biomass. The regression suggests an annual loss in biomass carbon to be between 12.8 and 29.9 mega tonnes of carbon. Furthermore, the results indicate that loss in carbon cannot only be ascribed to deforestation but that a considerable amount could stems from degradation of the remaining forest areas.

- The potentials to reduce carbon stock losses are smaller than previously suggested in the literature as a large proportion of the assumed carbon stock seems already to have been degraded. This historical (and probably also present) pressure on the forest resource should of course influence the establishment of a business as usual baseline for REDD payments. This simply because the historical rate of carbon emission most probably will not continue along the same line but rather slow down together with decreasing biomass density. Furthermore, if deforestation will be used as variable in forecasting emission levels, default biomass density values (as fore example suggested by IPCC 2006 guidelines) should be revised and down-graded. On the other hand, and maybe relevant under a REDD+ scheme, the gap between the current and historical carbon stock levels leaves room for carbon sequestration, both through reforestation and afforestation.

A second phase of the ILUA project is currently in the pipeline and should adapt to MRV requirements for REDD. The analysis provided in the present study has the potential to serve as input to the design of next ILUA phase in relation to carbon assessment and the development of Zambia's REDD readiness strategy in general. Likewise, already ongoing research projects in Zambia with REDD relevance have to be recognised and included in developing a MRV system. The study revealed that several research initiatives are ongoing in the country and that some capacities are available. It is therefore key to insure close collaboration across governmental and non-governmental stakeholders who are in a position to provide national specific input to the REDD readiness process.

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Annex I Field work schedule

Date	Activity
29 April 2009	Travel from Copenhagen to Rome. Briefing at FAO HQ with Peter Holmgren (NRCD) and the NFMA team (FOMR).
30 April 2009	Meetings with various resource persons at FAO HQ
1 May 2009	Work
2 May 2009	Work
3 May 2009	Travel from Rome to Lusaka
3-8 May 2009	Joint UN-REDD scoping mission
3 May 2009	Meeting in Lusaka with UN-REDD scoping team: FAO: Jesper Tranberg, Rebecca Tavani, Edward Kilawe and Kewin Kamelarczyk UNEP: Richard Kaguamba UNDP:Tim Clairs, Elspeth Halverson and Carina Kjelstad
4 May 2009	Briefing at UN-house Lusaka. Attendances apart from the UN-REDD team: Mrs. Elsie Atafuah (Global Mechnism of the UNFCCD), Dr. Noureddin (FAOR-Zambia), Mr. Kokwe (FAOR-Zambia), UN country representative. Meeting at with acting Primary Secretary at Ministry of Tourism, Environment and Natural Resources (MTENR). Meeting with the Zambian Climate Change Facility Unit headed by Prof. Prem Jain. Meeting with acting director of the Forestry Department
5 May 2009	Meeting at Ministry of Water and Energy Meeting at Ministry of Lands with Primary secretary Meeting at Environmental Council of Zambia Meeting at Ministry of Lands Meeting at Ministry of Lands with Primary secretary
6 May 2009	Meeting with Professor Emanual Chidumayo and staff from forestry department CP meeting at UN-house
7 May 2009	Stakeholder meeting
8 May 2009	Meeting at Ministry of Lands with Primary secretary Debriefing at MTENR Debriefing at FAOR
9-10 May 2009	Working at hotel.
11 May 2009	Working at FAO. Meetings with staff from the Forestry Department. Data collection
12 May 2009	Meeting with consultants at Centre for Energy, Environment and Engineering Zambia.
13May 2009	Working at FAO. Data collection.
14 May 2009	Presentation of preliminary study findings at the Forestry Department.
15 May 2009	Travel from Lusaka to Copenhagen.

Annex II Basic wood densities for tree species identified in ILUA

3. Scientific names	Wood density in tonnes per cubic metre			Substituting species or genus used where species specific data were not available	Reference
	Low	Medium	High		
Acacia albida	0,49	0,56	1,00	Acacia sp.	www.worldagroforestry.org
Acacia erioloba		1,06			http://datadryad.org/repo/handle/10255/dryad.235
Acacia gerrardi		0,77			http://datadryad.org/repo/handle/10255/dryad.235
Acacia nigrescens	0,49	0,56	1,00	Acacia sp.	www.worldagroforestry.org
Acacia nilotica	0,65		0,83		http://datadryad.org/repo/handle/10255/dryad.235
Acacia polyacantha	0,72		0,84		www.worldagroforestry.org
Acacia sieberana	0,49	0,56	1,00	Acacia sp.	www.worldagroforestry.org
Acacia tortilis	0,49	0,56	1,00	Acacia sp.	www.worldagroforestry.org
Acacia erubescens	0,49	0,56	1,00	Acacia sp.	www.worldagroforestry.org
Adansonia digitata		0,28			http://datadryad.org/repo/handle/10255/dryad.235
Adina microcephala	0,72		1,08		www.worldagroforestry.org
Afzelia bipindensis		0,82			www.worldagroforestry.org
Afzelia quanzensis	0,67		0,76		http://datadryad.org/repo/handle/10255/dryad.235
Agauria salicifolia	no data	no data	no data		
Albizia adianthifolia	0,48		0,72		www.worldagroforestry.org
Albizia amara		0,76			http://datadryad.org/repo/handle/10255/dryad.235
Albizia antunesiana	0,48	0,72	0,84		www.worldagroforestry.org
Albizia gummifera	0,36		0,84		www.worldagroforestry.org
Albizia harveyi	0,32		0,95	Albizia sp.	www.worldagroforestry.org
Albizia versicolor	0,48		0,84		www.worldagroforestry.org
Allophylus africanus		0,45			http://datadryad.org/repo/handle/10255/dryad.235
Amblygonocarpus andongensis	0,84		1,08		www.worldagroforestry.org
Anisophyllea boehmii	0,75		0,77	Anisophyllea laurina	http://datadryad.org/repo/handle/10255/dryad.235
Anisophyllea pomifera	0,75		0,77	Anisophyllea laurina	http://datadryad.org/repo/handle/10255/dryad.235

Annona senegalensis		0,40		Annona muricata	www.worldagroforestry.org
Azanza garckeana	no data	no data	no data		
Baikiaea plurijuga	0,82		0,96		www.worldagroforestry.org
Balanites aegyptiaca	0,72		0,84		www.worldagroforestry.org
Balanites maugahamii	0,72		0,84	Balanites aegyptiaca	www.worldagroforestry.org
Baphia bequaertii	0,60		0,72	Baphia nitida	www.worldagroforestry.org
Baphia massaiensis	0,60		0,72	Baphia nitida	www.worldagroforestry.org
Baphia obovata	0,60		0,72	Baphia nitida	www.worldagroforestry.org
Bauhinia galpinii		0,69		Bauhinia petersiana	http://datadryad.org/repo/handle/10255/dryad.235
Bauhinia petersiana		0,69			http://datadryad.org/repo/handle/10255/dryad.235
Bauhinia tomentosa		0,69		Bauhinia petersiana	http://datadryad.org/repo/handle/10255/dryad.235
Becium obovatum	no data	no data	no data		
Berchemia discolor		0,92			www.worldagroforestry.org
Berlinia giorgi	0,60		0,64	Berlinia bracteosa	http://datadryad.org/repo/handle/10255/dryad.235
Bersama abyssinica	0,72		0,84		www.worldagroforestry.org
Borassus aethiopium	1,02		1,14	Borassus flabellifer	www.worldagroforestry.org
Boscia albitrunca	no data	no data	no data		
Boscia angustifolia	no data	no data	no data		
Boscia cauliflora	no data	no data	no data		
Boscia salacifolia	no data	no data	no data		
Brachystegia allenii	0,60	0,70	0,71	Brachystegia speciformis	http://datadryad.org/repo/handle/10255/dryad.235
Brachystegia boehmii	no data	0,65	no data		http://datadryad.org/repo/handle/10255/dryad.235
Brachystegia bussei	0,60	0,70	0,71	Brachystegia speciformis	http://datadryad.org/repo/handle/10255/dryad.235
Brachystegia floribunda	0,60	0,70	0,71	Brachystegia speciformis	http://datadryad.org/repo/handle/10255/dryad.235
Brachystegia longifolia	0,60	0,70	0,71	Brachystegia speciformis	http://datadryad.org/repo/handle/10255/dryad.235
Brachystegia	0,60	0,70	0,71	Brachystegia	http://datadryad.org/repo/handle/10255/dryad.235

manga				speciformis	
Brachystegia microphylla	0,60	0,70	0,71	Brachystegia speciformis	http://datadryad.org/repo/handle/10255/dryad.235
Brachystegia spiciformis	0,60	0,70	0,71		http://datadryad.org/repo/handle/10255/dryad.235
Brachystegia stipulata	0,60	0,70	0,71	Brachystegia speciformis	http://datadryad.org/repo/handle/10255/dryad.235
Brachystegia taxifolia	0,60	0,70	0,71	Brachystegia speciformis	http://datadryad.org/repo/handle/10255/dryad.235
Brachystegia utilis		0,83			http://datadryad.org/repo/handle/10255/dryad.235
Brachystegia wangermeeana	0,60	0,70	0,71	Brachystegia speciformis	http://datadryad.org/repo/handle/10255/dryad.235
Bridelia cathartica	0,45		0,88	Bridelia sp.	www.worldagroforestry.org
Bridelia duvigneaudi	0,45		0,88	Bridelia sp.	www.worldagroforestry.org
Bridelia micrantha		0,67			www.worldagroforestry.org
Burkea africana	0,55	0,69	0,70		http://datadryad.org/repo/handle/10255/dryad.235
Burttia prunoides	no data	no data	no data		
Bysorcarpus orientalis	no data	no data	no data		
Canarium schweinfurthi	0,31		0,45		http://datadryad.org/repo/handle/10255/dryad.235
Canathium vulgare	0,56		1,06	Canthium sp.	www.worldagroforestry.org
Canathium zanzibaricum	0,56		1,06	Canthium sp.	www.worldagroforestry.org
Canthium lactescens		0,72			http://datadryad.org/repo/handle/10255/dryad.235
Cassia abbreviata		0,88			http://datadryad.org/repo/handle/10255/dryad.235
Cassia angolensis		0,88		Cassia abbreviata	http://datadryad.org/repo/handle/10255/dryad.235
Cassia petersiana		0,88		Cassia abbreviata	http://datadryad.org/repo/handle/10255/dryad.235
Cassia siamea		0,88		Cassia abbreviata	http://datadryad.org/repo/handle/10255/dryad.235
Cassia singueana		0,88		Cassia abbreviata	http://datadryad.org/repo/handle/10255/dryad.235
Cassia spectabilis		0,88		Cassia abbreviata	http://datadryad.org/repo/handle/10255/dryad.235
Cassine aethiopica		0,83			http://datadryad.org/repo/handle/10255/dryad.235
Cassipourea congensis		0,66			http://datadryad.org/repo/handle/10255/dryad.235
Cathormion altissimum	0,72	0,78	0,84	Cathormion umbellatum	www.worldagroforestry.org
Chrysophyllum bangweolense		0,50		Chrysophyllum sp.	www.worldagroforestry.org
Chrysophyllum gorungosanum		0,54			http://datadryad.org/repo/handle/10255/dryad.235
Chrysophyllum magalismontanum		0,50		Chrysophyllum sp.	www.worldagroforestry.org

Cleistanthus milleri	0,55		0,82	Cleistanthus sp.	www.worldagroforestry.org
Colophospermum mopane	0,90		1,20		www.worldagroforestry.org and http://datadryad.org/repo/handle/10255/dryad.235
Combretum celastroides		0,65		Combretum fragrans	http://datadryad.org/repo/handle/10255/dryad.235
Combretum collinum		0,65		Combretum fragrans	http://datadryad.org/repo/handle/10255/dryad.235
Combretum fragrans		0,65			http://datadryad.org/repo/handle/10255/dryad.235
Combretum imberbe		1,06			http://datadryad.org/repo/handle/10255/dryad.235
Combretum molle		0,76			http://datadryad.org/repo/handle/10255/dryad.235
Combretum mossambicense		0,65		Combretum fragrans	http://datadryad.org/repo/handle/10255/dryad.235
Combretum psidioides		0,65		Combretum fragrans	http://datadryad.org/repo/handle/10255/dryad.235
Combretum zeyheri		0,65		Combretum fragrans	http://datadryad.org/repo/handle/10255/dryad.235
Commiphora mollis		0,37			http://datadryad.org/repo/handle/10255/dryad.235
Cordia africana	0,36		0,72		www.worldagroforestry.org
Craibia affinis	no data	no data	no data		
Craterosiphon quarrei	no data	no data	no data		
Croton megalobotrys		0,55			http://datadryad.org/repo/handle/10255/dryad.235
Cryptosepalum exfoliatum	0,69		0,80	Cryptosepalum staudtii	http://datadryad.org/repo/handle/10255/dryad.235
Cryptosepalum maraviense	0,69		0,80	Cryptosepalum staudtii	http://datadryad.org/repo/handle/10255/dryad.235
Cryptosepalum pseudotaxus	0,69		0,80	Cryptosepalum staudtii	http://datadryad.org/repo/handle/10255/dryad.235
Cussonia arborea	0,36		0,48		wold agroforestry
Cussonia spicata	0,36		0,48	Cussonia arborea	wold agroforestry
Cyathea dregei	no data	no data	no data		
Dalbergia melanoxylon		1,25			wold agroforestry
Dalbergia nitidula	0,90		1,20	Dalbergia melanoxylon	http://datadryad.org/repo/handle/10255/dryad.235
Dalbergiella nyasae	no data	no data	no data		wold agroforestry
Danniella aslteeniana	0,48		0,60	Daniellia klainei	wold agroforestry
Delonix regia	0,44		0,80		wold agroforestry

Dialiopsis africana	no data	no data	no data		
Dialium angolense	0,75	1,10	1,25	Dialium sp.	wold agroforestry
Dialium engleranum		0,80			http://datadryad.org/repo/handle/10255/dryad.235
Dichrostachys cinerea	0,60		1,19		wold agroforestry
Diospyros batocana	0,64	1,03	1,25	Diospyros sp.	wold agroforestry
Diospyros chamaethamnus	0,64	1,03	1,25	Diospyros sp.	wold agroforestry
Diospyros kirkii		0,63			http://datadryad.org/repo/handle/10255/dryad.235
Diospyros mespiliformis	0,77		0,85		wold agroforestry
Diospyros mweroensis	0,64	1,03	1,25	Diospyros sp.	wold agroforestry
Diplorhynchus condylocarpon	0,67	0,72	0,84		www.worldagroforestry.org and http://datadryad.org/repo/handle/10255/dryad.235
Dombeya erythroleuca		0,48		Dombeya burgessiae	http://datadryad.org/repo/handle/10255/dryad.235
Dombeya rotundifolia		0,48		Dombeya burgessiae	http://datadryad.org/repo/handle/10255/dryad.235
Dracaena reflexa	no data	no data	no data		
Ekebergia banguelensis		0,51			http://datadryad.org/repo/handle/10255/dryad.235
Ekebergia capensis		0,51			http://datadryad.org/repo/handle/10255/dryad.235
Entada abyssinica	no data	no data	no data		
Entandrophragma caudatum		0,49		Entandrophragma excelsum	http://datadryad.org/repo/handle/10255/dryad.235
Entandrophragma delevoyi		0,49		Entandrophragma excelsum	http://datadryad.org/repo/handle/10255/dryad.235
Entandrophragma excelsum		0,49			http://datadryad.org/repo/handle/10255/dryad.235
Eriocoelum lawtoni	no data	no data	no data		
Erythrina abyssinica		0,43			http://datadryad.org/repo/handle/10255/dryad.235
Erythrina excelsa	0,24		0,38	Erythrina sp.	www.worldagroforestry.org
Erythrophleum africanum	0,88		1,08		www.worldagroforestry.org and http://datadryad.org/repo/handle/10255/dryad.235
Erythrophleum suaveolens	0,89	0,72	0,97		www.worldagroforestry.org
Eucalyptus camaldulensis	0,70		0,98		www.worldagroforestry.org
Eucalyptus		0,80			www.worldagroforestry.org

citriodora					
Eucalyptus cloeziana	no data	no data	no data		
Eucalyptus grandis	0,60		0,75		www.worldagroforestry.org
Eucalyptus paniculata	0,84		1,20		www.worldagroforestry.org
Eucalyptus pilularis	0,72		1,08		www.worldagroforestry.org
Eucalyptus resinifera	0,60		1,08		www.worldagroforestry.org
Eucalyptus robusta		0,77			www.worldagroforestry.org
Eucalyptus tereticonis	0,60		0,80		www.worldagroforestry.org
Eugenia bukobensis	0,45		1,10		www.worldagroforestry.org
Euphorbia candelabrum		0,20		No data available. Value approximated to insure that the mean value of 0.58 is not applied (because of the species' nature of being a succulent with a very low dry weight)	
Euphorbia cooperi		0,20		No data available. Value approximated to insure that the mean value of 0.58 is not applied (because of the species' nature of being a succulent with a very low dry weight)	
Euphorbia ingens		0,20		No data available. Value approximated to insure that the mean value of 0.58 is not applied (because of the species' nature of being a succulent with a very low dry weight)	
Euphorbia obovalifolia		0,20		No data available. Value approximated to	

				insure that the mean value of 0.58 is not applied (because of the species' nature of being a succulent with a very low dry weight)	
Fagara chalybea	0,60		0,84	Fagara leprieurii	http://datadryad.org/repo/handle/10255/dryad.235
Fagara macrophylla	0,60		0,84	Fagara leprieurii	http://datadryad.org/repo/handle/10255/dryad.235
Faurea intermedia		0,65		Faurea saligna	http://datadryad.org/repo/handle/10255/dryad.235
Faurea saligna		0,65			http://datadryad.org/repo/handle/10255/dryad.235
Faurea speciosa		0,72			http://datadryad.org/repo/handle/10255/dryad.235
Ficalhoa laurifolia	no data	no data	no data		
Ficus brachylepsis	0,19		0,74	Ficus sp.	www.worldagroforestry.org
Ficus brachypoda	0,19		0,74	Ficus sp.	www.worldagroforestry.org
Ficus capensis		0,29			http://datadryad.org/repo/handle/10255/dryad.235
Ficus carica	0,19		0,74	Ficus sp.	www.worldagroforestry.org
Ficus ingenis		0,51			http://datadryad.org/repo/handle/10255/dryad.235
Ficus stulhlmanni	0,19		0,74	Ficus sp.	www.worldagroforestry.org
Ficus sycomorus	0,41		0,44		http://datadryad.org/repo/handle/10255/dryad.235
Ficus verruculosa	0,19		0,74	Ficus sp.	www.worldagroforestry.org
Ficus wakefieldii	0,19		0,74	Ficus sp.	www.worldagroforestry.org
Flacourtia indica	0,85	0,86	0,88		www.worldagroforestry.org
Garcinia huillensis	0,69		1,12	Garcinia sp.	www.worldagroforestry.org
Garcinia jovis-tonantis	0,69		1,12	Garcinia sp.	www.worldagroforestry.org
Garcinia kingaensis	0,69		1,12	Garcinia sp.	www.worldagroforestry.org
Garcinia livingstonei		0,73			http://datadryad.org/repo/handle/10255/dryad.235
Garcinia pachyclada	0,69		1,12	Garcinia sp.	www.worldagroforestry.org
Garcinia punctata		0,82			http://datadryad.org/repo/handle/10255/dryad.235
Garcinia robsonoaa	0,69		1,12	Garcinia sp.	www.worldagroforestry.org
Garcinia smeathmannii	0,69		1,12	Garcinia sp.	www.worldagroforestry.org
Garcinia volkensii	0,69		1,12	Garcinia sp.	www.worldagroforestry.org
Gardenia imperialis	0,63		0,83	Gardenia sp.	www.worldagroforestry.org
Gardenia jovi-tonantis		0,73			http://datadryad.org/repo/handle/10255/dryad.235

Gmelina arborea	0,40	0,48	0,56		www.worldagroforestry.org
Grewia bicolor	0,73		0,90	Grewia sp.	www.worldagroforestry.org
Grewia spp	0,73		0,90	Grewia sp.	www.worldagroforestry.org
Grumilea buchanani	no data	no data	no data		
Gulbourtia coleosperma		0,66			www.worldagroforestry.org
Haplocoelum foliolosum	no data	no data	no data		
Harungana madagascariensis		0,47			http://datadryad.org/repo/handle/10255/dryad.235
Harungana massaeinsis		0,47		Harungana madagascariensis	http://datadryad.org/repo/handle/10255/dryad.235
Heeria reticulata	no data	no data	no data		
Hexalobus monopetalus		0,66			http://datadryad.org/repo/handle/10255/dryad.235
Homalium abdessammadi	no data	no data	no data		
Hoshindia opposita	no data	no data	no data		
Hymenocardia acida	no data	no data	no data		http://datadryad.org/repo/handle/10255/dryad.235
Hymenodictyon floribundum	no data	no data	no data		
Hyphaene ventricosa	no data	no data	no data		
Indigofera rhynchocarpa	no data	no data	no data		
Isoberlinia angolensis	0,72		0,96	Isoberlinia tomentosa	www.worldagroforestry.org
Isoberlinia tomentosa	0,72		0,96		www.worldagroforestry.org
Ixora rhodesiaca	0,94		1,01	Ixora sp.	www.worldagroforestry.org
Jacaranda mimosifolia	no data	no data	no data		
Julbernadia globiflora	0,72	0,78	1,08		www.worldagroforestry.org and http://datadryad.org/repo/handle/10255/dryad.235
Julbernadia paniculata	0,72	0,78	1,08	Julbernadia globiflora	
Khaya nyasica		0,52			www.worldagroforestry.org
Kigelia africana		0,56			http://datadryad.org/repo/handle/10255/dryad.235
Kirkia acuminata		0,51			http://datadryad.org/repo/handle/10255/dryad.235
Landolphia kirki	no data	no data	no data		
Lannea discolor		0,46			http://datadryad.org/repo/handle/10255/dryad.235

Lannea edulis		0,46		Lannea discolor	http://datadryad.org/repo/handle/10255/dryad.235
Lannea gossweileri		0,46		Lannea discolor	http://datadryad.org/repo/handle/10255/dryad.235
Lannea humilis		0,46		Lannea discolor	http://datadryad.org/repo/handle/10255/dryad.235
Lannea schimeri		0,46		Lannea discolor	http://datadryad.org/repo/handle/10255/dryad.235
Lannea stuhlmannii		0,46		Lannea discolor	http://datadryad.org/repo/handle/10255/dryad.235
Lonchocarpus capassa		0,69		Lonchocarpus sp.	www.worldagroforestry.org
Lonchocarpus eriocalyx		0,69		Lonchocarpus sp.	www.worldagroforestry.org
Lonchocarpus nelsii		0,77			http://datadryad.org/repo/handle/10255/dryad.235
Maesa lanceolata	no data	no data	no data		
Maesopsis eminii	0,38		0,48		www.worldagroforestry.org
Magnistipula bangweolensis	no data	no data	no data		
Magnistipula butayei	no data	no data	no data		
Magnistipula sapinii	no data	no data	no data		
Magnistipula thonninge	no data	no data	no data		
Maprounea africana	0,47		0,72	Maprounea guianensis	http://datadryad.org/repo/handle/10255/dryad.235
Markhamia acuminata		0,78			http://datadryad.org/repo/handle/10255/dryad.235
Markhamia obtusifolia		0,78		Markhamia acuminata	http://datadryad.org/repo/handle/10255/dryad.235
Marquesia acuminata		0,76		Marquesia macroura	http://datadryad.org/repo/handle/10255/dryad.235
Marquesia macroura		0,76			http://datadryad.org/repo/handle/10255/dryad.235
Maytenus cymosus		0,50		Maytenus heterophylla	http://datadryad.org/repo/handle/10255/dryad.235
Maytenus ovatus		0,50		Maytenus heterophylla	http://datadryad.org/repo/handle/10255/dryad.235
Memecylon flavovirens	0,77		1,15	Memecylon sp.	www.worldagroforestry.org
Milletia bequarti	no data	no data	no data		
Mimusops zeyheri		0,81			http://datadryad.org/repo/handle/10255/dryad.235
Mitragyna stipulosa		0,46		Mitragyna indet	http://datadryad.org/repo/handle/10255/dryad.235
Monopetalanthus richardsiae	0,46		0,53	Monopetalanthus pellegrini	http://datadryad.org/repo/handle/10255/dryad.235

Monotes africanus		0,75		Monotes glaber	http://datadryad.org/repo/handle/10255/dryad.235
Monotes elegans		0,75		Monotes glaber	http://datadryad.org/repo/handle/10255/dryad.235
Monotes glaber		0,75			http://datadryad.org/repo/handle/10255/dryad.235
Monotes katangensis		0,75		Monotes glaber	http://datadryad.org/repo/handle/10255/dryad.235
Newtonia buchanani	0,45		0,59		http://datadryad.org/repo/handle/10255/dryad.235
Ochna pulchra		0,63			http://datadryad.org/repo/handle/10255/dryad.235
Ochna schweinfurthiana		0,62			http://datadryad.org/repo/handle/10255/dryad.235
Ochthocosmus lemaireanus		0,73		Ochthocosmus barrae	http://datadryad.org/repo/handle/10255/dryad.235
Olax obtusifolia		0,77		Olax dissitiflora	http://datadryad.org/repo/handle/10255/dryad.235
Oldfieldia dactylophylla	0,82		0,85	Oldfieldia africana	http://datadryad.org/repo/handle/10255/dryad.235
Oncoba spinosa		0,58		Oncoba welwitschii	http://datadryad.org/repo/handle/10255/dryad.235
Ozoroa reticulata	no data	no data	no data		
Pachystela brevipes	no data	no data	no data		
Pandanus livingstoneanus	no data	no data	no data		
Parinari capensis		0,68		Parinari sp.	
Parinari curatellifolia	0,62		0,72		www.worldagroforestry.org and http://datadryad.org/repo/handle/10255/dryad.235
Parinari excelsa		0,68			www.worldagroforestry.org
Parinari polyandra		0,68		Parinari sp.	www.worldagroforestry.org
Parkia filicoidea		0,68		Parinari sp.	www.worldagroforestry.org
Peltophorum africanum		0,59			http://datadryad.org/repo/handle/10255/dryad.235
Peltophorum pterocarpum	0,51	0,66	0,78		www.worldagroforestry.org
Pericopsis angolensis		0,72			http://datadryad.org/repo/handle/10255/dryad.235
Phoenix dactylifera	no data	no data	no data		
Phoenix reclinata	no data	no data	no data		
Phyllanthus mulleranus	no data	no data	no data		
Phyllocomus lemaireanus	no data	no data	no data		
Piliostigima thonningii	no data	no data	no data		
Pinus caribaea	0,41		0,51		www.worldagroforestry.org

Pinus kesiya	0,53		0,56		www.worldagroforestry.org
Pinus lelophylla	no data	no data	no data		
Pinus merkusii		0,52			www.worldagroforestry.org
Pinus michoacana	no data	no data	no data		
Pinus oorcapa	0,60		0,72		www.worldagroforestry.org
Pinus patula	0,36		0,60		www.worldagroforestry.org
Podocarpus milanjianus	0,36		0,84		www.worldagroforestry.org
Protea angolensis	no data	no data	no data		
Protea gaguedi	no data	no data	no data		
Protea welwitschii	no data	no data	no data		
Pseudolachnostylis maprouneifolia		0,62			http://datadryad.org/repo/handle/10255/dryad.235
Psorospermum spp	no data	no data	no data		
Pteleopsis anisoptera	0,64		0,72	Pteleopsis hylodendron	http://datadryad.org/repo/handle/10255/dryad.235
Pteleopsis myritifolia	0,64		0,72	Pteleopsis hylodendron	http://datadryad.org/repo/handle/10255/dryad.235
Pterocapus antunesii		0,70			http://datadryad.org/repo/handle/10255/dryad.235
Pterocarpus angolensis	0,52		0,59		http://datadryad.org/repo/handle/10255/dryad.235
Pterocarpus brenanii		0,80			http://datadryad.org/repo/handle/10255/dryad.235
Pterocarpus chrysothrix	0,52		0,59	Pterocarpus angolensis	http://datadryad.org/repo/handle/10255/dryad.235
Pterocarpus rotundifolius	0,52		0,59	Pterocarpus angolensis	http://datadryad.org/repo/handle/10255/dryad.235
Raphia farinifera	no data	no data	no data		
Rauvolfia caffra	0,44		0,49		http://datadryad.org/repo/handle/10255/dryad.235
Rhus longipes		0,83			http://datadryad.org/repo/handle/10255/dryad.235
Rhus quantiniana		0,83		Rhus longipes	http://datadryad.org/repo/handle/10255/dryad.235
Ricinodendron rautanenil	0,19		0,23	Ricinodendron heudelotii	http://datadryad.org/repo/handle/10255/dryad.235
Rothmania fischeri	no data	no data	no data		
Rothmannia englerana	no data	no data	no data		
Rothmannia	no	no data	no		

whitefieldii	data		data		
Salix babylonica		0,44		Salix sp.	www.worldagroforestry.org
Salix subserrata		0,44		Salix sp.	www.worldagroforestry.org
Sapium ellipticum	0,48		0,72		www.worldagroforestry.org
Schrebera alata		0,61			http://datadryad.org/repo/handle/10255/dryad.235
Schrebera trichoclada		0,80			http://datadryad.org/repo/handle/10255/dryad.235
Sclerocarya caffra	0,47		0,56		www.worldagroforestry.org and http://datadryad.org/repo/handle/10255/dryad.235
Securidaca longepedunculata	no data	no data	no data		
Securidaca welwitschii	no data	no data	no data		
Securinega virosa	no data	no data	no data		
Spathodea campanulata		0,27			www.worldagroforestry.org
Steganotaenia aralicaea	no data	no data	no data		
Sterculia africana		0,28			http://datadryad.org/repo/handle/10255/dryad.235
Sterculia quinqueloba	0,60		0,96		www.worldagroforestry.org
Sterculis tragacantha	no data	no data	no data		
Stereospermum kunthianum		0,60			http://datadryad.org/repo/handle/10255/dryad.235
Strychnos cocculoides		0,65			http://datadryad.org/repo/handle/10255/dryad.235
Strychnos innocua		0,87			http://datadryad.org/repo/handle/10255/dryad.235
Strychnos madagascariensis	no data	no data	no data		
Strychnos potatorum		0,73			http://datadryad.org/repo/handle/10255/dryad.235
Strychnos pungens		0,70			http://datadryad.org/repo/handle/10255/dryad.235
Strychnos spinosa		0,65			http://datadryad.org/repo/handle/10255/dryad.235
Strychnos stuhlmanni		0,65		Strychnos spinosa	http://datadryad.org/repo/handle/10255/dryad.235
Swartzia madagascaiensis	0,96		1,20		www.worldagroforestry.org
Syzigium cordatum		0,75			www.worldagroforestry.org
Syzigium guineense	0,60		0,84		www.worldagroforestry.org
Syzigium owariense	0,45		1,10	Syzigium sp.	www.worldagroforestry.org
Tabernaemontana		0,55		Tabernaemontana	http://datadryad.org/repo/handle/10255/dryad.235

angolensis				crassa	
Tamarindus indica	0,80		0,90		www.worldagroforestry.org
Tarinna neurophylla		0,84			http://datadryad.org/repo/handle/10255/dryad.235
Terminalia brachystemma		0,88		Terminalia mollis	http://datadryad.org/repo/handle/10255/dryad.235
Terminalia mollis		0,88			http://datadryad.org/repo/handle/10255/dryad.235
Terminalia sericea		0,72			http://datadryad.org/repo/handle/10255/dryad.235
Terminalia stenostachya		0,88			http://datadryad.org/repo/handle/10255/dryad.235
Terminalia stuhlmannii		0,88		Terminalia mollis	http://datadryad.org/repo/handle/10255/dryad.235
Toona ciliata	0,33		0,60		www.worldagroforestry.org
Trema Orientalis	0,42		0,47		www.worldagroforestry.org
Trichilia emetica	0,56		0,60		www.worldagroforestry.org
Uapaca benguelensis		0,74		Uapaca sp. (air dry)	www.worldagroforestry.org
Uapaca guineensis	0,48		0,84		www.worldagroforestry.org
Uapaca kirkiana	0,58		0,72		www.worldagroforestry.org and http://datadryad.org/repo/handle/10255/dryad.235
Uapaca nitida		0,65			http://datadryad.org/repo/handle/10255/dryad.235
Uapaca pilosa		0,74		Uapaca sp. (air dry)	
Uapaca robynsii		0,74		Uapaca sp. (air dry)	
Uapaca sansibarica		0,53			http://datadryad.org/repo/handle/10255/dryad.235
Uvaria angolensis	no data	no data	no data		
Uvariustrum hexaloboides	no data	no data	no data		
Vangueriopsis lancifiora	no data	no data	no data		
Vincentella passargei	no data	no data	no data		
Viridivia suberosa	no data	no data	no data		
Vitex amboinensis	0,34		1.01	Vitex sp.	www.worldagroforestry.org
Vitex doniana		0,40			http://datadryad.org/repo/handle/10255/dryad.235
Vitex madiensis	0,34		1.01		www.worldagroforestry.org
Vitex mombasae	0,34		1.01		www.worldagroforestry.org
Vitex payos	0,34		1.01		www.worldagroforestry.org
Vitex potersiana	0,34		1.01		www.worldagroforestry.org
Voacanga schweinfurthi	no data	no data	no data		

Voacanga thouari	no data	no data	no data		
Xeroderris stuhlmannii		0,63			http://datadryad.org/repo/handle/10255/dryad.235
Ximenia americana		0,95			http://datadryad.org/repo/handle/10255/dryad.235
Ximenia caffra		0,95		Ximenia americana	http://datadryad.org/repo/handle/10255/dryad.235
Xylopia aethlopica	0,40		0,98	Xylopia sp.	www.worldagroforestry.org
Xylopia katangensis	0,40		0,98	Xylopia sp.	www.worldagroforestry.org
Xylopia odoratissima	0,40		0,98	Xylopia sp.	www.worldagroforestry.org
Xylopia rubescene	0,40		0,98	Xylopia sp.	www.worldagroforestry.org
Xylopia scutiflora	0,40		0,98	Xylopia sp.	www.worldagroforestry.org
Xylopia tomentosa	0,40		0,98	Xylopia sp.	www.worldagroforestry.org
Zanha africana		0,86			http://datadryad.org/repo/handle/10255/dryad.235
Zanthoxylum chalybeum	0,43		0,61	Zanthoxylum leprieurii	http://datadryad.org/repo/handle/10255/dryad.235
Zyziphus abyssinica		0,81			http://datadryad.org/repo/handle/10255/dryad.235
Zyziphus mauritiana	0,58		0,70		http://datadryad.org/repo/handle/10255/dryad.235
Zyziphus pubescens	0,54		1,08	Zyziphus sp.	www.worldagroforestry.org

Annex III Carbon stock estimates for all land use categories

Carbon stock by carbon pools for different land use categories in Zambia using different estimation methods. Estimates are displayed as total amount of carbon (in mega tonnes) and as amount of carbon per hectare (in tonnes). Confidence intervals are indicated with '+/-'. The method denoted 'Volume; BCEF' refers to the conversion of volume estimates to biomass using BCEF. 'Allometric (variable)' denotes the use of allometric equations with the in bracket indicated variables. Wd = basic wood density, AG = above ground, BG = below ground, n.a. = data not available. Calculation procedures and applied default values are described in details in chapter 2.

TOTAL – ALL AREAS

Carbon pool, unit and confidence interval	Method	Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	17,72	29,09	13,21	10,54	13,94
	+/- per ha	2,00	2,91	1,67	1,33	1,95
	Total (mega tonnes of carbon)	1333,55	2189,14	994,01	793,48	1049,23
	+/- total	150,57	218,71	125,90	99,97	146,39
Biomass BG	Density (tonnes of carbon/ha)	4,96	8,14	3,70	2,95	3,90
	+/- per ha	0,56	0,81	0,47	0,37	0,54
	Total (mega tonnes of carbon)	373,40	612,96	278,32	222,17	293,79
	+/- total	42,16	61,24	35,25	27,99	40,99
Dead wood	Density (tonnes of carbon/ha)	1,26	2,71	0,48	0,26	0,33
	+/- per ha	0,30	0,62	0,14	0,07	0,09
	Total (mega tonnes of carbon)	94,70	204,00	36,40	19,79	24,82
	+/- total	22,92	46,53	10,68	4,90	6,98
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

FOREST – MAIN LAND-USE CATEGORY

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	24,41	39,37	18,53	15,02	20,01
	+/- per ha	2,35	3,25	2,03	1,56	2,40
	Total (mega tonnes of carbon)	1219,56	1967,00	925,87	750,53	999,47
	+/- total	117,55	162,61	101,18	78,13	119,90
Biomass BG	Density (tonnes of carbon/ha)	6,83	11,02	5,19	4,21	5,60
	+/- per ha	0,66	0,91	0,57	0,44	0,67
	Total (mega tonnes of carbon)	341,48	550,76	259,24	210,15	279,85
	+/- total	32,91	45,53	28,33	21,88	33,57
Dead wood	Density (tonnes of carbon/ha)	1,79	3,86	0,68	0,37	0,47
	+/- per ha	0,43	0,88	0,20	0,09	0,13
	Total (mega tonnes of carbon)	89,50	192,73	33,84	18,60	23,51
	+/- total	21,68	43,90	9,84	4,53	6,50
Litter	Density (tonnes of carbon/ha)	2,48	2,48	2,48	2,48	2,48
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	123,71	123,71	123,71	123,71	123,71
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	31,00	31,00	31,00	31,00	31,00
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	1549,01	1549,01	1549,01	1549,01	1549,01
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

EVERGREEN FOREST

Carbon pool, unit and confidence interval		Method: Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	33,84	50,85	29,54	15,94	18,13
	+/- per ha	14,30	18,09	19,19	9,23	10,45
	Total (mega tonnes of carbon)	27,71	41,64	24,19	13,05	14,84
	+/- total	11,71	14,82	15,72	7,56	8,56
Biomass BG	Density (tonnes of carbon/ha)	9,48	14,24	8,27	4,46	5,08
	+/- per ha	4,00	5,07	5,37	2,58	2,93
	Total (mega tonnes of carbon)	7,76	11,66	6,77	3,65	4,16
	+/- total	3,28	4,15	4,40	2,12	2,40
Dead wood	Density (tonnes of carbon/ha)	6,09	11,94	2,99	1,03	1,32
	+/- per ha	7,09	13,01	3,95	1,32	1,71
	Total (mega tonnes of carbon)	4,98	9,77	2,45	0,84	1,08
	+/- total	5,80	10,65	3,23	1,08	1,40
Litter	Density (tonnes of carbon/ha)	5,20	5,20	5,20	5,20	5,20
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	4,26	4,26	4,26	4,26	4,26
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	31,00	31,00	31,00	31,00	31,00
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	25,39	25,39	25,39	25,39	25,39
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

SEMI-EVERGREEN FOREST

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	27,79	43,75	20,73	16,54	21,66
	+/- per ha	3,01	4,14	2,52	1,96	2,88
	Total (mega tonnes of carbon)	948,64	1493,45	707,73	564,79	739,29
	+/- total	102,67	141,49	86,01	67,05	98,27
Biomass BG	Density (tonnes of carbon/ha)	7,78	12,25	5,80	4,63	6,06
	+/- per ha	0,84	1,16	0,71	0,55	0,81
	Total (mega tonnes of carbon)	265,62	418,17	198,16	158,14	207,00
	+/- total	28,75	39,62	24,08	18,77	27,51
Dead wood	Density (tonnes of carbon/ha)	2,06	4,39	0,72	0,40	0,51
	+/- per ha	0,56	1,13	0,23	0,11	0,17
	Total (mega tonnes of carbon)	70,31	150,00	24,52	13,60	17,29
	+/- total	19,13	38,58	7,93	3,80	5,71
Litter	Density (tonnes of carbon/ha)	2,58	2,58	2,58	2,58	2,58
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	87,94	87,94	87,94	87,94	87,94
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	31,00	31,00	31,00	31,00	31,00
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	1058,50	1058,50	1058,50	1058,50	1058,50
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

DECIDUOUS FOREST

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	16,16	28,76	12,84	11,51	16,37
	+/- per ha	2,18	3,31	2,71	2,42	4,47
	Total (mega tonnes of carbon)	240,28	427,53	190,91	171,12	243,38
	+/- total	32,38	49,14	40,27	35,90	66,48
Biomass BG	Density (tonnes of carbon/ha)	4,53	8,05	3,60	3,22	4,58
	+/- per ha	0,61	0,93	0,76	0,68	1,25
	Total (mega tonnes of carbon)	67,28	119,71	53,45	47,91	68,15
	+/- total	9,07	13,76	11,27	10,05	18,61
Dead wood	Density (tonnes of carbon/ha)	0,91	2,12	0,45	0,27	0,34
	+/- per ha	0,42	0,94	0,30	0,14	0,18
	Total (mega tonnes of carbon)	13,55	31,49	6,65	4,08	5,03
	+/- total	6,17	13,91	4,39	2,14	2,67
Litter	Density (tonnes of carbon/ha)	2,10	2,10	2,10	2,10	2,10
	+/- per ha	n.a	n.a	n.a	n.a	n.a
	Total (mega tonnes of carbon)	31,22	31,22	31,22	31,22	31,22
	+/- total	n.a	n.a	n.a	n.a	n.a
Soil	Density (tonnes of carbon/ha)	31,00	31,00	31,00	31,00	31,00
	+/- per ha	n.a	n.a	n.a	n.a	n.a
	Total (mega tonnes of carbon)	460,82	460,82	460,82	460,82	460,82
	+/- total	n.a	n.a	n.a	n.a	n.a

OTHER NATURAL FOREST

Carbon pool, unit and confidence interval / Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	21,05	31,57	21,89	11,28	14,06
	+/- per ha	38,68	58,02	40,23	20,74	25,84
	Total (mega tonnes of carbon)	2,93	4,39	3,04	1,57	1,95
	+/- total	5,38	8,07	5,59	2,88	3,59
Biomass BG	Density (tonnes of carbon/ha)	5,89	8,84	6,13	3,16	3,94
	+/- per ha	10,83	16,25	11,26	5,81	7,23
	Total (mega tonnes of carbon)	0,82	1,23	0,85	0,44	0,55
	+/- total	1,51	2,26	1,57	0,81	1,01
Dead wood	Density (tonnes of carbon/ha)	4,67	10,51	1,56	0,64	0,78
	+/- per ha	8,58	19,31	2,87	1,17	1,44
	Total (mega tonnes of carbon)	0,65	1,46	0,22	0,09	0,11
	+/- total	1,19	2,68	0,40	0,16	0,20
Litter	Density (tonnes of carbon/ha)	2,10	2,10	2,10	2,10	2,10
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	0,29	0,29	0,29	0,29	0,29
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	31,00	31,00	31,00	31,00	31,00
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	4,31	4,31	4,31	4,31	4,31
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

PLANTATIONS

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Biomass BG	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Dead wood	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

Note: Due to plantations' low area representation in Zambia, no sample plots in the ILUA fell in *plantation* areas – i.e. ILUA did not capture any data on biomass stock in these land-use areas.

OTHER WOODED LAND - MAIN LAND-USE CATEGORY

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	7,18	13,96	4,32	2,54	2,91
	+/- per ha	2,30	4,28	1,63	1,08	1,22
	Total (mega tonnes of carbon)	43,52	84,63	26,18	15,43	17,65
	+/- total	13,96	25,96	9,88	6,53	7,42
Biomass BG	Density (tonnes of carbon/ha)	2,87	5,58	1,73	1,02	1,16
	+/- per ha	0,92	1,71	0,65	0,43	0,49
	Total (mega tonnes of carbon)	17,41	33,85	10,47	6,17	7,06
	+/- total	5,59	10,38	3,95	2,61	2,97
Dead wood	Density (tonnes of carbon/ha)	0,25	0,55	0,14	0,06	0,07
	+/- per ha	0,20	0,44	0,14	0,05	0,06
	Total (mega tonnes of carbon)	1,50	3,32	0,86	0,38	0,42
	+/- total	1,20	2,66	0,86	0,33	0,37
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	31,00	31,00	31,00	31,00	31,00
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	187,71	187,71	187,71	187,71	187,71
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

SCRUB LAND

Carbon pool, unit and confidence interval		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	10,37	20,15	4,80	2,18	2,53
	+/- per ha	4,60	7,68	2,56	1,30	1,60
	Total (mega tonnes of carbon)	12,01	23,32	5,56	2,52	2,93
	+/- total	5,32	8,89	2,96	1,50	1,86
Biomass BG	Density (tonnes of carbon/ha)	4,15	8,06	1,92	0,87	1,01
	+/- per ha	1,84	3,07	1,02	0,52	0,64
	Total (mega tonnes of carbon)	4,80	9,33	2,22	1,01	1,17
	+/- total	2,13	3,56	1,18	0,60	0,74
Dead wood	Density (tonnes of carbon/ha)	0,48	1,07	0,25	0,08	0,09
	+/- per ha	0,62	1,39	0,33	0,11	0,11
	Total (mega tonnes of carbon)	0,55	1,24	0,29	0,10	0,10
	+/- total	0,71	1,61	0,39	0,13	0,13
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	31,00	31,00	31,00	31,00	31,00
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	35,90	35,90	35,90	35,90	35,90
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

WOODED GRASS LAND

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	6,42	12,50	4,20	2,63	3,00
	+/- per ha	2,51	4,74	1,92	1,31	1,48
	Total (mega tonnes of carbon)	31,51	61,31	20,62	12,90	14,72
	+/- total	12,33	23,23	9,44	6,41	7,25
Biomass BG	Density (tonnes of carbon/ha)	2,57	5,00	2,35	1,47	1,68
	+/- per ha	1,01	1,89	1,08	0,73	0,83
	Total (mega tonnes of carbon)	12,60	24,52	11,55	7,23	8,24
	+/- total	4,93	9,29	5,29	3,59	4,06
Dead wood	Density (tonnes of carbon/ha)	0,19	0,42	0,12	0,06	0,06
	+/- per ha	0,18	0,40	0,15	0,06	0,07
	Total (mega tonnes of carbon)	0,95	2,08	0,58	0,28	0,31
	+/- total	0,90	1,96	0,75	0,30	0,34
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	31,00	31,00	31,00	31,00	31,00
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	151,81	151,81	151,81	151,81	151,81
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

OTHER LAND - MAIN LAND-USE CATEGORY

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	4,45	8,70	2,64	1,68	1,96
	+/- per ha	1,25	2,32	0,95	0,57	0,67
	Total (mega tonnes of carbon)	70,26	137,14	41,67	26,47	30,86
	+/- total	19,73	36,64	14,95	8,94	10,60
Biomass BG	Density (tonnes of carbon/ha)	1,78	3,48	1,06	0,67	0,78
	+/- per ha	0,50	0,93	0,38	0,23	0,27
	Total (mega tonnes of carbon)	28,10	54,86	16,67	10,59	12,34
	+/- total	7,89	14,66	5,98	3,58	4,24
Dead wood	Density (tonnes of carbon/ha)	0,23	0,50	0,11	0,05	0,06
	+/- per ha	0,15	0,32	0,07	0,04	0,04
	Total (mega tonnes of carbon)	3,70	7,95	1,70	0,81	0,90
	+/- total	2,43	5,09	1,06	0,57	0,63
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

GRASS LAND

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	2,49	5,18	1,88	1,07	1,27
	+/- per ha	1,43	2,98	1,63	0,79	0,96
	Total (mega tonnes of carbon)	15,13	31,51	11,41	6,48	7,75
	+/- total	8,70	18,16	9,95	4,80	5,82
Biomass BG	Density (tonnes of carbon/ha)	0,99	2,07	0,75	0,43	0,51
	+/- per ha	0,57	1,19	0,65	0,32	0,38
	Total (mega tonnes of carbon)	6,05	12,60	4,56	2,59	3,10
	+/- total	3,48	7,26	3,98	1,92	2,33
Dead wood	Density (tonnes of carbon/ha)	0,03	0,08	0,01	0,01	0,01
	+/- per ha	0,06	0,15	0,02	0,02	0,02
	Total (mega tonnes of carbon)	0,18	0,46	0,05	0,05	0,05
	+/- total	0,37	0,92	0,11	0,10	0,10
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

BARREN LAND

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	0,00	0,00	0,00	0,00	0,00
	+/- per ha	0,00	0,00	0,00	0,00	0,00
	Total (mega tonnes of carbon)	0,00	0,00	0,00	0,00	0,00
	+/- total	0,00	0,00	0,00	0,00	0,00
Biomass BG	Density (tonnes of carbon/ha)	0,00	0,00	0,00	0,00	0,00
	+/- per ha	0,00	0,00	0,00	0,00	0,00
	Total (mega tonnes of carbon)	0,00	0,00	0,00	0,00	0,00
	+/- total	0,00	0,00	0,00	0,00	0,00
Dead wood	Density (tonnes of carbon/ha)	0,00	0,00	0,00	0,00	0,00
	+/- per ha	0,00	0,00	0,00	0,00	0,00
	Total (mega tonnes of carbon)	0,00	0,00	0,00	0,00	0,00
	+/- total	0,00	0,00	0,00	0,00	0,00
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

MARSH LAND

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	1,83	2,83	1,74	1,01	1,26
	+/- per ha	2,58	3,73	3,10	1,81	2,29
	Total (mega tonnes of carbon)	2,44	3,78	2,32	1,35	1,68
	+/- total	3,44	4,97	4,13	2,41	3,05
Biomass BG	Density (tonnes of carbon/ha)	0,73	1,13	0,70	0,40	0,51
	+/- per ha	1,03	1,49	1,24	0,73	0,91
	Total (mega tonnes of carbon)	0,98	1,51	0,93	0,54	0,67
	+/- total	1,37	1,99	1,65	0,97	1,22
Dead wood	Density (tonnes of carbon/ha)	0,00	0,00	0,00	0,00	0,00
	+/- per ha	0,00	0,00	0,00	0,00	0,00
	Total (mega tonnes of carbon)	0,00	0,00	0,00	0,00	0,00
	+/- total	0,00	0,00	0,00	0,00	0,00
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

ANNUAL CROPS

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	6,18	11,96	3,51	2,36	2,75
	+/- per ha	1,94	3,56	1,55	1,07	1,27
	Total (mega tonnes of carbon)	29,07	56,24	16,50	11,10	12,91
	+/- total	9,11	16,74	7,29	5,04	5,96
Biomass BG	Density (tonnes of carbon/ha)	2,47	4,79	1,40	0,94	1,10
	+/- per ha	0,77	1,42	0,62	0,43	0,51
	Total (mega tonnes of carbon)	11,63	22,50	6,60	4,44	5,17
	+/- total	3,64	6,69	2,91	2,02	2,38
Dead wood	Density (tonnes of carbon/ha)	0,39	0,77	0,23	0,10	0,11
	+/- per ha	0,34	0,61	0,17	0,09	0,10
	Total (mega tonnes of carbon)	1,85	3,62	1,08	0,45	0,51
	+/- total	1,62	2,89	0,82	0,40	0,47
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

PERENNIAL CROPS

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	3,02	5,57	1,56	1,33	1,43
	+/- per ha	5,29	9,96	2,88	2,51	2,72
	Total (mega tonnes of carbon)	0,71	1,31	0,37	0,31	0,34
	+/- total	1,25	2,35	0,68	0,59	0,64
Biomass BG	Density (tonnes of carbon/ha)	1,21	2,23	0,62	0,53	0,57
	+/- per ha	2,12	3,99	1,15	1,00	1,09
	Total (mega tonnes of carbon)	0,28	0,53	0,15	0,13	0,13
	+/- total	0,50	0,94	0,27	0,24	0,26
Dead wood	Density (tonnes of carbon/ha)	1,43	3,22	0,70	0,20	0,21
	+/- per ha	3,21	7,22	1,57	0,45	0,48
	Total (mega tonnes of carbon)	0,34	0,76	0,17	0,05	0,05
	+/- total	0,76	1,70	0,37	0,11	0,11
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

PASTURES

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	1,22	3,06	0,32	0,29	0,29
	+/- per ha	3,25	8,13	0,84	0,77	0,77
	Total (mega tonnes of carbon)	0,57	1,42	0,15	0,13	0,13
	+/- total	0,00	3,77	0,39	0,36	0,36
Biomass BG	Density (tonnes of carbon/ha)	0,49	1,22	0,13	0,12	0,12
	+/- per ha	1,30	3,25	0,34	0,31	0,31
	Total (mega tonnes of carbon)	0,23	0,57	0,06	0,05	0,05
	+/- total	0,00	1,51	0,16	0,14	0,14
Dead wood	Density (tonnes of carbon/ha)	0,00	0,00	0,00	0,00	0,00
	+/- per ha	0,00	0,00	0,00	0,00	0,00
	Total (mega tonnes of carbon)	0,00	0,00	0,00	0,00	0,00
	+/- total	0,00	0,00	0,00	0,00	0,00
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

FALLOW CROPS

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	8,46	16,22	4,10	2,58	2,92
	+/- per ha	3,64	5,95	1,87	1,33	1,51
	Total (mega tonnes of carbon)	20,19	38,73	9,79	6,16	6,97
	+/- total	0,00	14,20	4,46	3,18	3,59
Biomass BG	Density (tonnes of carbon/ha)	3,38	6,49	1,64	1,03	1,17
	+/- per ha	1,46	2,38	0,75	0,53	0,60
	Total (mega tonnes of carbon)	8,08	15,49	3,91	2,46	2,79
	+/- total	0,00	5,68	1,79	1,27	1,44
Dead wood	Density (tonnes of carbon/ha)	0,54	1,26	0,16	0,10	0,11
	+/- per ha	0,48	1,16	0,14	0,12	0,12
	Total (mega tonnes of carbon)	1,28	3,00	0,39	0,25	0,27
	+/- total	1,15	2,77	0,33	0,28	0,29
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

URBAN AREAS

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	0,00	0,00	0,00	0,00	0,00
	+/- per ha	0,00	0,00	0,00	0,00	0,00
	Total (mega tonnes of carbon)	0,00	0,00	0,00	0,00	0,00
	+/- total	0,00	0,00	0,00	0,00	0,00
Biomass BG	Density (tonnes of carbon/ha)	0,00	0,00	0,00	0,00	0,00
	+/- per ha	0,00	0,00	0,00	0,00	0,00
	Total (mega tonnes of carbon)	0,00	0,00	0,00	0,00	0,00
	+/- total	0,00	0,00	0,00	0,00	0,00
Dead wood	Density (tonnes of carbon/ha)	0,00	0,00	0,00	0,00	0,00
	+/- per ha	0,00	0,00	0,00	0,00	0,00
	Total (mega tonnes of carbon)	0,00	0,00	0,00	0,00	0,00
	+/- total	0,00	0,00	0,00	0,00	0,00
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

Note: ILUA did not capture biomass in *urban* areas, which is probably due to the low number of sample plots falling in this land-use category.

RURAL AREAS

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	3,89	7,55	2,06	1,69	1,93
	+/- per ha	6,16	11,60	3,67	2,95	3,37
	Total (mega tonnes of carbon)	2,14	4,16	1,14	0,93	1,07
	+/- total	3,40	6,39	2,02	1,62	1,85
Biomass BG	Density (tonnes of carbon/ha)	1,56	3,02	0,82	0,68	0,77
	+/- per ha	2,47	4,64	1,47	1,18	1,35
	Total (mega tonnes of carbon)	0,86	1,66	0,45	0,37	0,43
	+/- total	1,36	2,56	0,81	0,65	0,74
Dead wood	Density (tonnes of carbon/ha)	0,07	0,19	0,03	0,03	0,04
	+/- per ha	0,17	0,41	0,06	0,07	0,08
	Total (mega tonnes of carbon)	0,04	0,10	0,01	0,02	0,02
	+/- total	0,09	0,23	0,03	0,04	0,04
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

INLAND WATER - MAIN LAND-USE CATEGORY

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	0,06	0,11	0,08	0,08	0,08
	+/- per ha	0,13	0,21	0,17	0,17	0,17
	Total (mega tonnes of carbon)	0,22	0,37	0,29	0,29	0,29
	+/- total	0,45	0,74	0,59	0,60	0,61
Biomass BG	Density (tonnes of carbon/ha)	0,01	0,02	0,02	0,02	0,02
	+/- per ha	0,03	0,04	0,03	0,03	0,03
	Total (mega tonnes of carbon)	0,04	0,07	0,06	0,06	0,06
	+/- total	0,09	0,15	0,12	0,12	0,12
Dead wood	Density (tonnes of carbon/ha)	0,00	0,00	0,00	0,00	0,00
	+/- per ha	0,00	0,00	0,00	0,00	0,00
	Total (mega tonnes of carbon)	0,00	0,00	0,00	0,00	0,00
	+/- total	0,00	0,00	0,00	0,00	0,00
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

RIVERS

Carbon pool, unit and confidence interval / Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	0,28	0,48	0,37	0,37	0,38
	+/- per ha	0,64	1,06	0,85	0,85	0,86
	Total (mega tonnes of carbon)	0,22	0,37	0,29	0,29	0,29
	+/- total	0,50	0,82	0,65	0,66	0,67
Biomass BG	Density (tonnes of carbon/ha)	0,06	0,10	0,07	0,07	0,08
	+/- per ha	0,13	0,21	0,17	0,17	0,17
	Total (mega tonnes of carbon)	0,04	0,07	0,06	0,06	0,06
	+/- total	0,10	0,16	0,13	0,13	0,13
Dead wood	Density (tonnes of carbon/ha)	0,00	0,00	0,00	0,00	0,00
	+/- per ha	0,00	0,00	0,00	0,00	0,00
	Total (mega tonnes of carbon)	0,00	0,00	0,00	0,00	0,00
	+/- total	0,00	0,00	0,00	0,00	0,00
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

LAKES

Carbon pool, unit and confidence interval \ Method		Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	0	0	0	0	0
	+/- per ha	0	0	0	0	0
	Total (mega tonnes of carbon)	0	0	0	0	0
	+/- total	0	0	0	0	0
Biomass BG	Density (tonnes of carbon/ha)	0	0	0	0	0
	+/- per ha	0	0	0	0	0
	Total (mega tonnes of carbon)	0	0	0	0	0
	+/- total	0	0	0	0	0
Dead wood	Density (tonnes of carbon/ha)	0	0	0	0	0
	+/- per ha	0	0	0	0	0
	Total (mega tonnes of carbon)	0	0	0	0	0
	+/- total	0	0	0	0	0
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

DAMS

Carbon pool, unit and confidence interval		Method: Volume; BCEF (low)	Volume; BCEF (average)	Allometric (dbh)	Allometric (dbh; height; low wd)	Allometric (dbh; height; high wd)
Biomass AG	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Biomass BG	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Dead wood	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Litter	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.
Soil	Density (tonnes of carbon/ha)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- per ha	n.a.	n.a.	n.a.	n.a.	n.a.
	Total (mega tonnes of carbon)	n.a.	n.a.	n.a.	n.a.	n.a.
	+/- total	n.a.	n.a.	n.a.	n.a.	n.a.

Note: No sample plots in ILUA fell in the land-use category of *dams.*

MRV Working Paper series

WP Nr.	Title	Date
01	*Role of satellite remote sensing in REDD by Peter Holmgren*	13 October 2008
02	*REDD-Workshop Monitoring, Assessment and Verification (report of the Washington meeting)*	16-17 September 2008
03	*Review of literature on monitoring to support REDD by Claudia Hiepe, Hideki Kanamaru*	16-17 September 2008
04	*Carbon Stock Assessment and Modelling in Zambia. A UN-REDD programme study by Kewin Bach Friis Kamelarczyk*	September 2009