

ETHIOPIA'S FOREST REFERENCE LEVEL SUBMISSION TO THE UNFCCC

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Acronyms

| | |
|---------------------|--|
| AD | Activity Data |
| AGB | above ground biomass |
| BGB | below ground biomass |
| CGIAR | Consultative Group on International Agriculture Research |
| CSA | Central Statistics Authority |
| DBH | diameter at breast height |
| EF | Emission Factor |
| FAO | Food and Agriculture Organization of the United Nations |
| FRL | Forest Reference Level |
| GLWD | Global Lakes and Wetlands Database |
| GHG | greenhouse gas |
| Ht | height |
| IPCC | Intergovernmental Panel on Climate Change |
| LULC | land use/land cover |
| MEFCC | Ministry of Environment, Forest and Climate Change |
| MMU | minimum mapping unit |
| NFI | national forest inventory |
| REDD | Reducing emissions from deforestation and forest degradation |
| RS | remote sensing |
| SU | sampling unit |
| tCO ₂ eq | ton of carbon dioxide equivalent |
| UNFCCC | United Nations Framework for Conventions on Climate Change |
| WBISPP | Wood Biomass Inventory and Strategic Planning Project |
| WD | wood density |

SUMMARY: THE PROPOSED FRL

Ethiopia's FRL is in the context of receiving results based payments for REDD+ implementation. The FRL includes deforestation and afforestation, AGB, BGB, deadwood and CO₂ emissions; it is national and based on a historical average of emissions and removals between 2000 and 2013. The Forest Reference Emission Level for deforestation is: 17,978,735 tCO₂ /year; the Forest Reference Level for afforestation is: 4,789,935 tCO₂ /year. The choice of construction approach and historical period is provisional and may change in the future following appropriate and comprehensive assessment and national circumstances. In this revised version of the FRL the estimates have been improved by estimating the emission factors using countrywide data from the National Forest Inventory and taking into account the revision of the first submission.

INTRODUCTION

Ethiopia welcomes the invitation to submit a Forest Reference Emission Level (FRL) on a voluntary basis expressed in Decision 12/CP.17, paragraph 13. This FRL submission is in the context of results-based payments for the implementation of reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+) under the United Nations Framework Convention on Climate Change (UNFCCC).

Ethiopia has followed the guidance provided by the UNFCCC through the decisions taken at the Conference of the Parties (CP), notably the modalities for forest reference emission levels and forest reference level in Decision 12/CP.17 and the guidelines for submissions of information on reference levels in the Annex of Decision 12/CP.17. The original FRL submission was made in December 2015. This revised version includes revisions that were already foreseen in the original (e.g. national-level emission factors from recently completed NFI) and some clarifications as a consequence of the technical assessment process over the last 8 months. This submission does not prejudge or modify any of Ethiopia's Nationally Determined Contributions or Nationally Appropriate Mitigation Actions pursuant to the Bali Action Plan.

Ethiopia intends to take a step-wise approach to its national FRL development as indicated may be useful in Decision 12/CP.17, paragraph 10. As such, the current FRL reflects the best available information at the time of submission. Its scope and methodologies applied may be modified if better data becomes available. The historical period considered and/or the construction approach may be revised.

SCALE

The Forest Reference Emission Level will cover the national territory of Ethiopia. Ground inventory data has been collected in the past three years through the Ethiopia's National Forest Inventory and wall-to-wall and sample based remote sensing have been carried out at the national scale. The current submission therefore uses national activity data and emission factors.

SCOPE: ACTIVITIES, POOLS AND GASES INCLUDED

REDD+ ACTIVITIES IN THE FRL

This FRL will include the REDD+ activities deforestation and afforestation (enhancement of forest carbon stocks). Deforestation will be defined as the conversion of forest land to other land. Forest land is defined by the Ethiopian forest definition (see related section) and any transition below the thresholds in this definition will be considered as deforestation (including the transition of forest land to open woodland). Afforestation is defined as the conversion of other land to forest land. Afforestation includes restoration of degraded shrubs and woodlands resulting in a transition above the thresholds in the forest definition.

Forest degradation is defined as the loss of carbon stock in forest land remaining forest land, and forest enhancement is defined as the enrichment of carbon stock in forest land remaining forest land (or the opposite of forest degradation). These activities are not accounted for in the FRL.

Though forest degradation in the REDD context is often considered a significant source of emissions in Ethiopia, due to the lack of accurate, reliable and consistent data at the national scale, forest degradation is omitted in this FRL. It is Ethiopia's intention to gradually account for forest degradation in the future and currently at local scales different methodologies are being piloted to assess and monitor forest degradation: the use of dense time series image analysis is being tested at project scale and the use of proxy data on fuelwood consumption is being explored. Ethiopia has the desire and intention to develop a robust methodology to assess forest degradation and exploring whether successful attempts at the local level may be transferred into a cost-effective accounting mechanism at the national level.

Ethiopia's efforts on natural forest restoration and the development of plantations are expected to result in reduction of forest degradation and deforestation. In Tigray and some parts of Amhara the cultivation of plantation as woodlot on farmers' own land has been able to supply most of the fuelwood needed (Ethiopia REDD+ Secretariat, 2015) which is expected to reduce the pressure on natural forest.

Displacement of emissions from deforestation to forest degradation is expected to be minimal. Deforestation is mainly caused by the expansion of agriculture land, while degradation is mainly driven by collection of fuelwood and charcoal, livestock grazing, collection of construction wood and illegal logging. Though there is some overlap between the drivers of deforestation and forest degradation (livestock grazing and wood collection may eventually result in a conversion from forest to open woodland), the expectation is that when addressing these drivers a positive effect will be seen both on deforestation and forest degradation.

CARBON POOLS IN THE FRL

The carbon pools included in the FRL will be above ground biomass (AGB), below ground biomass (BGB), and deadwood. The reason for selecting these pools is that they are expected to be the most significant pools and primary data has been collected on these pools through the national forest inventory (NFI). The methodology applied to collect the litter data in the field only includes the depth of the litter on the plot. This methodology implies to adopt an *ad hoc* model to estimate the carbon content in the litter correctly. This model has not been yet developed. According to some recent articles, the C fraction contained in litter consist of less than 0,00% of the total carbon stock (*Simegn et al., 2014, Mikrewongel, 2015, Wolde et al., 2014*).

With regard to the soil, this may constitute a very large carbon pool in Ethiopian forests however, little is known about emissions from soil after forest conversion and data collection in soils is very costly and needs monitoring over an extended period. For this reason, the soil carbon pool is not included in the FRL.

Ethiopia does not have a recent soil map, a study (*Tekalign et al., 1991*) indicates the Organic Carbon (OC) fraction to be between 0 to 3%. Currently there are no other extensive and complete studies.

GASES IN THE FRL

The proposed FRL only includes CO₂ emissions. Non- CO₂ emissions would be expected from burned areas but since Ethiopia is not systematically collecting data

on the occurrence of fires, data on fire occurrence is not thought to be sufficiently reliable for inclusion in the FRL. Ethiopia reported a burned forest area of 200 ha in 2003, 800 ha in 2006 and 100 ha in 2008 to FAO's global Forest Resources Assessment (FRA) in 2015 (FAO, 2015). To evaluate the significance of non- CO₂ gases, a calculation is proposed to estimate the likely range of non- CO₂ emissions by calculating annual non- CO₂ emissions for a burned area of 100ha of the lowest biomass forest (biome 1) and for a burned area of 800ha of the highest biomass forest (biome 4). Associated non-CO₂ emissions are accordingly calculated using equation 2.27 (IPCC 2006), using default emission factors from Table 2.5 (Tropical forest) and combustion factor values from Table 2.6 (all secondary forest). This calculation suggests the contribution of non- CO₂ to total forest-related emissions is in the range of 0.1 – 37.000 t CO₂ eq for CO, 0.1 – 33.000 t CO₂ eq for CH₄ and 3000 – 11.000 t CO₂ eq for N₂O. Therefore the contribution of non CO₂ gases is estimated to be <2% of total annual emissions from forest land in Ethiopia.

FOREST DEFINITION

In February 2015 Ethiopia adopted a new forest definition (MEF 2015) as follows: 'Land spanning more than 0.5 ha covered by trees (including bamboo) (with a minimum width of 20m or not more than two-thirds of its length) attaining a height of more than 2m and a canopy cover of more than 20% or trees with the potential to reach these thresholds in situ in due course (Minutes of Forest sector management, MEFC, Feb. 2015). Ethiopia is in the process of approving this as its national legal definition.

This forest definition differs from the definition used for international reporting to the Global Forest Resources Assessment (FRA) and from the forest definition used in the NFI which both applied the FAO forest definition with the thresholds of 10% canopy cover, a 0.5 ha area and a 5 m height.

The reason for changing the national forest definition is to better capture the natural primary state of Ethiopia's forest vegetation. Specifically, the reason for lowering the tree height from 5 meters to 2 meters is to capture natural forest vegetation types like the dryland forests, which of trees reaching a height of around

2-3 m. The proposed change in forest definition results in the inclusion of what previously was classified as Ethiopia's dense woodlands that have a wider distribution through the country (see Figure 1). Commercial agriculture is expanding mainly on dense woodlands and Ethiopia desires to enable REDD+ incentives for its conservation.

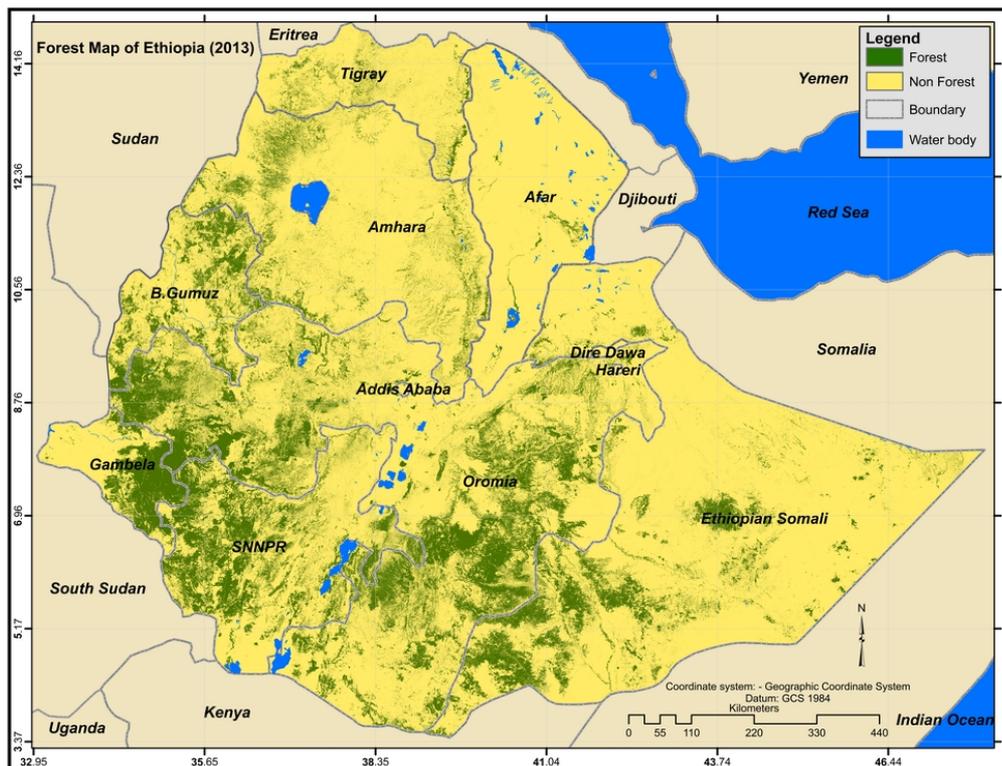


Figure 1: Extent of the forest cover under the current Ethiopia's forest

The reason for increasing the canopy cover threshold from 10% to 20% is to avoid acceptance of highly degraded forest lands into the forest definition and in this way provide incentives for protecting quality forest.

This forest definition also differs from the definition used for reporting greenhouse gas (GHG) emissions and removals from the forestry sector within the framework of the Clean Development Mechanism (CDM) that was submitted to the UNFCCC

earlier¹, which is “A minimum of 0.05 ha of land covered by trees attaining a height of more than 2m and a canopy cover of more than 20%.” The difference is an increase on area threshold. The main reason for increasing the area in for the FRL is due the limitation of technology for measurement and monitoring to detect changes in small areas of forest.

Since Ethiopia has improved the data quality on the forest area change assessment and changed the forest definition, some inconsistencies currently exist between the emissions and removals from forestry in the FRL and the GHG inventory. However, the future GHG inventory reporting in the Biennial Update Report (BUR) will use the improved data and new forest definition and full consistency will be sought when reporting results in the technical annex to the BUR.

DRIVERS OF DEFORESTATION AND FOREST DEGRADATION

A comprehensive study was published by Ethiopia’s REDD+ secretariat (2015) analysing the drivers of deforestation and forest degradation. The study found deforestation and forest degradation to be driven mainly by free livestock grazing, fodder use and fuelwood collection/charcoal production in all the regions followed by farmland expansion, land fires and construction wood harvesting. The underlying causes of deforestation and degradation based on framework analysis were identified to be population growth, unsecure land tenure and poor law enforcement.

Free grazing affects the plains and lowland woodlands to the largest extent. The large-scale investment agricultural schemes – both private ones and state owned ones - have been significant drivers in Gambella, Benishangul-Gumuz and Afar Regional States. In Ethiopian Somali and Afar Regional States charcoal is produced by almost all rural households as one of the core livelihood income sources.

The findings of this study are confirmed by map comparison of land-use replacing forest after deforestation assessed by Ethiopia’s National Forest Monitoring System, described under section 6.2.

1 <https://cdm.unfccc.int/DNA/cdf/index.html>

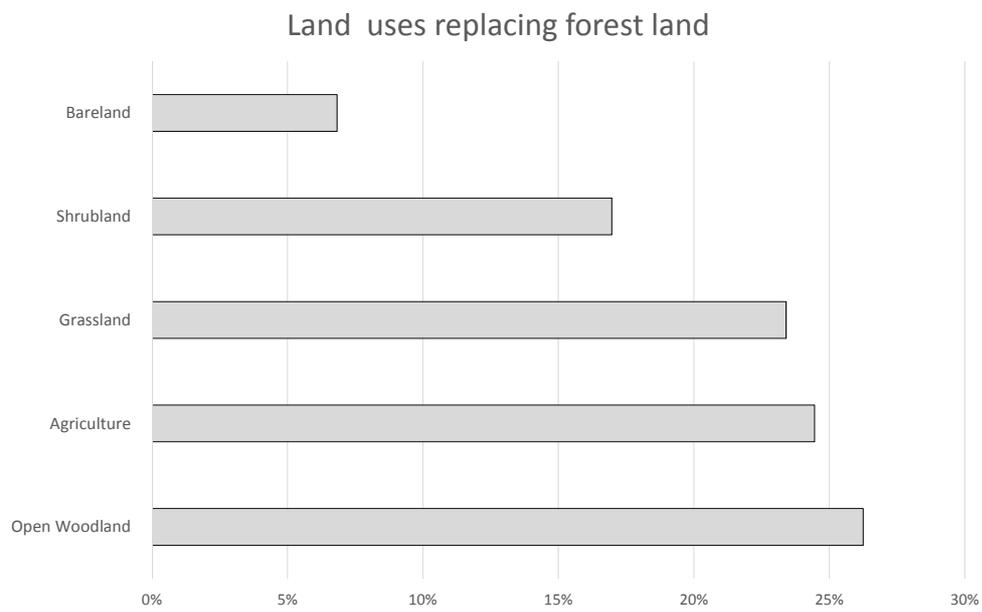


Figure 2: Land-uses replacing forest over the period 2000-2013 (as % of the total forest loss over this period)

HISTORICAL PERIOD

The historical period for which forest area change has been assessed is 2000-2013. This period was selected to assess change because:

- The year 2000 is well covered by standard products (Global Land Surveys (GLS) and most global products) making it easier to connect or compare to existing imagery and products
- data for this period is available from the Global Forest Change (GFC) product, (Hansen et al., 2013), which is used as a comparison and as a base for the change analysis.
- The period and dates are in line with requirements by FCPF Carbon Fund Methodological Framework (criterion 11, indicator 11.1 and 11.2)

However, Ethiopia is still exploring whether the emissions and removals over this period are representative of emissions and removals expected in absence of REDD+ implementation (and thus whether this historical period is appropriate as a benchmark against which to assess performance). Tree cover loss estimates from the Global Forest Change (GFC) product in 2013 suggest an upwards trend in tree cover loss in Ethiopia. Ethiopia is still exploring and evaluating which FRL methodology and/or choice of historical period best reflects emissions expected in the near future in absence of REDD+ implementation.

THE ETHIOPIAN BIOMES

A potential vegetation map of Ethiopia has been released by Friis and Sebsebe (2009) and Friis, Demissew and van Breugel (2010). This map divided the Ethiopian vegetation into 12 major types, which have been aggregated into 5 biomes.

The vegetation types are based on the information related to previous literature, field experience of the authors, as well as on an analysis of about 1300 species of woody plants in the flora of Ethiopia and Eritrea. The map is based on broad field surveys, mainly along the country roads, and on a set of classification criteria defining the altitudinal and rainfall limits for each of the vegetation types. The data on altitude was obtained from 90x90 meter resolution digital elevation model provided by the CGIAR-CSI (2008). The monthly total rainfall data with 30 arc seconds resolution is from WorldClim. The Global Lakes and Wetlands Database (GLWD) was used to delineate wetlands and lakes, and the AEON river database (average stream separation of 15 km) was used to define the boundaries of water bodies and related vegetation types.

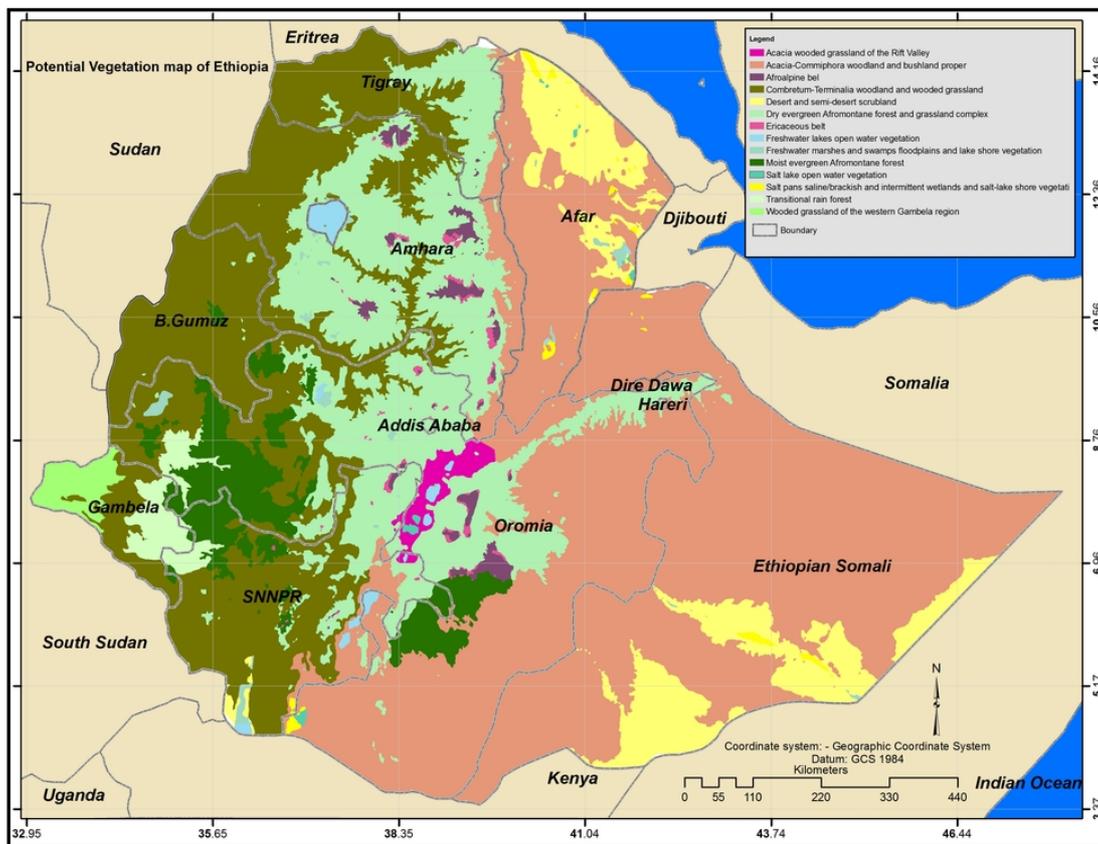


Figure 3: Potential vegetation map of Ethiopia

The potential vegetation map has been also used as an input to create the strata map that is the base layer used to design the national Forest and Landscape Inventory of Ethiopia.

As the Forest and Landscape Inventory is not focused only on forest strata, during 2015 a new aggregation map was proposed to better represent the reliable carbon stock estimates. Using the 12 vegetation types as input, these have been aggregated into 5 biomes following expert judgment by Ethiopian botanical scientists. Based on their knowledge of the vegetation types and their physiology they have suggested the following aggregation into four biomes with expected homogenous carbon contents (Figure 4).

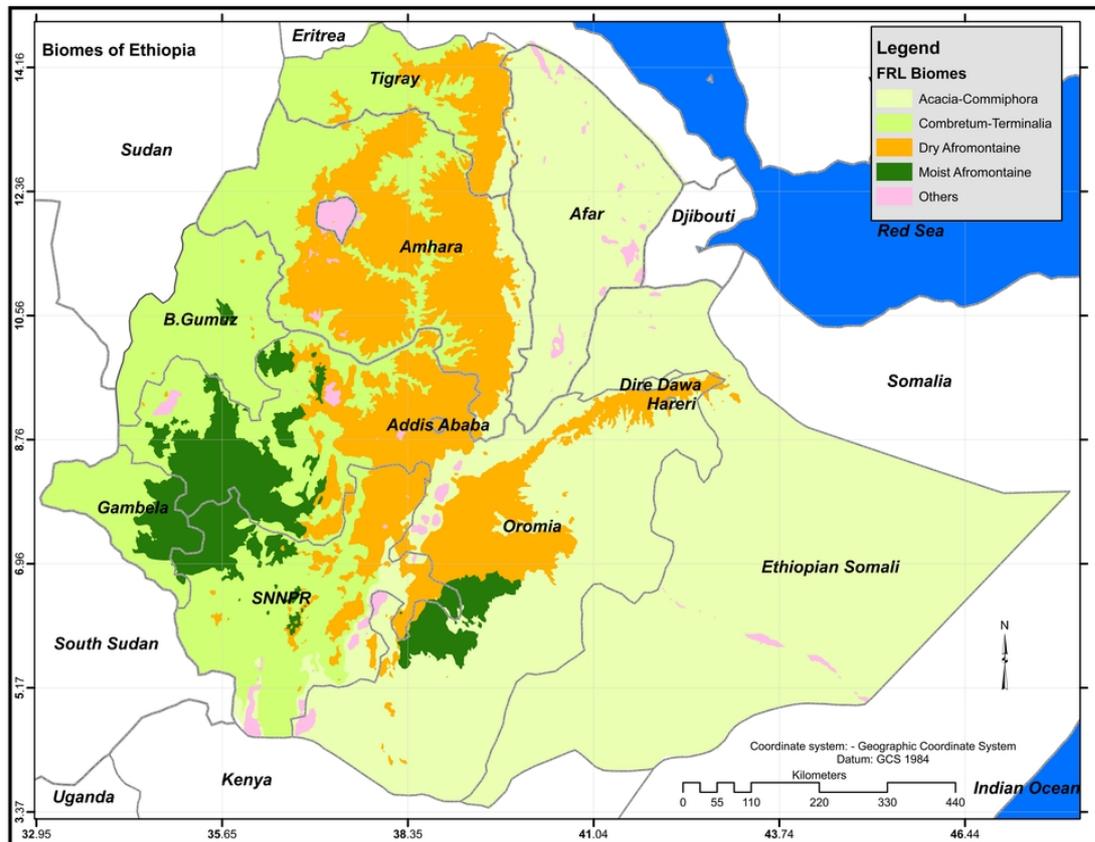


Figure 4: Biomes of Ethiopia

This new stratification has been adopted to estimate the carbon content for the FRL purposes.

Table 1: Biomes description

| Biome strata | Stratum name | Vegetation types (<i>Friis and Sebsebe 2009</i>) |
|---------------------|----------------------|--|
| 1 | Acacia-Commiphora | <i>Acacia-Commiphora</i> woodland and bushland (ACB); Acacia wooded grassland (ACB/RV); Desert and semi-desert scrubland (DSS) |
| 2 | Combretum-Terminalia | <i>Combretum-Terminalia</i> woodland and wooded grassland (CTW); Wooded grassland of the Western Gambela region (WGG) |
| 3 | Dry Afromontane | Dry evergreen Afro-Montane Forest and Grassland complex (DAF) Afro-Alpine vegetation (AA); Ericaceous Belt (EB); |
| 4 | Moist Afromontane | Moist Evergreen Afro-Montane Forest (MAF); Transitional Rain Forest (TRF) |
| 5 | Other | |

THE ACTIVITY DATA ASSESSMENT PROCESS

The activity data for deforestation and afforestation was assessed as average of annual forest loss and forest gain in hectares in the period 2000-2013. Satellite imagery was used in combination with sample data from Google Earth observations to determine the spatial extent of forest and forest area change. The creation of the forest and forest area change map is explained under section 8.1, 8.2, 8.3 and 8.4 (step 1 and 2). Errors in the map are identified through verification of the map classification by visual interpretation (section 8.4, step 3). Accordingly the map area estimates are corrected for systematic error (bias) in the map and confidence intervals are calculated around the bias-corrected area estimates as a measure of the random error remaining in the estimate after removal of the bias (8.4, step 3). The results are then compared against the Global Forest Change product and a possible explanation for differences is provided (section 8.5).

ETHIOPIA'S LAND USE AND LAND COVER MAP 2013

The Ministry of Environment, Forestry and Climate Change (MEFCC) has created a map of land use/land cover for the year 2013 using a supervised classification of Landsat data. The methodology used to create this map is explained in this section. This map is used to determine the spatial extent of forests in the FRL.

Image analysis

Landsat 8 imagery was acquired from www.glovis.usgs.gov for images with less than 3% cloud cover data acquisition dates from March 2013 to December 2013. The land use/land classes were identified and based on past mapping experiences of the Woody Biomass Inventory Strategic Planning Project (WBISPP, 2004) and the prevailing ground situation of the country from the forest inventory. Representative areas of interests (AOIs) were collected for each of the LULC classes using Google Earth.

Geometric and radiometric corrections were applied to the Landsat images. The AOIs served as training data and were used to classify the satellite data using the Maximum Likelihood algorithm. The libraries of radiometric signatures for the

Landsat scenes were iteratively edited to harmonize the scenes. The classified scene maps were mosaicked to form the thematic land cover/land use map for Ethiopia.

Table 2: Description of the Land Use/Land Cover Classes

| LULC Code | LULC Name | Description |
|-----------|----------------|---|
| 1 | Agriculture | Arable and fallow land that grow annual crops (wheat, maize, sorghum, 'teff', Cotton etc) or perennial crops (, sugar cane, 'enset', coffee and permanent fruit trees) on the small scale or commercial level by rain fed or irrigation schemes |
| 2 | Grassland | Land covered with the natural growth of <i>graminea</i> and herbaceous vegetation or a land sown with <i>introduced grass and leguminous for the grazing of livestock.</i> |
| 3 | Scrubland | Low bushes and stunted trees, mostly spiny either deciduous or evergreen. More than half of the surface of the ground is bare of vegetation. |
| 4 | Shrubland | Land with shrubs/bushes canopy cover $\leq 10\%$ or combined cover of bush, and shrubs $\leq 10\%$. Shrubs and bushes are woody perennial plants, 2 m in height at maturity in situ. |
| 5 | Open Woodland | Land covered by natural growth of <i>graminea</i> and herbaceous vegetation, with some scattered trees (tree canopy cover less than 3% . it is composed of a canopy of grass wooded ecosystem of <i>Combretum-Terminalia</i> and <i>Acacia-Commiphora</i> that can both tolerate burning and temporary flooding with the tall grass strata, in case of the former one. |
| 6 | Dense Woodland | A continuous stand of trees with a crown density of between 20 - 80%. Mature trees are usually single storied, although there may be layered under-stories of immature trees, and of bushes, shrubs and grasses/forbs. Maximum height of the canopy is generally not more than 20 meters, although emergents may exceed this. Dense woodland has more than 400 stems per hectare, whilst open woodland has between 150 and 400 stems per hectare. |
| 7 | High Forest | A relatively continuous cover of trees, which are evergreen or semi-deciduous, only being leafless for a short period, and then not simultaneously for all species. The canopy should preferably have more than one story." Three categories of high forest is recognized: Closed: crown cover of the upper stratum exceeds 80 percent; Dense: crown cover of the upper strata is between 50 to 80 percent; and Open: crown |

| LULC Code | LULC Name | Description |
|-----------|------------|---|
| | | cover of the upper stratum is between 20 to 50 percent. |
| 8 | Bareland | It is land of limited ability to support life and in which less than one-third of the area covered by vegetation or other cover. It may be constituted by bare exposed rock, Strip mines, quarries and gravel pits. In general, it is an area of thin soil, sand, or rocks. Vegetation, if present, is more widely spaced and scrubby than that in the Shrub and Brush category. Unusual conditions, such as a heavy rainfall, occasionally result in growth of a short-lived, more luxuriant plant cover. Wet, non-vegetated barren lands are included in the Non forested Wetland category. |
| 9 | Builtup | Urban or Built-up Land is comprised of areas of intensive use with much of the land covered by structures. Included in this category are cities, towns, villages, strip developments along highways, transportation, power, and communications facilities, and areas such as those occupied by mills, shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas. |
| 10 | Afropine | This vegetation-type is characterized by small trees, shrubs and shrubby herbs at higher altitudes, herbs and tuussock-forming grasses. Typical bushes and shrub species include <i>Erica arborea</i> , <i>E. trimera</i> and <i>Hypericum revolutum</i> . Among herbs in this zone are the giant lobelia <i>Lobelia rhychnopetalum</i> , <i>Kniphofia foliosa</i> , <i>Bartsia petitiiana</i> and various <i>Alchemilla species</i> . <i>Festuca</i> , <i>Poa</i> and <i>Agrostis spp.</i> are typical grasses. |
| 11 | Plantation | Broadleaved, conifer or mixed tree species established through planting and/or deliberate seeding in a commercial scale or woodlots exceeds 0.5ha,. Includes coppice from trees that were originally planted or seeded. |
| 12 | Saltpan | Dry Salt Flats occurring on the flat-floored bottoms of interior desert basins which do not qualify as Wetland. |
| 13 | Wetland | Wetlands are those areas dominated by wetland herbaceous vegetation or are non-vegetate where the water table is at, near, or above the land surface for a significant part of most years. These wetlands include, brackish and salt marshes and non-vegetated flats and also freshwater meadows, wet prairies, and open bogs. |
| 14 | Bamboo | Naturally regenerated/planted forest predominantly composed of bamboo vegetation, fulfilling the area, canopy cover and height criteria mentioned at number |

| LULC Code | LULC Name | Description |
|-----------|------------|--|
| | | 7. |
| 15 | Riverine | Are forests which fulfill the definition explained in no 7 and grow along with the major river banks and spans 20m to 50m buffer from the river. Predominantly it consists of common families of <i>Moraceae</i> , <i>Spidandaceae</i> , <i>mimosaceae</i> etc |
| 16 | Water body | Area occupied by major rivers of perennial or intermittent (width \geq 15m), lakes, ponds and reservoirs. |

THE FOREST/NON FOREST MAP

MEFCC considers high forest, dense woodland, plantation, bamboo and riverine as the forest classes of the country. The LULCs classes of 2013 map were aggregated into two broad categories of forest and non-forest classes based on the forest definition of Ethiopia, forested areas exceeding 0.5ha, height \geq 2m and canopy cover \geq 20%. The overall accuracy of the aggregated map is 81%. The user's and producers accuracy for the aggregated forest class is 51% and 56%.

FOREST CHANGE DETECTION IN ETHIOPIA

The activity data for deforestation and afforestation is assessed as average annual forest loss and average forest gain in hectares in the period 2000-2013.

The proposed approach by Ethiopia follows the GFOI guiding principle 1 for remote sensing (GFOI, 2014): 'When mapping forest change, it is generally more accurate to find change by comparing images as opposed to comparing maps estimated from images'. The approaches tested for change detection include purely automatic spectral methods (e.g. IMAD algorithm) and supervised change detection using change training points/loss and gain (Tewksebury et al. 2015). Post classification change detection is not a suitable option for Ethiopia because historical land cover maps do not have sufficient accuracy to derive change. Studies examining post classification change have shown two forest/non-forest maps can be highly accurate with user's accuracies of about 95%, the user's accuracy of the deforestation class in the change map is likely to be much lower, indicating that the forest change obtained by post-classification is inaccurate (Olofsson, et al., 2013).

The method chosen was a supervised classification of imagery, in which the user identifies representative spectral samples for each class in the digital image. The representative spectral samples are used as a dictionary and the classification algorithm uses this dictionary to classify all objects/pixels depending on what their spectral signature resembles most in the dictionary. In the case of change detection, the object to be classified is a multi-temporal stack of imagery, and the classes are change (loss and gain) or stable.

The imagery chosen for the exercise is Landsat data², adapted to forest land cover detection (FAO & JRC, 2012). The process assessed two mosaics for the year 2000 and 2013, to assess the change occurred in this period. For each year, all available pixels covering a specified area and date range are collected and corrected for sun-sensor-target anomalies³. A target day is fixed in order to get the maximum vegetation cover and least cloud cover as possible. The proximity to this target day, the pixel temperature and pixel wetness are computed to create a best-pixel mosaic. The two best pixel mosaics (one for each time period) are finally stacked into a consistent multi-temporal object. All the data collection, correction and composition are implemented within Google Earth Engine (GEE) API.

STEP BY STEP PROCESSES OF CHANGE DETECTION

The Ethiopian FRL considered two types of land use changes; non-forest land use change to forest as gain, and forest land use change to the non-forest land use as loss. Forest area change was corrected for bias using a stratified random sample, using visually interpreted high temporal and spatial resolution satellite imagery. The change detection process included:

1. Training data collection and validation;
2. Image classification and post classification editing;
3. Accuracy assessment and bias corrected area estimation.

² The choice is justified by the fact that the Landsat images covers the entire time period, correspond to the technical requirements, are consistent with the data used for the forest area map and are freely available and likely to be sustainably available in the future (GFOI, 2014).

³ http://landsat.usgs.gov/Landsat8_Using_Product.php

Step-1 Training Data Collection and validation

Supervised classification is dependent on the quality of the training sites (*Foody and Mathur, 2006*). In the absence of any reliable spatial data to indicate zones of change at the national level in Ethiopia, preliminary training dataset was generated automatically from the Global Forest Change product 2013 (GFC, *Hansen et al., 2013*). In order to reduce inclusion of potentially false detection in the training dataset, the GFC product was down-sampled to a 3x3 pixel kernel. The resulting product was randomly sampled with 300 points for each of the 2 classes (loss and gain).

Points for loss and gains were carefully assessed through a visual assessment using a time series of Landsat images and vegetation indices and very high resolution imagery available in the Google Earth, Bing Maps, and Here maps, all assessed using the Open Foris Collect Earth interface. Points with a high level of classification confidence, assigned by the technicians, were used for as the training dataset for the supervised classification.



Figure 5: High-resolution imagery from Google Earth and user interface from Open Foris Collect Earth to classify sample data

Setp-2 Image classification and post classification editing

Sets of criteria that assist for the filtering and acquisition of Landsat images such as date of acquisition, date and year range, month of image acquisition and target day that controls phenology and cloud cover were set by national experts and incorporated into [Google Earth Engine API](#) (table 3). Based on the selection and filtering criteria, the collection of relevant Landsat archives were filtered through to composite a best pixel mosaic.

| No | Criteria | Decisions |
|----|---|--|
| 1 | Path and Row | Landsat paths between 162 to 172 and Row between 50 and 58 |
| 2 | Extent of dates for each time period (2000 to 2013) | Start date for initial period in the year of 1997-01-01 to 2003-12-31 and range for the time period two start date 2010-01-01 and 2015-03-31 |
| 3 | Target day , the time with least clouds and most vegetation | Start Julian day 330th day of the year/November to end of 60th day of the year /February |
| 4 | Cloud cover | Maximum 90% |

Table 3: Criteria for image acquisition

To use specific bands of Landsat images and normalize different band naming between Landsat 5, 7 and 8 normalization function was implemented under GEE-API. A function to correct for latitudinal components of sun-sensor of target geometry was used from landsat.usgs.gov/Landsat8_Using_Product.php. This function further produces weighted pixel based on the user specified day of the year, reflectance values of band ratios, pixel temperature and wetness. To correct longitude and latitudes, solar elevation angel and radiometric characteristics of each pixel was implemented using the information obtained from metadata of acquired images. Using the quality function, each band of images from multiple temporal initial and final time of change assessment were mosaicked. Single images for each time periods were created using the same script and composited into a multi-temporal stack for detection of change between the two time periods (figure 5).

The classification process consists of compiling the spectral signature for all the training points, creating a model from this spectral library and applying the model to the entire imagery. Two classifiers have been tested, the CART algorithm (*Breiman et al, 1984*) and the RandomForest algorithm (*Breiman, 2001*).

The validated training points were used at the national scale to train and directly classify loss and gain from the mosaicked Landsat image. After a first run of classification is completed, the training dataset can be improved by visually assessing zones of false change (i.e stable areas classified as change) and missed changes (i.e change classified as stable). Examples of potentially incorrect classifications include agricultural area with strong greenness variations or shadows due to elevation, which could be mistaken for false change and areas with known deforestation classified as stable. The training sites are added on the misclassified locations for the correct class. The new sites were entered in the spectral library with appropriate labeling. Classification was iteratively improved by adding more points of gain, loss and stable (figure 6). The outputs from the two algorithms were visually compared and the RF classification was considered superior and used as the result. The processing chain, from classification of the change, iterative improvement of the training data, and export of the results was performed in the Google Earth Engine API, with the following [script](#) (a GEE [Trusted Tester account](#) is needed to open this link)

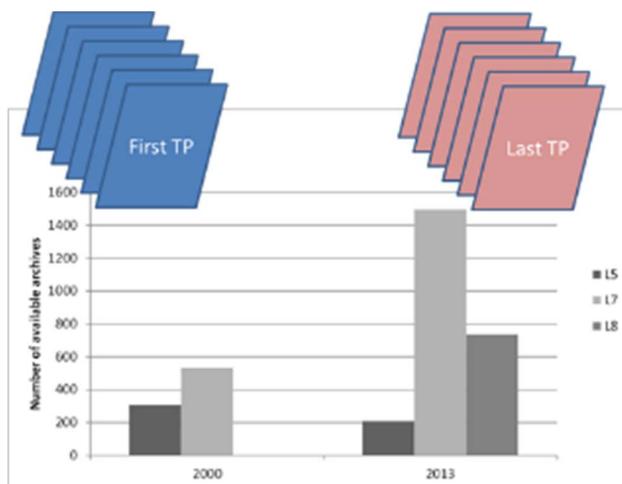


Figure 6: Number of available Landsat archives queried to create a best pixel mosaic in Google Earth Engine.

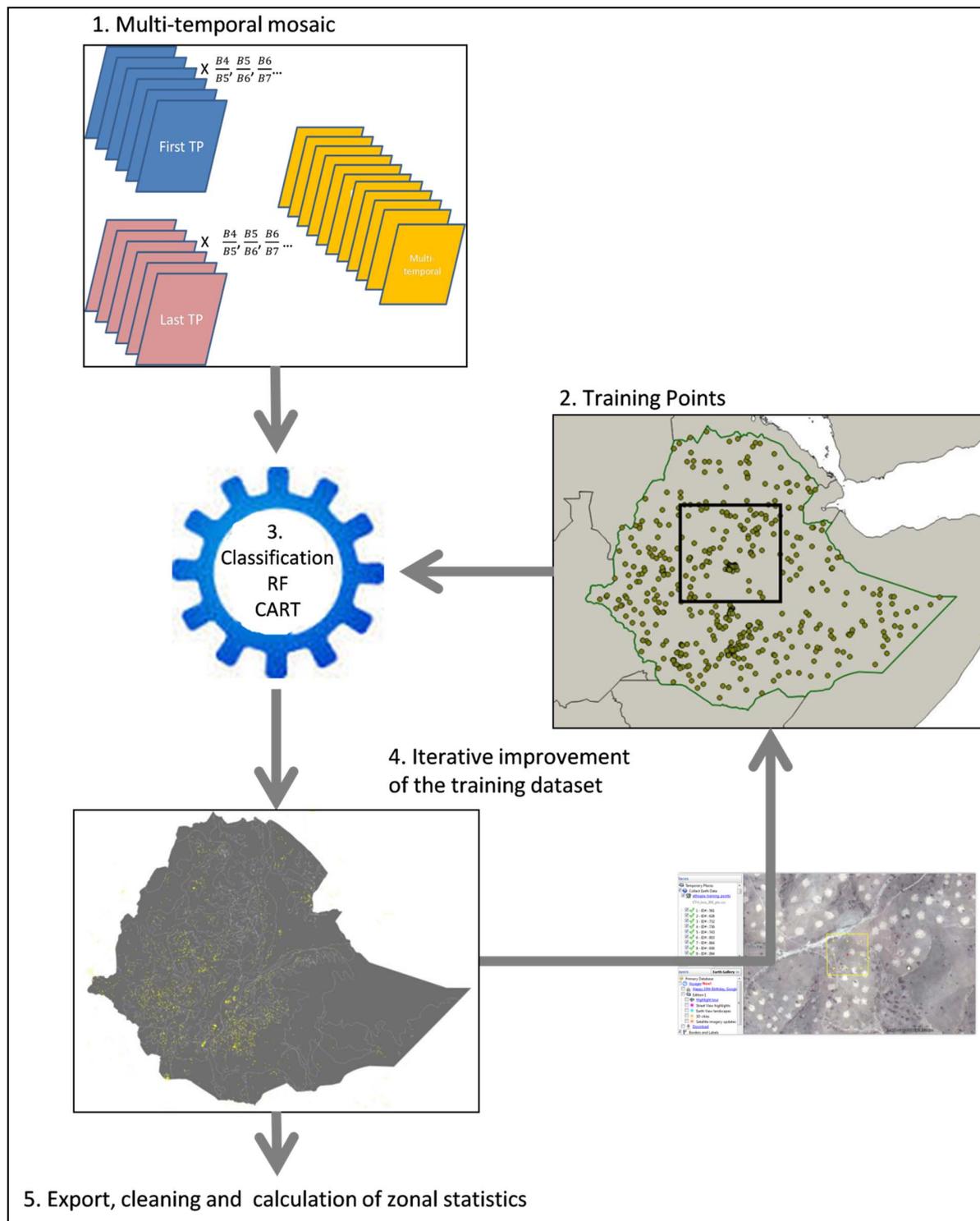


Figure 7: Iterative classification process for change detection.

Once the iterative process is determined to have no further improvements to the

classification, the results can be exported. The exported result from the GEE-API was filtered to only include loss or gains in clumps of 5 pixels to match the national minimum mapping unit of forest, 0.5 hectares. The 2013 land cover map was used to filter false loss by eliminating loss detected on forest and false gain by eliminating gain detected on non-forest. Manual editing was implemented to improve the change detection product by delineating false and missed changes using the Landsat composite image of 2000 and high-resolution imagery for 2013 from Google Earth. An accuracy assessment of the change was finally produced to estimate the reliability of the change measured (FAO, 2015), produce corrected estimates of change and confidence intervals around those estimates.

Step 3 Accuracy assessment and bias-corrected area estimates

According to IPCC, it is good practice for countries to produce emission estimates which: 1) neither over-nor underestimate actual emissions as far as can be judged, introducing a systematic error (or bias), and 2) reduce uncertainties as far as practicable given national circumstances. It is also good practice to quantify uncertainties and report them in a transparent manner. For emission estimates from deforestation and removal estimates from afforestation/reforestation, Ethiopia has assessed forest area loss and forest area gain creating a wall-to-wall forest change map. This estimation has four classes: forest loss, forest gain, stable forest and stable non-forest for the period 2000-2013. All surface estimations contains errors, most of which tend to be systematic (bias). Ethiopia has provided an estimate of forest loss and forest gain (and forest cover) which is corrected for the map bias. Classification errors were identified by collecting sample point data, independent of the training data. The sample data verifies whether the classification is correct or incorrect at the location of the sample points. This information is summarized in an error matrix and the matrix is used to correct the areas per class (forest loss, gain, stable forest and stable non-forest) for the map bias resulting in new area estimates, referred to as bias-corrected area estimates. To quantify and report uncertainty, Ethiopia also calculates and reports on confidence intervals around the bias-corrected area estimates, which provide an indication of the precision of the

estimate. Precision gives a description of random errors or variability. Large confidence intervals indicate a large statistical variability of the population. The process of correcting the map for bias is referred to as accuracy assessment.

The required overall number of samples which was calculated using the *Olofsson et al.* methodology (2014) adopting the following assumptions, using conservative user inputs to have a cost effective and robust sample size:

Table 4: Inputs needed for the statistical formula that calculates the number of overall samples for the accuracy assessment

| | Input values selected by Ethiopia |
|--|-----------------------------------|
| Target standard error | 0.01 |
| Expected user's accuracy forest loss | 0.5 |
| Expected user's accuracy forest gain | 0.5 |
| Expected user's accuracy stable forest | 0.9 |
| Expected user's accuracy stable non-forest | 0.9 |

The overall number of samples needed for the accuracy assessment are distributed over the four map classes as follows: a minimum of 50 samples were allocated to the "rare" map classes (classes covering a relatively small area) of forest loss and forest gain. The remaining samples are distributed proportionally based on the extent of the classes stable forest and stable non-forest.

Table 5: Samples distributed in the map classes for verification (collection of reference data)

| Classes | Sample points per map class |
|-------------------|-----------------------------|
| Forest loss | 84 |
| Forest gain | 97 |
| Stable forest | 790 |
| Stable non-forest | 1013 |

Ethiopia has collected reference sample data to check whether the map classification was correct at the location of the sample point. The sample data is

collected by visual interpretation of the point using a time series of very high resolution imagery and Landsat imagery. The visual interpretation of sample points is referred to as "reference data". Only points where the users had high confidence of the classification were used, therefore the total number of reference points used in the area estimation is 1984 samples.

An error matrix was used to compare the map classes against the reference data. The overall accuracy of the map is calculated by dividing the samples where the map and reference data agree (the bold sample counts in diagonal) divided by the total number of samples (sum of sample counts in all cells in the matrix).

Table 6: Error matrix of Ethiopia's forest change map 2000-2013.

| 2000-2013 | Classes | Reference | | | | Total | User's accuracy |
|--------------|--------------------------|-----------|-----|-----|------|-------|-----------------------|
| | | FL | FG | SF | SNF | | |
| Map data | Forest Loss (FL) | 20 | 2 | 12 | 50 | 84 | 24% |
| | Forest Gain (FG) | 2 | 17 | 59 | 19 | 97 | 18% |
| | Stable Forest (SF) | 7 | 5 | 523 | 255 | 790 | 66% |
| | Stable Non Forest (SNF) | 10 | 1 | 83 | 919 | 1013 | 91% |
| Total | | 39 | 25 | 677 | 1243 | 1984 | |
| | Producer's accuracy (PA) | 51% | 68% | 77% | 74% | | Overall accuracy: 75% |

FL= Forest Loss , FG= Forest Gain, SF= Stable Forest, SNF= Stable Non Forest, UA= Users Accuracy

In the error matrix, the rows provide information on the 'over-detections' (commission errors) by the map of a certain class, e.g. for the total of 84 samples checked in the forest loss class in the map, 64 samples were over detected. The commission errors for loss was when the map identified the sample as loss but the reference data identified the sample as forest gain (2 samples), stable forest (12 samples), and stable non-forest (50 samples). The columns in the error matrix provide information on the 'under-detections' (omission errors), e.g. out of the 39 reference data points classified as forest loss, the map missed or under-detected 19 samples as being forest loss. The next steps will identify these under- and over-detections (bias) in terms of hectares and correct the map area for the commission and omission errors by calculating bias-corrected area estimates.

To convert the sample counts into areas by which the map area per class can be corrected, we first need to convert the absolute sample counts into proportions of the total amount of samples per map class. E.g. for forest loss 20 out of 84 samples are in agreement which equals to a proportion of 0.24, $2/84 = 0.02$ was forest gain, $12/84 = 0.14$ was stable forest and $50/84 = 0.60$ was stable non-forest.

Table 7: Error matrix as proportion of agreement and disagreements by total number of samples in each map class

| 2000- 2013 | classes | Reference | | | |
|-----------------|-------------------------|-----------|-------|------|------|
| | | FL | FG | SF | SNF |
| Map data | Forest Loss (FL) | 0.24 | 0.02 | 0.14 | 0.6 |
| | Forest Gain (FG) | 0.02 | 0.18 | 0.61 | 0.2 |
| | Stable Forest (SF) | 0.01 | 0.01 | 0.66 | 0.32 |
| | Stable Non Forest (SNF) | 0.01 | 0.001 | 0.08 | 0.91 |

FL= Forest Loss , FG= Forest Gain, SF= Stable Forest, SNF= Stable Non Forest

In order to obtain the bias-corrected area estimate, first the map area was calculated multiplying proportional error matrix of the corresponding rows in the matrix (Table 8) multiplied by the map areas per class. The result of this multiplication is shown in Table 10

Table 8: Matrix which gives correct classification, omission (under detection) and commission (over detection) errors expressed in corresponding map area (ha)

| 2000- 2013 | classes | Reference data | | Map area |
|-----------------|----------------------------|------------------|----------------|----------------|
| | | FL | FG | |
| Map data | Forest Loss (FL) | 88,616 | 8,862 | 372,188 |
| | Forest Gain (FG) | 824 | 7,003 | 39,960 |
| | Bias corrected area | 1,192,559 | 246,063 | |

FL= Forest Loss, FG= Forest Gain

The bias-corrected area estimates are obtained by the map area minus the over-detections (commission errors) plus the under-detections (omission errors). E.g.

the bias-corrected area estimate of forest loss is calculated by $372,188 \text{ ha} - 88,616 \text{ ha} - 53,170 \text{ ha} - 221,540 \text{ ha} + 824 \text{ ha} + 907,955 \text{ ha} = 1,192,559 \text{ ha}$.

The 95% confidence interval for the bias-corrected area estimates are calculated by multiplying 1.96 by the standard error of the area estimate. The standard error of the area estimate is calculated using formula 11 in Olofsson et al 2014. The results are displayed in the table below:

| Classes | Bias corrected area (thousands of ha) | Confidence interval (thousands of ha) | Confidence interval (% of adjusted area) |
|-------------|---------------------------------------|---------------------------------------|--|
| Forest loss | 1,193 | +/- 579 | 49% |
| Forest gain | 246 | +/- 216 | 88% |

Table 9: Bias-corrected area estimates (thousands of ha)

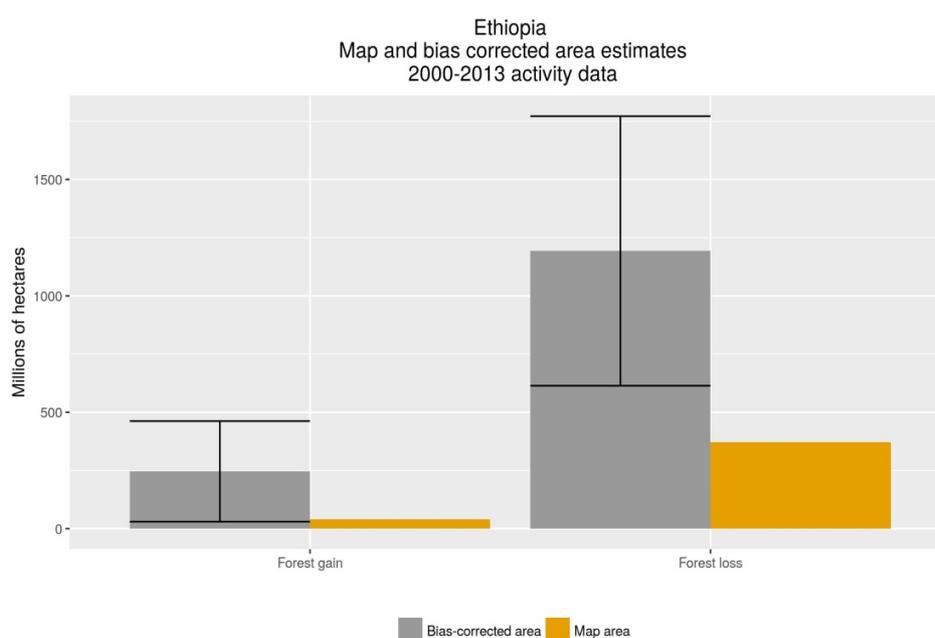


Figure 8: Map and bias-corrected area estimates of the AD

The results from the accuracy assessment for forest loss for the period 2000 to 2013 is 1,193 thousand ha +/- 579 thousand ha and for forest gain is 246 thousand ha +/- 216 thousand ha. The annual forest loss is approximately 92 thousand

ha/year and annual forest gain of approximately 19 thousand ha/year. This estimate is used as the activity data (see Figure below).

The forest change map has also been overlaid with a map of biomes to divide the forest loss, gain and forest cover estimates by biome. Forest loss and gain per biome is used for the calculation of emissions and removals. The gain and loss per biome is obtained by multiplying the loss/gain/forest areas in each biome by the overall correction in the map, e.g. forest loss per biome is multiplied by a factor $1,192,55/372,18 = 3.18$. The relatively high annual forest area gain in the Dry Afromontane biome gives some evidence that Ethiopia is already implementing several mitigating actions that aim to restore forest resources. The on-going mitigation actions reducing emissions are watershed management, agricultural intensification, trees on farm for fuelwood, declining livestock (due to stall-feeding, diseases, lack of own fodder and livestock raids), non-wood and alternative energy sources, and controlled migration.

Table 10: Bias-corrected area estimates by biomes (ha)

FL= Forest Loss , FG= Forest Gain

| Biome | Bias corrected area (thousands of ha) | |
|----------------------|--|--------------------|
| | Forest loss | Forest gain |
| Acacia-Commiphora | 194 | 30 |
| Combretum-Terminalia | 712 | 8 |
| Dry Afromontane | 66 | 179 |
| Moist Afromontane | 206 | 29 |
| Other Biome | 14 | 0.8 |
| Total | 1,193 | 246 |

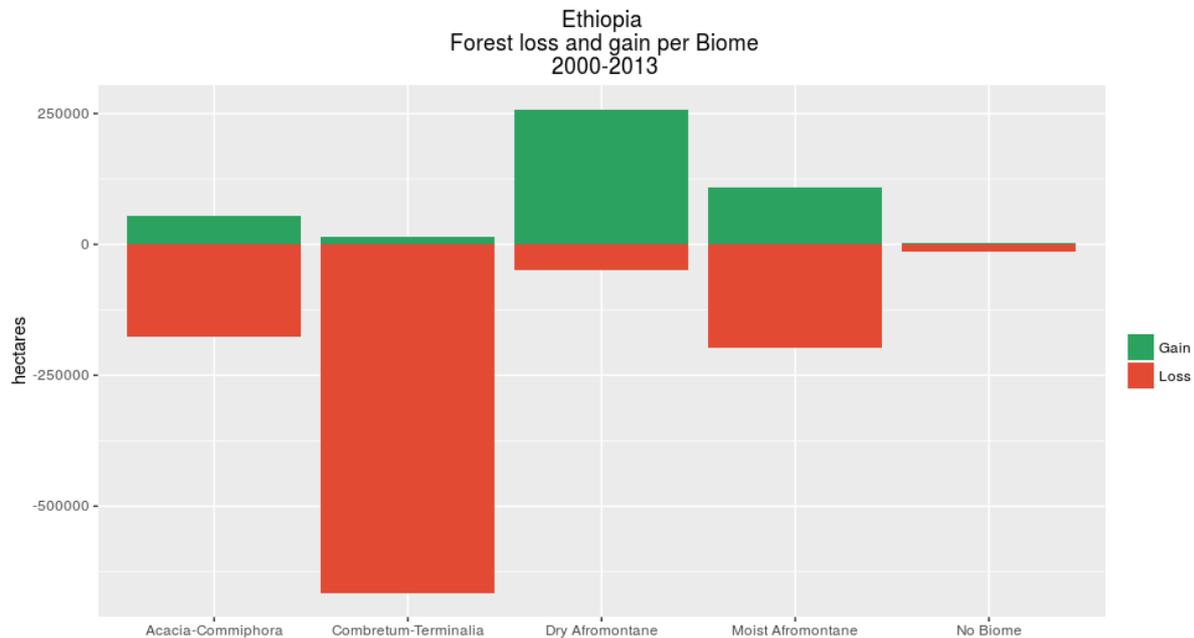


Figure 9: National forest area change detection 2000-2013 by biome.

Comparison of Activity Data results with data from Global Forest Change

The average annual loss of 92,000 ha/year over the period 2000-2013 found by the AD analysis is considerably higher than the tree cover loss found by the Global Forest Change product, i.e. around 3 times higher. The tree cover loss found by the Global Forest Product is not very different from the “raw” numbers in the map before the map bias correction. This difference is explained by the considerable correction of the area of change in the map for map bias. Remote Sensing is known to have difficulties detecting dry deciduous forest, especially when on sandy soils with high reflectance (Bodart et al., 2013). Both the forest loss map created by Ethiopia and the Global Forest Change map reflect this systematic error therefore systematically underestimating (dry) forests, and both losses and gains in these forests.

EMISSION FACTORS: NFI DATA ANALYSIS

DESCRIPTION OF ETHIOPIA'S FOREST AND LANDSCAPE INVENTORY

Ethiopia has designed a national Forest and Landscape Inventory since March 2014, as a TCP project. The collection of plot inventory data has been finalized and a complete data analysis is in course. The selection and implementation of an appropriate sampling design to collect raw forest data determines the output of forest information that will be used for various kinds of decision making processes. The sampling design, together with data collection procedures plays a crucial role in determining the accuracy and the quality of information from the field. Hence, the NFI of Ethiopia put strong emphasis on constructing a suitable forest inventory sampling design that regards the country's situation and need of forest information.

After a series of consultations with stakeholders, it was agreed to employ stratified systematic sampling with feasible sampling intensities on the respective strata according to potential vegetation. The NFI uses a stratification based on agro-ecological zones of Ethiopia; the agro-ecological zones were made using elevation and climate factors (altitude, temperature and rainfall) together with the land use/land cover map of WBISPP 2004 and the Potential Vegetation Atlas of Ethiopia (Friis and Sebsebe, 2009). The corresponding properties and the number of sampling units per stratum are described further in Table 11.

According to the importance of the carbon stock in the strata types, the sampling distances were determined and the plot coordinates were generated using grid generator. Accordingly, within the grid resolution of $1/4 \times 1/4$ degree square and triangular combination grids plots coordinates were generated in the Stratum I, while a $1/2 \times 1/2$ degree square and triangular combination grids were used for Strata II and IV, $1/2 \times 1/2$ degree square grid for Stratum III, and a 1×1 degree square grid in Stratum V, resulting in a total of 631 Sampling Units (SU).

Table 11: Description of NFI strata and number of sampling units located in each stratum

| Stratum | Description | Sampling units |
|---------|---|----------------|
| I | Comprises natural forest, plantation and Bamboo, that are found within the altitude range of 2300 to 3200 m.a.s.l. | 107 |
| II | Comprises of the North and South Eastern part of the woodland mainly <i>Acacia Commiphora</i> woodland of Somali, SNNPRs and Afar regions | 135 |
| III | Comprises mainly the woodland ecosystem found in the North and South Western woodland parts where <i>Combretum-Terminalia</i> woodland is dominant | 137 |
| IV | This stratum is commonly known as other land stratum where human activities are dominated and patches of evergreen Afromontain forest exist, mostly in the middle altitudes of Ethiopia (1500 to 2500 m.a.s.l.) | 232 |
| IV | This stratum refers to the desert and arid pats of Ethiopia where the elevation range is found below 500 m.a.s.l. and characterized by arid and semi-arid scrublands. | 20 |

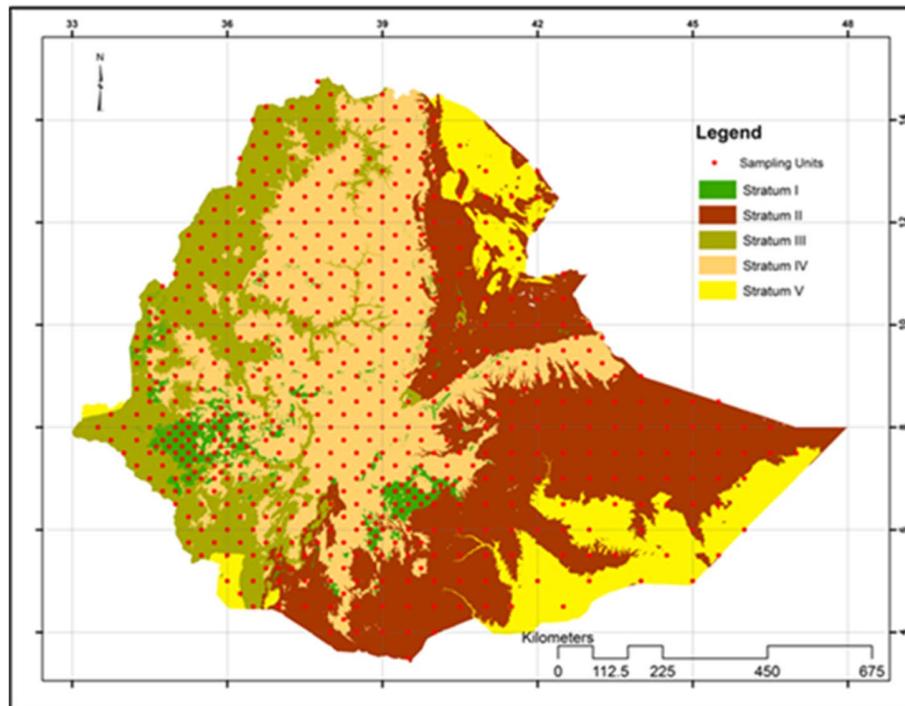


Figure 10: NFI sample unit per stratum

In the NFI, data was collected in the field through observations and measurements at different levels: within the limits of the sampling units (SU) and in smaller subunits within each SU, and Land Use/Cover Sections (LUCS). A sampling unit consists of four subunits (sample plots) that can be divided into LULC. Trees and stumps in the entire plot area have been recorded and small trees (in forest) and saplings were recorded in smaller subplots (see the table below).

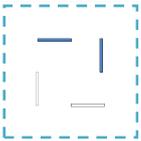
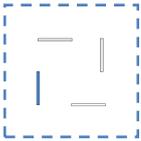
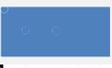
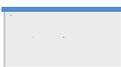
| Data collection level | | Measurements and observations | | |
|--------------------------------------|--|--|---|-------------|
| | | Forest | Other Wooded Lands and Woodlots (0.2-0.5ha) | Other lands |
| SU (sampling unit) |  | <ul style="list-style-type: none"> - Localisation and access to SU - Size: 1000 m x 1000 m (1 km²) | | |
| Plot |  | <ul style="list-style-type: none"> - Measurement of trees with Dbh ≥ 20 cm - Size: 250 m x 20 (5000 m²) | <ul style="list-style-type: none"> - Measurement of trees with Dbh ≥ 10 cm | |
| Circular Subplot |  | <ul style="list-style-type: none"> - Count of trees with Dbh < 10cm and height ≥ 1.30m, by species | | None |
| Rectangular Subplot |  Measurement of trees with 10cm ≤ Dbh < 20cm | None | None | |
| | | <ul style="list-style-type: none"> - Shrubs, bushes (count or measurement by species) - Presence or abundance or count of indicator plant species, NWFP Size 20m x 10m | None | |
| Fallen Deadwood Transect |  | <ul style="list-style-type: none"> - Measurements of fallen deadwood branches (diameter ≥ 2.5 cm) Size: 20 m | | |
| Land Use/Cover Section (LUCS) |  | <ul style="list-style-type: none"> - Land Use/Cover class - General information related to the area (designation, land tenure...) - Vegetation cover (trees, shrubs, grass) (- Environmental problems, fires, erosion, grazing activities) | | |
| | | <ul style="list-style-type: none"> - Stand structure and management: harvesting, silviculture, management plan... - Human-induced disturbances | <ul style="list-style-type: none"> - Crop management practices | |

Table 12: Tree and other vegetation measurements and observations in NFI.

Analysis of NFI Data

According to the Globalometree online database (<http://globalometree.org>), at least 63 allometric equations are specific to Ethiopia. Most of these equations are specific to plantations and/or species specific. Thus, these allometric equations are not suitable for a national scale application for all the biomes. In order to represent all the forest types in the first phase of analysis the allometric equation developed by Chave *et al.* (2014) was used to convert field measurements into above ground biomass estimates. The biomass estimates using Chave's equation results in values that are closer to the average biomass estimates for the different forest types from a review of secondary sources (e.g. theses, published and unpublished papers).

The following parameters are needed to calculate above ground biomass in carbon stock: diameter at breast height (dbh), tree height, a wood density factor and a carbon fraction. The dbh and height parameters are measured in the field. A carbon fraction of 0.47 has been applied, which is the default value for wood in the tropical and subtropical domain (IPCC 2006).

$$AGB = 0.0673 * (WD * DBH^2 * H)^{0.976}$$

Where:

AGB = above ground biomass (in kg dry matter)

WD = wood density (g/cm³)

DBH = diameter at breast height (in cm)

H = total height of the tree (in m)

In order to express the AGB pool in carbon stock, the AGB is multiplied by a carbon fraction of 0.47 (kg C/kg dry matter).

According to Chave *et al.* (2014) the inclusion of country specific wood density in the equation significantly improves biomass estimation. Therefore, MEFC conducted an extensive study to determine the most appropriate wood density estimate for the country and basic wood density of 421 indigenous and exotic tree species growing in Ethiopia (see table in annex). The overall average wood density

for the species is 0.612 g cm^{-3} . This overall average wood density is comparable with the global average value and that of tropical Africa (Chave et al. 2009; Reyes et al 1992; Brown and Lugo 1984, IPCC 2006). The minimum value of wood density was 0.262 for Moringa species, and the maximum was 1.040 g cm^{-3} for *Dodonaea angustifolia*.

The BGB carbon pool default conversion factors proposed by IPCC (2006) were applied using the ecological zone and ratios in Table 13.

Table 13: IPCC ratios for Below Ground Biomass (2006)

| Ecological Zone | Above Ground Biomass | R [tonne root d.m. (tonne shoot d.m.) ⁻¹] |
|--------------------------------|----------------------------|--|
| Tropica Moist Deciduous Forest | AGB<125 t ha ⁻¹ | 0,2 |
| | AGB>125 t ha ⁻¹ | 0,24 |
| Tropical Dry Forest | AGB<20 t ha ⁻¹ | 0,56 |
| | AGB>20 t ha ⁻¹ | 0,28 |
| Tropical shrubland | | 0,4 |
| Tropical Mountain System | | 0,27 |

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

For fallen deadwood, the De Vries' formula (De Vries, 1986) was applied, estimating log volume in $\text{m}^3 \text{ ha}^{-1}$. This formula requires the length of the transect (L) and the log diameter (d) at the point of intersection

Where:

V = volume per hectare of deadwood,

d = log diameter at the point of intersection of the transect perpendicular to the axis of the log,

L = length of the transect.

Two decomposition classes were recorded for deadwood particles: sound and rotten. Missing data in the decomposition classes were assumed to be sound deadwood piece. Because a rotten wood contains less biomass than a sound wood, the wood density of dead wood is scaled down using lower wood densities than for standing trees, as follows:

Sound deadwood biomass: Volume * 90% * Default WD,

Rotten deadwood biomass: Volume * 50% * Default WD.

The default wood density for the species is 0.612 g cm^{-3} , similarly as for trees.

The NFI data analysis is based on the analysis of 539 accessible and surveyed sample units from the NFI out of the 631 sample units from the original sampling design. The surveyed sample units are from the different regions (Table 14).

The calculations for the EF are based on the land use sections of each sample unit classified as forest.

Table 14: Number of SUs accessible and SUs accessible with cover sections classified as forest per region

| Region | N of accessible sampling units | N of accessible sampling units with forest |
|------------------|--------------------------------|--|
| Tigray | 31 | 5 |
| Afar | 23 | |
| Amhara | 94 | 12 |
| Oromia | 200 | 68 |
| Somali | 80 | 1 |
| Beneshangul Gumu | 28 | 12 |
| SNNPR | 68 | 25 |
| Gambela | 15 | 5 |
| Total | 539 | 128 |

Table 15: Number of NFI SU analyzed per Stratum and per Biome

| | Biome | | | | | Total |
|--------------------|-------------------|----------------------|-----------------|-------------------|----------|------------|
| | Acacia-Commiphora | Combretum-Terminalia | Dry Afromontane | Moist Afromontane | Others | |
| Stratum I | 5 | 13 | 18 | 59 | | 95 |
| Stratum II | 107 | | | | | 107 |
| Stratum III | 1 | 93 | | 6 | 1 | 101 |
| Stratum IV | 36 | 38 | 114 | 29 | 1 | 218 |
| Stratum V | 15 | 2 | | | 1 | 18 |
| Total | 164 | 146 | 132 | 94 | 3 | 539 |

Table 16: Number of SU classified as forest strata included in the EF analysis.

| | Acacia-Commiphora | Combretum-Terminalia | Dry Afromontane | Moist Afromontane | Others | Total |
|--------------------|-------------------|----------------------|-----------------|-------------------|--------|------------|
| Stratum I | 1 | 9 | 12 | 50 | | 72 |
| Stratum II | 2 | | | | | 2 |
| Stratum III | | 14 | | 2 | | 16 |
| Stratum IV | 1 | 7 | 17 | 12 | | 37 |
| Stratum V | 1 | | | | | 1 |
| Total | 5 | 30 | 29 | 64 | | 128 |

The NFI sample plot design implies a different sampling probability for trees in the plots and small trees in the sub-plots. Thus, two different areal weighting methods

for tree and sapling data were applied. All results were first computed at the LUCS level by plots, and then aggregated up to strata level by regions.

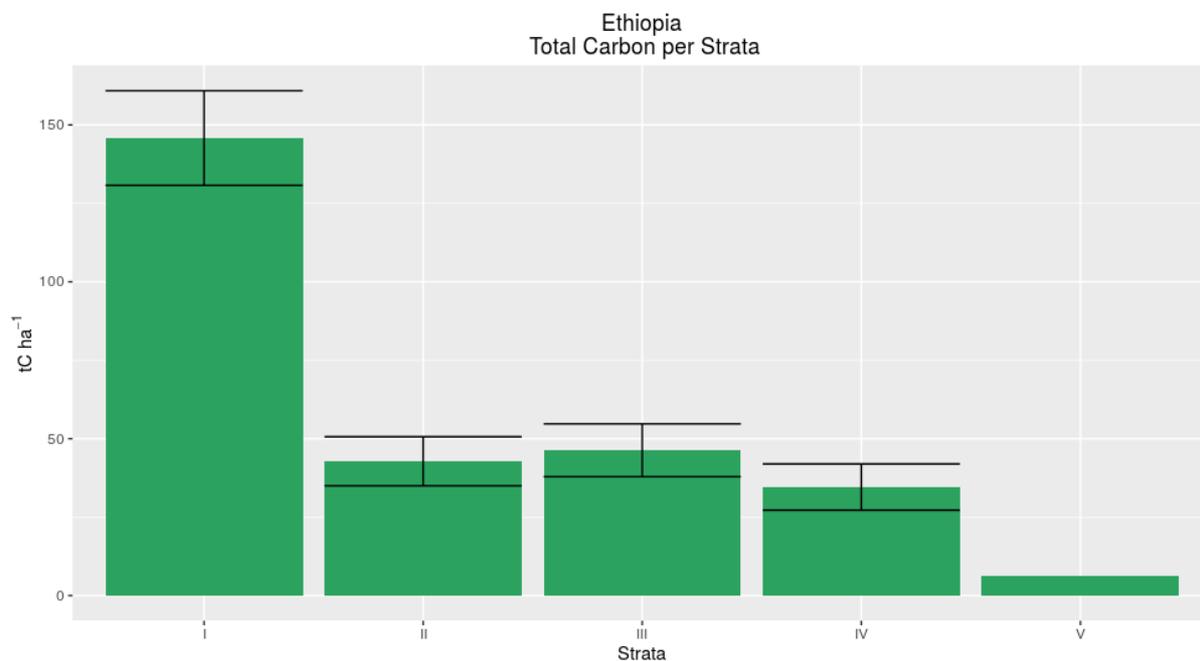


Figure 11: Carbon estimated per strata per all the land uses

From Strata to Biomes estimates

The biome stratification for the FRL was introduced when the NFI was in progress. A new estimation methodology has been introduced, called *a posteriori*, for the FRL purposes. The methodology was needed because the NFI design is based on a pre-stratification assumption using five stratum that do not perfectly overlap with the biome strata.

In order to ensure consistency in the estimates, a robust statistical procedure has been chosen based on a methods described by *Model Assisted Survey Sampling* (Sarndal et al., 1992)

The first step involves using a ratio estimator, defined by the ratio between the variable y (tons of carbon) and the variable x (hectares of forest). Both y and x have been measured for each plot. The index d , which in statistical literature is referred to as a "domain", is the biomes.

The sample selected (the 631 plots from the sample design) is called s . s_d is the portion of the sample that fall into biome d (so, for example, for the NFI strata 1, s_d correspond to the 5 plots that have fallen into the biome 1).

The NFI design is stratified, therefore each stratum has a different sampling intensity defined by the inclusion probability (π_k) of each plot. The π_k has been computed by dividing the number of hectares sampled in each strata by the total area of the strata (when sampling intensity is higher, inclusion probability is higher). Because the total area of the strata is much bigger than the area actually inventoried, the π_k value can be very small. In the same domain, the plots can come from different strata and therefore they can have different inclusion probabilities.

The domain ratio estimator has been calculated using the following equation:

$$\hat{t}_{dra} = \sum_{U_d} x_k \frac{\sum_{s_d} \check{y}_k}{\sum_{s_d} \check{x}_k} = (\sum_{U_d} x_k) \hat{B}_d$$

Where:

- \check{y}_k is the π_k expanded value carbon of each plot divided by the plot's inclusion probability (π_k): $\check{y}_k = \frac{y_k}{\pi_k}$;
- \check{x}_k is the π_k expanded value of hectares of forest of each plot divided by the plot's inclusion probability (π_k): $\check{x}_k = \frac{x_k}{\pi_k}$.

The domain ratio estimator provides the total domain. The average has been calculated dividing by the size of the domain as follows:

$$\frac{\sum_{k \in s_d} \check{y}_k}{\sum_{k \in s_d} \check{x}_k}$$

This calculation has been used to compute the estimates per hectare for each biome.

The variance computation proposed by the Sarndal methodology is:

$$\hat{V}(\hat{t}_{dra}) = \left(\frac{\sum U_d x_k}{\sum_{s_d} \check{x}_k} \right)^2 \sum \sum_{s_d} \check{\Delta}_{kl} \check{e}_{ks} \check{e}_{ls}$$

where:

- \check{e}_{ks} is the π_k -expanded value of the residuals e_{ks} divided by the inclusion probability:

$$\check{e}_{ks} = e_{ks} / \pi_k = (y_k - \hat{y}_k) / \pi_k,$$

and:

$$e_{ks} = y_k - \hat{B}_d x_k$$

- $\check{\Delta}_{kl}$ and the π_k -expanded covariance of sampling indicators and variance indicated by the Bernoulli pairwise plot selection probabilities: where each pair of plots are here indexed using k and l .

When the plots k and l come from different strata, their selection has been independent:

$$\pi_{kl} = \pi_k \pi_l \text{ and } \check{\Delta}_{kl} \text{ is therefore } 0.$$

When the plots k and l come from the same stratum then:

$$\pi_{kl} = \sum_{s \ni k \& l} p(s) = \frac{\binom{N-2}{n-2}}{\binom{N}{n}} = \frac{n(n-1)}{N(N-1)}; \quad k \neq l = 1, \dots, N$$

While

$$\pi_k = \sum_{s \ni k} p(s) = \binom{N-1}{n-1} / \binom{N}{n} = n/N; \quad k = 1, \dots, N$$

As k and l are from the same plot and from the same stratum $\pi_k = \pi_l$.

$\check{\Delta}_{kl}$ is then computed as:

$$\check{\Delta}_{kl} = 1 - \frac{n(N-1)}{N(n-1)}$$

For N very big (as it is in our case) $\check{\Delta}_{kl}$ approximates to 0.

For $k=l$, $\check{\Delta}_{kl}$ approximates to 1

To summarize, the

equals 0 whenever k is different from l .

The variance formula can be then approximated to:

$$\text{variance} = \frac{\sum_{k \in s_d} \left(\frac{y_k - Bx_k}{\pi_k} \right)^2}{\sum_{k \in s_d} \check{x}_k}$$

Where B is a biome-specific factor akin to a slope in a regression between y and x . The comparative advantage of this approach is that the result is not approximated or inaccurate conversed because the biomes and NFI strata do not perfectly spatially intersect. The variance values differs in the new estimates because they combine the variance from the NFI strata and the biomes.

In order to correctly apply the BGB ratios from the IPCC (2006), the ecological zone layers have been applied. Tables 15, 16 and 17 shows that the distribution of SU by biomes and ecological zones differs from the distribution by biomes and NFI strata.

Table 17: distribution of the all the SUs per Biome and Ecological Zones:

| Biomes | Ecological Zones | | | | | | Total Result |
|-----------------------------|------------------|---------------------|---------------------------------|--------------------------|--------------------|----------|--------------|
| | Tropical desert | Tropical dry forest | Tropical moist deciduous forest | Tropical mountain system | Tropical shrubland | Water | |
| Acacia-Commiphora | 18 | 0 | 0 | 54 | 123 | 0 | 195 |
| Combretum-Terminalia | 0 | 43 | 13 | 92 | 31 | 0 | 179 |
| Dry Afromontaine | 0 | 1 | | 148 | 2 | 0 | 151 |
| Moist Afromontaine | 0 | 1 | 7 | 85 | 0 | 0 | 93 |
| Others | 1 | 1 | 0 | 2 | 4 | 1 | 9 |
| Total | 19 | 46 | 20 | 381 | 160 | 1 | 627 |

The difference in the distribution is why there is not direct correspondence between AGB and BGB in some estimates.

Comparison NFI Results and Secondary Data Sources

Numerous studies have been undertaken in Ethiopia already assessing forest carbon stock. To validate the results from the NFI the findings have been compared with these secondary data sources. The secondary data and information was obtained from various sources, some processed and other raw data, including MSc theses, PhD dissertations, research reports, project reports and grey literature. For some of the secondary sources, original data (raw data) were obtained from the respective researchers and re-analysed. In total, 1602 sampling units were involved, excluding the sample number from the WBISPP, 2004. The results of the analysis of secondary data sources are given in Figure 12.

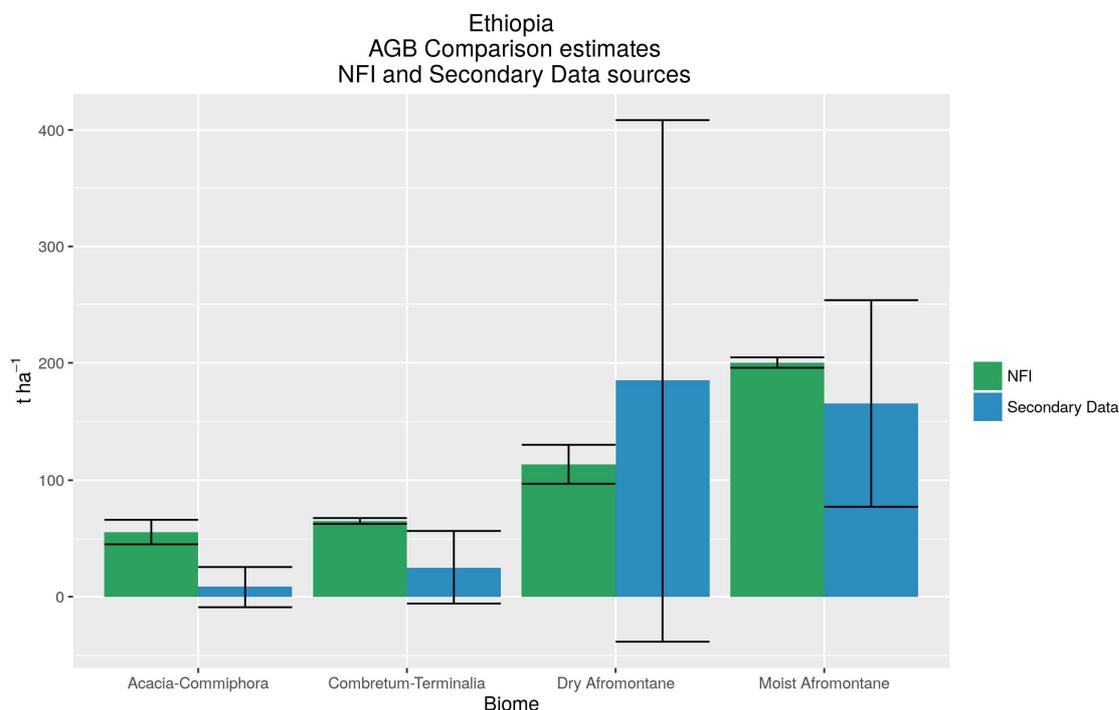


Figure 12: The average AGB (tC/ha) with their confidence intervals for forest in the 4 biomes is compared between primary (NFI) and secondary (literature and local studies)

The use of primary data greatly reduces the confidence intervals of the NFI analysis when compared to the secondary data analysis. When comparing the results from secondary and primary data analysis, there is a large difference in AGB estimates for Dry and Moist Afromontane forests, where the secondary sources suggest much higher carbon contents (220% and 62% higher for Dry and Moist Afromontane forest, respectively). This difference is believed to be attributed to the sample design in the secondary data, which most likely targeted primary and dense forest patches. Therefore, the NFI data is thought to be more representative for estimating emissions and removals from country-wide forest area changes.

A further comparison has been done with the IPCC default values, showing a substantial concordance with the NFI estimates (cfr. table 18).

Table 18: IPCC 2006 default AGB values comparison with the Biomes estimates. The asterisk identifies the most represented ecological zones in Ethiopia

| Ecological zones | Above-ground biomass (t ha⁻¹) | Correspondent above-ground biomass range for Biomes (t ha⁻¹) |
|---------------------------------|---|--|
| Tropical moist deciduous forest | 260 (160-430) | 65-200 |
| Tropical dry forest | 120 (120-130) | 65 |
| Tropical shrubland* | 70 (20-200) | 55-65 |
| Tropical mountain systems* | 40-190 | 113-200 |

| Biomes | Above-ground biomass (t ha⁻¹) |
|----------------------|---|
| Acacia-Commiphora | 55 |
| Combretum-Terminalia | 65 |
| Dry Afromontaine | 113 |
| Moist Afromontaine | 200 |

Results and Proposed Emission Factors

The results of the analysis of the average forest carbon stock in the Above Ground Biomass (AGB), Below Ground Biomass (BGB) and deadwood carbon pools are provided in Figure 13, 14 and 15 respectively. The deadwood results for the *Acacia-*

Commiphora biome are not considered reliable as some very large diameters strongly influence the results. It is expected that this data will become available once the national level data has been collected in the course of 2016.

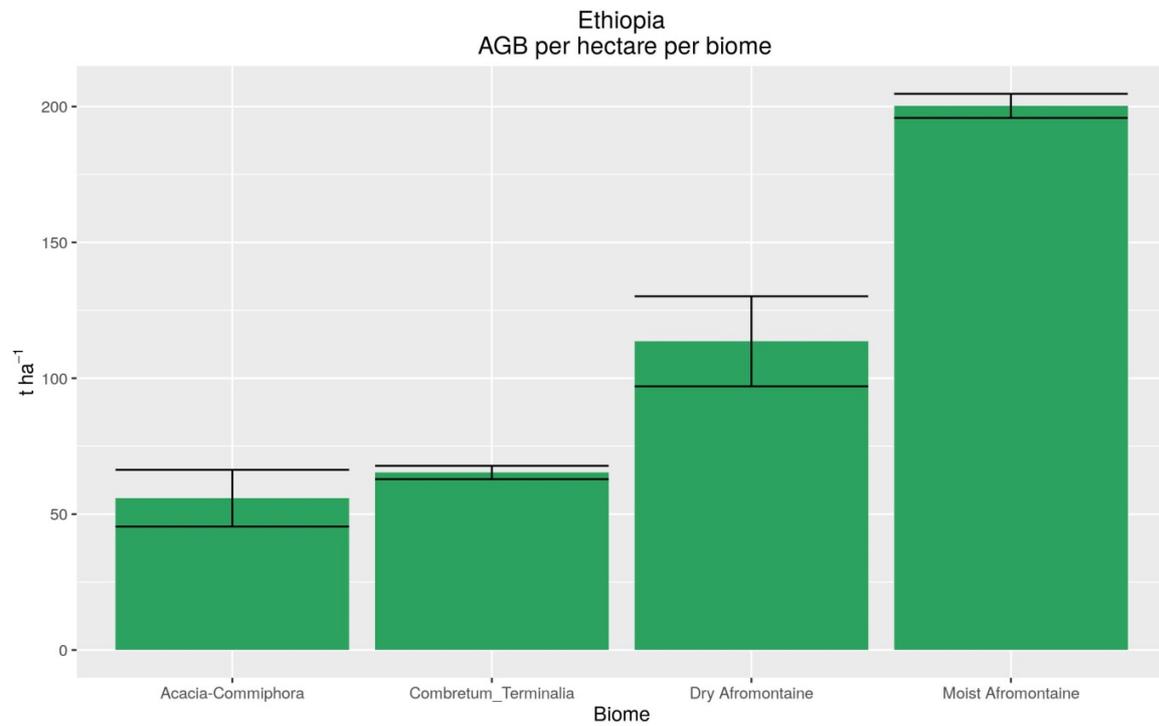


Figure 13: NFI results for the average AGB carbon stock per biome in forest

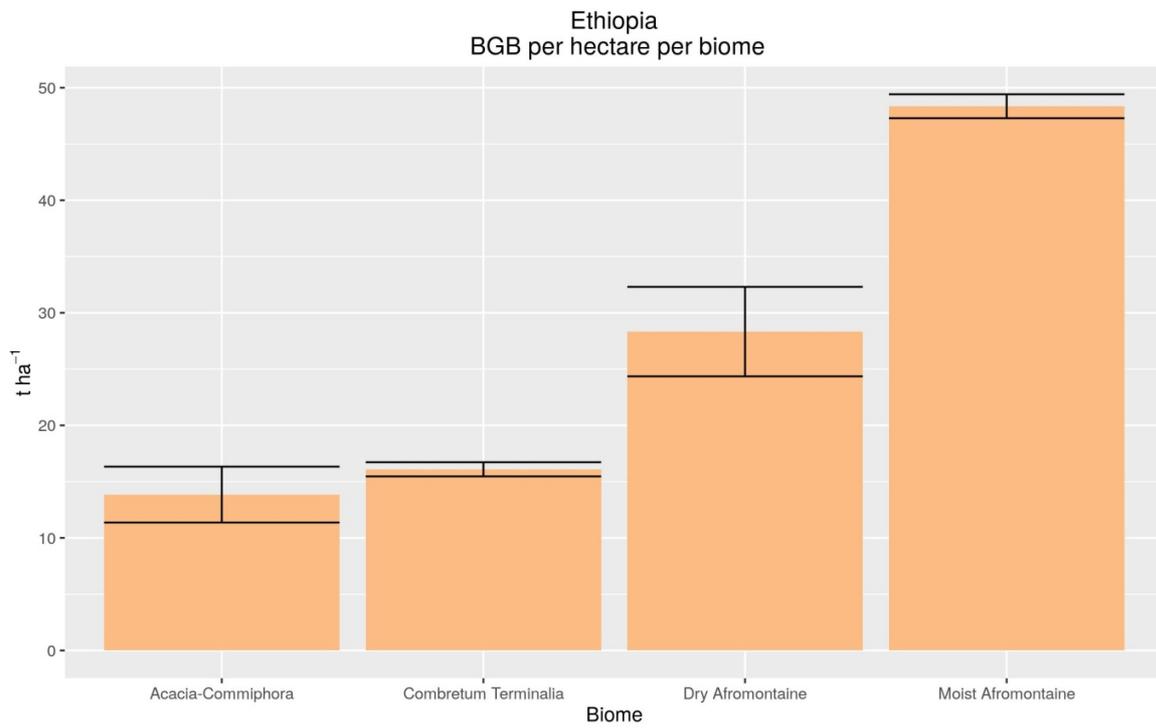


Figure 14: NFI results for the average BGB carbon stock per biome in forest

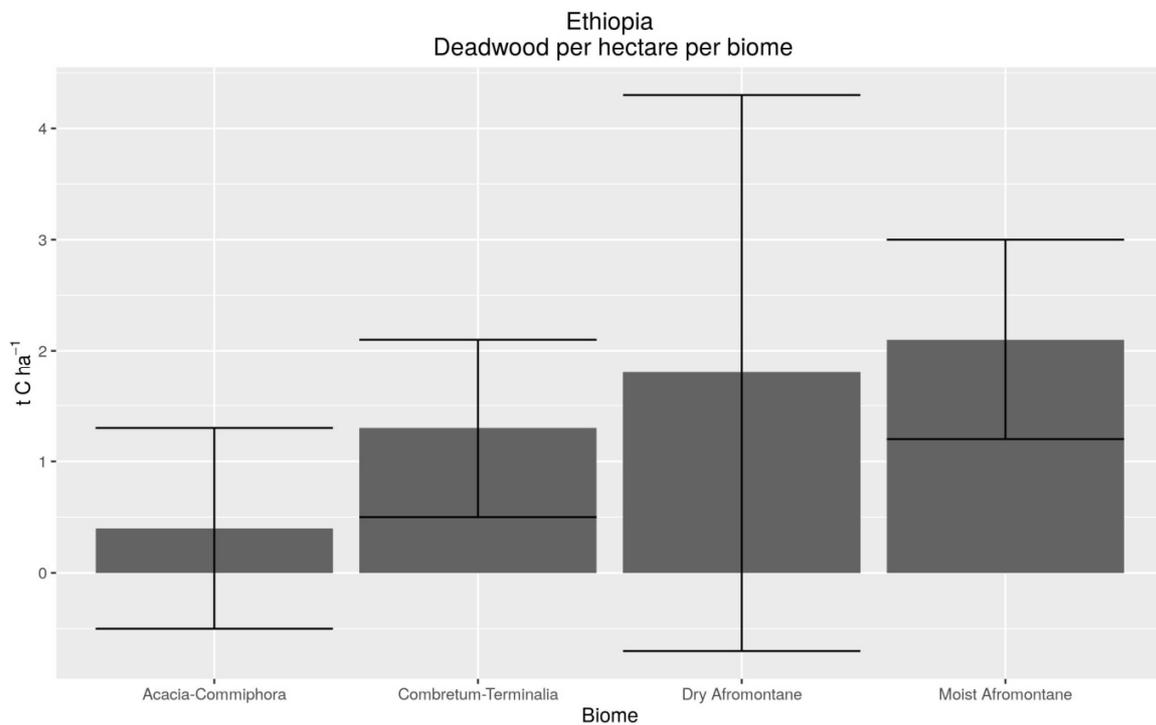


Figure 15: NFI results for deadwood carbon stock per biome in forest

Ethiopia assumes total oxidation of AGB, BGB and deadwood after forest conversion, therefore emission factors are approximated by the full carbon stock in AGB, BGB and deadwood for forest in the different biomes. The removal factor for forest gain is estimated as the inverse of the emission factor therefore assuming full average carbon stock for each hectare of gain detected. As such, Ethiopia does not take into account the age structure in the forest, which would introduce too much complexity (for the time being). Assuming the full carbon stock is removed from the atmosphere at the time gain is detected may over-estimate the removals corresponding to the early years of forest growth. However, this may be compensated by the fact that gain is generally detected by remote sensing in a later stage of growth (therefore removals already preceded the time of detection).

RELEVANT POLICIES, PLANS AND FUTURE CHANGES

Ethiopia's development agenda is governed by two key strategies: the Second Growth and Transformation Plan (GTP-2) and the Climate Resilient Green Economy (CRGE) strategy. Both strategies prioritize attainment of middle income status by 2025 and, through the CRGE Strategy, to achieve this by taking low carbon, resilient, green growth actions. Both strategies emphasize agriculture and forestry; The CRGE Strategy targets 7 million hectares for forest expansion. GTP-2 Goal 15 aims to: "Protect, restore and promote sustainable use of terrestrial ecosystems by managing forests, combating desertification, and halting and reversing land degradation and halt biodiversity loss."

The strategic directions of the forest sector in GTP-2 are enabling the community to actively participate in environmental protection and forest development activities, and implementing the green economy strategy at all administration levels and embarking on environmental protection and forest development at a scale. In the GTP-2, the sector has thus set goals mainly in relation to building climate resilient green economy, environmental protection and forest development. This will be applied mainly in priority sectors identified by the CRGE strategy. In addition, a goal of the sector is mobilizing resources that can enable full implementation the CRGE strategy. In terms of forest development, the aim is to increase the share of the forest sector in the overall economy. The strategy also aims to increase the forest coverage through research-based forest development. A target set during the GTP-2, is to reduce deforestation by half.

PROPOSED FOREST REFERENCE LEVEL

CONSTRUCTION APPROACH AND PROPOSED FOREST REFERENCE EMISSION LEVEL FOR DEFORESTATION AND FOREST REFERENCE LEVEL FOR AFFORESTATION

Ethiopia proposes a Forest Reference Emission Level based on average annual emissions and removals over the period 2000-2013 assessed by AD x EF. The emissions from deforestation in the FRL are assessed at 17.9 mln t CO₂ e/yr while the removals from afforestation are assessed at 4.8. mln t CO₂ e/yr.

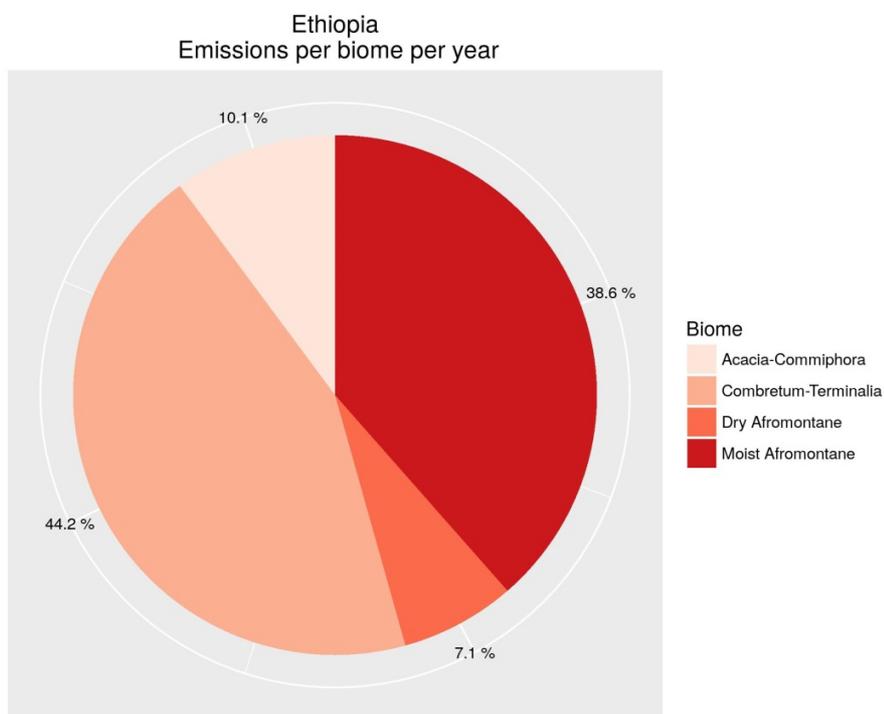


Figure 16: Emission by Biome.

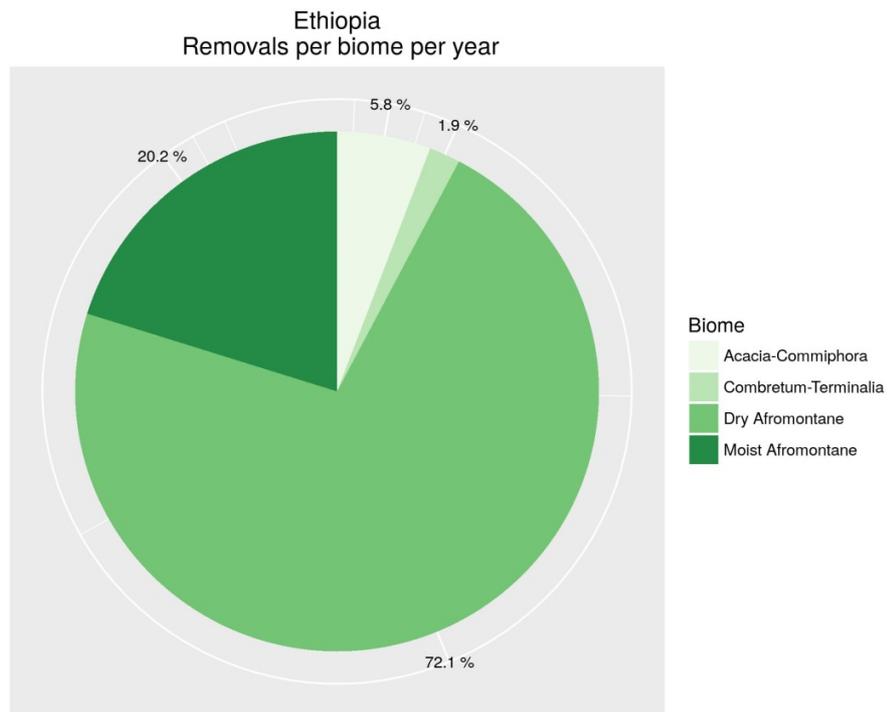


Figure 17: Reductions per biome

UPDATING FREQUENCY

In order to ensure the accuracy of the FRL with updated socio-economic conditions and in order to incorporate new or improved data that may be available, the FRL will be revised periodically. Ethiopia proposed this FRL to be valid at least for 5 years, yet it may be improved and updated more frequently. Ethiopia is also evaluating the possibility of undertaking a new region based forest inventory, with a 5 year cycle.

FUTURE IMPROVEMENTS

Forest degradation is believed to be an important source of emissions by Ethiopia and several measures are being put in place to reduce emissions from forest degradation (e.g. the promotion of energy efficient cooking stoves, planting trees on-farm boundaries for fuelwood and the provision of non-wood and alternative energy sources). Therefore, Ethiopia is strongly interested in testing and developing a cost-effective, robust and reliable methods for consistent measuring and monitoring of emissions from forest degradation for its future inclusion in the FRL.

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ANNEX

ANNEX I

| Strata | SU | SU area (Ha) | Strata Area (Ha) | Sampling Intensity | Samples distribution (%) |
|---------------|------------|--------------|--------------------|--------------------|--------------------------|
| Stratum I | 107 | 214 | 4,058,626 | 5.27272E-05 | 59.0 |
| Stratum II | 135 | 270 | 39,339,300 | 6.86337E-06 | 7.7 |
| Stratum III | 137 | 274 | 19,689,121 | 1.39163E-05 | 15.6 |
| Stratum IV | 232 | 464 | 35,588,651 | 1.30379E-05 | 14.6 |
| Stratum V | 20 | 40 | 14,445,525 | 2.76902E-06 | 3.1 |
| TOTALS | 631 | 1,262 | 113,121,223 | 8.93138E-05 | 100 |

| Biome | SU | SU area (Ha) | Biome Area (Ha) | Sampling Intensity | Samples distribution (%) |
|----------------------|------------|--------------|--------------------|--------------------|--------------------------|
| Acacia-Commiphora | 195 | 390 | 58,654,959 | 6.64905E-06 | 9.7 |
| Combretum-Terminalia | 179 | 358 | 25,715,132 | 1.39218E-05 | 20.4 |
| Dry Afromontaine | 151 | 302 | 19,720,064 | 1.53144E-05 | 22.4 |
| Moist Afromontaine | 93 | 186 | 8,440,625 | 2.20363E-05 | 32.3 |
| Others | 9 | 18 | 1,736,549 | 1.03654E-05 | 15.2 |
| TOTALS | 627 | 1,254 | 114,267,329 | 6.82868E-05 | 100 |

Table 19: sampling distribution and sampling intensity comparisons between NFI strata and biomes.

NOTE: The difference between the number of SU (631 and 627) is due to the fact that 4 SU during the sampling design are accidentally fall outside the national boundaries currently adopted.

ANNEX II

Table 20: Basic Wood Density of Indigenous and Exotic Tree Species in Ethiopia

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|----|---------------------------------|------------------------------------|---|---------------|-----------------|
| 1 | <i>Acacia abyssinica</i> | 0.826 | average of genus (ICRAF database) | M | |
| 2 | <i>Acacia albida</i> | 0.562 | http://www.worldagroforestry.org/regions/southeast_asia/resources/db/wd | M | |
| 3 | <i>Acacia asak</i> | 0.769 | average of genus (ICRAF database) | M | |
| 4 | <i>Acacia brevispica</i> | 0.769 | >> | M | |
| 5 | <i>Acacia bussei</i> | 0.769 | >> | M | |
| 6 | <i>Acacia decurrens</i> | 0.816 | Getachew Desalegn et al., 2012 | H | Air dry density |
| 7 | <i>Acacia dolichocephala</i> | 0.769 | average of genus | M | |
| 8 | <i>Acacia drepanolobium</i> | 0.769 | >> | M | |
| 9 | <i>Acacia etbaica</i> | 0.590 | Vreugdenhil et al., 2012 | H | |
| 10 | <i>Acacia gerrardii</i> | 0.775 | Tropical Africa: global database (Zanne et al., 2009) | M | |
| 11 | <i>Acacia goetzei</i> | 0.883 | >> | M | |
| 12 | <i>Acacia hokii</i> | 0.769 | average of genus (ICRAF database) | M | |
| 13 | <i>Acacia lahai</i> | 0.769 | >> | M | |
| 14 | <i>Acacia macrothyrsa</i> | 0.769 | >> | M | |
| 15 | <i>Acacia mellifera</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 16 | <i>Acacia mollis</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 17 | <i>Acacia nilotica</i> | 0.723 | Vreugdenhil et al., 2012 | H | |
| 18 | <i>Acacia oerofota</i> | 0.769 | average of genus | M | |
| 19 | <i>Acacia pentagon</i> | 0.826 | average of genus (ICRAF database) | M | |
| 20 | <i>Acacia polyacantha</i> | 0.769 | average of genus | M | |
| 21 | <i>Acacia reficiens</i> | 0.769 | >> | M | |
| 22 | <i>Acacia robusta</i> | 0.769 | >> | M | |
| 23 | <i>Acacia senegal</i> | 0.741 | Vreugdenhil et al., 2012 | H | |
| 24 | <i>Acacia seyal</i> | 0.497 | Vreugdenhil et al., 2012 | H | |
| 25 | <i>Acacia sieberiana</i> | 0.769 | average of genus | M | |
| 26 | <i>Acacia tortilis</i> | 0.590 | Vreugdenhil et al., 2012 | H | |
| 27 | <i>Acacia xiphocarpa</i> | 0.769 | average of genus | M | |
| 28 | <i>Acacia Zanzibarica</i> | 0.769 | average of genus | M | |
| 29 | <i>Acalypha acrogyna</i> | 0.300 | A. Cauturus (Zanne et al.; global database), | L | |
| 30 | <i>Acanthus sp.</i> | 0.592 | Global database (Zanne et al., 2009) | M | |
| 31 | <i>Acokanthera schimperi</i> | 0.784 | <i>Acokanthera oppositifolia</i> (from Global database) | L | |
| 32 | <i>Acrocarpus fraxinifolius</i> | 0.610 | Getachew Desalegn et al., 2012 | H | air dry density |
| 33 | <i>Adansonia digitata</i> | 0.590 | Vreugdenhil et al., 2012 | H | |
| 34 | <i>Adathada schimperiana</i> | 0.640 | same species from wood density for trees of Uganda | L | |
| 35 | <i>Alangium chinense</i> | 0.420 | http://db.worldagroforestry.org/wd/species/Alangium_chinense | M | |
| 36 | <i>Alangium Chinese</i> | 0.408 | >> | M | |
| 37 | <i>Albizia aylemeri</i> | 0.579 | Genus average | M | |
| 38 | <i>Albizia glaberrima</i> | 0.555 | http://db.worldagroforestry.org/wd/species/Alangium_chinense | M | |
| 39 | <i>Albizia grandibracteata</i> | 0.534 | <i>Albizia gummifera</i> | L | |
| 40 | <i>Albizia gummifera</i> | 0.580 | Getachew Desalegn et al., 2012 | H | air dry density |
| 41 | <i>Albizia lebbeck</i> | 0.596 | http://db.worldagroforestry.org/wd/species/Alangium_chinense | M | |
| 42 | <i>Albizia lophantha</i> | 0.579 | Genus average | M | |

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|----|---------------------------------|------------------------------------|--|---------------|-----------------|
| 43 | <i>Albizia malacophylla</i> | 0.579 | Genus average | M | |
| 44 | <i>Albizia schimperiana</i> | 0.530 | Getachew Desalegn et al., 2012 | H | air density dry |
| 45 | <i>Alchornea laxiflora</i> | 0.525 | <i>A. hirtella</i> ; Zanne et al.; <i>global database</i> | L | |
| 46 | <i>Alchornea euphorbiaceae</i> | 0.525 | >> | L | |
| 47 | <i>Alihornea euphorbiscara</i> | 0.525 | >> | L | |
| 48 | <i>Allophylus abyssinicus</i> | 0.580 | Getachew Desalegn et al., 2012 | H | air density dry |
| 49 | <i>Allophylus abyssinicus</i> | 0.491 | Vreugdenhil et al., 2012 | H | |
| 50 | <i>Allophylus rubifolius</i> | 0.494 | Genus average | M | |
| 51 | <i>Alstonia boonei</i> | 0.387 | http://db.worldagroforestry.org/wd/species/Alstonia boonei | L | |
| 52 | <i>Annona crassiflora</i> | 0.400 | http://db.worldagroforestry.org/wd/species/Alstonia boonei | L | |
| 53 | <i>Anogeissus leiocarpa</i> | 0.880 | >> | L | |
| 54 | <i>Antialis toxicalia</i> | 0.432 | <i>Antiaris africana</i> ; | L | |
| 55 | <i>Antiaris toxicaria</i> | 0.470 | Getachew Desalegn et al., 2012 | H | air density dry |
| 56 | <i>Apodytes dimidiata</i> | 0.610 | http://db.worldagroforestry.org/wd/genus/Apodytes | M | |
| 57 | <i>Apodytes dimidiata</i> | 0.710 | Getachew Desalegn et al., 2012 | H | air density dry |
| 58 | <i>Argomaellera maerophylla</i> | 0.640 | Wood density of trees of Uganda | L | |
| 59 | <i>Arundinaria alpine</i> | 0.630 | Getachew Desalegn et al., 2012 | H | air density dry |
| 60 | <i>Azadirachta indica</i> | 0.728 | http://db.worldagroforestry.org/wd/genus/Apodytes | M | |
| 61 | <i>Balanites aegyptiaca</i> | 0.542 | Vreugdenhil et al., 2012 | H | |
| 62 | <i>Balanites glabra</i> | 0.684 | Genus average | M | |
| 63 | <i>Baphia abyssinica</i> | 0.559 | <i>B. Nitida (global database: Zanne et al., 2009)</i> | L | |
| 64 | <i>Berberis holstii</i> | 0.641 | Genus average | M | |
| 65 | <i>Berchemia discolor</i> | 0.895 | http://db.worldagroforestry.org/wd/genus/Apodytes | M | |
| 66 | <i>Bersama abyssinica</i> | 0.671 | http://db.worldagroforestry.org/wd/genus/Bersama & also global database | H | |
| 67 | <i>Blighia unijugata</i> | 0.700 | Getachew Desalegn et al., 2012 | H | air density dry |
| 68 | <i>Blighia unijugata</i> | 0.564 | http://db.worldagroforestry.org/wd/genus/Apodytes | M | |
| 69 | <i>Boswellia hildebrandtii</i> | 0.500 | <i>Boswellia</i> sp | L | |
| 70 | <i>Boswellia microphylla</i> | 0.500 | >> | L | |
| 71 | <i>Boswellia neglecta</i> | 0.500 | >> | L | |
| 72 | <i>Boswellia papyrifera</i> | 0.500 | >> | L | |
| 73 | <i>Boswellia rivae</i> | 0.500 | >> | L | |
| 74 | <i>Boswellia sp</i> | 0.500 | <i>Boswellia serrata (FAO data)</i> | L | |
| 75 | <i>Bridelia cathartica</i> | 0.587 | Genus average | M | |
| 76 | <i>Bridelia micrantha</i> | 0.540 | http://db.worldagroforestry.org/wd/genus/Apodytes | M | |
| 77 | <i>Brucea antidysenterica</i> | 0.640 | Wood density of Trees of Uganda | L | |
| 78 | <i>Buddleia polystachya</i> | 0.400 | Vreugdenhil et al., 2012 | H | |
| 79 | <i>Caesalpinia trochae</i> | 0.951 | Genus average | M | |
| 80 | <i>Caesalpinia volkensii</i> | 0.951 | http://db.worldagroforestry.org/wd/genus/Caesalpinia Genus average | M | |
| 81 | <i>Callistemon citrinus</i> | 0.951 | >> | M | |

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|-----|---------------------------------|------------------------------------|---|---------------|-----------------|
| 82 | <i>Calotropis procera</i> | 0.794 | Genus average | M | |
| 83 | <i>Canthium euryooides</i> | 0.643 | Genus average | M | |
| 84 | <i>Canthium giordanii</i> | 0.643 | Genus average | M | |
| 85 | <i>Canthium oligocarpum</i> | 0.643 | Genus average | M | |
| 86 | <i>Canthium setiglarum</i> | 0.643 | Genus average | M | |
| 87 | <i>Capparis cartilagenia</i> | 0.691 | Genus average | M | |
| 88 | <i>Capparis micrantha</i> | 0.691 | Genus average | M | |
| 89 | <i>Capsicum conicum</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 90 | <i>Carissa edulis</i> | 0.650 | <i>Carissa spinarium</i> http://www.hindawi.com/journals/tswj/2012/790219/tab1/ | L | |
| 91 | <i>Cassia didymobotrya</i> | 0.745 | http://db.worldagroforestry.org/wd/genus/Apodytes | M | |
| 92 | <i>Cassia sinqueana</i> | 0.706 | http://db.worldagroforestry.org/wd/genus/Apodytes | M | |
| 93 | <i>Cassipourea malosana</i> | 0.673 | Genus average | M | |
| 94 | <i>Casuarina equisetifolia</i> | 0.766 | http://db.worldagroforestry.org/wd/genus/Apodytes | M | |
| 95 | <i>Catha edulis</i> | 0.658 | http://db.worldagroforestry.org/wd/genus/Apodytes | M | |
| 96 | <i>Celtis africana</i> | 0.745 | http://db.worldagroforestry.org/wd/species/Celtis_africana | M | |
| 97 | <i>Celtis africana</i> | 0.760 | Getachew Desalegn et al., 2012 | H | air dry density |
| 98 | <i>Celtis kranssiana</i> | 0.604 | Genus average | M | |
| 99 | <i>Celtis philippinensis</i> | 0.611 | http://db.worldagroforestry.org/wd | M | |
| 100 | <i>Celtis zenkeri</i> | 0.59 | FAO database | M | |
| 101 | <i>Chaionanthus mildbraedii</i> | 0.705 | Average Chionanthus | L | |
| 102 | <i>Citrus aurantifolia</i> | 0.699 | Genus average | M | |
| 103 | <i>Citrus aurantium</i> | 0.699 | Genus average | M | |
| 104 | <i>Citrus grandis</i> | 0.590 | http://db.worldagroforestry.org/wd | M | |
| 105 | <i>Citrus medica</i> | 0.770 | http://db.worldagroforestry.org/wd | M | |
| 106 | <i>Citrus meolica</i> | 0.699 | Genus average | M | |
| 107 | <i>Citrus reticulata</i> | 0.699 | Genus average | M | |
| 108 | <i>Citrus sinensis</i> | 0.699 | Genus average | M | |
| 109 | <i>Clausena anisata</i> | 0.482 | http://db.worldagroforestry.org/wd/species/Clausena_anisata | M | |
| 110 | <i>Clematis hirsuta</i> | 0.526 | Genus average | M | |
| 111 | <i>Coffea arabica</i> | 0.620 | http://db.worldagroforestry.org/wd/species/Coffea_arabica | M | |
| 112 | <i>Combretum aculeatum</i> | 0.474 | Vreugdenhil et al., 2012 | H | |
| 113 | <i>Combretum binderianum</i> | 0.880 | http://db.worldagroforestry.org/wd/species | M | |
| 114 | <i>Combretum colinum</i> | 0.590 | Vreugdenhil et al., 2012 | H | |
| 115 | <i>Combretum ghasalense</i> | 0.845 | http://db.worldagroforestry.org/wd/species | M | |
| 116 | <i>Combretum molle</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 117 | <i>Combretum voldensii</i> | 0.845 | http://db.worldagroforestry.org/wd/species | M | |
| 118 | <i>Commiphora africana</i> | 0.276 | http://db.worldagroforestry.org/wd/species | M | |
| 119 | <i>Commiphora africana</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 120 | <i>Commiphora alaticaulis</i> | 0.389 | http://db.worldagroforestry.org/wd/species | M | |
| 121 | <i>Commiphora billia</i> | 0.389 | http://db.worldagroforestry.org/wd/species | M | |
| 122 | <i>Commiphora bioviniana</i> | 0.646 | http://db.worldagroforestry.org/wd/species | M | |
| 123 | <i>Commiphora</i> | 0.389 | Genus average | M | |

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|-----|---------------------------------|------------------------------------|---|---------------|-----------------|
| | <i>boranensis</i> | | | | |
| 124 | <i>Commiphora bruceau</i> | 0.389 | Genus average | M | |
| 125 | <i>Commiphora confusa</i> | 0.389 | Genus average | M | |
| 126 | <i>Commiphora ellenbeckii</i> | 0.389 | Genus average | M | |
| 127 | <i>Commiphora erlangeriana</i> | 0.389 | Genus average | M | |
| 128 | <i>Commiphora erythraea</i> | 0.389 | Genus average | M | |
| 129 | <i>Commiphora habessinica</i> | 0.389 | Genus average | M | |
| 130 | <i>Commiphora ogadensis</i> | 0.389 | Genus average | M | |
| 131 | <i>Commiphora schimperi</i> | 0.389 | Genus average | M | |
| 132 | <i>Commiphora sphaerophylla</i> | 0.389 | Genus average | M | |
| 133 | <i>Commiphora tenuis</i> | 0.389 | Genus average | M | |
| 134 | <i>Cordia africana</i> | 0.482 | http://db.worldagroforestry.org/wd/species/Cordia africana | M | |
| 135 | <i>Cordia africana</i> | 0.410 | Getachew Desalegn et al., 2012 | H | air density dry |
| 136 | <i>Cordia alliodora</i> | 0.390 | Getachew Desalegn et al., 2012 | H | air density dry |
| 137 | <i>Cordia monoica</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 138 | <i>Cordia ovalis</i> | 0.544 | Genus average | M | |
| 139 | <i>Crasocephalum montuosum</i> | 0.331 | <i>C. Manii</i> | M | |
| 140 | <i>Crasocephalus montus</i> | 0.331 | <i>C. Manii</i> | M | |
| 141 | <i>Croton dichogamus</i> | 0.525 | Genus average | M | |
| 142 | <i>Croton macrostachyus</i> | 0.518 | http://db.worldagroforestry.org/wd/species/Croton macrostachyus | M | |
| 143 | <i>Croton macrostachyus</i> | 0.560 | Getachew Desalegn et al., 2012 | H | air density dry |
| 144 | <i>Cupressus lusitanica</i> | 0.430 | Getachew Desalegn et al., 2012 | H | air density dry |
| 145 | <i>Cussonia holstii</i> | 0.409 | Genus average | M | |
| 146 | <i>Cussonia ostinii</i> | 0.409 | Genus average | M | |
| 147 | <i>Dalbergia boehmii</i> | 0.821 | Genus average | M | |
| 148 | <i>Dalbergia melanoxyton</i> | 0.728 | Vreugdenhil et al., 2012 | H | |
| 149 | <i>Dichrostachys cinerea</i> | 0.482 | <i>Vreugdenhil et al., 2012</i> | H | |
| 150 | <i>Diospyros abyssinica</i> | 0.790 | Getachew Desalegn et al., 2012 | H | air density dry |
| 151 | <i>Diospyros mespiliformis</i> | 0.758 | Genus average | M | |
| 152 | <i>Discopodium penninervium</i> | 0.482 | <i>Vreugdenhil et al., 2012</i> | H | |
| 153 | <i>Dodonaea angustifolia</i> | 1.040 | http://db.worldagroforestry.org/wd/species | M | |
| 154 | <i>Dombeya bruceana</i> | 0.580 | Genus average | M | |
| 155 | <i>Dombeya quenguesta</i> | 0.580 | Genus average | M | |
| 156 | <i>Dombeya torrida</i> | 0.451 | <i>Vreugdenhil et al., 2012</i> | H | |
| 157 | <i>Dombeya torrida</i> | 0.588 | http://db.worldagroforestry.org/wd/species | M | |
| 158 | <i>Dovyalis abyssinica</i> | 0.579 | http://db.worldagroforestry.org/wd/species | M | |
| 159 | <i>Dracaena afromontane</i> | 0.418 | Genus average | M | |
| 160 | <i>Dracaena fragrans</i> | 0.418 | genus average (http://db.worldagroforestry.org/wd/genus/Dracaena) | M | |
| 161 | <i>Dracaena steudneri</i> | 0.418 | >> | M | |
| 162 | <i>Ehretia cymosa</i> | 0.560 | http://globalspecies.org/ntaxa/2529407 | L | |
| 163 | <i>Ehretia cymosa</i> | 0.484 | http://db.worldagroforestry.org/wd/species | M | |

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|-----|---------------------------------|------------------------------------|--|---------------|-----------------|
| 164 | <i>Ekebergia capensis</i> | 0.580 | Getachew Desalegn et al., 2012 | H | air dry density |
| 165 | <i>Embelia schimperii</i> | 0.775 | <i>Embelia oleifera</i> | L | |
| 166 | <i>Erica arborea</i> | 0.357 | Vreugdenhil et al., 2012 | H | |
| 167 | <i>Erythrina abyssinica</i> | 0.426 | http://db.worldagroforestry.org/wd/species/Erythrina_abyssinica | M | |
| 168 | <i>Erythrina brucei</i> | 0.314 | Genus average http://db.worldagroforestry.org/wd/genus/Erythrina | M | |
| 169 | <i>Erythrococca abyssinica</i> | 0.58 | Average of tropical Africa | L | |
| 170 | <i>Erythrococca Kirkii</i> | 0.58 | Average of tropical Africa | L | |
| 171 | <i>Erythrococca trichogynol</i> | 0.58 | Average of tropical Africa | L | |
| 172 | <i>Erythroxyllum fisherrii</i> | 0.802 | Average Genus (http://db.worldagroforestry.org/wd/genus/Erythroxyllum) | M | |
| 173 | <i>Eucalyptus camaldulensis</i> | 0.853 | Getachew Desalegn et al., 2012 | H | air dry density |
| 174 | <i>Eucalyptus citriodora</i> | 0.830 | http://db.worldagroforestry.org/wd/species | M | |
| 175 | <i>Eucalyptus deanei</i> | 0.570 | Getachew Desalegn et al., 2012 | H | air dry density |
| 176 | <i>Eucalyptus deglupta</i> | 0.410 | Getachew Desalegn et al., 2012 | H | air dry density |
| 177 | <i>Eucalyptus delegatensis</i> | 0.530 | Getachew Desalegn et al., 2012 | H | air dry density |
| 178 | <i>Eucalyptus dunii</i> | 0.610 | Getachew Desalegn et al., 2012 | H | air dry density |
| 179 | <i>Eucalyptus fastigata</i> | 0.650 | Getachew Desalegn et al., 2012 | H | air dry density |
| 180 | <i>Eucalyptus globulus</i> | 0.780 | Getachew Desalegn et al., 2012 | H | air dry density |
| 181 | <i>Eucalyptus grandis</i> | 0.560 | Getachew Desalegn et al., 2012 | H | air dry density |
| 182 | <i>Eucalyptus grandis</i> | 0.665 | http://db.worldagroforestry.org/wd/species | M | |
| 183 | <i>Eucalyptus microcorys</i> | 0.860 | Getachew Desalegn et al., 2012 | H | air dry density |
| 184 | <i>Eucalyptus nitens</i> | 0.760 | Getachew Desalegn et al., 2012 | H | air dry density |
| 185 | <i>Eucalyptus obliqua</i> | 0.670 | Getachew Desalegn et al., 2012 | H | air dry density |
| 186 | <i>Eucalyptus paniculata</i> | 0.830 | Getachew Desalegn et al., 2012 | H | air dry density |
| 187 | <i>Eucalyptus pilularis</i> | 0.948 | Getachew Desalegn et al., 2012 | H | air dry density |
| 188 | <i>Eucalyptus regnans</i> | 0.480 | Getachew Desalegn et al., 2012 | H | air dry density |
| 189 | <i>Eucalyptus saligna</i> | 0.680 | Getachew Desalegn et al., 2012 | H | air dry density |
| 190 | <i>Eucalyptus viminalis</i> | 0.670 | Getachew Desalegn et al., 2012 | H | air dry density |
| 191 | <i>Euclea schimperii</i> | 0.741 | http://db.worldagroforestry.org/wd/species/Erythrina_abyssinica | M | |
| 192 | <i>Euphorbia abyssinica</i> | 0.471 | http://db.worldagroforestry.org/wd/species | M | |
| 193 | <i>Euphorbia candelabrum</i> | 0.471 | genus average | M | |
| 194 | <i>Euphorbia sp.</i> | 0.314 | Vreugdenhil et al., 2012 | H | |
| 195 | <i>Euphorbia tirucallii</i> | 0.471 | genus average | M | |

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|-----|--------------------------------|------------------------------------|---|---------------|------------------|
| 196 | <i>Fagaropsis angolensis</i> | 0.700 | Getachew Desalegn et al., 2012 | H | air dry density |
| 197 | <i>Faurea saligna</i> | 0.704 | http://db.worldagroforestry.org/wd/species | M | |
| 198 | <i>Ficus brachypoda</i> | 0.441 | http://db.worldagroforestry.org/wd/species | M | |
| 199 | <i>Ficus elastica</i> | 0.607 | http://db.worldagroforestry.org/wd/species | M | |
| 200 | <i>Ficus exasperata</i> | 0.377 | http://db.worldagroforestry.org/wd/species | M | |
| 201 | <i>Ficus gnaphalocarpa</i> | 0.441 | Genus average | M | |
| 202 | <i>Ficus mucoso</i> | 0.441 | Average Ficus (http://db.worldagroforestry.org/wd/genus/Ficus) | M | |
| 203 | <i>Ficus oxata</i> | 0.441 | >> | M | |
| 204 | <i>Ficus sp.</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 205 | <i>Ficus sur</i> | 0.441 | http://globalspecies.org/ntaxa/869708 | L | |
| 206 | <i>Ficus sycomorus</i> | 0.422 | http://globalspecies.org/ntaxa/869708 | L | |
| 207 | <i>Ficus sycomorus</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 208 | <i>Ficus thonningii</i> | 0.432 | http://globalspecies.org/ntaxa/911819 | M | |
| 209 | <i>Ficus vasta</i> | 0.441 | Average Ficus (http://db.worldagroforestry.org/wd/genus/Ficus) | M | |
| 210 | <i>Filicium decipiens</i> | 0.960 | http://db.worldagroforestry.org/wd/species | M | |
| 211 | <i>Flacourtia indica</i> | 0.778 | http://db.worldagroforestry.org/wd/species | M | |
| 212 | <i>Flueggea virosa</i> | 0.770 | Genus average | M | |
| 213 | <i>Foeniculum vulgare</i> | 0.58 | Average of tropical Africa | L | |
| 214 | <i>Galiniera saxifraga</i> | 0.399 | Vreugdenhil et al., 2012 | H | |
| 215 | <i>Gardenia ternifolia</i> | 0.672 | Genus average | M | |
| 216 | <i>Gardenia volkensii</i> | 0.571 | Vreugdenhil et al., 2012 | H | |
| 217 | <i>Grevillea robusta</i> | 0.530 | Getachew Desalegn et al., 2012 | H | air dry density |
| 218 | <i>Grewia auriculifera</i> | 0.583 | http://db.worldagroforestry.org/wd/species | M | |
| 219 | <i>Grewia bicolor</i> | 0.456 | Vreugdenhil et al., 2012 | H | |
| 220 | <i>Grewia ferruginea</i> | 0.583 | Genus average | M | |
| 221 | <i>Grewia flavescens</i> | 0.583 | Genus average | M | |
| 222 | <i>Grewia mollis</i> | 0.583 | Genus average | M | |
| 223 | <i>Grewia tembensis</i> | 0.583 | Genus average | M | |
| 224 | <i>Grewia tenax</i> | 0.583 | Genus average | M | |
| 225 | <i>Grewia trichocarpa</i> | 0.583 | Genus average | M | |
| 226 | <i>Grewia villosa</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 227 | <i>Hagenia abyssinica</i> | 0.591 | http://db.worldagroforestry.org/wd/species/Hagenia_abyssinica | M | |
| 228 | <i>Hagenia abyssinica</i> | 0.560 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 229 | <i>Halleria lucida</i> | 0.715 | http://db.worldagroforestry.org/wd/species | M | |
| 230 | <i>Haplocoelum foliolosum</i> | 0.788 | http://db.worldagroforestry.org/wd/species | M | |
| 231 | <i>Heteromorpha trifoliata</i> | 0.58 | Average of tropical Africa | L | |
| 232 | <i>Hildebrandtia africana</i> | 0.58 | Average of tropical Africa | L | |
| 233 | <i>Hippocratea africana</i> | 0.876 | H. maingayi | L | |
| 234 | <i>Hippocratea macrophylla</i> | 0.876 | H. maingayi | L | |
| 235 | <i>Hippocratea pallens</i> | 0.876 | H. maingayi | L | |
| 236 | <i>Hypericum revolutum</i> | 0.726 | Genus average | M | |
| 237 | <i>Ilex mitis</i> | 0.466 | Vreugdenhil et al., 2012 | H | |
| 238 | <i>Indigofera garekeana</i> | 0.580 | Average of tropical Africa | L | |
| 239 | <i>Jasminum abyssinicum</i> | 0.580 | Average of tropical Africa | L | |
| 240 | <i>Juniperus procera</i> | 0.628 | http://db.worldagroforestry.org/wd/genus/Juniperus | M | |
| 241 | <i>Juniperus procera</i> | 0.540 | Getachew Desalegn et al., 2012 | H | air dry |

| No | Scientific name | Basic Density (g/cm3) | Reference | Data quality* | Remark |
|-----|------------------------------------|-----------------------|---|---------------|------------------|
| 242 | <i>Justicia schimperiana</i> | 0.580 | Average of tropical Africa | L | density] |
| 243 | <i>Kigelia eethopun</i> | 0.661 | http://db.worldagroforestry.org/wd/genus | M | |
| 244 | <i>Kirkia burgeri</i> | 0.661 | >> | M | |
| 245 | <i>Lannea fruticosa</i> | 0.515 | http://db.worldagroforestry.org/wd/genus | M | |
| 246 | <i>Lannea schimperi</i> | 0.515 | Genus average | M | |
| 247 | <i>Lannea stuhlmannii</i> | 0.515 | >> | M | |
| 248 | <i>Lannea welwitschii</i> | 0.405 | http://db.worldagroforestry.org/wd/species/Lannea welwitschii | M | |
| 249 | <i>Lantana trifolia</i> | 0.58 | Average of tropical Africa | L | |
| 250 | <i>Lecaniodiscus fraxinifolius</i> | 0.405 | >> | L | |
| 251 | <i>Lecaniodiscus laxiflorus</i> | 0.405 | >> | L | |
| 252 | <i>Lepidotrichilia volkensis</i> | 0.58 | Average of tropical Africa | L | |
| 253 | <i>Lippia citriodora</i> | 0.700 | <i>Lippia mcvaughii</i> | L | |
| 254 | <i>Lippia javanica</i> | 0.700 | >> | L | |
| 255 | <i>Lippia spp.</i> | 0.700 | >> | L | |
| 256 | <i>Lonchocarpus laxiflorus</i> | 0.761 | genus average | M | |
| 257 | <i>Lonicera johnstonii</i> | 0.58 | Average of tropical Africa | L | |
| 258 | <i>Lycium europaeum</i> | 0.58 | Average of tropical Africa | L | |
| 259 | <i>Macaranga capensis</i> | 0.416 | global data base | M | |
| 260 | <i>Macaranga kilimandscharica</i> | 0.404 | Genus average (http://db.worldagroforestry.org/wd/genus/Macaranga) | M | |
| 261 | <i>Maerua angolensis</i> | 0.58 | Average of tropical Africa | L | |
| 262 | <i>Maerua calophylla</i> | 0.58 | Average of tropical Africa | L | |
| 263 | <i>Maerua crassifolia</i> | 0.58 | Average of tropical Africa | L | |
| 264 | <i>Maesa lanceolata</i> | 0.676 | Genus average (http://db.worldagroforestry.org/wd/genus) | M | |
| 265 | <i>Magnifera indica</i> | 0.630 | Wood density of trees of Uganda | L | |
| 266 | <i>Malacantha alnifolia</i> | 0.450 | http://db.worldagroforestry.org/wd/genus/Malacantha | M | |
| 267 | <i>Manilkara butugi</i> | 0.880 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 268 | <i>Manilkora butugi</i> | 0.953 | Average Genus, Africa | M | |
| 269 | <i>Maytenus addat</i> | 0.713 | Genus average(http://db.worldagroforestry.org/wd/genus/Maytenus) | M | |
| 270 | <i>Maytenus arbutifolia</i> | 0.713 | Genus average(http://db.worldagroforestry.org/wd/genus/Maytenus) | M | |
| 271 | <i>Maytenus auriculifera</i> | 0.713 | Genus average(http://db.worldagroforestry.org/wd/genus/Maytenus) | M | |
| 272 | <i>Maytenus gracilipes</i> | 0.713 | Average Genus, Africa | M | |
| 273 | <i>Maytenus heterophylla</i> | 0.495 | http://db.worldagroforestry.org/wd/genus | M | |
| 274 | <i>Maytenus ovatus</i> | 0.403 | Vreugdenhil et al., 2012 | H | |
| 275 | <i>Maytenus senegalensis</i> | 0.713 | http://db.worldagroforestry.org/wd/genus | M | |
| 276 | <i>Maytenus undatus</i> | 0.732 | http://db.worldagroforestry.org/wd/genus | M | |
| 277 | <i>Melacantha alnifolia</i> | 0.620 | Average Genus, Africa | M | |
| 278 | <i>Melia azedarach</i> | 0.463 | http://db.worldagroforestry.org/wd/genus | M | |

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|-----|--------------------------------|------------------------------------|---|---------------|------------------|
| 279 | <i>Milicia excelsa</i> | 0.570 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 280 | <i>Millettia ferruginea</i> | 0.738 | Average Millettia, Africa | M | |
| 281 | <i>Mimusops kummel</i> | 0.856 | Average, Africa (http://db.worldagroforestry.org/wd/genus/Mimusops) | M | |
| 282 | <i>Mimusops kummel</i> | 0.880 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 283 | <i>Mimusops kummel</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 284 | <i>Moringa oleifera</i> | 0.262 | http://db.worldagroforestry.org/wd/genus | M | |
| 285 | <i>Moringa stenopetala</i> | 0.262 | http://db.worldagroforestry.org/wd/genus | M | |
| 286 | <i>Morus alba</i> | 0.622 | http://db.worldagroforestry.org/wd/genus | M | |
| 287 | <i>Morus mesozygia</i> | 0.722 | http://db.worldagroforestry.org/wd/species/Morus_mezozygia | M | |
| 288 | <i>Morus mesozygia</i> | 0.690 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 289 | <i>Myenus reticulata</i> | 0.58 | Average of tropical Africa | L | |
| 290 | <i>Myrica salicifolia</i> | 0.618 | http://db.worldagroforestry.org/wd/species | M | |
| 291 | <i>Myrsine africana</i> | 0.721 | http://db.worldagroforestry.org/wd/species | M | |
| 292 | <i>Myrsine melanophloeos</i> | 0.732 | http://db.worldagroforestry.org/wd/species | M | |
| 293 | <i>Mystroxydon aethiopicum</i> | 0.58 | Average of tropical Africa | L | |
| 294 | <i>Nuxia congesta</i> | 0.512 | Vreugdenhil et al., 2012 | H | |
| 295 | <i>Ocotea kenyensis</i> | 0.545 | Genus average | M | |
| 296 | <i>Ocotea kenyensis</i> | 0.560 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 297 | <i>Ocotea viridis</i> | 0.545 | Genus average | M | |
| 298 | <i>Olea africana</i> | 0.590 | Vreugdenhil et al., 2012 | H | |
| 299 | <i>Olea capensis</i> | 0.805 | http://db.worldagroforestry.org/wd/species/Olea_capensis | M | |
| 300 | <i>Olea capensis</i> | 0.990 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 301 | <i>Olea europaea</i> | 0.807 | http://db.worldagroforestry.org/wd/species/Olea_europaea | M | |
| 302 | <i>Olea hochstetteri</i> | 0.800 | Genus average | M | |
| 303 | <i>Olea welwitschii</i> | 0.814 | http://db.worldagroforestry.org/wd/species/Olea_europaea | M | |
| 304 | <i>Olea welwitschii</i> | 0.820 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 305 | <i>Olinia rochetiana</i> | 0.768 | http://db.worldagroforestry.org/wd/species/Olea_europaea | M | |
| 306 | <i>Olinia Usamberansis</i> | 0.825 | http://db.worldagroforestry.org/wd/species/Olea_europaea | M | |
| 307 | <i>Oncoba spinosa</i> | 0.647 | http://db.worldagroforestry.org/wd/species/Olea_europaea | M | |
| 308 | <i>Opilia campestris</i> | 0.58 | Average of tropical Africa | L | |
| 309 | <i>Ormocarpum mimosoides</i> | 0.742 | <i>Ormocarpum kirkii</i> | L | |
| 310 | <i>Osryia lanceolata</i> | 0.854 | <i>Osyris arborea</i> | L | |
| 311 | <i>Osyris compressa</i> | 0.854 | <i>Osyris arborea</i> | L | |
| 312 | <i>Osyris wightiana</i> | 0.854 | >> | L | |

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|-----|-----------------------------------|------------------------------------|---|---------------|------------------|
| 313 | <i>Otestegia steudneri</i> | 0.58 | Average of tropical Africa | L | |
| 314 | <i>Oxyanthus sp.</i> | 0.525 | Genus value | M | |
| 315 | <i>Oxyanthus speciosus</i> | 0.525 | http://db.worldagroforestry.org/wd/species/Oxyanthus_speciosus | M | |
| 316 | <i>Oxytenanthera abyssinica</i> | 0.608 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 317 | <i>Ozoroa insignis</i> | 0.715 | <i>Ozoroa longipetiolata</i> | L | |
| 318 | <i>Ozoroa pulcherrima</i> | 0.715 | >> | L | |
| 319 | <i>Pappea capensis</i> | 0.883 | http://db.worldagroforestry.org/wd/species/Oxyanthus_speciosus | M | |
| 320 | <i>Persea americana</i> | 0.561 | http://db.worldagroforestry.org/wd/species/Oxyanthus_speciosus | M | |
| 321 | <i>Peterocarpus lucens</i> | 0.58 | Average of tropical Africa | L | |
| 322 | <i>Piliostigma thonningii</i> | 0.371 | Vreugdenhil et al., 2012 | H | |
| 323 | <i>Pinus patula</i> | 0.450 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 324 | <i>Pinus radiata</i> | 0.450 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 325 | <i>Pistacia falcata</i> | 0.720 | http://db.worldagroforestry.org/wd/species/Oxyanthus_speciosus | M | |
| 326 | <i>Pistacia lentiscus</i> | 0.720 | Genus average | M | |
| 327 | <i>Pittosporum abyssinicum</i> | 0.645 | Genus average (http://db.worldagroforestry.org/wd/species/Pittosporum_abyssinicum) | M | |
| 328 | <i>Pittosporum viridiflorum</i> | 0.633 | http://db.worldagroforestry.org/wd/species/Oxyanthus_speciosus | M | air dry density] |
| 329 | <i>Podocarpus falcatus</i> | 0.523 | Genus average (http://db.worldagroforestry.org/wd/genus/Podocarpus) | M | |
| 330 | <i>Podocarpus falcatus</i> | 0.520 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 331 | <i>Polyscias ferruginea</i> | 0.286 | http://db.worldagroforestry.org/wd/species/Polyscias_ferruginea | M | |
| 332 | <i>Polyscias fulva</i> | 0.440 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 333 | <i>Polyscias ferrogenia</i> | 0.38 | <i>Polyscias nodosa</i> | L | |
| 334 | <i>Pouteria adolfi-friederici</i> | 0.600 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 335 | <i>Pouteria abyssinica</i> | 0.711 | Genus average (http://db.worldagroforestry.org/wd/species/Pouteria) | M | |
| 336 | <i>Pouteria altissima</i> | 0.442 | http://db.worldagroforestry.org/wd/species/Pouteria_altissima | M | |
| 337 | <i>Premna schimperi</i> | 0.658 | Average Genus (http://db.worldagroforestry.org/wd/genus/Premna) | M | |
| 338 | <i>Prosopis juliflora</i> | 0.827 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 339 | <i>Protea gaguedi</i> | 0.663 | <i>Protea angolensis</i> | L | |
| 340 | <i>Prunus africana</i> | 0.850 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 341 | <i>Prunus persica</i> | 0.588 | Genus average (http://db.worldagroforestry.org/wd/species/Pouteria) | M | |
| 342 | <i>Pseudocedrela kotschy</i> | 0.621 | http://db.worldagroforestry.org/wd/species/Pouteria_altissima | M | |

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|-----|------------------------------------|------------------------------------|---|---------------|--------|
| 343 | <i>Psidium guajava</i> | 0.859 | Genus average (http://db.worldagroforestry.org/wd/species/Pouteria) | M | |
| 344 | <i>Psydrax schimperiana</i> | 0.743 | Genus average (http://db.worldagroforestry.org/wd/species/Pouteria) | M | |
| 345 | <i>Pterolobium stellatum</i> | 0.58 | Average of tropical Africa | L | |
| 346 | <i>Rabus steudneri</i> | 0.58 | Average of tropical Africa | L | |
| 347 | <i>Rapanea melanophixas</i> | 0.732 | http://db.worldagroforestry.org/wd/species/Pouteria_altissima | M | |
| 348 | <i>Rapanea simensis</i> | 0.722 | genus average | L | |
| 349 | <i>Rhamnus prinoides</i> | 0.579 | genus average | L | |
| 350 | <i>Rhamnus sp.</i> | 0.579 | Genus average | L | |
| 351 | <i>Rhinorea friisii</i> | 0.689 | <i>R. ferruginea</i> | L | |
| 352 | <i>Rhinorea laxiflora</i> | 0.689 | <i>R. ferruginea</i> | L | |
| 353 | <i>Rhoicissus tridentata</i> | 0.538 | <i>R. revoilii</i> | L | |
| 354 | <i>Rhus glutinosa</i> | 0.620 | genus average | M | |
| 355 | <i>Rhus natalensis</i> | 0.620 | genus average | M | |
| 356 | <i>Rhus retinorrhoea</i> | 0.620 | genus average | M | |
| 357 | <i>Rhus vulgaris</i> | 0.620 | genus average | M | |
| 358 | <i>Rothmania urcelliformis</i> | 0.642 | Africa (extratropical): global database | L | |
| 359 | <i>Rothmannia whitfieldii</i> | 0.745 | <i>R. Fischeri: global database</i> | L | |
| 360 | <i>Rubus steudneri</i> | 0.350 | <i>Rubus alceifolius: global database</i> | L | |
| 361 | <i>Rumex nervosus</i> | 0.58 | Average of tropical Africa | M | |
| 362 | <i>Salix subserata</i> | 0.525 | http://db.worldagroforestry.org/wd/species/Sapium_ellipticum | M | |
| 363 | <i>Sapium ellipticum</i> | 0.576 | http://db.worldagroforestry.org/wd/species/Sapium_ellipticum | M | |
| 364 | <i>Schefflera abyssinica</i> | 0.405 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 365 | <i>Schefflera abyssinica</i> | 0.491 | Vreugdenhil et al., 2012 | H | |
| 366 | <i>Schefflera volkensii</i> | 0.405 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 367 | <i>Scherebera alata</i> | 0.790 | Uganda data | M | |
| 368 | <i>Sclerocarya birrea</i> | 0.515 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 369 | <i>Securidaca longepedunculata</i> | 0.880 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 370 | <i>Securidaca virosa</i> | 0.880 | <i>Securidaca longepedunculata</i> | L | |
| 371 | <i>Senna singueana</i> | 0.706 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 372 | <i>Sideroxylon oxyacantha</i> | 0.715 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 373 | <i>Sideroxylon sp.</i> | 0.715 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 374 | <i>Solanum incanum</i> | 0.428 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 375 | <i>Spathodea nilotica</i> | 0.504 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 376 | <i>Steganotaenia</i> | 0.370 | Uganda data | M | |

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|-----|------------------------------------|------------------------------------|---|---------------|------------------|
| | <i>araliacea</i> | | | | |
| 377 | <i>Sterculia africana</i> | 0.482 | Vreugdenhil et al., 2012 | H | |
| 378 | <i>Sterculia setigera</i> | 0.320 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 379 | <i>Stereospermum kunthianum</i> | 0.741 | Vreugdenhil et al., 2012 | H | |
| 380 | <i>Strychnos innocua</i> | 0.870 | http://db.worldagroforestry.org/wd/species/Schefflera_abyssinica | M | |
| 381 | <i>Strychnos mitis</i> | 0.733 | http://db.worldagroforestry.org/wd/genus/Strychnos | M | |
| 382 | <i>Strychnos spinosa</i> | 0.733 | genus average | M | |
| 383 | <i>Syzygium guineense</i> | 0.712 | http://db.worldagroforestry.org/wd/genus/Syzygium | M | |
| 384 | <i>Syzygium guineense</i> | 0.740 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 385 | <i>Tamarindus indica</i> | 0.624 | Vreugdenhil et al., 2012 | H | |
| 386 | <i>Tapura fisherii</i> | 0.660 | Genus average: global database | M | |
| 387 | <i>Teclea nobilis</i> | 0.798 | http://db.worldagroforestry.org/wd/genus/Teclea | M | |
| 388 | <i>Teclea simplicifolia</i> | 0.798 | <i>Teclea nobilis</i> | L | |
| 389 | <i>Terminalia laxiflora</i> | 0.654 | genus average | M | |
| 390 | <i>Terminalia brownii</i> | 0.654 | Average of genus (http://db.worldagroforestry.org/wd/genus/Terminalia) | M | |
| 391 | <i>Terminalia brownii</i> | 0.495 | Vreugdenhil et al., 2012 | H | |
| 392 | <i>Terminalia laxiflora</i> | 0.574 | Vreugdenhil et al., 2012 | H | |
| 393 | <i>Terminalia macroptera</i> | 0.819 | http://db.worldagroforestry.org/wd/genus/Teclea | M | |
| 394 | <i>Terminalia mollis</i> | 0.654 | genus average | M | |
| 395 | <i>Terminalia prundioides</i> | 0.654 | genus average | M | |
| 396 | <i>Terminalia schimperiana</i> | 0.654 | genus average | M | |
| 397 | <i>Terminalia sopinos</i> | 0.654 | genus average | M | |
| 398 | <i>Thunbergia alata</i> | 0.640 | Uganda data | M | |
| 399 | <i>Toddalia asiatica</i> | 0.798 | <i>Toddalia nobilis</i> | L | |
| 400 | <i>Trema guineensis</i> | 0.366 | genus average | M | |
| 401 | <i>Trema orientalis</i> | 0.366 | genus average | M | |
| 402 | <i>Trichilea prieuriana</i> | 0.647 | http://db.worldagroforestry.org/wd/species/Trichilea_prieuriana | M | |
| 403 | <i>Trichilia dregeana</i> | 0.482 | http://db.worldagroforestry.org/wd/species/Trichilea_prieuriana | M | |
| 404 | <i>Trichilia madagascariense</i> | 0.622 | http://db.worldagroforestry.org/wd/species/Trichilea_prieuriana | M | |
| 405 | <i>Trichilia puerianu</i> | 0.622 | http://db.worldagroforestry.org/wd/species/Trichilea_prieuriana | M | |
| 406 | <i>Trichocladus ellipticus</i> | 0.640 | Uganda data | M | |
| 407 | <i>Trilepisium madagariense</i> | 0.499 | http://db.worldagroforestry.org/wd/species/Trilepisium_madagariense | M | |
| 408 | <i>Trilepisium madagascariense</i> | 0.560 | Getachew Desalegn et al., 2012 | H | |
| 409 | <i>Urera hypselodendron</i> | 0.324 | average of genus (http://db.worldagroforestry.org/wd/genus/Urera) | M | air dry density |

| No | Scientific name | Basic Density (g/cm ³) | Reference | Data quality* | Remark |
|-----|-------------------------------|------------------------------------|---|---------------|------------------|
| 410 | <i>Vepris dainellii</i> | 0.700 | <i>Vepris undulate</i> | L | |
| 411 | <i>Vernonia amygdalina</i> | 0.413 | average (http://db.worldagroforestry.org/wd/genus/Vernonia) | M | |
| 412 | <i>Vernonia auriclifera</i> | 0.413 | average (http://db.worldagroforestry.org/wd/genus/Vernonia) | M | |
| 413 | <i>Warburgia ugandensis</i> | 0.865 | http://db.worldagroforestry.org/wd/species/Warburgia_ugandensis | M | |
| 414 | <i>Warburgia ugandensis</i> | 0.770 | Getachew Desalegn et al., 2012 | H | air dry density] |
| 415 | <i>Ximenia americana</i> | 0.867 | http://db.worldagroforestry.org/wd/species/Warburgia_ugandensis | M | |
| 416 | <i>Ximenia caffra</i> | 0.812 | genus average | M | |
| 417 | <i>Zanthoxylum chalybeum</i> | 0.629 | http://db.worldagroforestry.org/wd/species/Warburgia_ugandensis | M | |
| 418 | <i>Ziziphus mauritania</i> | 0.711 | http://db.worldagroforestry.org/wd/species/Warburgia_ugandensis | M | |
| 419 | <i>Ziziphus mucronata</i> | 0.758 | http://db.worldagroforestry.org/wd/species/Warburgia_ugandensis | M | |
| 420 | <i>Ziziphus spina-christi</i> | 0.482 | Vreugdenhil et al., 2012 | H | |

* data quality refers to author's personal judgement of the goodness of the wood density value depending on whether they are locally relevant or not. L = low; M = medium and H = high quality.