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 breadth 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

2. 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 CO_2 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 tCO_2 /year; the Forest Reference Level for afforestation is: 4.789.935 tCO_2 /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.

3. 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.

4. 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.

5. SCOPE: ACTIVITIES, POOLS AND GASES INCLUDED

5.1. 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.

5.2. 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.

5.3. GASES IN THE FRL

The proposed FRL only includes CO_2 emissions. Non- CO_2 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- CO_2 gases, a calculation is proposed to estimate the likely range of non- CO_2 emissions by calculating annual non- CO_2 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-CO_2 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- CO_2 to total forest-related emissions is in the range of 0.1 – 37.000 t CO_2 eq for CO, 0.1 – 33.000 t CO_2 eq for CH4 and 3000 – 11.000 t CO_2 eq for N2O. Therefore the contribution of non CO_2 gases is estimated to be <2% of total annual emissions from forest land in Ethiopia.

5.4. 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, MEFCC, 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.

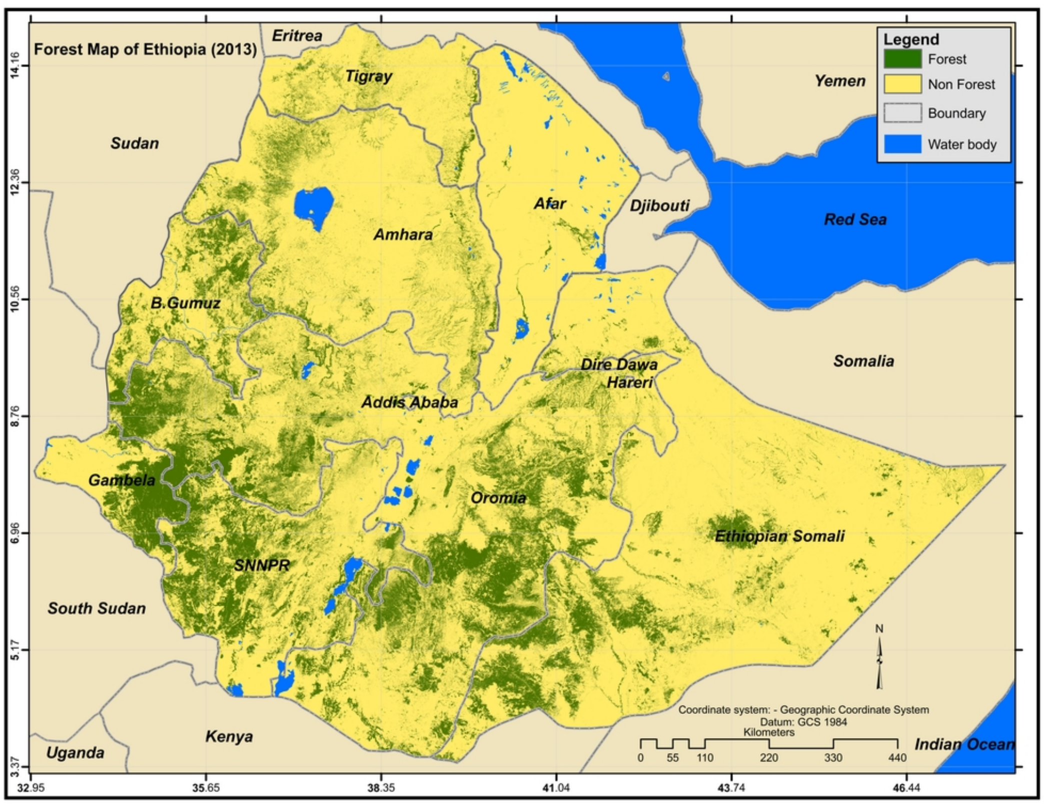


Figure 1: Extent of the forest cover under the current Ethiopia's forest definition

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 earlier[1], 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.

5.5. 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

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

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.

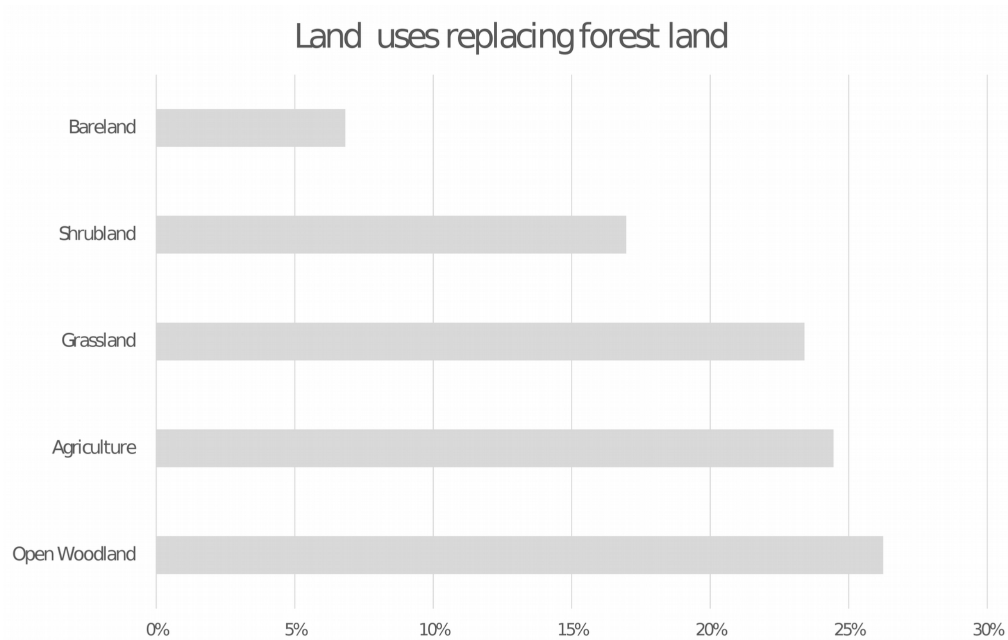


Figure 2: Land-uses replacing forest over the period 2000-2013 (as % of the total forest loss over this period)

6. 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.

7. 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.

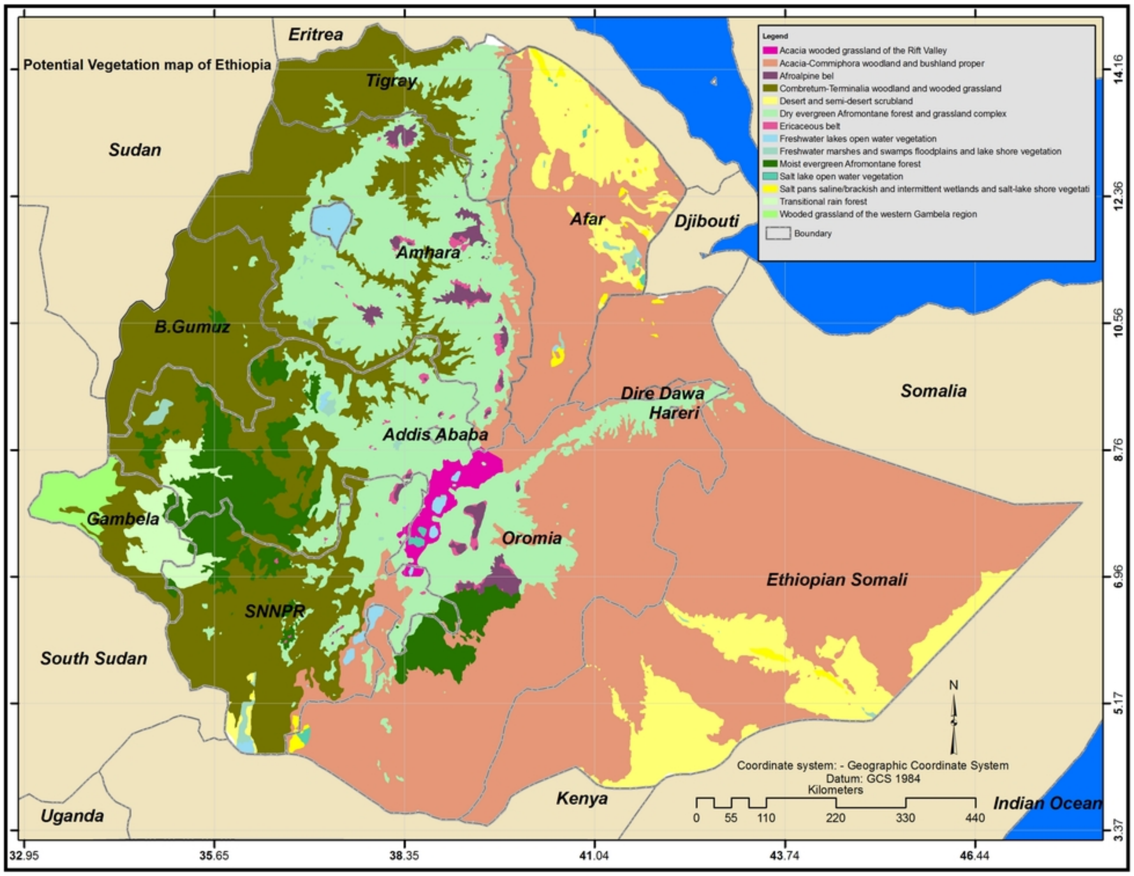


Figure 3: Potential vegetation map of Ethiopia

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).

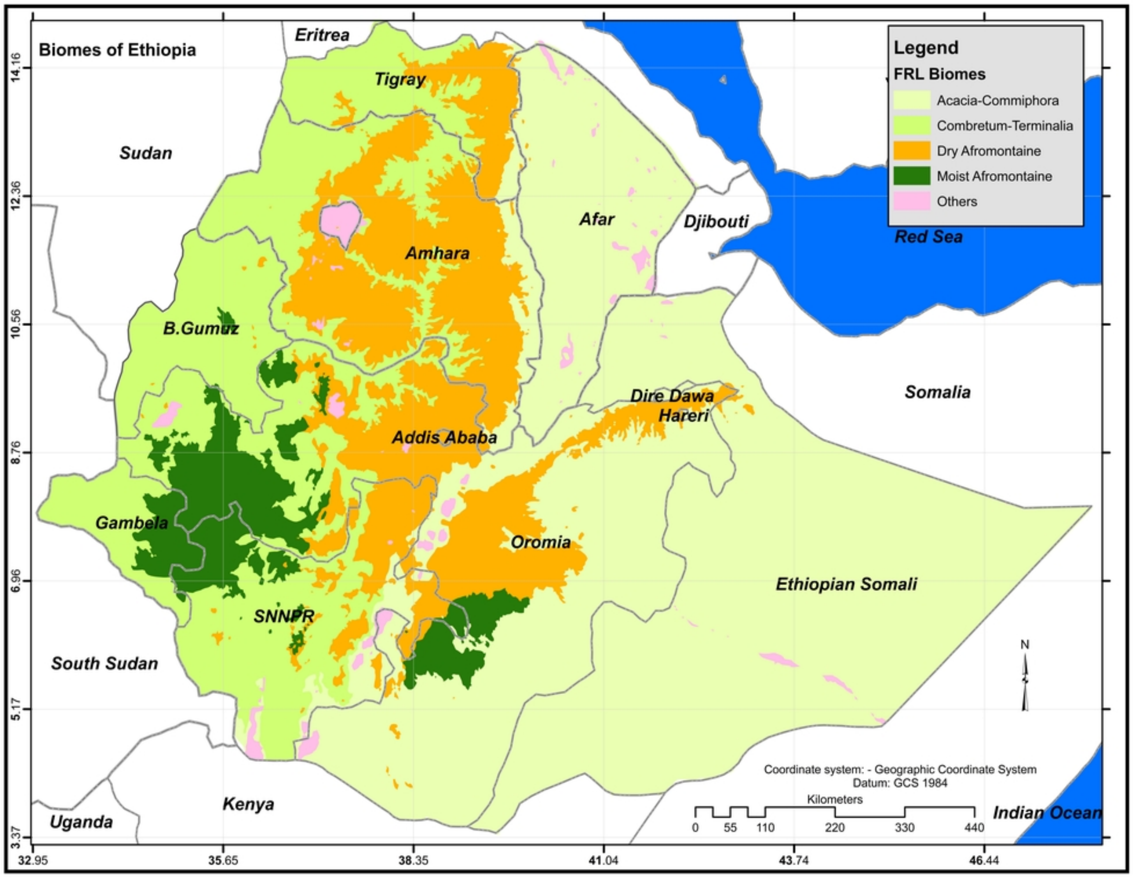


Figure 4: Biomes of Ethiopia

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 (*Friis and Sebsebe 2009*)**
1	Acacia-Commiphora	*Acacia-Commiphora* woodland and bushland (ACB); Acacia wooded grassland (ACB/RV); Desert and semi-desert scrubland (DSS)
2	Combretum-Terminalia	*Combretum-Terminalia* 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	

8. 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).

8.1. 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 *graminea* and herbaceous vegetation or a land sown *with introduced grass and leguminous for the grazing of livestock.*
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 ≤ 10% or combined cover of bush, and shrubs ≤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 graminea and herbaceous vegetation, with some scattered trees (tree canopy cover less than 3% . it is composed of a canopy of grass wooded ecosystem of *Combretum-Terminalia* and *Acacia-Commiphora* 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	Afrolpine	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 *Erica arborea*, *E. trimera* and *Hypericum revolutum*. Among herbs in this zone are the giant lobelia L*obelia rhynchopetalum, Kniphofia foliosa, Bartsia petitiana* and various A*lchemilla species. Festuca, Poa* and *Agrostis spp.* 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 *Moraceae, Spidandaceae, mimosaceae* etc
16	Water body	Area occupied by major rivers of perennial or intermittent (width ≥ 15m), lakes, ponds and reservoirs.

8.2. 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 ≥ 2m and canopy cover ≥ 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%.

8.3. 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 data[2], 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 anomalies[3]. 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.

8.4. 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 images. 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 labelling. 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)

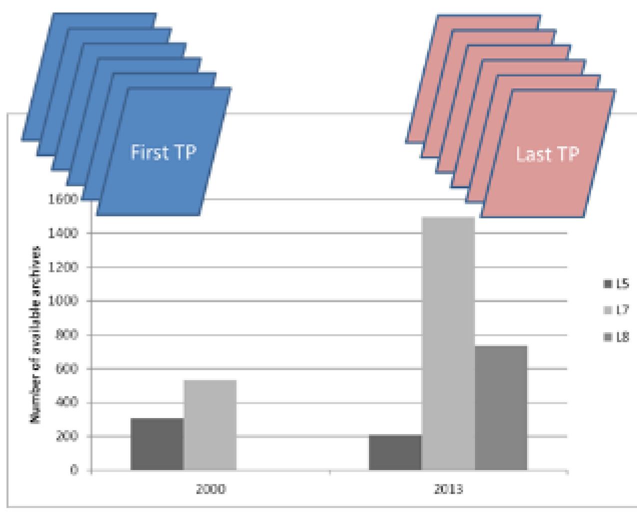


Figure 6: Number of available Landsat archives queried to create a best pixel mosaic in Google Earth Engine.

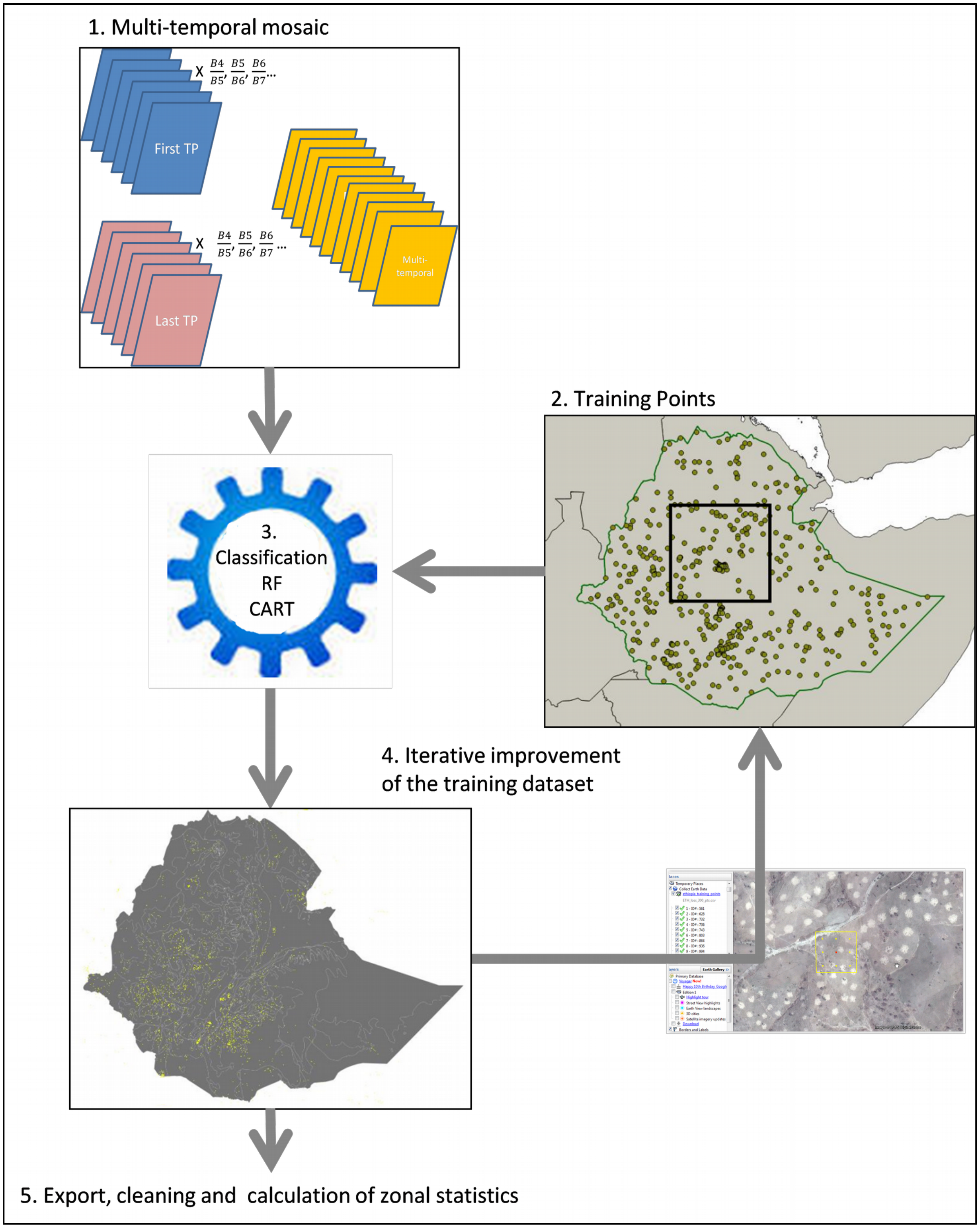


Figure 7: Iterative classification process for change detection.

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**					
		FL	**FG**	**SF**	**SNF**	**Total**	**User's accuracy**
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		
		FL	FG	Map area
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 ha – 88,616 ha – 53,170 ha– 221,540 ha + 824 ha + 907,955 ha = 1,192,559 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:

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

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%

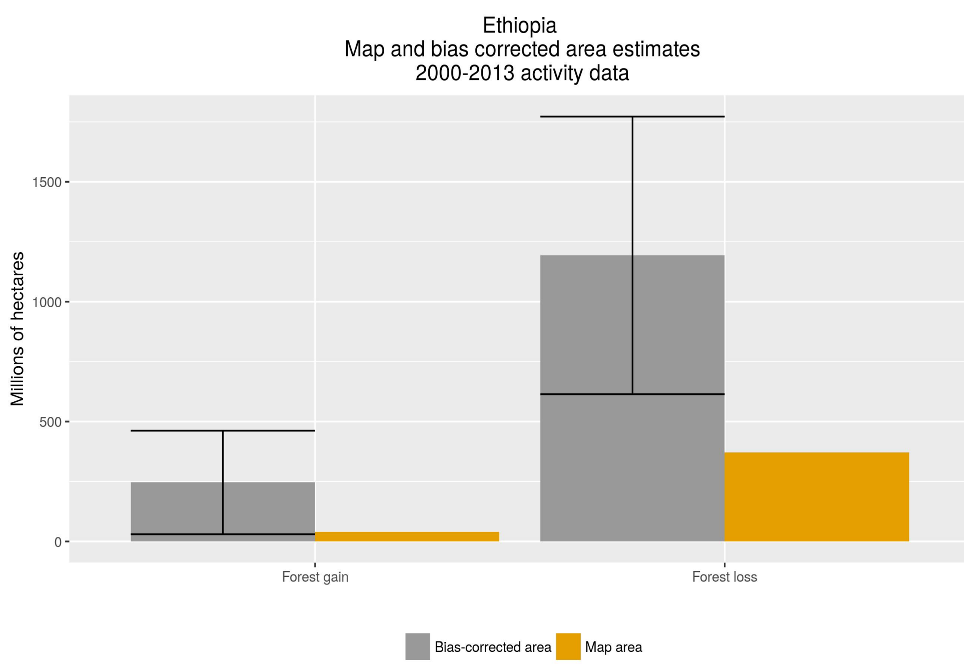


Figure 8: Map and bias-corrected area estimates of the AD

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**

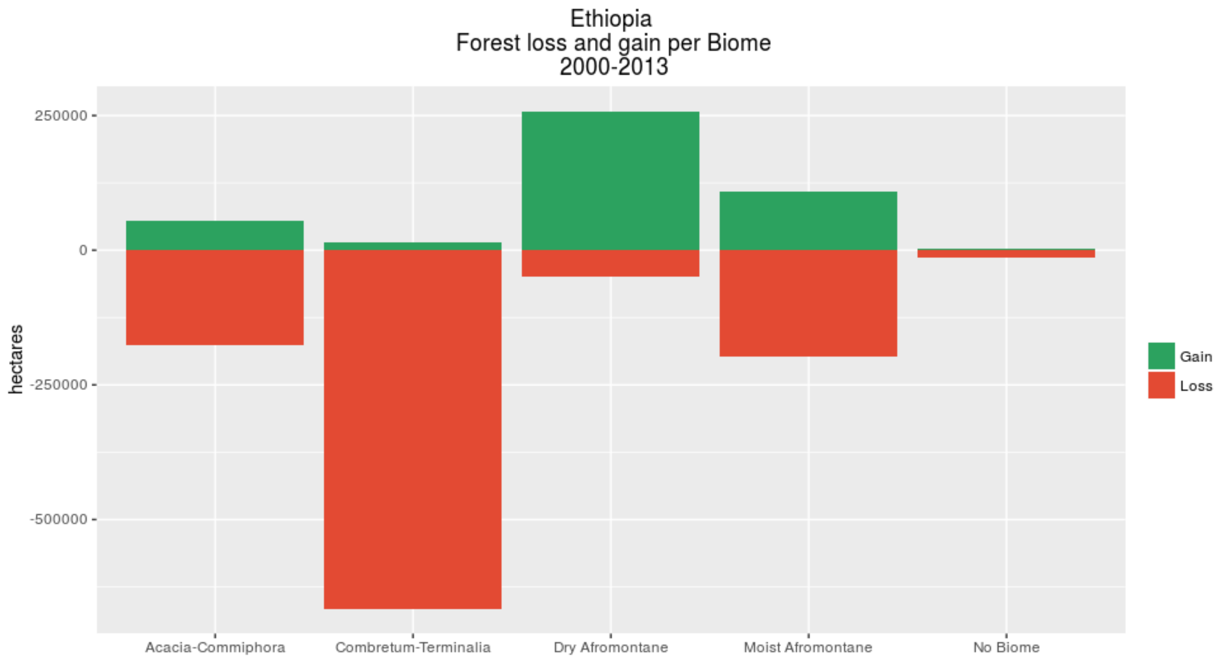


Figure 9: National forest area change detection 2000-2013 by biome.

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. Remoting 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.

9. EMISSION FACTORS: NFI DATA ANALYSIS

9.1. 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 x 1/4 degree square and triangular combination grids plots coordinates were generated in the Stratum I, while a ½ x ½ degree square and triangular combination grids were used for Strata II and IV, ½ x ½ degree square grid for Stratum III, and a 1x1 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 *Acacia Commiphora* woodland of Somali, SNNPRs and Afar regions	135
III	Comprises mainly the woodland ecosystem found in the North and South Western woodland parts where *Combretum-Terminalia* 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

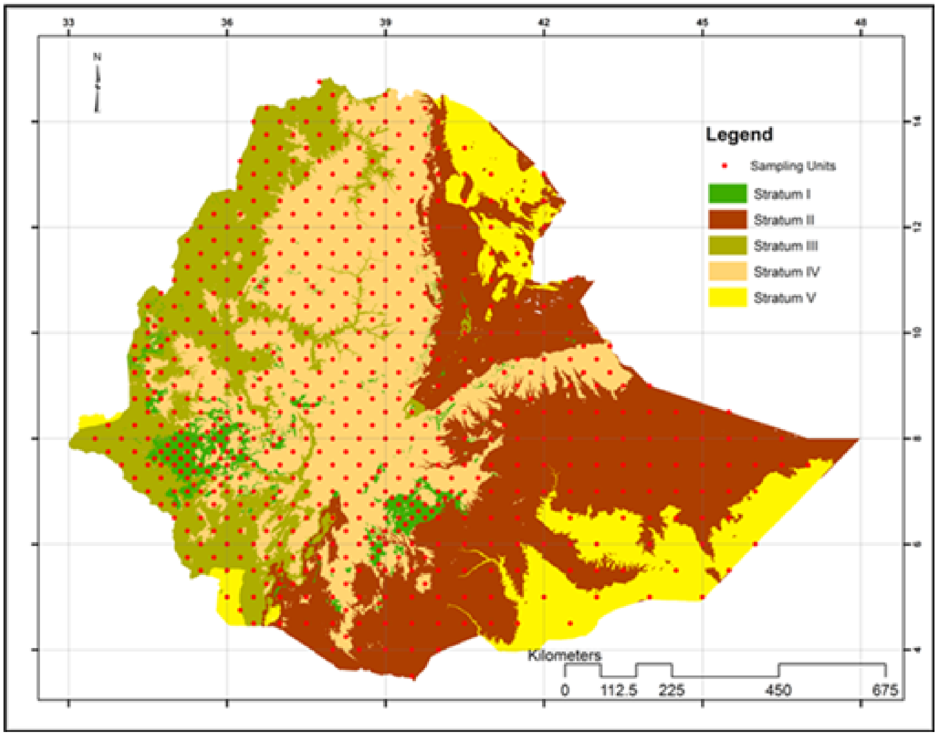


Figure 10: NFI sample unit per stratum

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).

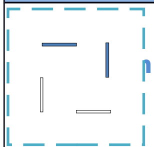
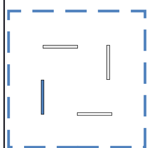
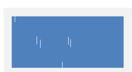
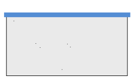
<table>
<tr><th colspan="2" rowspan="2">Data collection level</th><th colspan="3">Measurements and observations</th></tr>
<tr><th>Forest</th><th>Other Wooded Lands and Woodlots (0.2-0.5ha)</th><th>Other lands</th></tr>
<tr><td> pling</td><td></td><td colspan="3">- Localisation and access to SU
- Size: 1000 m x 1000 m (1 km²)</td></tr>
<tr><td></td><td></td><td>- Measurement of trees with Dbh ≥ 20 cm
- Size: 250 m x 20 (5000 m²)</td><td colspan="2">- Measurement of trees with Dbh ≥ 10 cm</td></tr>
<tr><td></td><td></td><td colspan="2">- Count of trees with Dbh < 10cm and height ≥ 1.30m, by species</td><td>None</td></tr>
<tr><td rowspan="3"> Rectangular Subplot</td><td rowspan="3">Measurement of trees with 10cm ≤ Dbh < 20cm</td><td>None</td><td colspan="2">None</td></tr>
<tr><td colspan="2">- Shrubs, bushes (count or measurement by species)</td><td>None</td></tr>
<tr><td colspan="2">- Presence or abundance or count of indicator plant species, NWFP
Size 20m x 10m</td><td>- Indicator plant species</td></tr>
<tr><td> Fallen Deadwood Transect</td><td></td><td colspan="3">- Measurements of fallen deadwood branches (diameter ≥ 2.5 cm)
Size: 20 m</td></tr>
<tr><td rowspan="2">Land Use/Cover Section (LUCS)</td><td rowspan="2"></td><td colspan="3">- Land Use/Cover class
- General information related to the area (designation, land tenure…)
- Vegetation cover (trees, shrubs, grass)
(- Environmental problems, fires, erosion, grazing activities)</td></tr>
<tr><td colspan="2">- Stand structure and management: harvesting, silviculture, management plan...
- Human-induced disturbances</td><td>- Crop management practices</td></tr>
</table>

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

Analysis of NFI Data

According to the Globallometree online database (http://globallometree.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, MEFCC 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

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

For fallen deadwood, the De Vries' formula (De Vries, 1986) was applied, estimating log volume in m3 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					
	Acacia-Commiphora	**Combretum-Terminalia**	**Dry Afromontane**	**Moist Afromontane**	**Others**	**Total**
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.

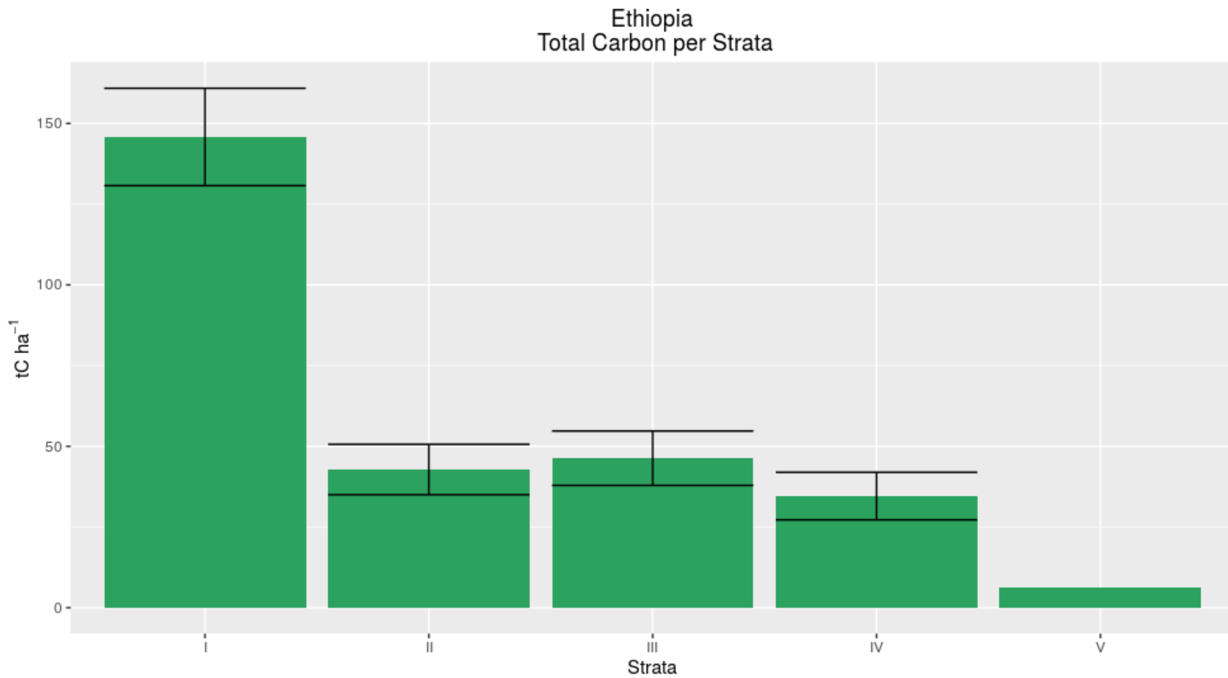


Figure 11: Carbon estimated per strata per all the land uses

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:

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

Where:

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

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:

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

- $\check{e}_{ks}$ and the π_k-expanded covariance of sampling indicators and variance indicated by the Bernouilli 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:

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

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

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

While

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

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

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

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

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

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

$$\breve{\Delta}_{kk} = 1 - \pi_k$$

To summarize, the

equals 0 whenever k is different from l.

The variance formula can be then approximated to:

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

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:

	Ecological Zones						
Biomes	**Tropical desert**	**Tropical dry forest**	**Tropical moist deciduous forest**	**Tropical mountain system**	**Tropical shrubland**	**Water**	**Total Result**
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.

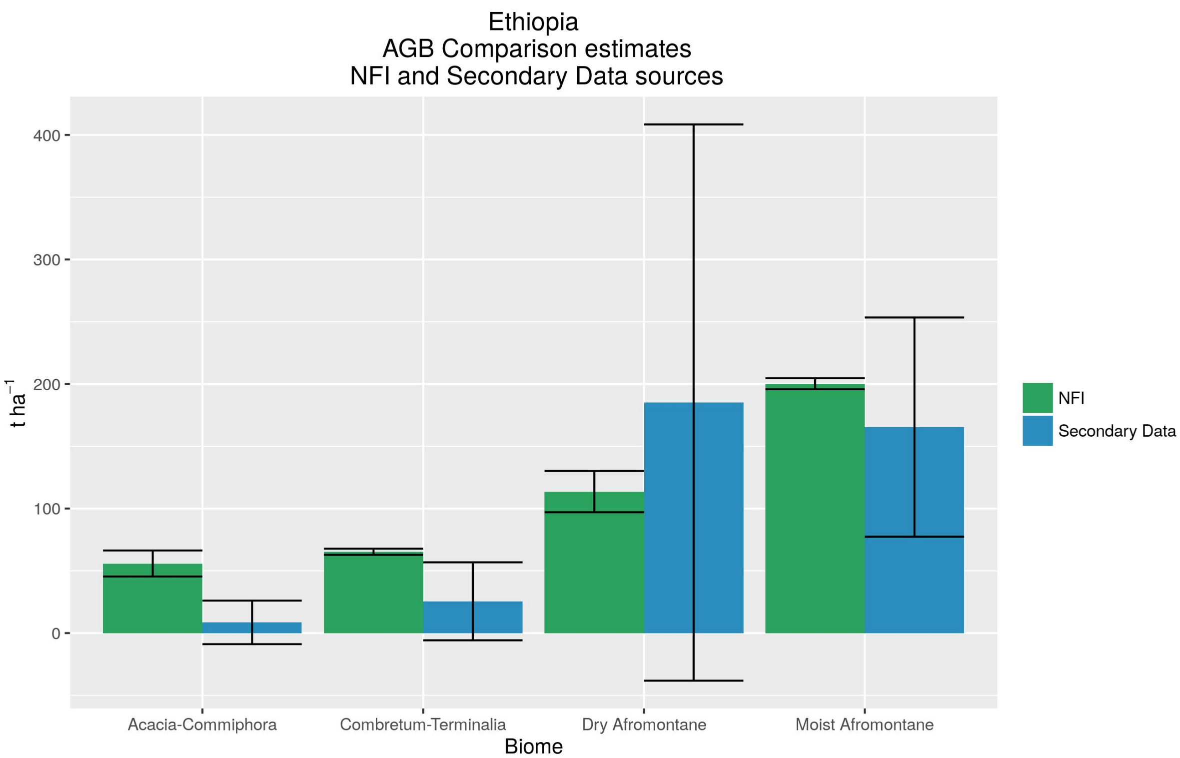


Figure 12: The average AGB (tC/ha) with their confidence intervals for forest in the 4 biomes is compared between primary (NFI) and secondary (literature and local studies)

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 forest, 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 the 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 sy-stems*	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.

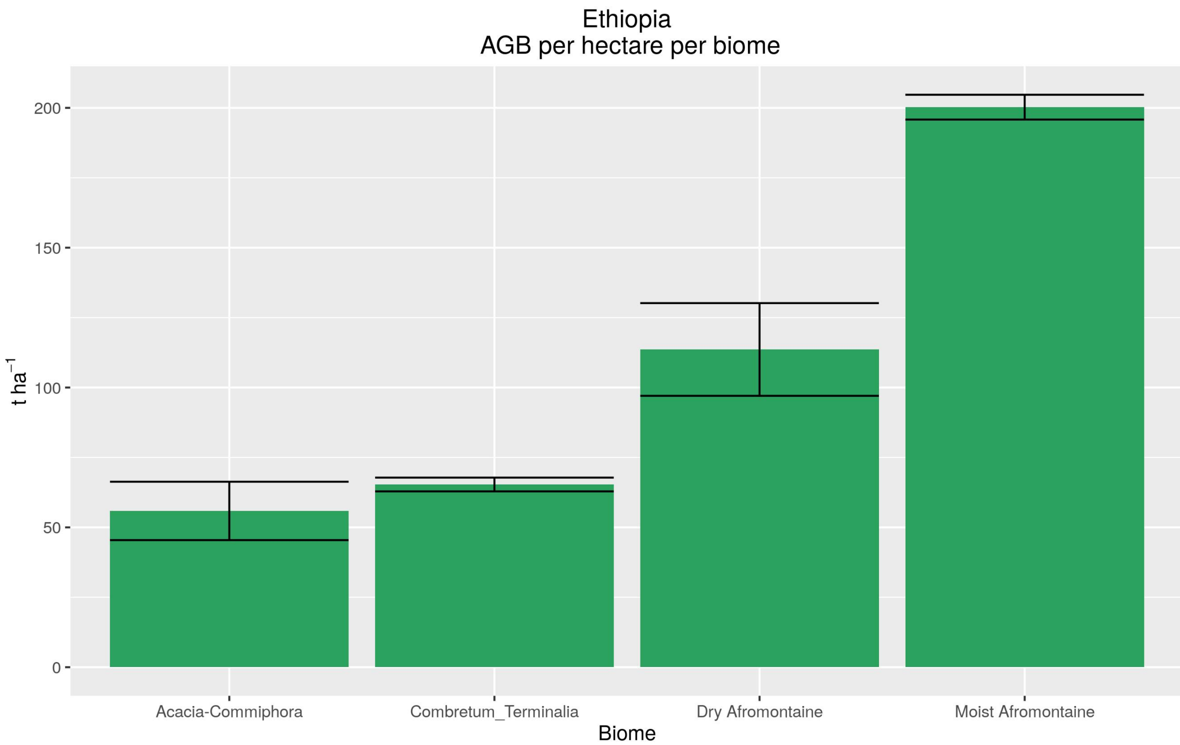


Figure 13: NFI results for the average AGB carbon stock per biome in forest

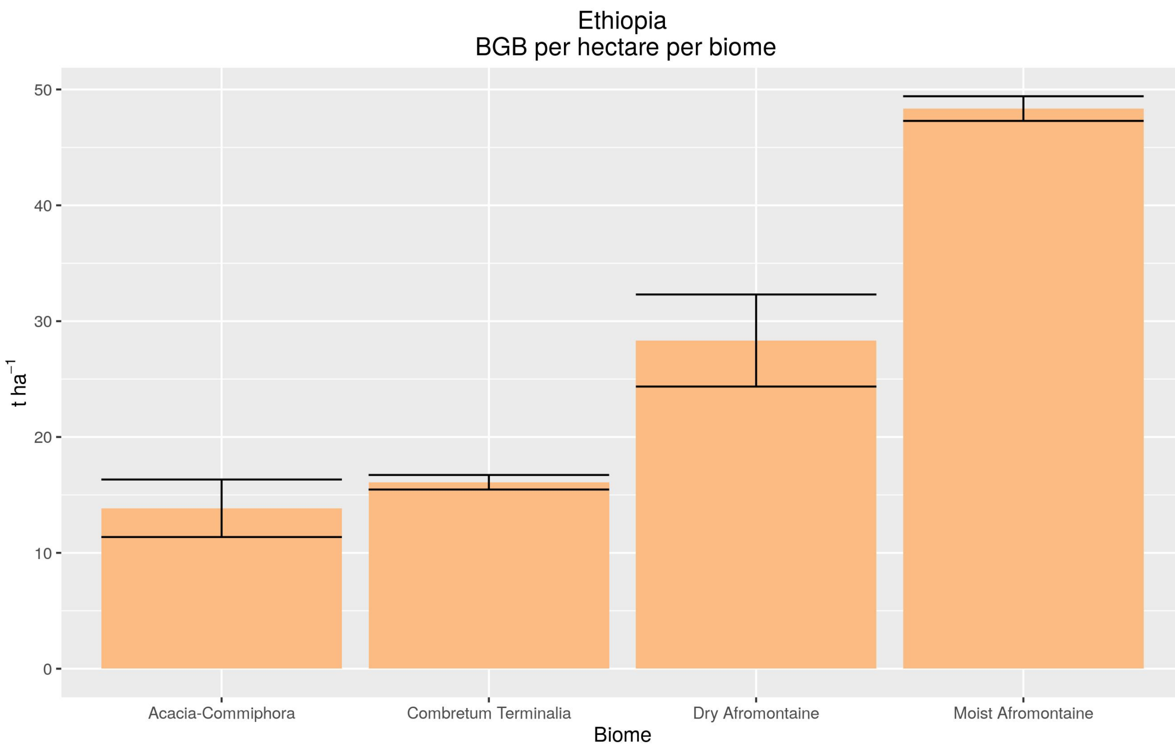


Figure 14: NFI results for the average BGB carbon stock per biome in forest

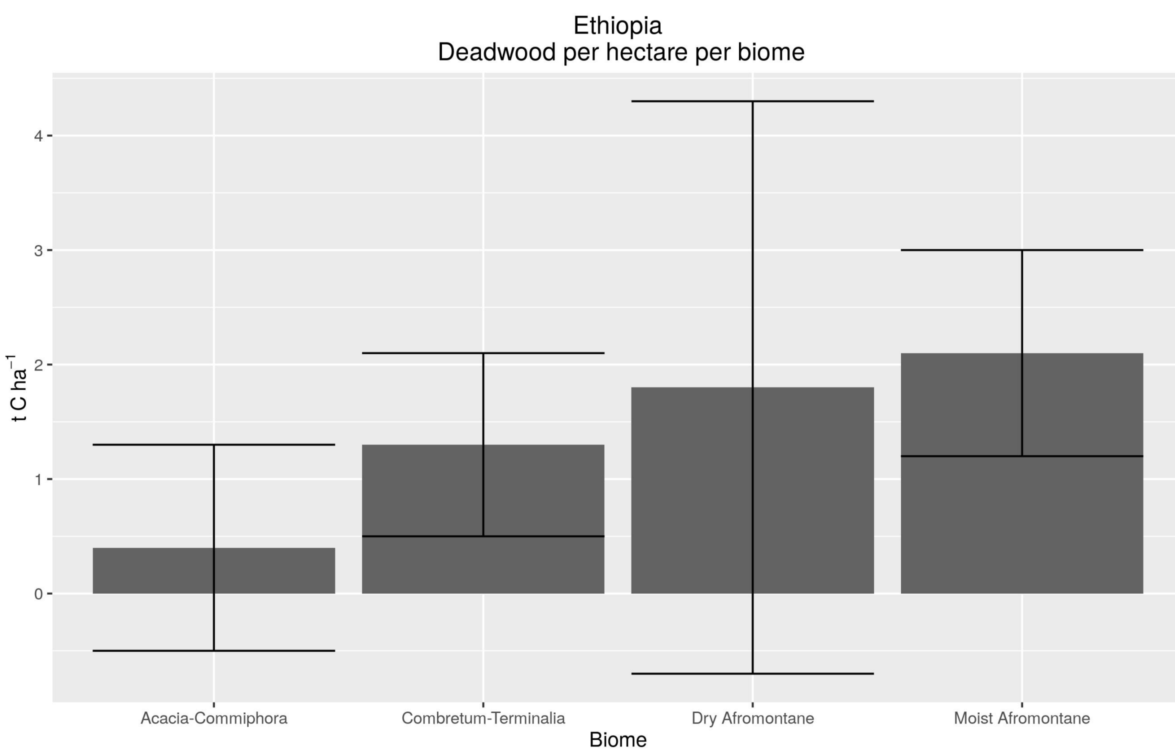


Figure 15: NFI results for deadwood carbon stock per biome in forest

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).

10. 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.

11. PROPOSED FOREST REFERENCE LEVEL

11.1. 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 CO_2 e/yr while the removals from afforestation are assessed at 4.8. mln t CO_2 e/yr.

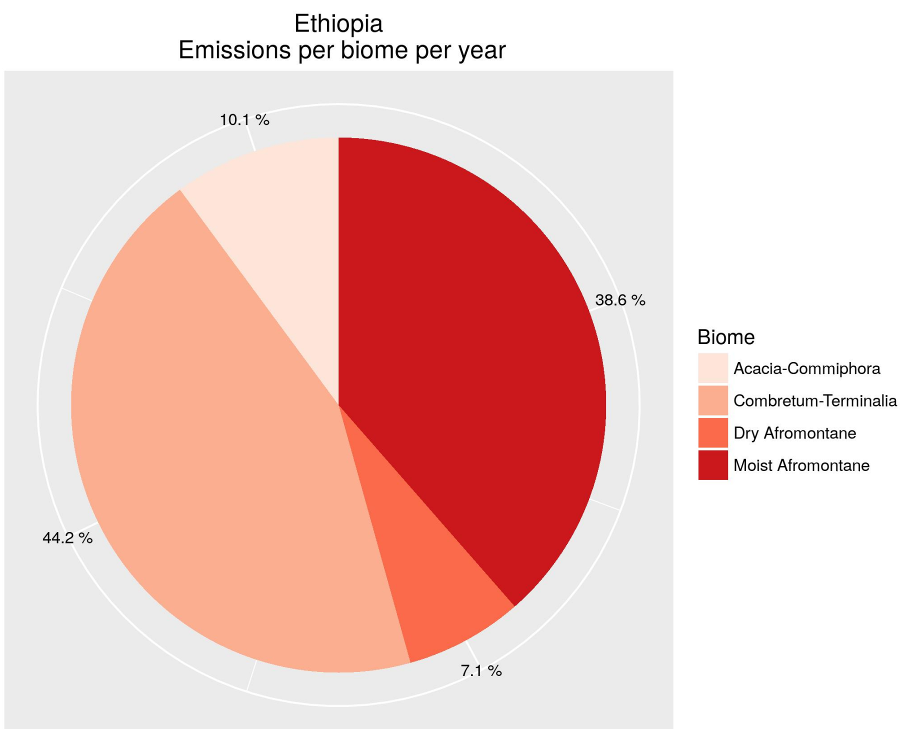


Figure 16: Emission by Biome.

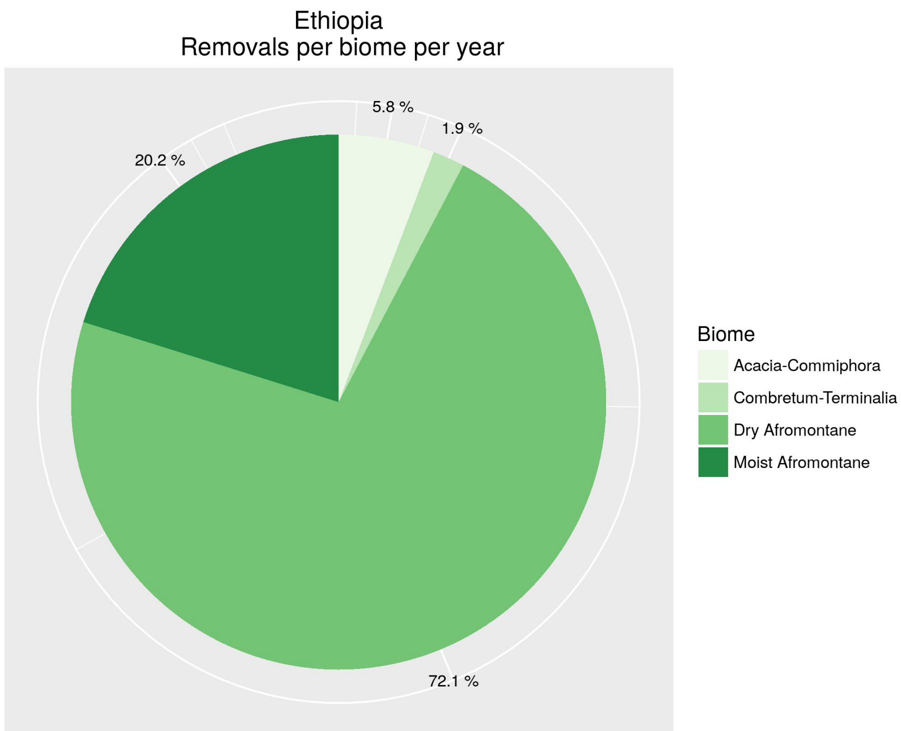


Figure 17: Reductions per biome

12. 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 5 years, yet it may be improved or completed more frequently. Ethiopia is also evaluating the possibility of undertaking a new region based forest inventory, with a 5 year cycle.

13. 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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15. ANNEX

15.1. 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.*

15.2.ANNEX II

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

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
1	*Acacia abyssinica*	0.826	average of genus (ICRAF database)	M	
2	*Acacia albida*	0.562	http://www.worldagroforestry.org/regions/southeast_asia/resources/db/wd	M	
3	*Acacia asak*	0.769	average of genus (ICRAF database)	M	
4	*Acacia brevispica*	0.769	>>	M	
5	*Acacia bussei*	0.769	>>	M	
6	*Acacia decurrens*	0.816	Getachew Desalegn et al., 2012	H	Air dry density
7	*Acacia dolichocephala*	0.769	average of genus	M	
8	*Acacia drepanolobium*	0.769	>>	M	
9	*Acacia etbaica*	0.590	Vreugdenhil et al., 2012	H	
10	*Acacia gerrardii*	0.775	Tropical Africa: global database (Zanne et al., 2009)	M	
11	*Acacia goetzei*	0.883	>>	M	
12	*Acacia hokii*	0.769	average of genus (ICRAF database)	M	
13	*Acacia lahai*	0.769	>>	M	
14	*Acacia macrothyrsa*	0.769	>>	M	
15	*Acacia mellifera*	0.482	Vreugdenhil et al., 2012	H	
16	*Acacia mollis*	0.482	Vreugdenhil et al., 2012	H	
17	*Acacia nilotica*	0.723	Vreugdenhil et al., 2012	H	
18	*Acacia oerofota*	0.769	average of genus	M	
19	*Acacia pentagon*	0.826	average of genus (ICRAF database)	M	
20	*Acacia polyacantha*	0.769	average of genus	M	
21	*Acacia reficiens*	0.769	>>	M	
22	*Acacia robusta*	0.769	>>	M	
23	*Acacia senegal*	0.741	Vreugdenhil et al., 2012	H	
24	*Acacia seyal*	0.497	Vreugdenhil et al., 2012	H	
25	*Acacia sieberiana*	0.769	average of genus	M	
26	*Acacia tortilis*	0.590	Vreugdenhil et al., 2012	H	
27	*Acacia xiphocarpa*	0.769	average of genus	M	
28	*Acacia Zanzibarica*	0.769	average of genus	M	
29	*Acallypha acrogyna*	0.300	A. Cauturus (Zanne et al.; global database),	L	
30	*Acanthus sp.*	0.592	Global database (Zanne et al., 2009)	M	
31	*Acokanthera schimperi*	0.784	*Acokanthera oppositifolia (from Global database)*	L	
32	*Acrocarpus fraxinifolius*	0.610	Getachew Desalegn et al., 2012	H	air dry density
33	*Adansonia digitata*	0.590	Vreugdenhil et al., 2012	H	
34	*Adathada schimperiana*	0.640	same species from wood density for trees of Uganda	L	
35	*Alangium chinense*	0.420	http://db.worldagroforestry.org//wd/species/Alangium_chinense	M	
36	*Alangium Chinese*	0.408	>>	M	
37	*Albizia aylemeri*	0.579	Genus average	M	
38	*Albizia glaberiima*	0.555	http://db.worldagroforestry.org//wd/species/Alangium_chinense	M	
39	*Albizia*	0.534	Albizia gummifera	L	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
	grandibracteata				
40	*Albizia gummifera*	0.580	Getachew Desalegn et al., 2012	H	air dry density
41	*Albizia lebbeck*	0.596	http://db.worldagroforestry.org//wd/species/Alangium_chinense	M	
42	*Albizia lophantha*	0.579	Genus average	M	
43	*Albizia malacophylla*	0.579	Genus average	M	
44	*Albizia schimperiana*	0.530	Getachew Desalegn et al., 2012	H	air dry density
45	*Alchernea laxiflora*	0.525	*A. hirtella; Zanne et al.; global database*	L	
46	*Alchornea euphorbiacae*	0.525	>>	L	
47	*Alihornea euphorbiscara*	0.525	>>	L	
48	*Allophylus abyssinicus*	0.580	Getachew Desalegn et al., 2012	H	air dry density
49	*Allophylus abyssinicus*	0.491	Vreugdenhil et al., 2012	H	
50	*Allophylus rubifolius*	0.494	Genus average	M	
51	*Alstonia boonei*	0.387	http://db.worldagroforestry.org//wd/species/Alstonia_boonei	L	
52	*Annona crassiflora*	0.400	http://db.worldagroforestry.org//wd/species/Alstonia_boonei	L	
53	*Anogeissus leiocarpa*	0.880	>>	L	
54	*Antialis toxicalia*	0.432	*Antiaris africana;*	L	
55	*Antiaris toxicaria*	0.470	Getachew Desalegn et al., 2012	H	air dry density
56	*Apodytes dimidiata*	0.610	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
57	*Apodytes dimidiata*	0.710	Getachew Desalegn et al., 2012	H	air dry density
58	*Argomaellera maerophylla*	0.640	Wood density of trees of Uganda	L	
59	*Arundinaria alpine*	0.630	Getachew Desalegn et al., 2067	H	air dry desnity
60	*Azadirachta indica*	0.728	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
61	*Balanites aegyptiaca*	0.542	Vreugdenhil et al., 2012	H	
62	*Balanites glabra*	0.684	Genus average	M	
63	*Baphia abyssinica*	0.559	*B. Nitida (global database: Zanne et al., 2009)*	L	
64	*Berberis holstii*	0.641	Genus average	M	
65	*Berchemia discolor*	0.895	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
66	*Bersama abyssinica*	0.671	http://db.worldagroforestry.org//wd/genus/Bersama & also global database	H	
67	*Blighia unijugata*	0.700	Getachew Desalegn et al., 2012	H	air dry density
68	*Blighia unijugata*	0.564	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
69	*Boswellia hildebrandtii*	0.500	Boswellia sp	L	
70	*Boswellia microphylla*	0.500	>>	L	
71	*Boswellia neglecta*	0.500	>>	L	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
72	*Boswellia papyrifera*	0.500	>>	L	
73	*Boswellia rivae*	0.500	>>	L	
74	*Boswellia sp*	0.500	*Boswellia serrata (FAO data)*	L	
75	*Bridelia cathartica*	0.587	Genus average	M	
76	*Bridelia micrantha*	0.540	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
77	*Brucea antidysenterica*	0.640	Wood density of Trees of Uganda	L	
78	*Buddleia polystachya*	0.400	Vreugdenhil et al., 2012	H	
79	*Caesalpinia trothae*	0.951	Genus average	M	
80	*Caesalpinia volkensii*	0.951	http://db.worldagroforestry.org//wd/genus/Caesalpinia) Genus average	M	
81	*Callistemon citrinus*	0.951	>>	M	
82	*Calotropis procera*	0.794	Genus average	M	
83	*Canthium euryoides*	0.643	Genus average	M	
84	*Canthium giordanii*	0.643	Genus average	M	
85	*Canthium oligocarpum*	0.643	*Genus average*	M	
86	*Canthium setiglarum*	0.643	Genus average	M	
87	*Capparis cartilagenia*	0.691	Genus average	M	
88	*Capparis micrantha*	0.691	Genus average	M	
89	*Capsicum conicum*	0.482	Vreugdenhil et al., 2012	H	
90	*Carissa edulis*	0.650	*Carissa spinarium* http://www.hindawi.com/journals/tswj/2012/790219/tab1/	L	
91	*Cassia didymobotrya*	0.745	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
92	*Cassia sinqueana*	0.706	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
93	*Cassipourea malosana*	0.673	Genus average	M	
94	*Casuarina equisetifolia*	0.766	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
95	*Catha edulis*	0.658	http://db.worldagroforestry.org//wd/genus/Apodytes	M	
96	*Celtis africana*	0.745	http://db.worldagroforestry.org//wd/species/Celtis_africana	M	
97	*Celtis africana*	0.760	Getachew Desalegn et al., 2012	H	air dry density
98	*Celtis kranssiana*	0.604	Genus average	M	
99	*Celtis philippinensis*	0.611	http://db.worldagroforestry.org//wd	M	
100	*Celtis zenkeri*	0.59	FAO database	M	
101	*Chaionanthus mildbraedii*	0.705	Average Chionanthus	L	
102	*Citrus aurantifolia*	0.699	Genus average	M	
103	*Citrus aurantium*	0.699	Genus average	M	
104	*Citrus grandis*	0.590	http://db.worldagroforestry.org//wd	M	
105	*Citrus medica*	0.770	http://db.worldagroforestry.org//wd	M	
106	*Citrus meolica*	0.699	Genus average	M	
107	*Citrus reticulata*	0.699	Genus average	M	
108	*Citrus sinensis*	0.699	Genus average	M	
109	*Clausena anisata*	0.482	http://db.worldagroforestry.org//wd/species/Clausena_anisata	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
110	*Clematis hirsuta*	0.526	Genus average	M	
111	*Coffea arabica*	0.620	http://db.worldagroforestry.org//wd/species/Coffea_arabica	M	
112	*Combretum aculeatum*	0.474	Vreugdenhil et al., 2012	H	
113	*Combretum binderianum*	0.880	http://db.worldagroforestry.org//wd/species	M	
114	*Combretum colinum*	0.590	Vreugdenhil et al., 2012	H	
115	*Combretum ghasalense*	0.845	http://db.worldagroforestry.org//wd/species	M	
116	*Combretum molle*	0.482	Vreugdenhil et al., 2012	H	
117	*Combretum voldensii*	0.845	http://db.worldagroforestry.org//wd/species	M	
118	*Commiphora africana*	0.276	http://db.worldagroforestry.org//wd/species	M	
119	*Commiphora africana*	0.482	Vreugdenhil et al., 2012	H	
120	*Commiphora alaticaulis*	0.389	http://db.worldagroforestry.org//wd/species	M	
121	*Commiphora billia*	0.389	http://db.worldagroforestry.org//wd/species	M	
122	*Commiphora bioviniana*	0.646	http://db.worldagroforestry.org//wd/species	M	
123	*Commiphora boranensis*	0.389	Genus average	M	
124	*Commiphora bruceau*	0.389	Genus average	M	
125	*Commiphora confusa*	0.389	Genus average	M	
126	*Commiphora ellenbeckii*	0.389	Genus average	M	
127	*Commiphora erlangeriana*	0.389	Genus average	M	
128	*Commiphora erythraea*	0.389	Genus average	M	
129	*Commiphora habessinica*	0.389	Genus average	M	
130	*Commiphora ogadensis*	0.389	Genus average	M	
131	*Commiphora schimperi*	0.389	Genus average	M	
132	*Commiphora sphaerophylla*	0.389	Genus average	M	
133	*Commiphora tenuis*	0.389	Genus average	M	
134	*Cordia africana*	0.482	http://db.worldagroforestry.org//wd/species/Cordia_africana	M	
135	*Cordia africana*	0.410	Getachew Desalegn et al., 2012	H	air dry density
136	*Cordia alliodora*	0.390	Getachew Desalegn et al., 2012	H	air dry density
137	*Cordia monoica*	0.482	Vreugdenhil et al., 2012	H	
138	*Cordia ovalis*	0.544	Genus average	M	
139	*Crasocephalum montuosum*	0.331	*C. Manii*	M	
140	*Crassocephalus montus*	0.331	*C. Manii*	M	
141	*Croton dichogamus*	0.525	Genus average	M	
142	*Croton macrostachyus*	0.518	http://db.worldagroforestry.org//wd/species/Croton_macrostachyus	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
143	*Croton macrostachyus*	0.560	Getachew Desalegn et al., 2012	H	air dry density
144	*Cupressus lusitanica*	0.430	Getachew Desalegn et al., 2012	H	air dry density
145	*Cussonia holstii*	0.409	Genus average	M	
146	*Cussonia ostinii*	0.409	Genus average	M	
147	*Dalbergia boehmii*	0.821	Genus average	M	
148	Dalbergia melanoxylon	0.728	Vreugdenhil et al., 2012	H	
149	*Dichrostachys cinerea*	*0.482*	*Vreugdenhil et al., 2012*	H	
150	*Diospyros abyssinica*	*0.790*	*Getachew Desalegn et al., 2012*	H	*air dry density*
151	*Diospyros mespiliformis*	*0.758*	*Genus average*	M	
152	*Discopodium penninervium*	*0.482*	*Vreugdenhil et al., 2012*	H	
153	*Dodonaea angustifolia*	*1.040*	*http://db.worldagroforestry.org//wd/species*	M	
154	*Dombeya bruceana*	*0.580*	*Genus average*	M	
155	*Dombeya quenguesta*	*0.580*	*Genus average*	M	
156	*Dombeya torrida*	*0.451*	*Vreugdenhil et al., 2012*	H	
157	*Dombeya torrida*	*0.588*	*http://db.worldagroforestry.org//wd/species*	M	
158	*Dovyalis abyssinica*	*0.579*	*http://db.worldagroforestry.org//wd/species*	M	
159	*Dracaena afromontane*	*0.418*	*Genus average*	M	
160	*Dracaena fragrans*	0.418	*genus average (http://db.worldagroforestry.org//wd/genus/Dracaena)*	M	
161	*Dracaena steudneri*	0.418	>>	M	
162	*Ehretia cymosa*	0.560	http://globalspecies.org/ntaxa/2529407	L	
163	*Ehretia cymosa*	0.484	http://db.worldagroforestry.org//wd/species	M	
164	*Ekebergia capensis*	0.580	Getachew Desalegn et al., 2012	H	air dry density
165	*Embelia schimperi*	0.775	*Embelia oleifera*	L	
166	*Erica arborea*	0.357	Vreugdenhil et al., 2012	H	
167	*Erythrina abyssinica*	0.426	http://db.worldagroforestry.org//wd/species/Erythrina_abyssinica	M	
168	*Erythrina brucei*	0.314	*Genus average http://db.worldagroforestry.org//wd/genus/Erythrina*	M	
169	*Erythrococca abyssinica*	0.58	Average of tropical Africa	L	
170	*Erythrococca Kirkii*	0.58	Average of tropical Africa	L	
171	*Erythrococca trichogynol*	0.58	Average of tropical Africa	L	
172	*Erythroxylum fisherriii*	0.802	Average Genus (http://db.worldagroforestry.org//wd/genus/Erythroxylum)	M	
173	*Eucalyptus camaldulensis*	0.853	Getachew Desalegn et al., 2012	H	air dry density
174	*Eucalyptus citriodora*	0.830	http://db.worldagroforestry.org//wd/species	M	
175	*Eucalyptus deanei*	0.570	Getachew Desalegn et al., 2012	H	air dry density

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
176	*Eucalyptus deglupta*	0.410	Getachew Desalegn et al., 2012	H	air dry density
177	*Eucalyptus delegatensis*	0.530	Getachew Desalegn et al., 2012	H	air dry density
178	*Eucalyptus dunii*	0.610	Getachew Desalegn et al., 2012	H	air dry density
179	*Eucalyptus fastigata*	0.650	Getachew Desalegn et al., 2012	H	air dry density
180	*Eucalyptus globulus*	0.780	Getachew Desalegn et al., 2012	H	air dry density
181	*Eucalyptus grandis*	0.560	Getachew Desalegn et al., 2012	H	air dry density
182	*Eucalyptus grandis*	0.665	http://db.worldagroforestry.org//wd/species	M	
183	*Eucalyptus microcorys*	0.860	Getachew Desalegn et al., 2012	H	air dry density
184	*Eucalyptus nitens*	0.760	Getachew Desalegn et al., 2012	H	air dry density
185	*Eucalyptus obliqua*	0.670	Getachew Desalegn et al., 2012	H	air dry density
186	*Eucalyptus paniculata*	0.830	Getachew Desalegn et al., 2012	H	air dry density
187	*Eucalyptus pilularis*	0.948	Getachew Desalegn et al., 2012	H	air dry density
188	*Eucalyptus regnans*	0.480	Getachew Desalegn et al., 2012	H	air dry density
189	*Eucalyptus saligna*	0.680	Getachew Desalegn et al., 2012	H	air dry density
190	*Eucalyptus viminalis*	0.670	Getachew Desalegn et al., 2012	H	air dry density
191	*Euclea schimperi*	0.741	http://db.worldagroforestry.org//wd/species/Erythrina_abyssinica	M	
192	*Euphorbia abyssinica*	0.471	http://db.worldagroforestry.org//wd/species	M	
193	*Euphorbia candelabrum*	0.471	genus average	M	
194	*Euphorbia sp.*	0.314	Vreugdenhil et al., 2012	H	
195	*Euphorbia tirucallii*	0.471	genus average	M	
196	*Fagaropsis angolensis*	0.700	Getachew Desalegn et al., 2012	H	air dry density
197	*Faurea saligna*	0.704	http://db.worldagroforestry.org//wd/species	M	
198	*Ficus brachypoda*	0.441	http://db.worldagroforestry.org//wd/species	M	
199	*Ficus elastica*	0.607	http://db.worldagroforestry.org//wd/species	M	
200	*Ficus exasperata*	0.377	http://db.worldagroforestry.org//wd/species	M	
201	*Ficus gnaphalocarpa*	0.441	Genus average	M	
202	*Ficus mucuso*	0.441	Average Ficus (http://db.worldagroforestry.org//wd/genus/Ficus)	M	
203	*Ficus oxata*	0.441	>>	M	
204	*Ficus sp.*	0.482	Vreugdenhil et al., 2012	H	
205	*Ficus sur*	0.441	http://globalspecies.org/ntaxa/869708	L	
206	*Ficus sycomorus*	0.422	http://globalspecies.org/ntaxa/869708	L	
207	*Ficus sycomorus*	0.482	Vreugdenhil et al., 2012	H	
208	*Ficus thonningii*	0.432	http://globalspecies.org/ntaxa/911819	M	
209	*Ficus vasta*	0.441	Average Ficus	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
			(http://db.worldagroforestry.org//wd/genus/Ficus)		
210	*Filicium decipiens*	0.960	http://db.worldagroforestry.org//wd/species	M	
211	*Flacourtia indica*	0.778	http://db.worldagroforestry.org//wd/species	M	
212	*Flueggea virosa*	0.770	Genus average	M	
213	*Foeniculum vulgare*	0.58	Average of tropical Africa	L	
214	*Galiniera saxifraga*	0.399	Vreugdenhil et al., 2012	H	
215	*Gardenia ternifolia*	0.672	Genus average	M	
216	*Gardenia volkensii*	0.571	Vreugdenhil et al., 2012	H	
217	*Grevillea robusta*	0.530	Getachew Desalegn et al., 2012	H	air dry density
218	*Grewia auriculifera*	0.583	http://db.worldagroforestry.org//wd/species	M	
219	*Grewia bicolor*	0.456	Vreugdenhil et al., 2012	H	
220	*Grewia ferruginea*	0.583	Genus average	M	
221	*Grewia flavescens*	0.583	Genus average	M	
222	*Grewia mollis*	0.583	Genus average	M	
223	*Grewia tembensis*	0.583	Genus average	M	
224	*Grewia tenax*	0.583	Genus average	M	
225	*Grewia trichocarpa*	0.583	Genus average	M	
226	*Grewia villosa*	0.482	Vreugdenhil et al., 2012	H	
227	*Hagenia abyssinica*	0.591	http://db.worldagroforestry.org//wd/species/Hagenia_abyssinica	M	
228	*Hagenia abyssinica*	0.560	Getachew Desalegn et al., 2012	H	air dry density]
229	*Halleria lucida*	0.715	http://db.worldagroforestry.org//wd/species	M	
230	*Haplocoelum foliolosum*	0.788	http://db.worldagroforestry.org//wd/species	M	
231	*Heteromorpha trifoliata*	0.58	Average of tropical Africa	L	
232	*Hildebrandtia africana*	0.58	Average of tropical Africa	L	
233	*Hippocratae africana*	0.876	H. maingayi	L	
234	*Hippocratea macrophylla*	0.876	H. maingayi	L	
235	*Hippocratea pallens*	0.876	H. maingayi	L	
236	*Hypericum revolutum*	0.726	Genus average	M	
237	*Ilex mitis*	0.466	Vreugdenhil et al., 2012	H	
238	*Indigofera garekeana*	0.580	Average of tropical Africa	L	
239	*Jasminum abyssinicum*	0.580	Average of tropical Africa	L	
240	*Juniperus procera*	0.628	http://db.worldagroforestry.org//wd/genus/Juniperus	M	
241	*Juniperus procera*	0.540	Getachew Desalegn et al., 2012	H	air dry density]
242	*Justicia schimperiana*	0.580	Average of tropical Africa	L	
243	*Kigelia eethopun*	0.661	http://db.worldagroforestry.org//wd/genus	M	
244	*Kirkia burgeri*	0.661	>>	M	
245	*Lannea fruticosa*	0.515	http://db.worldagroforestry.org//wd/genus	M	
246	*Lannea schimperi*	0.515	Genus average	M	
247	*Lannea stuhlmannii*	0.515	>>	M	
248	*Lannea welwitschii*	0.405	http://db.worldagroforestry.org//wd/species/Lannea_welwitschii	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
249	*Lantana trifolia*	0.58	Average of tropical Africa	L	
250	*Lecaniodiscus fraxinifolius*	0.405	>>	L	
251	*Lecaniodiscus laxiflorus*	0.405	>>	L	
252	*Lepidotrichilia volkensii*	0.58	Average of tropical Africa	L	
253	*Lippia citriodora*	0.700	*Lippia mcvaughii*	L	
254	*Lippia javanica*	0.700	>>	L	
255	*Lippia spp.*	0.700	>>	L	
256	*Lonchocarpus laxiflorus*	0.761	genus average	M	
257	*Lonicera johnstonii*	0.58	Average of tropical Africa	L	
258	*Lycium europaeum*	0.58	Average of tropical Africa	L	
259	*Macaranga capenesis*	0.416	global data base	M	
260	*Macaranga kilimandscharica*	0.404	Genus average (http://db.worldagroforestry.org//wd/genus/Macaranga)	M	
261	*Maerua angolensis*	0.58	Average of tropical Africa	L	
262	*Maerua calophylla*	0.58	Average of tropical Africa	L	
263	*Maerua crassifolia*	0.58	Average of tropical Africa	L	
264	*Maesa lanceolata*	0.676	Genus average (http://db.worldagroforestry.org//wd/genus	M	
265	*Magnifera indica*	0.630	Wood density of trees of Uganda	L	
266	*Malacantha alnifolia*	0.450	http://db.worldagroforestry.org//wd/genus/Malacantha	M	
267	*Manilkara butugi*	0.880	Getachew Desalegn et al., 2012	H	air dry density]
268	*Manilkora butugi*	0.953	Average Genus, Africa	M	
269	*Maytenus addat*	0.713	Genus average(http://db.worldagroforestry.org//wd/genus/Maytenus)	M	
270	*Maytenus arbutifolia*	0.713	Genus average(http://db.worldagroforestry.org//wd/genus/Maytenus)	M	
271	*Maytenus auriculifera*	0.713	Genus average(http://db.worldagroforestry.org//wd/genus/Maytenus)	M	
272	*Maytenus gracilipes*	0.713	Average Genus, Africa	M	
273	*Maytenus heterophylla*	0.495	http://db.worldagroforestry.org//wd/genus	M	
274	*Maytenus ovatus*	0.403	Vreugdenhil et al., 2012	H	
275	*Maytenus senegalensis*	0.713	http://db.worldagroforestry.org//wd/genus	M	
276	*Maytenus undatus*	0.732	http://db.worldagroforestry.org//wd/genus	M	
277	*Melacantha alnifolia*	0.620	Average Genus, Africa	M	
278	*Melia azedarach*	0.463	http://db.worldagroforestry.org//wd/genus	M	
279	*Milicia excelsa*	0.570	Getachew Desalegn et al., 2012	H	air dry density]
280	*Millettia ferruginea*	0.738	Average Millettia, Africa	M	
281	*Mimusops kummel*	0.856	Average, Africa (http://db.worldagroforestry.org//wd/genus/Mi	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
			musops)		
282	*Mimusops kummel*	0.880	Getachew Desalegn et al., 2012	H	air dry density]
283	*Mimusops kummel*	0.482	Vreugdenhil et al., 2012	H	
284	*Moringa oleifera*	0.262	http://db.worldagroforestry.org//wd/genus	M	
285	*Moringa stenopetala*	0.262	http://db.worldagroforestry.org//wd/genus	M	
286	*Morus alba*	0.622	http://db.worldagroforestry.org//wd/genus	M	
287	*Morus mesozygia*	0.722	http://db.worldagroforestry.org//wd/species/Morus_mesozygia	M	
288	*Morus mesozygia*	0.690	Getachew Desalegn et al., 2012	H	air dry density]
289	*Myenus reticulata*	0.58	Average of tropical Africa	L	
290	*Myrica salicifolia*	0.618	http://db.worldagroforestry.org//wd/species	M	
291	*Myrsine africana*	0.721	http://db.worldagroforestry.org//wd/species	M	
292	*Myrsine melanophloeos*	0.732	http://db.worldagroforestry.org//wd/species	M	
293	*Mystroxylon aethiopicum*	0.58	Average of tropical Africa	L	
294	*Nuxia congesta*	0.512	Vreugdenhil et al., 2012	H	
295	*Ocotea kenyensis*	0.545	Genus average	M	
296	*Ocotea kenyensis*	0.560	Getachew Desalegn et al., 2012	H	air dry desnity
297	*Ocotea viridis*	0.545	Genus average	M	
298	*Olea africana*	0.590	Vreugdenhil et al., 2012	H	
299	*Olea capensis*	0.805	http://db.worldagroforestry.org//wd/species/Olea_capensis	M	
300	*Olea capensis*	0.990	Getachew Desalegn et al., 2012	H	air dry density]
301	*Olea europaea*	0.807	http://db.worldagroforestry.org//wd/species/Olea_europaea	M	
302	*Olea hochstetteri*	0.800	Genus average	M	
303	*Olea welwitschii*	0.814	http://db.worldagroforestry.org//wd/species/Olea_europaea	M	
304	*Olea welwitschii*	0.820	Getachew Desalegn et al., 2012	H	air dry density]
305	*Olinia rochetiana*	0.768	http://db.worldagroforestry.org//wd/species/Olea_europaea	M	
306	*Olinia Usamberansis*	0.825	http://db.worldagroforestry.org//wd/species/Olea_europaea	M	
307	*Oncoba spinosa*	0.647	http://db.worldagroforestry.org//wd/species/Olea_europaea	M	
308	*Opilia campestris*	0.58	Average of tropical Africa	L	
309	*Ormocarpum mimosoides*	0.742	*Ormocarpum kirkii*	L	
310	*Osryia lanceolata*	0.854	*Osyris arborea*	L	
311	*Osyris compressa*	0.854	*Osyris arborea*	L	
312	*Osyris wightiana*	0.854	>>	L	
313	*Otestegia steudneri*	0.58	Average of tropical Africa	L	
314	*Oxyanthus sp.*	0.525	Genus value	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
315	*Oxyanthus speciosus*	0.525	http://db.worldagroforestry.org//wd/species/Oxyanthus_speciosus	M	
316	*Oxytenanthera abyssinica*	0.608	Getachew Desalegn et al., 2012	H	air dry density]
317	*Ozoroa insignis*	0.715	*Ozoroa longipetiolata*	L	
318	*Ozoroa pulcherrima*	0.715	>>	L	
319	*Pappea capensis*	0.883	http://db.worldagroforestry.org//wd/species/Oxyanthus_speciosus	M	
320	*Persea americana*	0.561	http://db.worldagroforestry.org//wd/species/Oxyanthus_speciosus	M	
321	*Peterocarpus lucens*	0.58	Average of tropical Africa	L	
322	*Piliostigma thonningii*	0.371	Vreugdenhil et al., 2012	H	
323	*Pinus patula*	0.450	Getachew Desalegn et al., 2012	H	air dry density]
324	*Pinus radiata*	0.450	Getachew Desalegn et al., 2012	H	air dry density]
325	*Pistacia falcata*	0.720	http://db.worldagroforestry.org//wd/species/Oxyanthus_speciosus	M	
326	*Pistacia lentiscus*	0.720	Genus average	M	
327	*Pittosporum abyssinicum*	0.645	Genus average (http://db.worldagroforestry.org//wd/species/Pittosporum_abyssinicum)	M	
328	*Pittosporum viridiflorum*	0.633	http://db.worldagroforestry.org//wd/species/Oxyanthus_speciosus	M	air dry density]
329	*Podocarpus falcatus*	0.523	Genus average (http://db.worldagroforestry.org//wd/genus/Podocarpus)	M	
330	*Podocarpus falcatus*	0.520	Getachew Desalegn et al., 2012	H	air dry density]
331	*Polyscias ferruginea*	0.286	http://db.worldagroforestry.org//wd/species/Polyscias_ferruginea	M	
332	*Polyscias fulva*	0.440	Getachew Desalegn et al., 2012	H	air dry density]
333	*Polyscious ferrogenia*	0.38	*Polyscias nodosa*	L	
334	*Pouteria adolfi-friederici*	0.600	Getachew Desalegn et al., 2012	H	air dry density]
335	*Pouteria abyssinica*	0.711	Genus average (http://db.worldagroforestry.org//wd/species/Pouteria)	M	
336	*Pouteria altissima*	0.442	http://db.worldagroforestry.org//wd/species/Pouteria_altissima	M	
337	*Premna schimperi*	0.658	Average Genus (http://db.worldagroforestry.org//wd/genus/Premna)	M	
338	*Prosopis juliflora*	0.827	Getachew Desalegn et al., 2012	H	air dry density]
339	*Protea gaguedi*	0.663	*Protea angolensis*	L	
340	*Prunus africana*	0.850	Getachew Desalegn et al., 2012	H	air dry density]
341	*Prunus persica*	0.588	Genus average (http://db.worldagroforestry.org//wd/species/Pouteria)	M	
342	*Pseudocedrela*	0.621	http://db.worldagroforestry.org//wd/species/P	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
	kotschyi		outeria_altissima		
343	*Psidium guajava*	0.859	Genus average (http://db.worldagroforestry.org//wd/species/Pouteria)	M	
344	*Psydrax schimperiana*	0.743	Genus average (http://db.worldagroforestry.org//wd/species/Pouteria)	M	
345	*Pterolobium stellatum*	0.58	Average of tropical Africa	L	
346	*Rabus steudneri*	0.58	Average of tropical Africa	L	
347	*Rapanea melanophixas*	0.732	http://db.worldagroforestry.org//wd/species/Pouteria_altissima	M	
348	*Rapanea simensis*	0.722	genus average	L	
349	*Rhamnus prinoides*	0.579	genus average	L	
350	*Rhamnus sp.*	0.579	Genus average	L	
351	*Rhinorea friisii*	0.689	*R. ferruginea*	L	
352	*Rhinorea laxiflora*	0.689	*R. ferruginea*	L	
353	*Rhoicissus tridentala*	0.538	*R. revoilii*	L	
354	*Rhus glutinosa*	0.620	genus average	M	
355	*Rhus natalensis*	0.620	genus average	M	
356	*Rhus retinorrhoea*	0.620	genus average	M	
357	*Rhus vulgaris*	0.620	genus average	M	
358	*Rothmania urcelliformis*	0.642	Africa (extratropical): global database	L	
359	*Rothmannia whitfieldii*	0.745	*R. Fischeri: global database*	L	
360	*Rubus steudneri*	0.350	*Rubus alceifolius: global database*	L	
361	*Rumex nervousus*	0.58	Average of tropical Africa	M	
362	*Salix subserata*	0.525	http://db.worldagroforestry.org//wd/species/Sapium_ellipticum	M	
363	*Sapium ellipticum*	0.576	http://db.worldagroforestry.org//wd/species/Sapium_ellipticum	M	
364	*Schefflera abyssinica*	0.405	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
365	*Schefflera abyssinica*	0.491	Vreugdenhil et al., 2012	H	
366	*Schefflera volkensii*	0.405	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
367	*Scherebera alata*	0.790	Uganda data	M	
368	*Sclerocarya birrea*	0.515	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
369	*Securidaca longepedunculata*	0.880	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
370	*Securindaca virosa*	0.880	*Securidaca longepedunculata*	L	
371	*Senna singueana*	0.706	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
372	*Sideroxylon oxyacantha*	0.715	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
373	*Sideroxylon sp.*	0.715	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
374	*Solanum incanum*	0.428	http://db.worldagroforestry.org//wd/species/S	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
			chefflera_abyssinica		
375	*Spathodea nilotica*	0.504	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
376	*Steganotaenia araliacea*	0.370	Uganda data	M	
377	*Sterculia africana*	0.482	Vreugdenhil et al., 2012	H	
378	*Sterculia setigera*	0.320	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
379	*Stereospermum kunthianum*	0.741	Vreugdenhil et al., 2012	H	
380	*Strychnos innocua*	0.870	http://db.worldagroforestry.org//wd/species/Schefflera_abyssinica	M	
381	*Strychnos mitis*	0.733	http://db.worldagroforestry.org//wd/genus/Strychnos	M	
382	*Strychnos spinosa*	0.733	genus average	M	
383	*Syzygium guineense*	0.712	http://db.worldagroforestry.org//wd/genus/Syzygium	M	
384	*Syzygium guineense*	0.740	Getachew Desalegn et al., 2012	H	air dry density]
385	*Tamarindus indica*	0.624	Vreugdenhil et al., 2012	H	
386	*Tapura fisherii*	0.660	Genus average: global database	M	
387	*Teclea nobilis*	0.798	http://db.worldagroforestry.org//wd/genus/Teclea	M	
388	*Teclea simplicifolia*	0.798	*Teclea nobilis*	L	
389	*Terminalia laxiflora*	0.654	genus average	M	
390	*Terminalia brownii*	0.654	Average of genus (http://db.worldagroforestry.org//wd/genus/Terminalia)	M	
391	*Terminalia brownii*	0.495	Vreugdenhil et al., 2012	H	
392	*Terminalia laxiflora*	0.574	Vreugdenhil et al., 2012	H	
393	*Terminalia macroptera*	0.819	http://db.worldagroforestry.org//wd/genus/Teclea	M	
394	*Terminalia mollis*	0.654	genus average	M	
395	*Terminalia prundioides*	0.654	genus average	M	
396	*Terminalia schimperiana*	0.654	genus average	M	
397	*Terminalia sopinos*	0.654	genus average	M	
398	*Thunbergia alata*	0.640	Uganda data	M	
399	*Toddalia asiatica*	0.798	*Toddalia nobilis*	L	
400	*Trema guineensis*	0.366	genus average	M	
401	*Trema orientalis*	0.366	genus average	M	
402	*Trichilea prieuriana*	0.647	http://db.worldagroforestry.org//wd/species/Trichilia_prieuriana	M	
403	*Trichilia dregeana*	0.482	http://db.worldagroforestry.org//wd/species/Trichilia_prieuriana	M	
404	*Trichilia madagascariense*	0.622	http://db.worldagroforestry.org//wd/species/Trichilia	M	
405	*Trichilia pouerianu*	0.622	http://db.worldagroforestry.org//wd/species/Trichilia	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
406	*Trichocladus ellipticus*	0.640	Uganda data	M	
407	*Trilepisium madagariense*	0.499	http://db.worldagroforestry.org//wd/species/Trilepisium_madagariense	M	
408	*Trilepisium madagascariense*	0.560	Getachew Desalegn et al., 2012	H	
409	*Urera hypselodendron*	0.324	average of genus (http://db.worldagroforestry.org//wd/genus/Urera)	M	air dry density
410	*Vepris dainellii*	0.700	*Vepris undulate*	L	
411	*Vernonia amygdalina*	0.413	average (http://db.worldagroforestry.org//wd/genus/Vernonia)	M	
412	*Vernonia auriclifera*	0.413	average (http://db.worldagroforestry.org//wd/genus/Vernonia)	M	
413	*Warburgia ugandensis*	0.865	http://db.worldagroforestry.org//wd/species/Warburgia_ugandensis	M	
414	*Warburgia ugandensis*	0.770	Getachew Desalegn et al., 2012	H	air dry density]
415	*Ximenia americana*	0.867	http://db.worldagroforestry.org//wd/species/Warburgia_ugandensis	M	
416	*Ximenia caffra*	0.812	genus average	M	
417	*Zanthoxylum chalybeum*	0.629	http://db.worldagroforestry.org//wd/species/Warburgia_ugandensis	M	
418	*Ziziphus mauritania*	0.711	http://db.worldagroforestry.org//wd/species/Warburgia_ugandensis	M	
419	*Ziziphus mucronata*	0.758	http://db.worldagroforestry.org//wd/species/Warburgia_ugandensis	M	
420	*Ziziphus spina-christi*	0.482	Vreugdenhil et al., 2012	H	

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