ETHIOPIA'S FOREST REFERENCE LEVEL SUBMISSION TO THE UNFCCC

January 2016

CONTENTS

List of Tables

List of Figures

Acronyms

AD	Activity Data
AGB	Above Ground Biomass
BGB	Below Ground Biomass
CGIAR	Consultative Group on International Agriclture 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	Green House Gas
Ht	Height
IPCC	Inter-governmental Panel on Climate Change
LULC	Land Use/Land Cover
MEFCC	Ministry of Environemnt, Forest and Climate Change
MMU	Minimum Mapping Unit
NFI	National Forest Inventory
QGIS	Quantun Geographical Information System
REDD	Reduction from Deforestation and Degradation
RS	Remoste Sensing
SU	Sampling Unit
tCo_2 eq	Ton Carbondioxide equivalen
UNFCCC	United Nations Framework for Conventions on Climate Change
WBISPP	Wood Biomass Innventory and Strategic Planning Project
WD	Wood Desnity

ACKNOWLEDGEMENTS

The Governmnt of the Federal Democratic Repubic of Ethiopia wouldlike to thank the World Bank and donor partners, the Royal Norwegian Government and the United Kindom for the financial support to REDD+ readiness implementation and the FAO for its technical support. We also appreciate the contribution of the national experts who provide continous support to the the National MRV Task Force.

Ethiopia appreciates the UNFCCC for giving the opprtuinity to submit its FRL intended for accessing the results-based payments under the global REDD+ mechanism. Ethiopia also hopes to receive technical and financial support to continue to better undertand the dynamics of its forest resources and manage them for contribution towards global effort in mitigating climate change.

Summary: The Proposed FRL

Ethiopia's Forest Reference Level (FRL) is prepared in the context of results based payments for REDD+ implementation. The country has been in the REDD+ Readiness implementation sicne January 2013. The FRL includes deforestation and afforestation, AGB, BGB, deadwood and CO2 emissions; it is national and based on a historical average of emissions and removals between 2000 and 2013. The Forest Reference Emission Level for deforestation is 19,498,496.10 tCO2/year; the Forest Reference Level for afforestation is 10,247,080.97 tCO2/year. The choice of construction approach and historical period is provisional and may change in the future following a trend analysis and, if appropriate, a comprehensive assessment of details on national circumstances as relevant information is made available.

1. INTRODUCTION

Ethiopia welcomes the invitation to submit a Forest Reference 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. 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 as a result of the outcomes of the trend analysis.

2. SCALE

The Forest Reference Level covers the national territory of Ethiopia. Ground inventory data is currently being collected through Ethiopia's National Forest Inventory (NFI). At the time this submission document is prepared only the NFI data for Oromia Regional State has been collected and analyzed but national plot data is scheduled to have been collected by the beginning of 2016 and analyzed in the first half of 2016. The current submission therefore uses national activity data but –ad interim- emission factors from OromiaRegional State. The Oromia emission factors data will be replaced by national emission factors in the course of 2016 using the same datasource (plot measurements from the NFI) and methodological approach.

3. SCOPE: Activities, Pools and Gases included

3.1 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 section 4) and any transition below the thresholds in this definition will be considered as deforestation (including the transition of forest land to open woodland). Afforestation[1] is defined as the conversion of other land to forest land. Afforestation includes restoration of degraded 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 included in the FRL.

Though forest degradation is 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 by start from first quarter of 2016 following a step-wise approach. Ethiopia has the desire and intention to develop a robust methodology to assess forest degradation and is 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 installation of plantations are expected to result in a reduction of forest degradation and deforestation. In Tigray and some parts of Amhara the cultivation of plantation wood on farmers' own land has been able to supply most of the fuelwood needed (https://reddplusethiopia.wordpress.com/drivers-of-deforestation-and-forest-degradation: DD&FD:MidTermReport, 2015) which is expected to reduce the

[1] As information of forest cover before the year 2000 is not available, no distinction is made between reforestation and afforestation and any new forest land is accounted for as afforestation.

pressure on natural forest. The invasive species (*Prosopis juliflora*) has become the main wood source for charcoal production in Afar and Ethiopian Somali Regional States and it has an important ecosystem role to allow regeneration of the other tree species.

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 selective 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 woodland), the expectation is that when addressing these drivers a positive effect is expected both on deforestation and forest degradation.

3.2 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 NFI. Litter has only been collected in some subplots and initial findings indicated litter to constitute an insignificant source of carbon, therefore no additional data has been collected and the choice was made to omit this pool. Soil may constitute a very large carbon pool in Ethiopian forests however, little is known about emissions from soil after forest conversion at national scale and data collection in soils is very costly and needs monitoring over an extended period.

Accordingly to the principal studies, the loss in soil organic carbon following deforestation and land use change depends on the post deforestation land use type, intensity of land management, erosion intensity and whether or not soil/land management practices have been properly implemented or not. Under a normal oxen driven tillage system in the highlands of Ethiopia, soil organic carbon declines but slowly following deforestation and subsequent cultivation approaching a new steady state after 25-30 years2. The intensity of loss will be high under mechanized farming system and where erosion intensity is also high. Overall, considering soil organic pool into REDD+ carbon accounting might present several difficulties given the variable rate of carbon loss due to requiring numerous network of monitoring points representing different socio-economic, land management, geographic and climatic contexts leading to high cost. Given the difficulty in obtaining accurate data on a national scale for dynamic as complex as those of the soil in Ethiopian ecosystems, in this first submission the soil carbon pool is not included in the FRL.

3.3 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 collecting data on the occurrence of fires, data on fire occurrence is not thought to be suffiently reliable for inlcusion in the FREL. 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 FRA2015 (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 calculations suggests the contribution of non-CO_2 to total forest-related emissions is in the range of 0.1 – 37 thsnd tCO_2eq for CO, 0.1 – 33 thsnd tCO_2 eq for CH_4 and 0.03 – 11 thsnd tCO_2eq for N_2O. Therefore the contribution of nonCO_2 gases is estimated to be <2% of total annual emissions from forest land in Ethiopia.

3.4 Forest definition

In February 2015 Ethiopia adopted a new forest definition as follows: 'Land spanning at least 0.5 ha covered by trees and bamboo), attaining a height of at

---

[2] **Lemenih**, M., Tolera, M. and Karltun, E. (2008). Deforestation: Impact On Soil Quality, Biodiversity and Livelihoods in the Highlands of Ethiopia, In: Ilya B. Sanchez and Carl L. Alonso, Deforestation Research Progress, Nova Science Publishers, Inc. PP. 21-39

least 2m and a canopy cover of at least 20% or trees with the potential to reach these thresholds in situ in due course' (Minutes of Forest sector management, MEFCC, Feb. 2015).

This forest definition differs from the definition used for international reporting to the Global Forest Resources Assessment (FAO) and from the forest definition used in the National Forest Inventory 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 Ethiopia to change its national forest definition is to better capture dry and lowland-moist vegetation resources. In specific, the reason for lowering the tree height from 5 to 2 m is to capture *Termilania-Combretum* dense woodlands found in Gambella and Benishangul Gumuz Regional States which in its primary state consists of trees reaching a height of around 2-3 m and above . The proposed change in forest definition results in the inclusion of what previously was classified as Ethiopia's dense woodlands which have a wider distribution through the country (see Figure 1). Commercial agriculture is expanding mainly on dense woodlands and Ethiopia desires to allow the FRL to create REDD^{+} incentives for the conservation of these important areas.

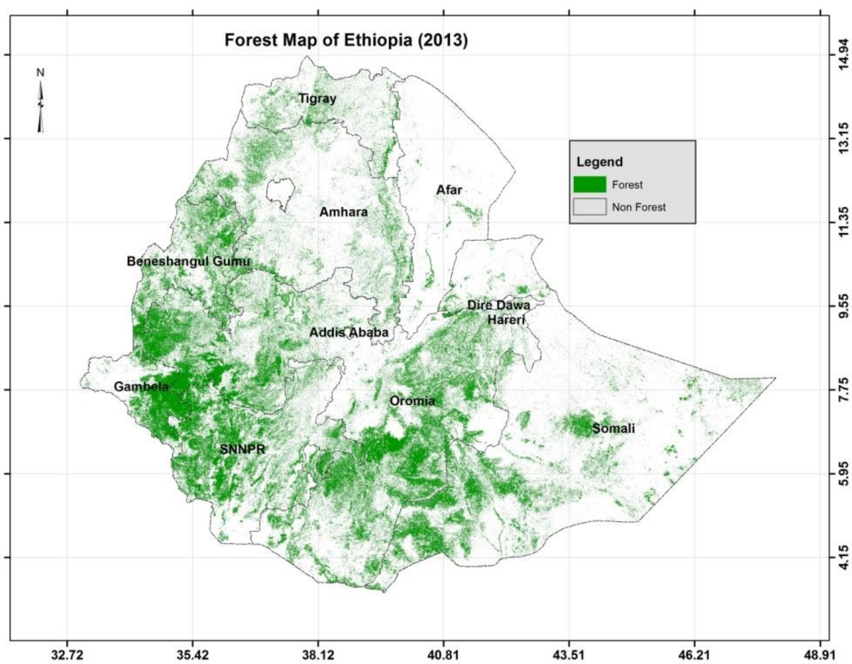


Figure 1: Illustration of the approximate impact of the revised forest definition: Dense woodlands are now considered forest with the new definition

The reason for increasing the canopy cover threshold from 20 to 10% 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 the Clean Development Mechanism (CDM) that was submitted to the UNFCCC earlier (see https://cdm.unfccc.int/DNA/cdf/index.html), 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 only difference is an increase on area threshold. The main reason is the fact that our technology for measurement and monitoring caanot afford to detect changes in small areas of forest. The MMU for the Landsat 7 is 0.8ha.

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, 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.

3.5 Drivers of Deforestation and Forest Degradation

A comprehensive study was published by Ethiopia's REDD$^+$ secretariat (2015) analyzing the drivers of deforestation and forest degradation. The study found deforestation and forest degradation to be driven mainly by free livestock grazing, fodder use and fuelwood collection/charcoal production in all the regions followed by farmland expansion, land fires and construction wood harvesting. The underlying causes of deforestation and degradation based on framework analysis were identified to be population growth, unsecure land tenure and poor law enforcement. Free grazing affects the plains and lowland woodlands to the largest extent. The large-scale investment agricultural schemes – both private ones and state owned ones - have been significant drivers in Gambella, Benishangul-Gumuz and Afar

Regional States. In Ethiopian Somali and Afar Regional States charcoal is produced by almost all rural households as one of the core livelihood income sources.

The findings of this study are confirmed by the detection of the land-use replacing

Forest after deforestation (Figure 2) assessed by Ethiopia's National Forest Monitoring System and described under section 6.2

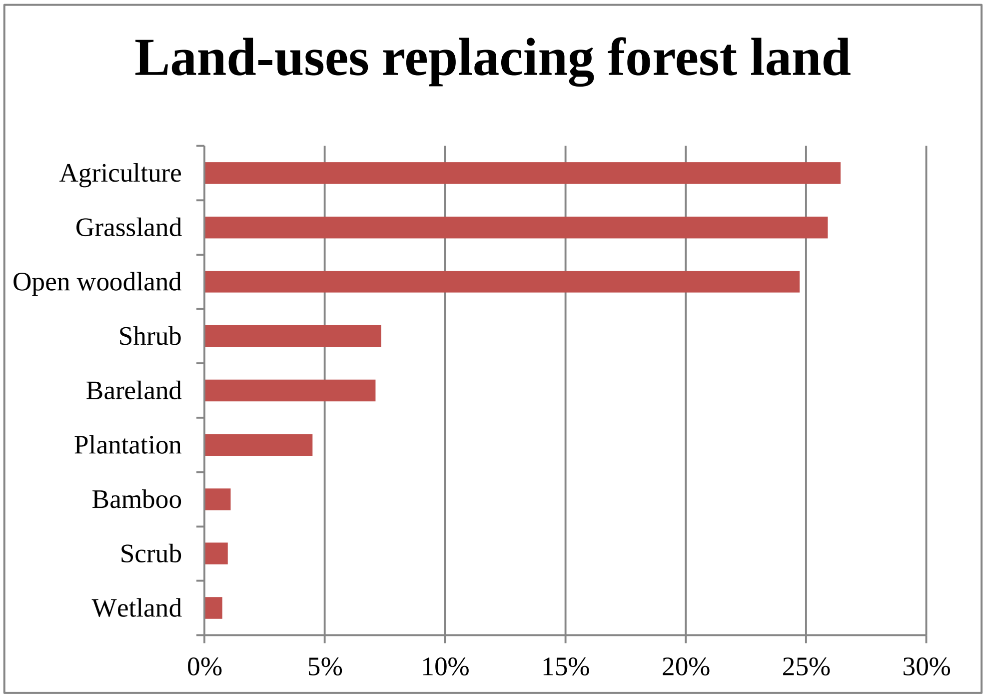


Figure 2: Land-uses replacing forest over the period 2000-2013 (as % of the total forest loss over this period)

4.1 Ethiopia's Land Use and Land Cover Map 2013

MEFCC has created a map of land use/land cover for the year 2013 using a supervised classification and maximum likelihood classifier on Landsat data. An accuracy assessment is carried out in order to produce statistics for the 2013 land use/land cover categories. An accuracy assessment combines the map data, the 2013 land use/land cover map, with higher quality reference data to produce adjusted area estimates for each land use/land cover class.

4.1.1 2013 Data Preparation

Collection of Images

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.

Image Analysis

Sixteen land use/land classes were identified and descriptions were prepared based on past mapping experiences of the Woody Biomass Inventory Strategic Planning Project (WBISPP) and the prevailing ground situation of the country from the forest inventory (table 1). Representative area of interests(AOIs) were collected for each of the LULC classes using Google Earth. The AOIs were uniquely identified with the code incorporating name of the region, name of the grid and Land use/land cover type. Moreover, the relation between Path and Row of each of the scenes and AoIs were predefined to ease the classification.

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 library 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 1: Decription of the Land Use/Land Cover Classes in the 2013 Map

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.

LULC Code	LULC Name	Description
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 Accacia-Comiphora that can both tolerate burning and temporary flooding with the tall grass stratums, 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 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.

LULC Code	LULC Name	Description
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 Lobelia rhynchopetalum, Kniphofia foliosa, Bartsia petitiana and various Alchemilla 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 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

LULC Code	LULC Name	Description
16	Water body	Area occupied by major rivers of perennial or intermittent (width ≥ 15m), lakes, ponds and reservoirs.

4.1.2 Accuracy Assessment

The accuracy assessment combines the 2013 land cover map data with higher quality reference data to produce the adjusted area estimates for each land cover class. The adjusted area estimates provide the crucial data for reporting accurate estimates of forest area. Interpreted images of the whole country were mosaicked with the R based written programming language. The accuracy assessment ofn the Ministry of Environment, Forestry and Climate Change (MoEFCC) of 2013 map of the year 2013 was conducted based on Good practices for estimating area and assessing accuracy of land change' (Olofsson, 2014). The guidance has three major methodological components of Sampling Design, Response Design and Analysis.

The scientific background for the accuracy assessment methodology can be found in the publication Good practices for estimating area and assessing accuracy of land change,(Olofsson et al. 2014). This publication is used as a framework to provide recommendations for designing and implementing an accuracy assessment for land cover maps, and for estimating area based on the results from the accuracy assessment.

Sampling Design

This methodological component encompasses sample size determination and allocating the overall sample size to each of the map classes. The target standard error for overall accuracy was ɑ = 0.01 and the expected user's accuracy for each class was 50% , the most conservative estimate of user's accuracy. The resulting overall sample size is 2,500 samples with minimum sample size of 50 samples per class. The samples for each class were spatially distributed using a stratified random sampling approach.

Response Design

The response design was employed to collect consistent reference data that matches the description of the map land cover classes. In order to address the MMU specification in the land cover descriptions for the map legend a bounding box of 70m by 70m (about 0.5 hectares) was visualized for the assessment.

Multiple exercises were completed by the interpreters to ensure the agreement between the map land cover class descriptions and reference samples. Medium to very high resolution imagery was used as reference data through the Collect Earth interface.

Analysis

A total of 2117 reference points were collected for the accuracy analysis. The sixteen LULCs classes of 2013 map were aggregated in to 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 definition is inclusive of the map forest sub-categories: forest, bamboo, dense woodland, riverine and plantations. The overall accuracy of the aggregated map is 81%. The user's and producers accuracy for the aggregated forest class is 51% and 56%.

Mapping is a dynamic process and Ethiopia is striving to achieve an improved version of the LULC map with improved accuracies.

4.2 Activity data: 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 between 2000-2013.

4.2.1 Methodology and Data Used

The proposed approach by Ethiopia follows the GFOI guiding principle 1 for remote sensing (GFOI, 2014): images, not maps are compared for change detection. The approaches tested for change detection include purely automatic spectral methods (e.g. IMAD algorithm) and supervised change detection using stable and change training points (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.

The method chosen was a supervised classification of imagery, in which the user identifies representative spectral samples for each class in the digital image. These samples are called "training sites" and can be polygons (area of interest) or points (training points). The spectral signature of the training sites 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 procedure to generate these two inputs is described below.

The imagery chosen for the exercise is Landsat data, because it is freely available for the time period, adapted to forest land cover detection (FAO & JRC, 2012) and likely to be sustainably available in the future (GFOI, 2014). 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 (see here for calculations). 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 the Google Earth Engine API.

Production of Training Sites

Supervised classification is usually dependent on the quality of the training sites (Foody and Mathur, 2006), and a particular attention is paid to that part of the process. In the absence of any reliable spatial data to indicate zones of change at the national level in Ethiopia, a preliminary training dataset was generated automatically from the Global Forest Change product 2013 (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 3 classes (loss, gain and no change, at the centre of 9 pixels with pure classes).

The no-change class is composed of non-forest and forest pixels, and the random sampling is further augmented to include 100 more points from the forest stable layer pixel to compensate for what proportionality would give (in the Global Forest change, the forest layer represents 15% of the country when applying a 20% tree cover threshold). The calculation for the creation of this automatic training dataset is entirely implemented in R.

The points for loss and gains must be carefully assessed as they are supposed to accurately represent a class which is occurring rarely in the imagery. Visual assessment using very high resolution imagery available in the Google Earth, Bing Maps, and Here maps repository is performed using the Collect Earth interface.

Supervised Classification

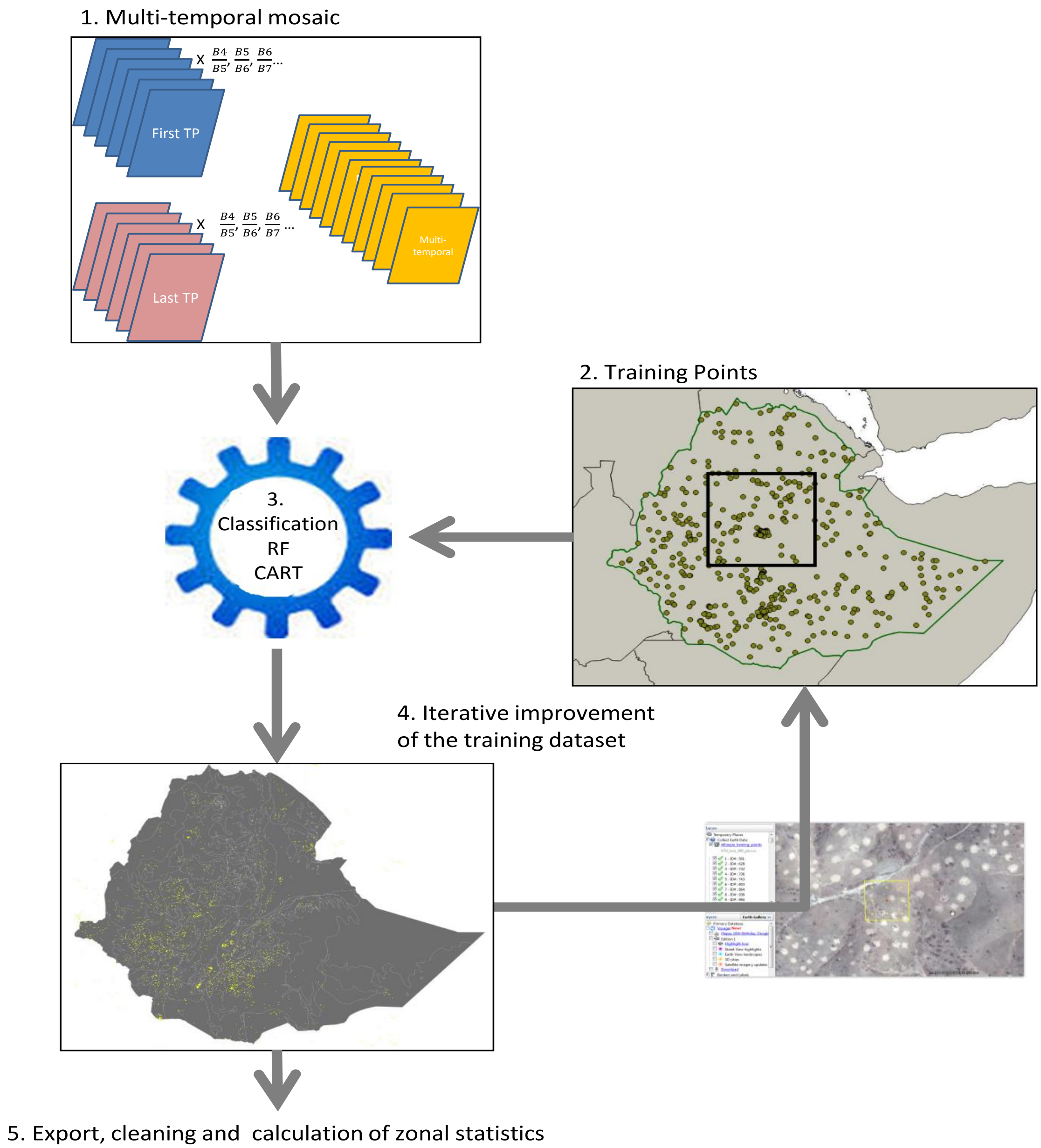
The classification process consists of compiling the spectral signature for all the training points, creating a model from this spectral library and applying the model to the entire imagery. Two classifiers have been tested, the CART algorithm (Breiman et al, 1984) and the RandomForest algorithm (Breiman,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

Iterative Improvement of the Training Dataset

After a first run of classification algorithm is complete, the training dataset can be improved by visually assessing zones of obvious false change, stable classified as change and missed changes, change classified as stable. Examples of potential incorrect classifications include agricultures 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 entered in the spectral library with appropriate classification.

The classification process can be re-initiated and this iteration repeated by carefully checking the next batch of results. The number of iterations for this process is variable and depends on the expected accuracy of results and scale of the work .

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 Google Earth Engine API Trusted Tester account is needed to open this link).



Export, Cleaning and Statistics

Once the iteration process is stationary (no further improvement of the classification) the results can be exported and cleaned (filtering of zones of change to match the national MMU=0.5 ha ~5 pixels).

Accordingly, the 2013 land cover map is used to filter false loss by eliminating loss detected on forest and what was in the MEFCC 2013 map classified as dense woodland and considered forest following the new forest definition (section 4).

An accuracy assessment of the change must finally be produced to estimate the reliability of the change measured (FAO, 2015) and produce corrected estimates of change.

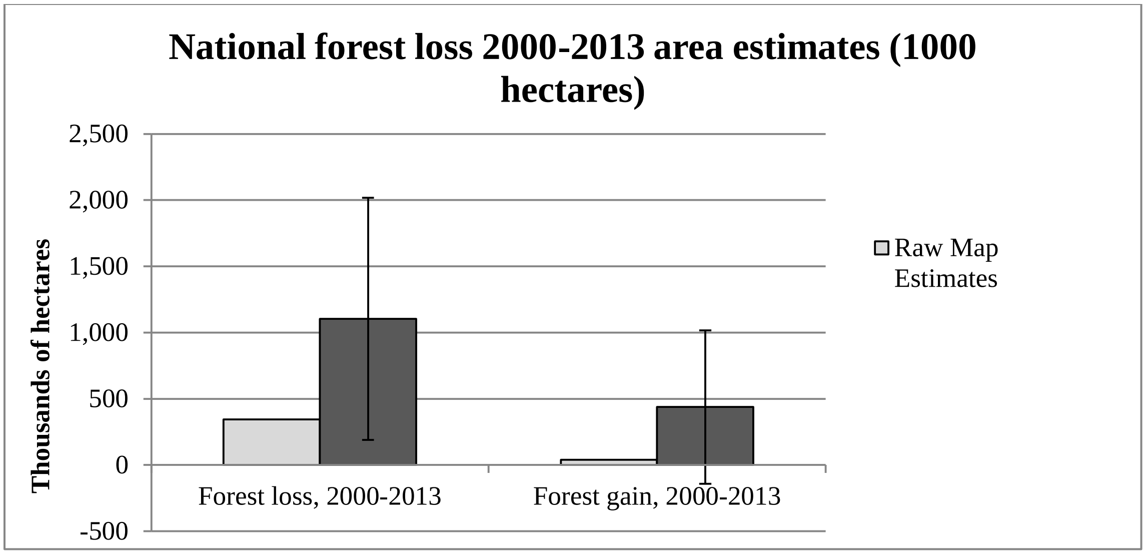
4.2.2 Accuracy Assessment

An accuracy assessment is carried out to assess the uncertainty of the forest area change estimates and to improve the forest area change estimates by correcting for the systematic error in the map (map bias). The accuracy assessment is conducted by obtaining better data for sample points and comparing this data with the map classification. Better data can be higher resolution data than the resolution of the imagery used for the supervised classification or a better interpretation, in this case human interpretation rather than an algorithm. This results in an estimation of the map accuracy by class and an adjustment the area estimate from the map to compensate for map bias.

The scientific background for the accuracy assessment methodology can be found in the publication Good practices for estimating area and assessing accuracy of land change, (Olofsson et al. 2014). This publication is used as a framework to provide recommendations for designing and implementing an accuracy assessment for land cover maps, and for estimating area based on the results from the accuracy assessment. The setup of the sampling design, reference data collection and the analysis of the results followed the practice suggested by an FAO accuracy assessment guide (FAO, 2016).

4.2.3 Results Forest Area Change Detection

The results of the forest area change detection are provided in Figure 4.



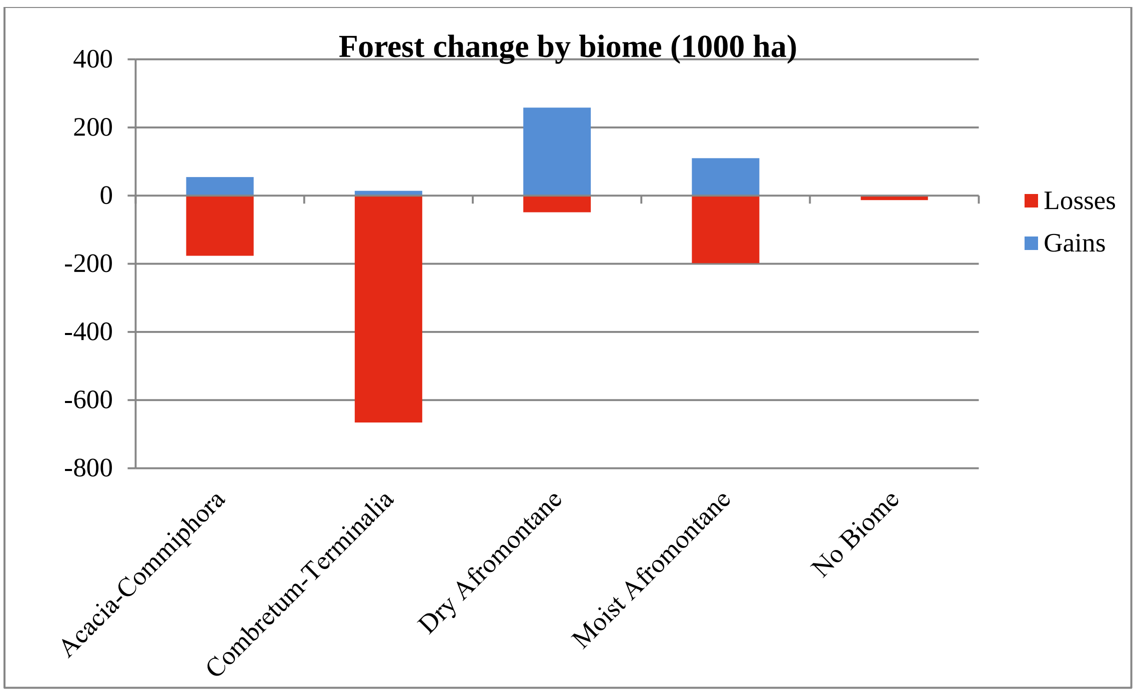


Figure 3: Results of the national forest area change detection 2000-2013, at the national scale and by biome.

The primary results from the accuracy assessment are adjusted area estimates calculated by combining sample and map area estimates and their associated confidence intervals. The adjusted area estimate for forest loss is 1.1 million ha +/- 0.91 million ha and for forest gain is 0.4 million ha +/- [RS experts to fill] over the period 2000-2013 which corresponds to an annual forest loss of approximately

70,000 ha/yr and annual forest gain of approximately 30,000 ha/yr. tThis estimate is used as the activity data.

The relatively high annual forest area gain in the Dry Afromontane biome gives some evidence that Ethiopia is already implementing several mitigating actions which 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. There is an on-going trend of farmland intensification (except in Gambella, Afar, Somali) through agroforestry practices, various small-scale irrigation systems, fertilizers and other kinds of farming improvements allowing reduction of the total farmland area extent up to 3 per cents a year in some woredas.

4.2.4 Comparison of Activity Data results with data from Global Forest Change

The average annual loss of 84,882.4 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 adjustment of the area of change in the map when correcting for map bias. Remoting sensing is known to have difficulties detecting dry deciduous forest, especially when on sandy soils with high reflectance. 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.

4.3 Historical Period considered and Trend Analysis

The initial historical period over which forest area change has been assessed is the period 2000-2013. The reasons selecting this period to assess change were:

- The year 2000 is well covered with standard products (Global Land Surveys (GLS) + most global products) making it easier to connect or compare to existing imagery and products
- The period is covered with the Global Forest Change product also referred to as Hansen data used as comparison and as base for the change analysis.
- The period and dates are in line with requirements by 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 product 2013 (Hansen *et al.*, 2013) suggest an upwards trend in tree cover loss in Ethiopia. An Analysis of Variance (ANOVA) on these data points gives a p-value of 0.001803, since this value is < 0.05 this means the trend is significant but how meaningful this is will depend on an accuracy assessment. Ethiopia is still exploring whether or not there is a trend and evaluating which FRL methodology and/or choice of historical period best reflects emissions expected in the near future in absence of REDD+ implementation.

4.4 Stratification for Combining Activity Data and Emission Factors

Friis and Sebesebe (2009) and Friis, Demissew and van Breugel (2010) divided the Ethiopian vegetation into 12 major types, 5 of which with 12 subtypes (Figure 5). The vegetation types are based on information from previous literature, field experience of the authors, as well as on an analysis of the information for 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 used was obtained from the 90x90 meters resolution digital elevation model provided by the CGIAR-CSI (2008) with a 3 arc seconds resolution. 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.

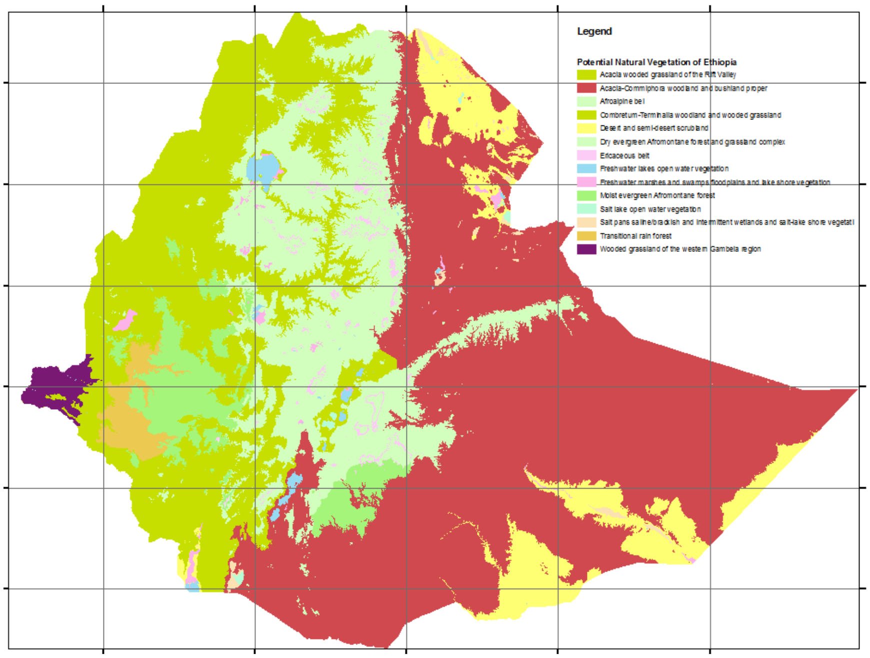


Figure 4: : Potential Natural Vegetation of Ethiopia (Friis and Sebesebe 2009)

These vegetation types do not have sufficient sampling unit representation for reliable carbon stock estimates from the ground collected data from the inventory and are therefore grouped into 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 an expected homogenous carbon contents (Figure 6).

Table 2: Description of the Biomes

Biome strata	Stratum name	Vegetation type (Friss and Sebesebe 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	

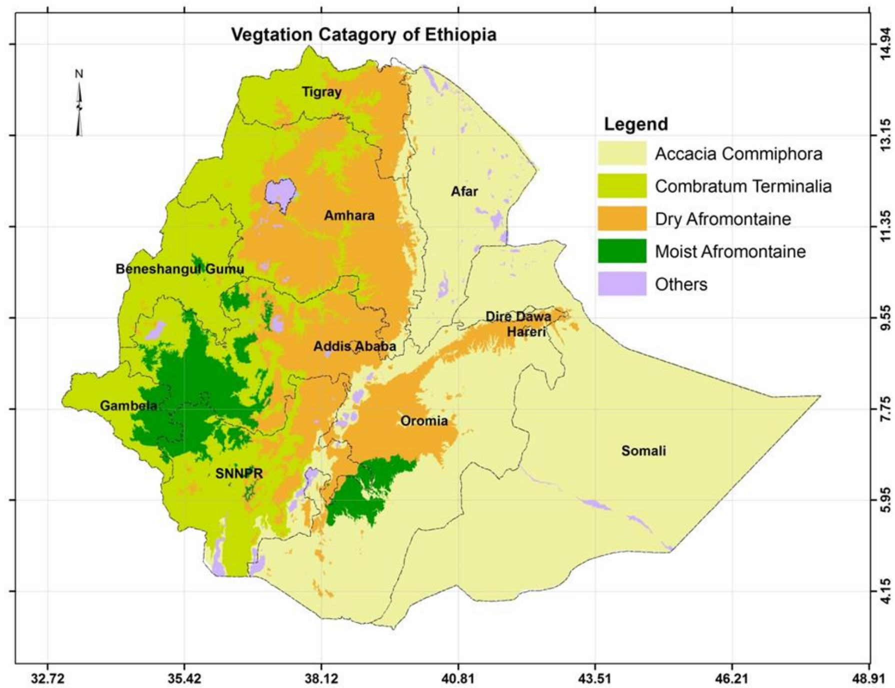


Figure 5: Biomes of Ethiopia used to stratify the EF and AD results compilation.

4.5 Emission Factors: NFI Data Analysis

4.5.1 Description of Ethiopia's Forest and Landscape Inventory

Ethiopia has designed a national Forest and Landscape Inventory Since March 2014, as TCP project. The collection of plot inventory data is still on-going and final results for the national scale are expected to be available by early summer 2016. The selection and implementation of appropriate sampling design to collect row forest data determines the output of forest information that will be used for various kinds of decision making processes. The sample 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 took great emphasis to craft suitable forest inventory sampling design that fits the country's situation and need of forest information.

After series of consultations with stakeholders, it was agreed to employ stratified systematic sampling with reasonable sampling intensities on the respective stratums according to the potential of vegetation they possessed. The NFI uses a stratification based on Agro ecological Zones of Ethiopia with three dimensional factors (Altitude, Temperature and Rain fall) together with the land use/land cover map of WBISPP 2004 and the Potential Vegetation Atlas of Ethiopia (Feriis and Sebsebe, 2009) were used to create non overlapping stratums in the GIS environment. Finally, a total of five inventory stratums were found (Figure 7). Their corresponding properties and the number of sampling units per stratum are described in Table 4.

According to the significance of the stratum types, the sampling distances were determined and the plot coordinates were generated using grid dot generator. Accordingly, within the distance variation of 1/4 x 1/4 degree Square and Triangular Combination grids plots coordinates were generated in the Stratum I, and ½ x ½ degree Square and Triangular Combination grids for Stratum II and IV, ½ x ½ degree Square grid for Stratum III, and 1x1 degree square grids in Stratum five, resulting in a total of 631 Sampling Units (SU).

Table 3: 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 is found within the altitude range of 2300 to 3200 masl	107
II	Comprises of the North and South Eastern part of the woodland mainly Acacia Comiphora woodland of Somali, SNNPRs and Afar regions	135
III	Comprises mainly of the woodland ecosystem found in the North and South Western woodland parts where Termilania-Comberatum woodland is dominant	137
IV	This stratum is commonly known as other land stratum where human activities are dominated and patch of evergreen afromontain forest existed , mostly in the middle altitudes of	232

	Ethiopia (1500 to 2500masl)	
IV	This stratum is refered to the desert and arid pats of Ethiopia where their elevation range is found below 500masl and characterized arid and semi-arid scrublands.	20

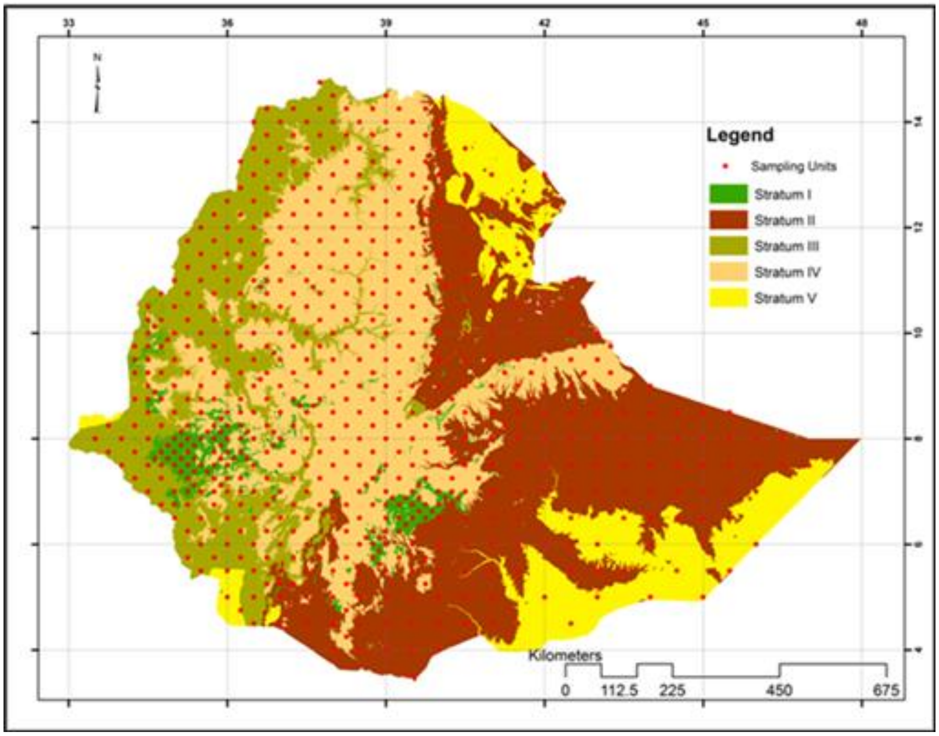
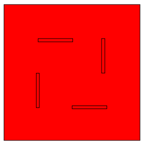
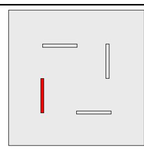
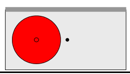
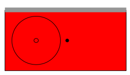
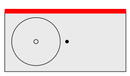


Figure 6: The 5 NFI strata and distribution of the sampling units

In NFI, data is 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 or sample plots and each sample plot can be divided into land LULC sections. Trees and stumps in the entire plot area have been recorded and small trees (in forest) and saplings were recorded in smaller subplots (see Table 4).

Table 4: Tree and other vegetation measurements and observations in NFI.

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

4.5.2 Analysis of NFI Data

The NFI sample plot design causes that there can be differerent sampling probability for trees in the plots and small trees in the sub-plots, so in result computing two different areal weighting methods for tree and sapling data were applied. Basically, all results were first computed at the LUCS level by plots, and then aggreted up to 'NFI stratum-biome' level by regions. Estimates for biomes were computed as weighted averages across NFI strata by regions, where the areas (i.e., weights) of NFI strata were taken from the inventory design (Fig.9).

Accordingly to the online Globallometry database (http://globallometree.org), at least 63 allometric equation are specific for Ethiopia. The big part of these equation is specific for plantations and/or species specific therefore not suitable for a national scale application and for all the biomes. In order to represent all the forest types in this first analysis forconvert field measurements into above ground biomass estimates the allometric equation proposed by Chave et al. (2014) is used Chave equation gave values that are closer also to averages calculated for the different forest types as obtained in the review of secondary sources like thesis, published and unpublished papers, etc).

The following parameters are needed to express above ground biomass in carbon stock the following parameters are needed: 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 0.5 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)

Accordingly, to express the AGB pool in carbon stock, the AGB is multiplied by a carbon fraction (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 Ethiopia did 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 is collected (Table 2). The overall average wood density for the species is 0.612 g/cm^3. This 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 observed was 0.262 for *Moringa species,* and the maximum was 1.040 g/cm^3 for *Dodonaea angustifolia* species.

Table 5: 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 Iahai*	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	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
38	*Albizia glaberiima*	0.555	http://db.worldagroforestry.org//wd/species/Alangium_chinense	M	
39	*Albizia grandibracteata*	0.534	Albizia gummifera	L	
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	
72	*Boswellia papyrifera*	0.500	>>	L	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
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	
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	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
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 allliodora*	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	
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*

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
					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
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

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
					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 (http://db.worldagroforestry.org//wd/genus/Ficus)	M	
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	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
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	
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	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
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/ Mimusops)	M	
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/	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
			genus		
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	
315	*Oxyanthus speciosus*	0.525	http://db.worldagroforestry.org//wd/species/ Oxyanthus_speciosus	M	
316	*Oxytenanthera*	0.608	Getachew Desalegn et al., 2012	H	air dry

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
	abyssinica				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 kotschyi*	0.621	http://db.worldagroforestry.org//wd/species/ Pouteria_altissima	M	
343	*Psidium guajava*	0.859	Genus average (http://db.worldagroforestry.org//wd/species /Pouteria)	M	
344	*Psydrax schimperiana*	0.743	Genus average	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
			(http://db.worldagroforestry.org//wd/species /Pouteria)		
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/ Schefflera_abyssinica	M	
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/	M	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
			Schefflera_abyssinica		
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	
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	

No	Scientific name	Basic Density (g/cm3)	Reference	Data quality*	Remark
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.

To estimate the BGB carbon pool default values proposed by IPCC (2006) have been applied. For the biomes 1, 2 and 3 a root-to-shoot ratio of 27% is applied as suggested for tropical mountain systems (Singh et al 1994). This is slightly below the 28% ratio suggested for tropical dry forest (Mokany et al 2006). For biome 4 a root-to-shoot ratio of 24% is applied as suggested for tropical moist deciduous forest (Mokany et al 2006). A root-to-shoot ratio of 24% was also applied at all plantation trees.

For fallen deadwood, De Vries' formula (De Vries, 1986) have been 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.

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

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.

There two decomposition classes recorded for deadwood particles: sound and rotten. If the decomposition class was missing in the data, it was assumed that deadwood piece was sound. 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.

4.5.3 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 against these secondary data sources. This 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-analyzed. 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 8.

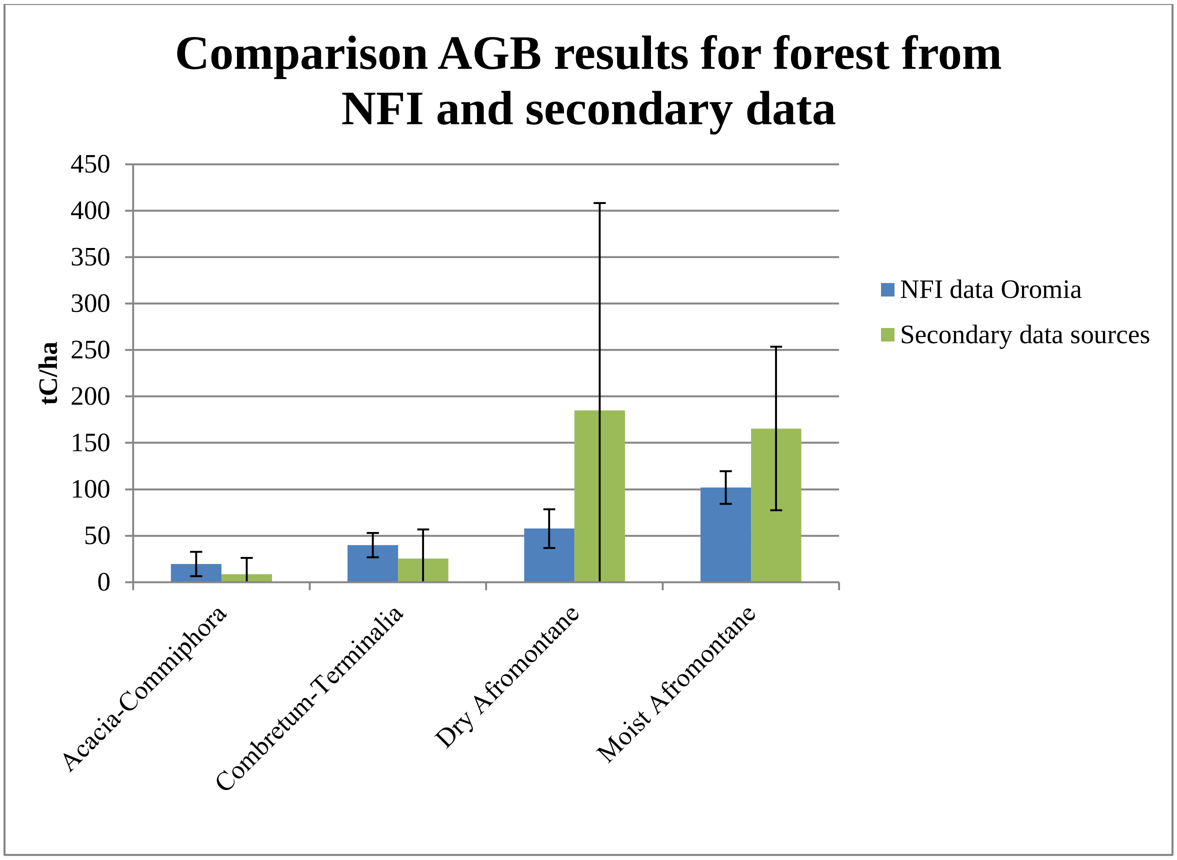


Figure 8: The average AGB (tC/ha) with their confidence intervals for forest in the 4 biomes is compared between primary (NFI) and secondary (literature and local studies) data

Most remarkable in the comparison of primary and secondary data is the strong reduction of the confidence intervals of the NFI analysis compared to the secondary data analysis and the large difference in AGB estimates for Dry and Moist Afromontane forest, where the secondary sources suggest a much higher carbon contents (220% and 62% higher for Dry and Moist Afromontane forest respectively). This difference is believed to be due 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.

4.5.4 Results and Proposed Emission Eactors

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 9, 10 and 11 respecitvely. The deadwood results for the Acacia-Comiphora biome are not considered reliable as some very large diameters are strongly influencing the results. It is expected that this data will become available once the national level data has been collected in the course of 2016.

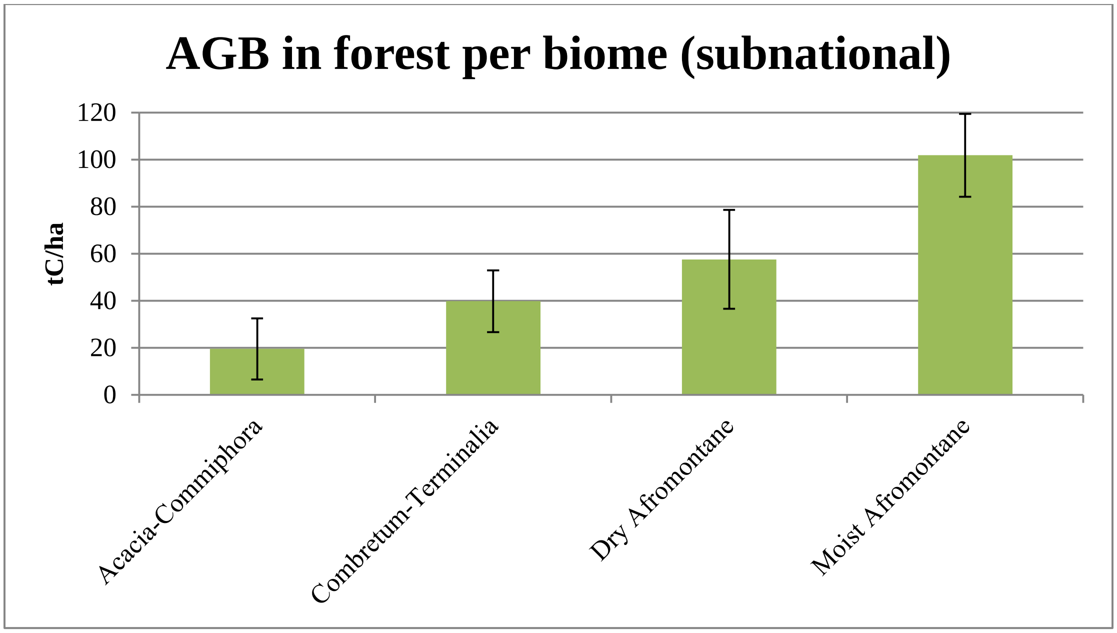


Figure 9 : NFI results for average AGB forest carbon stock per biome

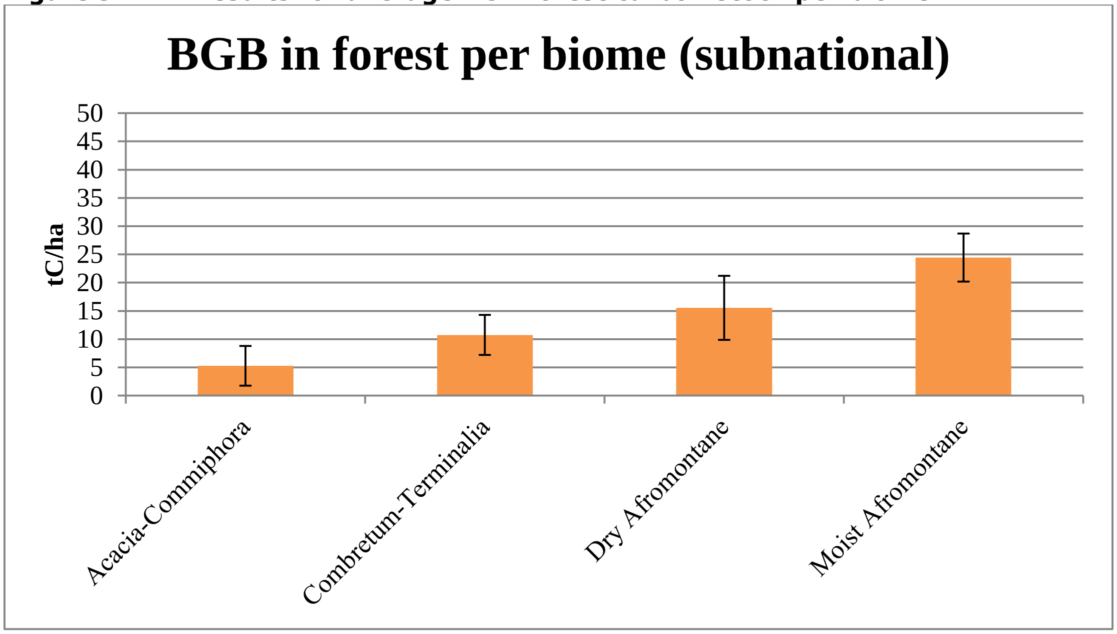


Figure 10: NFI results for average BGB forest carbon stock per biome

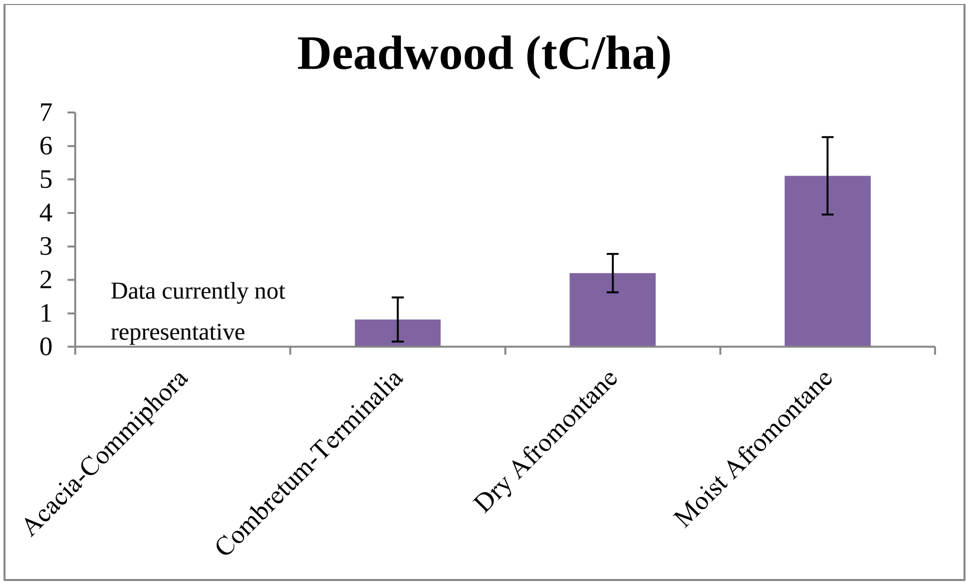


Figure 11: NFI results for average deadwood forest carbon stock per biome.

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 forestregrowt. 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).

5.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 II are enabling the community to actively participate in environmental protection and forest development ctivities, and implementing the green economy strategy at all administration levels and embarking on environmental protection and forest development at a scale. In the Second Growth and Transformation Plan, 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, mobilizing resources which can enable to fully implement the CRGE strategy is also another goal of the sector. In terms of forest development, it is planned to increase the share of the forest sector in the overall economy. It is also planned to increase the forest coverage through research-based forest development. During the GTP-2, doforestation is set to be reduced by half .

6.Proposed Forest Reference Level

6.1 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 over the period 2000-2013 assessed by AD x EF of 19.5 mln tCO2e/yr and a Forest Reference Level based on average annual removals over the period 2000-2013 assessed by AD x EF of -10.2.0 mln tCO2e/yr (Figures 12 and 13).

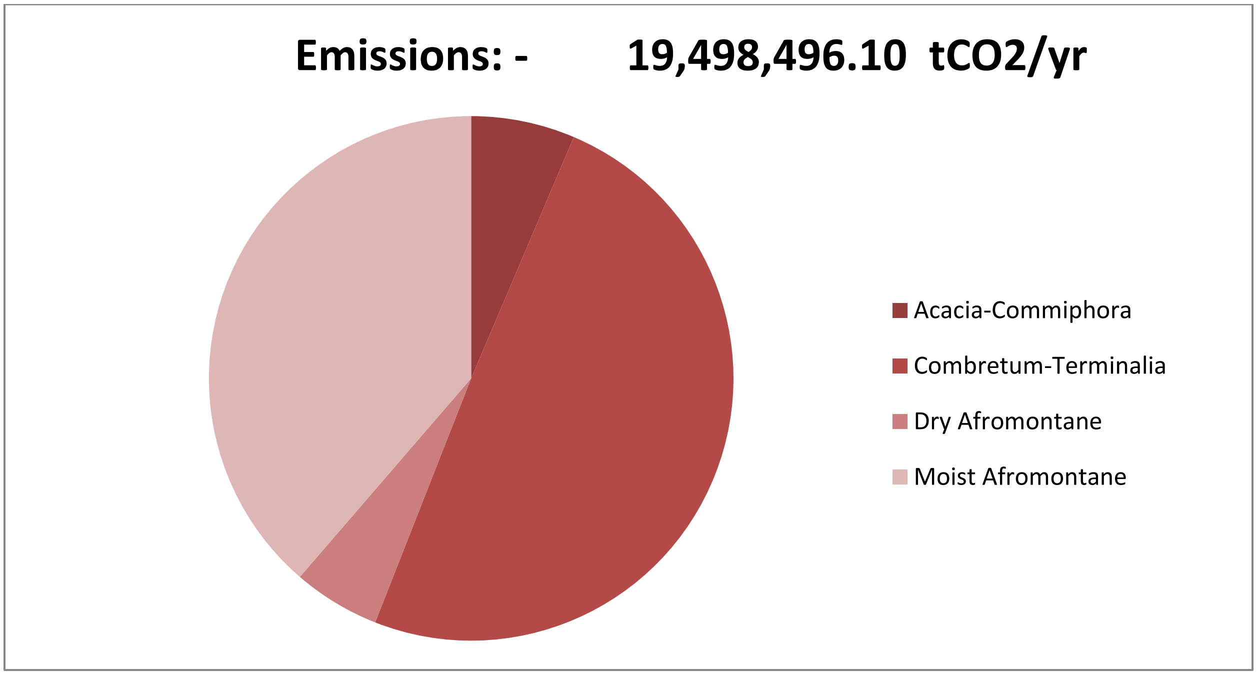


Figure 12: Emission by Biome.

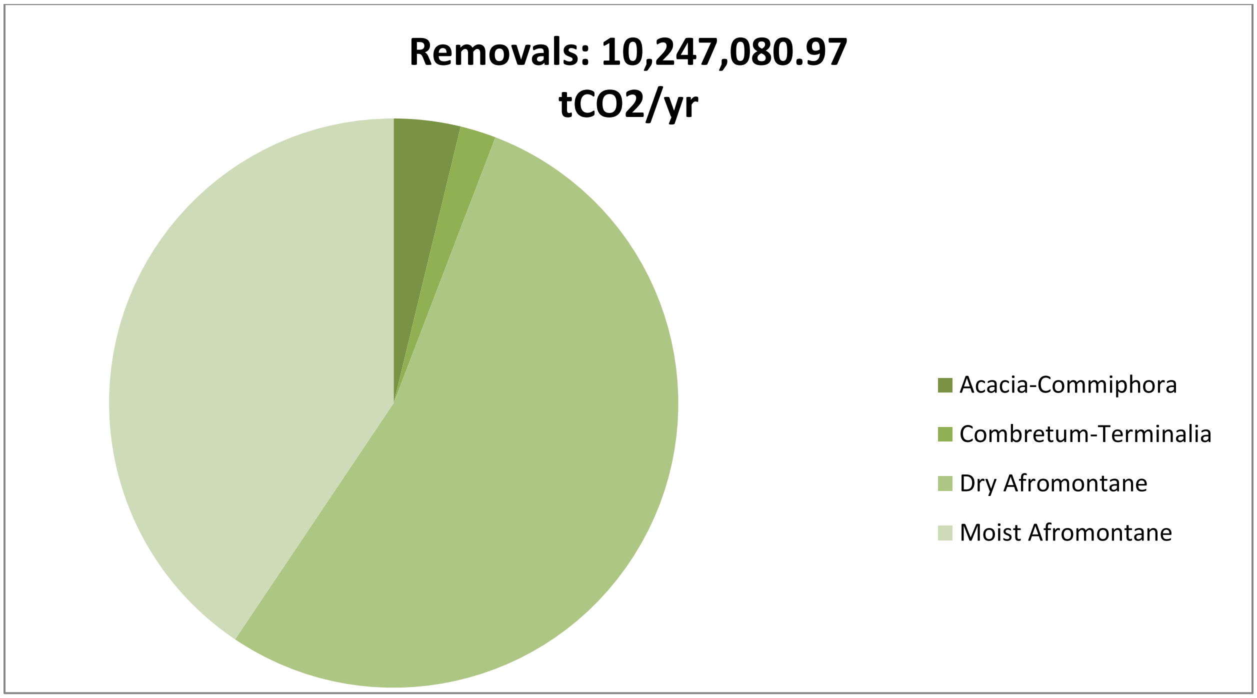


Figure 13: Removal by Biomes.

6.2 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.

7.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 boundries 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 method for consistent measuring and monitoring of emissions from forest degradation for its future inclusion in the FRL.

8.REFERENCES

1. Breiman, L., Freidman, JH, Olshen, RA, and Stonem CJ. 1984. Classification and regression trees. Wadsworth, Belmont CA.
2. Breiman. 2001. Random Forests. Machine Learning. 45, 2-32. https://www.stat.berkeley.edu/~breiman/RandomForests/cc_home.htm
3. CGIAR-CSI SRTM 90m DEM Digital Elevation Database, versión 4. CGIAR Consortium for Spatial Information (CGIAR-CSI). URL: http://srtm.csi.cgiar.org/Index.asp
4. Brown, S. (1997). Estimating biomass and biomass change of tropical forests: a Primer. FAO Forestry Paper 134:120-130.
5. Brown, S. (2002). Measuring carbon in forests: current status and future challenges. Environmental Pollution 116: 363-372.
6. Brown, S. and A. E. Lugo (1990). Tropical secondary forests. Journal of Tropical Ecology 6:1-32.
7. Brown, S. and Lugo, A. (1982). The storage and production of organic matter in tropical forests and their role in the global carbon cycle. Biotropica 14: 161-187.
8. Brown, S.A.J., Gillespie, J.R. and Lugo, A.E.(1989). Biomass estimation methods for tropical forests with application to forest inventory data. Forest Science 35: 110-115.
9. Chave J, Coomes D, Jansen S. 2009. Towards a worldwide wood economics spectrum. Ecology Letters, 12, 351–366.
10. Chave, J., Andalo, C., Brown, S., Cairns, M.A., Chambers, J.Q., Eamus, D., Fölster, H.,Fromard, F., Higuchi, N., Kira, T., Lescure, J.-P., Nelson, B., Ogawa, H., Puig, H.,Riéra, B., Yamakura, T., 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145, 87–99.
11. Cornelissen, J. H. C., S. Lavorel, E. Garnier, S. Diaz, N. Buchmann, D. E. Gurvich, P. B. Reich, H. ter Steege, H. D. Morgan, M. G. A. van der Heijden, J. G. Pausas, and H. Poorter. 2003. A handbook of protocols for standardized and December 2006 WOOD DENSITY IN NEOTROPICAL FORESTS 2365 easy measurement of plant functional traits worldwide. Australian Journal of Botany 51:335–380.
12. CSA (2007). Population and Housing Census Report-Country – 2007 (http://www.csa.gov.et/index.php/2013-02-20-14-51-51/2013-04-01-11-53-00/census-2007)
13. Demel Teketay, Mulugeta Lemenih, Tesfaye Bekele, Yonas Yemshaw, Sisay Feleke, Wubalem Tadesse, Yitebitu Moges, Tesfaye Hunde & Demeke Nigussie (2010). Forest Resources and Challenges of Sustainable Forest Management and Conservation in Ethiopia. In: Bongers F & T. Tennigkeit (eds). Degraded forests in Eastern Africa: management and restoration. Earthscan Publications.
14. FAO & JRC. 2012. *Global forest land-use change* 1990–2005, by E.J. Lindquist, R. D'Annunzio, A. Gerrand, K. MacDicken, F. Achard, R. Beuchle, A. Brink, H.D. Eva, P. Mayaux, J. San-Miguel-Ayanz & H-J. Stibig. FAO

Forestry Paper No. 169. Food and Agriculture Organization of the United Nations and European Commission Joint Research Centre. Rome, FAO. http://www.fao.org/docrep/017/i3110e/i3110e.pdf

15. FAO 2015. Global forest Resources Assessment. Rome, Italy.
16. FAO. 2015. Map Accuracy Assessment and Area Estimation: A Practical Guide.
17. Foody and Mathur. 2006. The use of small training sets containing mixed pixels for accurate hard image classification: Training on mixed spectral responses for classification by a SVM. Remote Sensing of Environment. 103:2, 179-189.
18. Friis, I., Demissew, S., & Breugel, P. V. (2010). Atlas of the potential vegetation of Ethiopia. Det Kongelige Danske Videnskabernes Selskab.
19. FSR (2015). Ethiopia Forest Sector Review. Focus on commercial forestry and industrialization. UNIQUE forestry and land use / CONSCIENTIA, Addis Ababa, Ethiopia.
20. Hedberg, I. (1996). Flora of Ethiopia and Eritrea (pp. 802-804). Springer Netherlands.
21. GFOI. 2014. Space data services: Support for National Forest Monitoring Systems.http://www.gfoi.org/wp-content/uploads/2015/03/Space_Data_Services_External__v1.1.pdf
22. Hansen, M. C., et al. 2013. High-resolution global maps of 21st-century forest cover change. Science, *342*(6160), 850-853.
23. Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., & Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.
24. Hurni K, Zeleke G, Kassie M, Tegegne B, Kassawmar T, Teferi E, Moges A, Tadesse D, Ahmed M, Degu Y, Kebebew Z, Hodel E, Amdihun A, Mekuriaw A, Debele B, Deichert G, Hurni H. 2015. Economics of Land Degradation (ELD) Ethiopia Case Study. Soil Degradation and Sustainable Land Management in the Rainfed Agricultural Areas of Ethiopia: An Assessment of the Economic Implications. Report for the Economics of Land Degradation Initiative. 94 pp.
25. Lehner, B. & Döll, P. (2004). Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology 296: 1-22.
26. Helina Tilahun and Emily Schmidt (2012). Spatial Analysis of Livestock Production Patterns in Ethiopia. ESSP II Working Paper 44, IFPRI, Addis Ababa, Ethiopia.
27. Olofsson, P., Foody, G. M., Stehman, S. V., & Woodcock, C. E. 2013. Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation.*Remote Sensing of Environment*, *129*, 122-131.
28. Olofsson, P., Foody, G. M., Herold, M., Stehman, S. V., Woodcock, C. E., & Wulder, M. A. 2014. Good practices for estimating area and assessing accuracy of land change. *Remote Sensing of Environment*, *148*, 42-57.
29. Pearcy R. W., Ehleringer J. R., Mooney H. A., Rundel P. W. . 1989. Plant physiological ecology. Chapman and Hall, New York, New York, USA.
30. Reusing, M. (2000). Change detection of natural high forests in Ethiopia using remote sensing and GIS techniques. International Archives of

Photogrammetry and Remote Sensing. Vol. XXXIII, Part B7. Amsterdam 2000

31. Reyes, G., S. Brown, J. Chapman, and A. E. Lugo. 1992. Wood densities of tropical tree species. General Technical Report SO-88. USDA Forest Service, Southern Forest Experiment Station, New Orleans, Louisiana, USA
32. Tewkesbury, A. P., Comber, A. J., Tate, N. J., Lamb, A., & Fisher, P. F. 2015. A critical synthesis of remotely sensed optical image change detection techniques. Remote Sensing of Environment, 160, 1-14.
33. De Vries P.G., 1986. Sampling theory for forest inventory. A teach-yourself course, Springer-Verlag, Berlin, 420 p.
34. WBISPP (2004). A strategic plan for the sustainable development, conservation and management of the woody biomass resources: Final report. Federal Democratic Republic of Ethiopia, Ministry of Agriculture. 60 pp.
35. Westerman R. L. 1990. Soil testing and plant analysis, 3rd ed. Soil Science Society of America, Madison, Wisconsin, USA.
36. de Wit, M. & Stankiewicz, J. 2006. Changes in Surface Water Supply across Africa with Predicted Climate Change. Science 311: 1917-1921.