THE UNITED REPUBLIC OF TANZANIA

TANZANIA'S FOREST REFERENCE EMISSION LEVEL SUBMISSION TO THE UNFCCC

DECEMBER 2016

SUMMARY

Approach	Historical average of emissions associated with gross-deforestation between the years 2002-2013
Scale	• National: As a sum of two sub-national FRELs: Main land Tanzania and Zanzibar covers 94.76 million ha • Reserved Area Strata covers 26,580,970 ha
Scope	• REDD+ activities: Deforestation • Carbon pools: Above-ground biomass, Below-ground biomass and Dead wood • Gases: CO_2
Data sets used for Activity data	Landsat 7 ETM+, Landsat 8 OLI; Landcover maps; Ortho-photographs; RapidEye
Emissions Factor (EF)	Based on National Forest Inventory (NFI) (NAFORMA, ZWBS)
Tier	Three (Based on NFI and local Allometric Equations)
Reference period	Mainland: 11 years, two data points (2002–2013) Zanzibar: 8 years, two data points (2004–2012)
Forest definition	Crown cover (%): ≥10 Tree height (m): ≥3 Area (ha): ≥0.5
Adjustment for national policy or economic growth	None
National FREL	58,462,472.67 t CO_2e
Reserved Area FREL	32,220,890.17 t CO_2e
Areas for improvement	• Additional REDD+ activities: Degradation, Enhancement of carbon stock, Sustainable Management of Forest and Forest Conservation • More data points • Additional carbon pools: Litter and Soil Carbon • Technical capacity

ACKNOWLEDGEMENTS

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ACRONYMS/ABBREVIATIONS

AD	Activity Data
AGB	Above-ground biomass
BGB	Below-ground biomass
CDM	Clean Development Mechanism
CO_2e	Carbon Dioxide equivalent
CoP	Conference of the Parties
DFNR	Department of Forestry and Non-Renewable Natural Resources
DW	Deadwood biomass
EF	Emission Factor
ETM+	Enhanced Thematic Mapper Plus
FBD	Forestry and Beekeeping Division
FREL	Forest Reference Emission Level
FRL	Forest Reference Level
GHG	Green House Gas
GFC	Global Forest Change
ha	hectare
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature and Natural Resources.
INC	Initial National Communication
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LULUCF	Land Use- Land Use Change and Forestry
LULC	Land Use-Land Cover
MANR	Ministry of Agriculture and Natural Resources
MRV	Measuring, Reporting and Verification
$MtCO_2e$	Million tonnes of CO_2 equivalent
MNRT	Ministry of Natural Resources and Tourism
NAFORMA	National Forest Resources Monitoring and Assessment
NCMC	National Carbon Monitoring Center
NFI	National Forest Inventory
NIBIO	Norwegian Institute of Bioeconomy Research

REDD+	Reducing Emissions from Deforestation and forest Degradation in developing countries; and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries.
RCMRD	Regional Centre for Mapping and Resource Development
RGoZ	Revolutionary Government of Zanzibar
SUA	Sokoine University of Agriculture
SNC	Second National Communication
TFS	Tanzania Forest Services Agency
TFCG	Tanzania Forest Conservation Group
TNC	Third National Communication
tC	Tonnes of Carbon
tCO_2e	Tonnes of CO_2 equivalent
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation
VPO	Vice President's Office
ZWBS	Zanzibar Woody Biomass Survey

1. INTRODUCTION

1.1 Background

The United Nations Framework Convention on Climate Change (UNFCCC), invited developing country Parties to submit voluntarily Forest Reference Emissions Level (FREL) for a technical assessment (Decisions 12/CP.17 and 13/CP.19). This is in the context of results-based payments for reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries (REDD+).

Tanzania has been a part to the UNFCCC since 1996 and accordingly, presents a proposal of her national FREL for her possible participation in the REDD+ activities (Paragraph 70, Decision 1/CP.16, paragraph 71(b) (UNFCCC, 2011). The purpose of the proposed Tanzania FREL is to facilitate access to international and regional funding, expand the forest resources base for domestic and export needs under public, private partnerships, to meet sustainable development goal and to assess achievement in forest resource management. This submission entails the FREL technical assessment in accordance with the guidelines and procedures adopted in decision 13/CP.19 (UNFCCC, 2014). Further, the information regarding methodologies used in constructing the FREL, that is, activities, pools, gases and the forest definition are provided following the guidelines of the Inter governmental Panel on Climate Change (IPCC) (IPCC, 2003: 2006). The proposed FREL is voluntary and it is mainly for the purpose of benefiting from the results-based payment, as per Decisions 9/CP.19, 13/CP.19 and 14/CP.19 (UNFCCC, 2014). According to Decision 12/CP.17, this submission will follow a stepwise approach, which allows incorporating better data, improved methodologies and adding more pools, where appropriate overtime.

1.2 Forest Reference Emission Level development process for Tanzania

Tanzania started REDD+ readiness process in 2008. This was possible through a generous support of the Government of the Kingdom of Norway among others, where the two countries agreed to cooperate for five years (2008-2013) on climate

change issues. During the REDD+ readiness phase, Tanzania undertook the following activities:

- Prepared the National Framework for REDD+;
- Prepared the National REDD+ Strategy and Action Plan;
- Conducted research and capacity building in support of REDD+;
- Carried out nine REDD+ pilot projects;
- Prepared draft of REDD+ Social and Environmental Safeguards and Standard; and
- Raised awareness on REDD+ among different stakeholders.

Moreover, Tanzania is in the process of establishing a National Carbon Monitoring Centre (NCMC). The NCMC is currently operating at a transitional phase and expects to be operational by 2019. This is a strategy of preparing the country for a result based payment mechanism under REDD+. In the result based payment mechanism, countries are required to quantify their achievements by establishing a robust and transparent forest carbon Measurement, Reporting and Verification (MRV) system. MRV provides a system on how to account for forest carbon, including changes over time. This system establishes the FREL against which the REDD+ achievements will be determined over time. NCMC started its activities in January 2016 where one of its initial tasks was to establish the MRV system for the estimation of FREL for the country. The first technical meeting on FREL for Tanzania was held at NCMC on 12th April 2016 and attended by experts from the Government, higher learning and research institutions, and the private sector. The meeting reached a common understanding and a way forward on the national forest definition; the scale; scope; activities, and data points for the REDD+ FREL of Tanzania. The following technical working groups were established to take up the process of FREL development:

- Technical working group on forest definition: This group worked on forest definition and came up with a proposed forest definition to be used in FREL process;
- Technical working group on activity data: This group worked on issues related to historical data, reference year for land cover- land use changes, and suggested future projections;

- Technical working group on emission factors: This group worked on possible emission factors to be included in the FREL process, taking into consideration the country circumstances;
- Technical working group on FREL: This working group reviewed other countries' FREL submissions to UNFCCC for drawing experiences, and practices relevant to Tanzania. The group suggested the content and layout of the FREL document, compiled activity data and emission factors and finally computed FREL.

The working groups were facilitated by NCMC to undertake their tasks. The groups presented their findings and suggestions to the second technical meeting held on 5th May 2016. This technical meeting reached a consensus on the proposed forest definition, proposed data and methodological approaches for estimating emission factors, activity data and the choice of REDD+ activity to be used for the FREL process. Having these deliverables from the technical meetings, NCMC organized a first FREL multi-stakeholder consultation meeting, which was held on 19th - 20th May 2016. The stakeholders who attended the meeting were from the Government, Government agencies, Universities, research institutions, NGOs and the private sector.

The outcomes of the four-national technical working groups and workshops/meetings included:

- A proposed forest definition for the REDD+ and CDM processes, which was later endorsed by the Government;
- Consensus on the use of the National Forest Resource Monitoring and Assessment (NAFORMA) data for Mainland Tanzania and Zanzibar Wood Biomass Survey (ZWBS) data for Zanzibar in estimating emission factors. The NAFORMA and ZWBS are comprehensive national forest inventories, which were conducted recently in Tanzania. NAFORMA was carried out from 2009 to 2013 (MNRT, 2015) while ZWBS was carried out in 2012 (RGoZ, 2013). While NAFORMA was the first NFI for mainland Tanzania, ZWBS of 2012 was preceded by ZWBS of 1997;

- Consensus on the adoption of Approach 3 of the IPCC Good Practice Guidelines (spatially explicitly) in the development of activity data for deforestation based on the available data and country circumstance; and
- Consensus on the inclusion of a stratum for reserved areas[1].

The preliminary results from this national process were then presented to the side meeting at the Oslo REDD+ exchange workshop held on 16th to 17th June 2016 in Ås, Norway. The team from Tanzania presented the country's expert views on how the FREL for the country would be developed. This was followed by presentations and discussions from and among international experts including Land Use Land Use Changes and Forestry (LULUCF) experts who had revised the previously submitted FREL from other countries, methodological experts in forest carbon monitoring and change estimations, and experts who had been involved in the development of other countries' FREL. The main goal of the side meeting was to share experiences with other experts on FREL development. Recommendations from the meeting were as follows:

- Based on the assessment of the available data, expertise and capacity, it is possible for Tanzania to submit her FREL in early December 2016, and have it reviewed by the UNFCCC technical assessment experts in March 2017. Accordingly, Tanzania should target to have the FREL document ready by October 2016, scrutinized by stakeholders in November 2016 and ready for submission by early December 2016. For this to be practical, it was advised that the FREL technical group should start working on the draft document, which would have details of all the procedures, processes and methodologies followed and plans for the future. Thus, each technical working group on FREL should clearly document all the procedure and methods used in detail to ensure transparency, accuracy, consistency and compatibility and that it is confined with the UNFCCC guidelines on the development of FREL; and

[1] Reserved areas are: Conservation Areas i.e. National Parks, Game Reserves, and Nature Forest Reserves (protective) and National Forest Reserves/forest reserves (Protective and/ Productive).

- Develop the Emission factor from the NAFORMA and ZWBS classification of forest types. The historical activity data for forest change detections used the 2002 Landsat 7 and the 2013 Landsat 8 data. This was based on the availability of both Landsat 7-year 2002 and Landsat 8 year 2013. Data collection for NAFORMA and ZWBS was finalized in 2013 and 2012, respectively; thus, it would be appropriate to link NAFORMA and ZWBS data with the remote sensing data (*see section 4.3 for details on the choice of data and years of data collection*).

The second and final formal stakeholder consultation and validation workshop was held on 20th December 2016 at NCMC, SUA - Morogoro. The workshop was officiated by the Permanent Secretary, Vice President's Office and attended by participants representing Government institutions, Government Agencies, NGOs and the private sector. The workshop participants reviewed and discussed the FREL document and provided comments and inputs aiming at improving the FREL document.

1.3. Consistency with GHGs Inventory reporting

The United Republic of Tanzania has been reporting on the GHGs inventory through her national communication reports submitted to the UNFCCC. The Initial National Communication (INC) was submitted in 2003 based on the GHGs inventory carried out in 1993. The Second National Communication (SNC) submitted in 2014 was based on the GHGs inventory carried out between 1995 and 2005, using 2000 as the base year. Both national communications used IPCC 2006 guidelines` Tier 1 approach.

These previous GHGs inventories employed outdated data, which were collected between 1993 and 2005, and since data for some sectors were missing, in such cases default global values were applied. This FREL used emission factors based on the recent data from the National Forest Inventories (NFI) in Mainland Tanzania and Zanzibar. The emission factors, which were derived from the NFI data in this submission, are therefore, considered as up-to-date and more detailed (Tier 3) compared to the previous GHGs inventories. Hence, data generated in the FREL development process will benefit the Third National Communication (TNC).

2. SCALE: AREA COVERED BY THE FOREST REFERENCE EMISSION LEVEL (FREL)

2.1 National FREL

This FREL submission considered country circumstance, that Tanzania is a Union of Mainland Tanzania and Zanzibar. A national FREL for gross deforestation was developed as a sum of FREL for Mainland Tanzania and that of Zanzibar as per UNFCCC Decision 12/CP.17. The national FREL therefore, covers a total area of 94.76 million ha of the United Republic of Tanzania (Figure 1) that is, 94.51 million ha in Mainland Tanzania and 250,000 ha of surface land in Zanzibar.

Tanzania is located between 1˚ 00' S and 12˚ 00' S and between 30˚ 00' E and 41˚00' E at an altitude between 358 m a.s.l. and 5950 m a.s.l. Mainland Tanzania is characterized by tropical climate, which can be divided into four distinct climatic zones, namely, the hot humid coastal plain, the semi-arid zone of the central plateau, the high-moist lake regions, and the temperate highland areas. The country has the mean maximum daytime temperatures ranging from 10˚C to 31˚C and the mean annual rainfall ranging from 500 to 2500 mm across the four zones. Zanzibar is characterized by tropical and humid climate with mild temperatures, with the average annual temperature of 31.5˚C, and the mean annual rainfall ranging from 1000 to 2500 mm.

The total forested land in Mainland Tanzania is 48.1 million ha, which is equivalent to 54.4% of the total land area of 88.3 million ha. Broadly, forested land in the country is comprised of forest and woodlands. Forests include montane, lowland, mangrove, and plantation forests, while woodlands include open and closed woodlands, and thickets. Woodlands occupy 44.7 million ha (~93.0% of the total forested land and 50.6% of Mainland Tanzania), followed by cultivated land (25.2%), bushland and grassland (16.6%) and forests (3.5%). In Zanzibar, forest cover is about 106,458 ha, which is equivalent to 40% of the total land area. This include bush and tall trees in coral rag areas (81%), mangroves (15%), and forest plantations (4%). Other land cover types are a mixture of trees and agricultural crops, clove plantation, coconut plantation, and mixed wood vegetation (RGoZ, 2013).

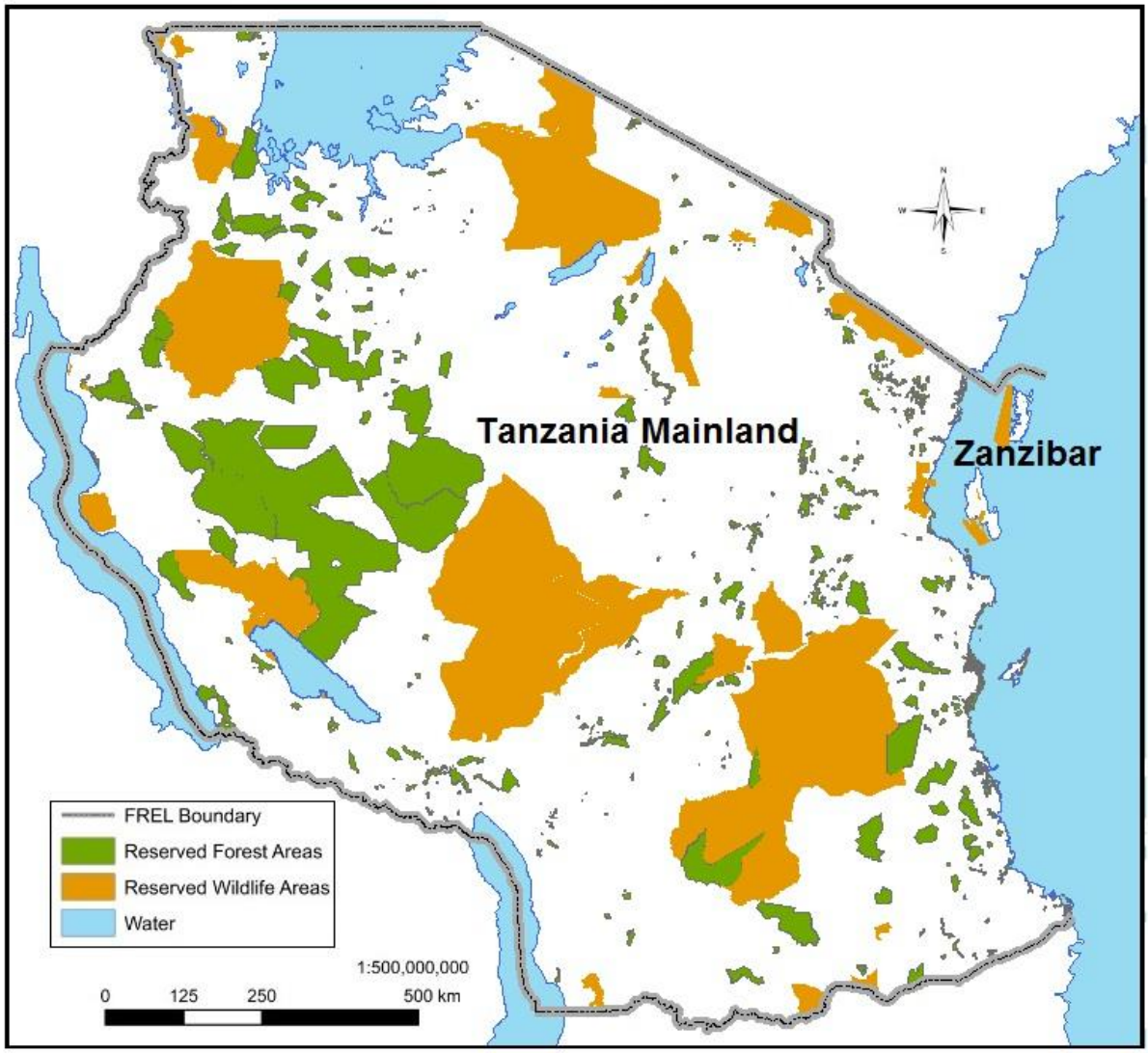

Figure 1: Area covered by the FREL: Mainland Tanzania and Zanzibar and Reserved Areas.

Forests in Tanzania play an important role in the daily livelihoods. They are an important source of energy for cooking, building timber, traditional medicine, tourism, fodder, water catchments, shelter for wildlife and estuaries for fish breeding areas. Furthermore, these forests also have high biodiversity, containing over 10,000 plant species, hundreds of which are nationally endemic, 724 species of flora and fauna identified as threatened in the IUCN Red List, and 276 species of flora and fauna classified as endangered (IUCN, 2013).

2.2 FREL for Reserved Areas

Reserved areas in Tanzania (Mainland and Zanzibar) include Conservation Areas, namely, National Parks, Game Reserves, and Nature Forest Reserves (Protective); and Forest Reserves (Protected and Production). These nature forest reserves and forest reserves are managed by either the Central Government or the Local Government Authorities. All reserved areas are included in this submission except the village land forest reserves and Wildlife Management Areas (WMA), due to inadequate spatial coverage data. The combined size of the considered reserved areas is 26,580,970 ha, that means, 26,425,806 ha are in mainland Tanzania and 155,164 ha are in Zanzibar.

The reserved area occupies almost 50% of the forested area in Tanzania. These reserved areas are legally protected, and therefore, it is possible to reverse the current forest losses with interventions.

3. SCOPE: ACTIVITIES, POOLS AND GASES INCLUDED IN THE CONSTRUCTION OF THE FREL

3.1. REDD+ Activities

REDD+ activities, which are referred to in the Decision 1/CP.16, paragraph 70 of the UNFCCC, include reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries. Deforestation is the only REDD+ activity considered in this submission; this is because of the availability of deforestation data and inadequate data for the other REDD+ components. Deforestation in this submission is defined as a change of forest cover to non-forest covers.

The total forest area under conservation in Tanzania is *ca* 14 million ha. Apart from their high carbon storage capacity, these forests have a unique biodiversity potential. In this submission, conservation of carbon stock is not included due to lack of past continuous forest inventory data for the conserved forest to depict both area and carbon stock changes. The presence of NAFORMA and ZWBS will largely mitigate this challenge and allow inclusion of conservation of forest carbon stock in the future submissions. The emphasis will be on the managed forest areas that include national parks, game reserves, nature forest reserves, local Government authority forest reserves, national forest reserves, community conserved forest areas, private, sacred forests and Wildlife Management Areas (WMA).

Forest degradation is not included in this submission although it is considered as a significant source of emission. The main drivers of forest degradation are extraction of wood fuel (charcoal and firewood), logging, grazing and wild fire. Forest degradation is taking place all over the country in a fragmented manner and degraded forests frequently maintain a closed canopy. This poses a significant challenge to the assessment and monitoring of forest degradation by means of remote sense techniques. However, NAFORMA and ZWBS have included assessment of harvesting or natural mortality through stumps measurements, which can be used to determine forest degradation. Moreover, there have been national

wild fires monitoring projects, which have been coordinated by Tanzania Forest Services (TFS) Agency and Tanzania Forestry Research Institute (TAFORI); these can also be used to determine forest degradation. However, these datasets are inadequate and have not been analyzed.

The enhancement of carbon stock has not been included in this submission. The assessment of enhancement of carbon stock should consider forest growth and area gain. Tanzania has a potential to include the enhancement of carbon stock in the future as one of the activities since there is a good number of afforestation, reforestation, and natural-regeneration programmes by the Government and the private sector, including smallholders' tree growers. However, accurate national data on the past reforested and afforested areas and the annual tree survival rate are missing. Future monitoring of afforestation and reforestation programmes through institutions such as NCMC will provide data for the enhancement of carbon stock.

Sustainable management of forest has also not been included in this submission despite the efforts on implementing sustainable forest management in Tanzania and different policy reforms, which go back to the colonial eras. However, the inclusion of sustainable management of forest in this submission is limited by inadequate data on the following, and which should be addressed in the future:

- Removals and emissions from forest management;
- Growing stock under different forest management regimes;
- Relevant historical data on forest management and governance at national level;
- The existing forest areas set for sustainable forest management and their monitoring plans;
- New areas subjected to sustainable forest management; and
- Inadequate and outdated forest management plans.

3.2 Carbon pools

The carbon pools included in this FREL submission are:

- Above-ground biomass (AGB);
- Below-ground biomass (BGB); and
- Deadwood biomass (DW).

These pools are included because of their significant size in Tanzania, the expected high rate of change, and most importantly, the availability of appropriate and accurate methods of estimation.

Soils and litter carbon pools are not included in this submission. Soil data were partially collected by NAFORMA and ZWBS but they could not be used due to uncertainties in monitoring changes. Data on litter were not collected by NAFORMA and ZWBS because of frequent fires that burnt the litter layer in the woodlands, which is the most dominant forest type in Tanzania.

3.3 Gases

This FREL submission considered carbon dioxide (CO_2) gas only. In this submission, the focus is more on reducing emission from forest related activities whereby CO_2 is the most emitted gas. Other GHGs may be considered in the future when accurate methods and reliable data become available.

4. INFORMATION USED AND METHODS FOR FREL CONSTRUCTION

4.1 Forest definition

In defining forest, this submission considered internationally agreed parameters (height, crown cover, and area) and technological capability of the country to monitor change in the forest area/carbon stocks and ensure social, economic and cultural aspects. Based on the national circumstance, that Tanzania is a Union of Mainland Tanzania and Zanzibar with different forest types and conditions, local policy and legal frameworks, the following definition is adopted;

'Forest' means an area of land with at least 0.5 ha, with a minimum tree crown cover of 10% or with existing tree species planted or natural having the potential of attaining more than 10% crown cover, and with trees which have the potential or have reached a minimum height of 3m at maturity in situ.

This definition is meant to cater for REDD+ and Clean Development Mechanism (CDM) programmes under UNFCCC. This definition was developed through a stakeholder's consultative process as shown in Section 1.2.

4.2. The Reference Period

The historical reference period is defined as the period from which the data for estimating past changes in forest areas are obtained. Both the initial and the last data point of the reference period for the current FREL are largely dictated by the availability of activity data and additional data for comparison.

For Mainland Tanzania, the reference period is 2002-2013. Year 2002 was chosen as the start of the reference period because of the availability of Landsat 7 ETM+ prior to the failure in line scanner of Landsat 7 Satellite in 2003. The year 2013 was selected because Landsat 8 OLI is available, with an improved image quality, and the year coincides with the period of NAFORMA measurements that are used as a background for forest classification or activity data stratification.

For Zanzibar, the reference period is 2004-2012. Year 2004 was chosen as the start of the reference period because of the availability of Ortho-photographs covering the two islands (Unguja and Pemba). These Ortho-photographs were also the basis for Land Cover Map that was used in ZWBS in 2005. The year 2012 was selected because of the availability of RapidEye data and coincided with the second phase of ZWBS, which was used as a background for forest classification or activity data stratification. Landsat data were not used for Zanzibar, because in most parts of the Island, Landsat Images were covered by clouds.

4.3 Activity Data

4.3.1 Mainland Tanzania and Zanzibar

Activity data used for the construction of Tanzania's FREL, were generated based on a land use land cover (LULC) change analysis for the period between 2002 and 2013 for Mainland Tanzania, and 2004 and 2012 for Zanzibar Islands. The analysis of the LULC change focused on changes from forest to non-forest. The classification scheme followed closely the approach described in the IPCC's Good Practice Guidance for LULUCF (IPCC, 2006). Using consultative workshops and considering the existing forest definition, the LULC was categorized into seven classes. These classes were later grouped into four broad classes. Table 1 provides a list of these classes along with their descriptions.

The forest cover change detection entailed an iterative process consisting of the following steps:

- Image acquisition and pre-processing;
- Collection of training data and Classification;
- Post-classification processing; and
- Accuracy assessment.

Table 1 Land Use Land Cover classes used in the activity data

LULC Classes	LULC Classes for mapping	National Land Cover Description
Forest Land	Forest	An area of land with at least 0.5 ha, with a minimum tree crown cover of 10% or with the existing tree species planted or natural having the potential of attaining more than 10% crown cover, and with trees which have the potential or have reached a minimum height of 3 m at maturity in situ. It includes montane, lowland, mangrove and plantation forests, woodlands and thickets.
Bushland	Non Forest	Bushland predominantly comprises of plants, which are multi-stemmed from a single root base. It includes dense and open bushland
Grassland		For the most part, grassland occurs in combination with either limited wooded or bushed component, or with scattered subsistence cultivation.
Cultivated Land		The land, which is actively used, and grows agriculture crops including agroforestry systems, wooded crops, herbaceous crops and grain crops
Other Lands		The land that includes settlement, bare land and rock outcrop, Costal bare lands, Ice cap / snow
Wetland	Wetland	The land which is water logged, may be wooded such as marshland, perennial flooded plains and swampy areas.
Water	Water	Includes inland water and Indian Ocean

Image acquisition and pre-processing

Bi-temporal analyses of LULC change require an extensive data selection and preparation to ensure comparability of the imagery. Appropriate selection of imagery acquisition dates is as crucial to the change detection method as is the choice of the sensor(s), change categories, and change detection algorithms. In consideration of cloud cover, the seasonality and phenological effects, better Landsat 7 and 8 images were selected for image processing from a large number of images. The images targeted were those acquired during the dry seasons (July-November) of the years

2002 and 2013 with minimum cloud cover (≤ 10%). However, getting all the images conforming to the criteria proved to be problematic in some areas. Owing to this constraint, for some places, the images acquired in the wet season were used. Landsat 7 and 8 OLI images were the major source of data for forest change assessment in Tanzania Mainland. The images were downloaded from freely available USGS and Earth Explorer websites (http://earthexplorer.usgs.gov/ and http://glovis.usgs.gov/). More than 50 Landsat 7 ETM+ (for 2002) and Landsat 8 (for 2013) images were downloaded. The Landsat 7 ETM+ scenes were pre-processed to surface reflectance level using the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) atmospheric and topographic correction algorithm. The Landsat 8 OLI scenes had already been processed to surface reflectance level by the USGS internal L8SR algorithm. Details of the pre-processing approach used by the USGS are provided in:
http://landsat.usgs.gov/documents/cdr_sr_product_guide_ee.pdf and http://landsat.usgs.gov/documents/Provisional_Landsat_8_SURFACE_REFLECTANCE_EE.pdf.).

It was difficult to find cloud free images for Zanzibar Islands, since most of the year is covered with clouds. As a result, the processed Ortho-photographs of 2004 at a scale of 1: 10,000 and images from the RapidEye satellite of the year 2012 were used. Details of the Ortho-Photographs and the RapidEye images used are described in the ZWBS of 2005 and 2012 (RGoZ, 2013).

Collection of training data and Classification

The collection of training data and classification were the iterative processes whereby each training data were evaluated using generated variables from the Random Forest (RF) (Figure 2a and 2b) and adjusted accordingly to produce better results.

```
Confusion matrix
> print(randfor$confusion)
    1   2  3  4   5   6   7   8   9 10  11  12  13  14  15 16  17  18 19
1  96   2  0  0   0   0   0   1   0  2   0   0   0   0   0  0   0   0  1
2   1 102  0  0   0   0   0   0   0  0   0   0   0   0   0  0   0   0  0
3   0   0 89 12   0   0   0   0   0  0   0   1   0   0   0  0   0   0  0
4   0   0 16 83   0   2   0   0   0  0   0   0   0   0   0  0   0   0  0
5   0   0  0  0 103   0   0   0   0  0   0   0   0   1   0  0   0   0  0
6   0   0  0  0   0 102   0   0   0  0   0   0   0   0   0  0   0   0  0
7   0   0  0  0   0   0 101   0   0  0   0   0   0   0   0  0   0   0  0
8   0   0  0  0   0   0   0 102   0  0   0   0   0   0   0  0   0   0  0
9   0   0  0  0   0   0   0   0 100  0   3   0   0   0   0  0   0   0  0
10  4   0  0  0   0   0   0   1   0 95   0   1   0   1   0  0   0   0  0
11  0   0  0  0   0   0   0   0   1  0 100   0   0   0   0  0   0   0  0
12  0   0  0  0   0   0   0   0   0  0   0 102   0   0   0  0   0   0  0
13  0   0  0  0   1   0   0   0   0  0   0   0 103   0   0  0   0   0  0
14  0   0  0  0   0   0   0   0   0  0   0   0   0 104   0  0   0   0  2
15  0   0  0  0   0   0   0   0   0  0   0   0   0   0 102  0   0   0  0
16  0   0  0  0   0   0   0   0   0  0   0   0   0   1   0 99   0   0  0
17  0   0  0  0   0   0   0   0   0  0   0   0   0   0   0  0 100   0  0
18  0   0  0  0   0   0   0   0   0  0   0   0   0   0   0  0   0 103  2
19  0   0  0  0   1   0   0   0   0  0   0   0   0   1   0  0   0   2 97
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Figure 2a: Internally generated confusion matrix (out-of-bag error) generated after running the RF algorithm (path 167, raw 64)

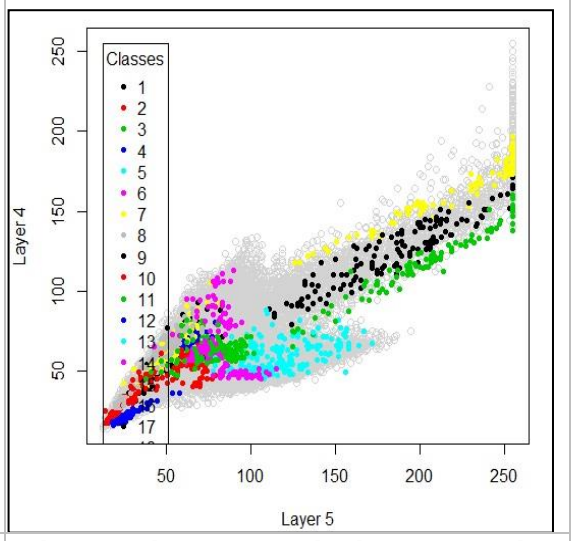

Figure 2b: Spectral signature plot generated by the RF classifier (path 167, raw 64)

The collection of training data was done for each Landsat scene separately using a layer stacked bi-temporal image (from 2002 and 2013), that means, six bands from each image (bands 1, 2, 3, 4, 5 and 7 from Landsat 7 and bands 2, 3, 4, 5, 6 and from Landsat 8). This process was carried out to minimize classification errors due to seasonality between scenes. Training polygons for deforestation, stable forest, wetland, water and other non-forest classes were digitized using image interpretation expertise and the Global Forest Change (GFC) product (Hansen et al., 2013).

The stacking of bi-temporal images increases the efficiency at which spectral information can be extracted because it eliminates the need for two separate classifications, and improves accuracy by eliminating the misinterpretation of classes between dates. Post-classification tends to produce less accurate change detection as the errors present in the classified map products are multiplied when maps are compared (Olofsson et al., 2014).

The classification of the bi-temporal stacked scenes was carried out using the RF algorithm. The RF algorithm is a machine learning technique whereby several decision trees are created and the response is calculated based on the outcome of

all the decision trees. According to Ned (2010), RF has several advantages when compared with other image classification methods: it is non-parametric, it is easy to parameterize, it is not sensitive to over-fitting; it is good at dealing with outliers in training data, and it is able to calculate useful information about errors, variable importance, and data outliers. This information can be used to evaluate the performance of the model and make changes to the training data if necessary. The RF model, which was developed using the training data, was then applied to the layer stacked images to generate forest change map for each scene. The initial assessment of the classification output was done by overlaying the output on the color composite and was visually checked for classification accuracy.

Post-classification processing

Post-classification processing included recoding, majority filtering, clumping, elimination, and mosaicking. The classified images were recoded to the five classes namely, stable forest, deforestation, non-forest, wetland, and water. Then, a 3 by 3 majority filter was employed to the recoded image to reduce the salt and paper effect; and lastly, the classes were filtered to a minimum mapping unit of about 0.5 ha to conform to the forest definition, that is, the minimum size is 0.5 ha.

Final interpretations from all scenes were mosaicked to produce a wall-to-wall forest change map for the entire country (Figure 3a and 3b). This was the basis for extracting statistics such as the total and annual rates of deforestation (Table 2a and 2b). The annual deforestation rate in Mainland Tanzania is estimated to be 580,000 ha while that of Zanzibar is 7,100 ha, making deforestation the most significant REDD+ activity. The main drivers of deforestation are establishment of settlement, extraction of wood for energy and expansion of agriculture. The observed rate of deforestation in this submission is comparable with that of NAFORMA which reported an annual deforestation rate of 372,816 ha for forest and 248,871 ha for woodlands between 1995 and 2010 (MNRT, 2015). With the current forest definition, most of the woodlands are categorised as forests.

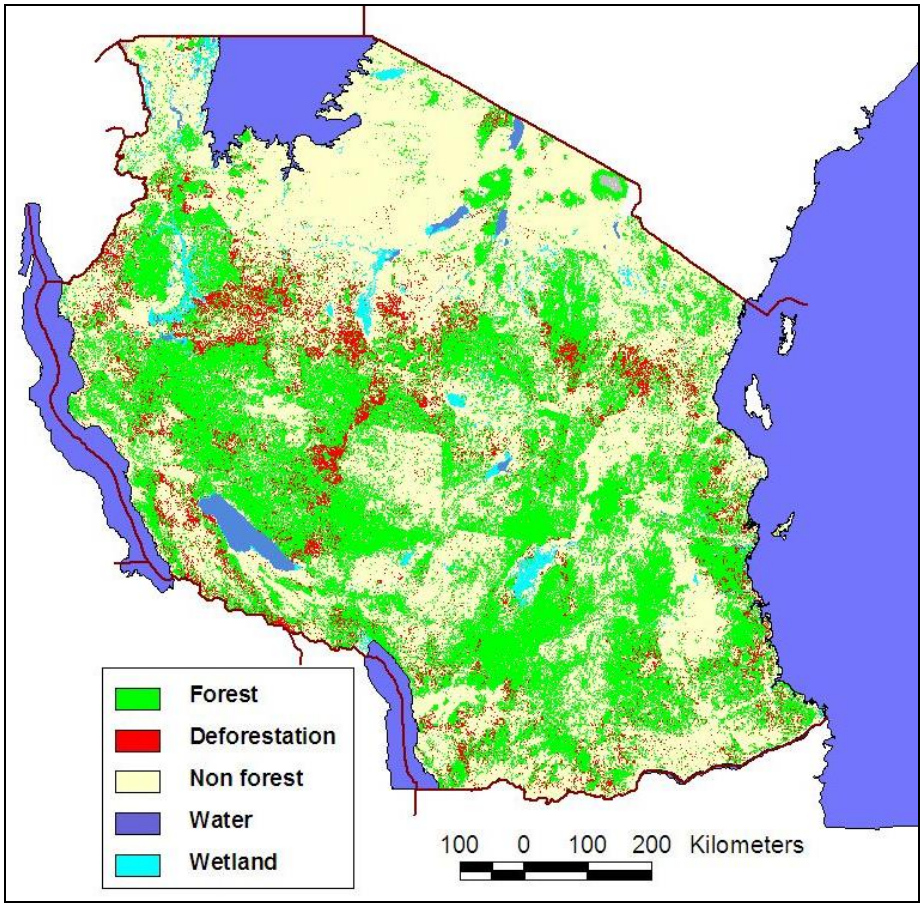

Figure 3a: Forest change maps for the Mainland Tanzania.

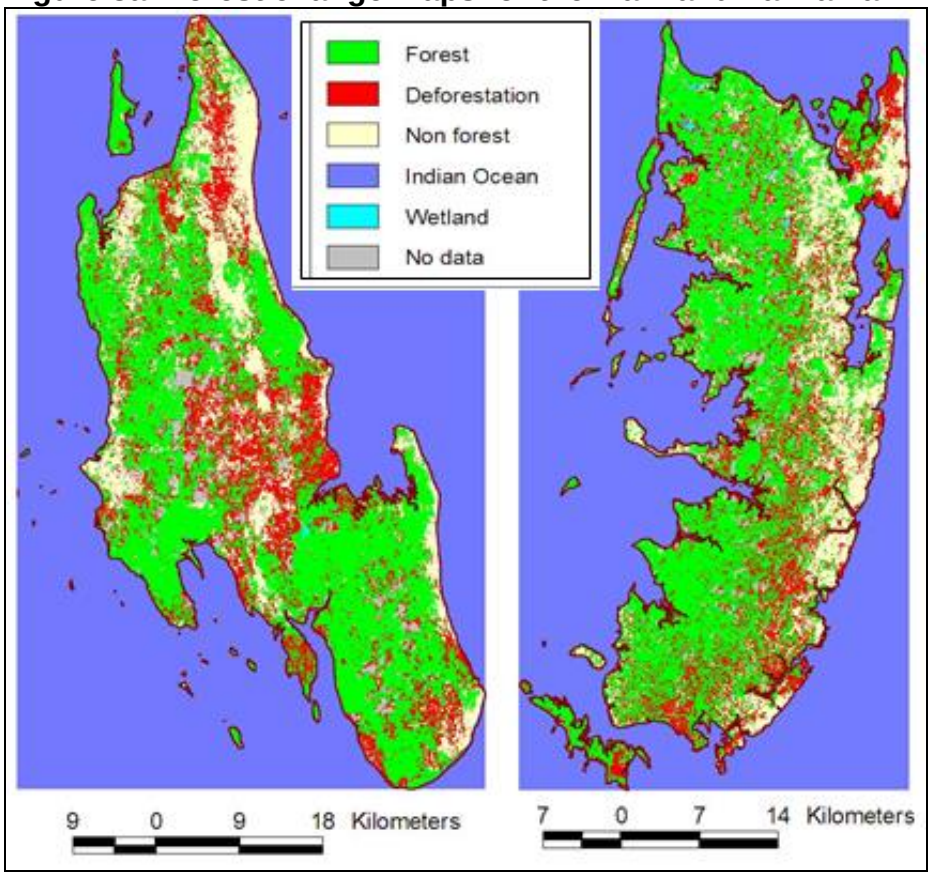

Figure 3b: Forest change maps for the Unguja (left) and Pemba (right) islands.

Table 2a: Forest change statistics (2002 – 2013) for the Tanzania Mainland

No.	Change class	Area (x 1,000 ha)	Annual loss (ha/yr)
1	Forest	32,000.9	
2	Deforestation	6,406.7	582,427.27
3	Non forest	47,595.3	
4	Wetland	4,506.9	
5	Water	1,697.3	
6	No data (clouds/shadow)	304.9	

Table 2b: Forest change statistics (2004 – 2012) for the Zanzibar Island

No.	Change class	Area (x 1,000 ha)			Annual loss (ha/yr)		
		Unguja	Pemba	Total	Unguja	Pemba	Total
1	Forest	84,048.50	56,837.00	140,885.50			
2	Deforestation	36,092.70	20,651.20	56,743.90	4,511.59	2,581.40	7,092.99
3	Non forest	30,192.80	19,754.50	49,947.30			
4	Wetland	184.93	48.47	433.39			
5	No data)	7,819.97	3,670.91	11,490.88			

Accuracy assessment

Accuracy was evaluated against two external datasets: NAFORMA and the RMRC LULC map. The NAFORMA sampling design followed a stratified systematic cluster sampling, taking into account cost and error estimations (Tomppo et al., 2010; URT, 2010). Three variables were used to compose the strata (18 in total) namely; time to measure a cluster; the mean volume of the growing stock on land on a cluster; and slope. This resulted in a total of 3,419 clusters and 32,660 plots. The 2000 Regional Centre for Mapping and Resource Development (RCMRD) LULC map was developed from Landsat Imagery (30m by 30m) resolution using supervised classification
[http://geoportal.rcmrd.org/layers/servir%3Atanzania_landcover_2000_scheme_ii]
The 2000 RCMRD map was determined to have an overall accuracy of about 86% (RCMRD, 2012) and was found to represent the LULC classes in Tanzania.

The two datasets, namely, NAFORMA (points) and RCMRD (raster layer) were combined using ArcGIS spatial analyst tool “extract value to points” to produce a

LULC change reference data. The results of Land Cover Change Accuracy Assessment for Mainland Tanzania are shown in Table 4.

Table 4: Land cover Change Accuracy Assessment for Mainland Tanzania

No.	Change class	Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	Users Accuracy (%)
1	Forest - forest	18,215	13,601	12,774	70	94
2	Forest - non	1,402	1,453	1,102	79	76
3	Non - non	7,147	11,692	6,331	89	54
4	Water - water	96	44	24	25	55
5	Wetland - wetland	231	301	97	42	32
Total		**27,091**	**27,091**	**20,226**	**75**	**75**

For the Zanzibar Island, a combination of datasets from the Zanzibar Woody Biomass Survey (ZWBS), which were conducted between 2012 and 2013, and the random validation points obtained from a visual interpretation of the 2004 aerial photographs by a remote sensing expert, were used to produce a LULC change reference dataset. The ZWBS sampling design was based on stratified sampling (RGZ, 2013). The sample plots were distributed within the initial LULC classes according to their expected variance. The final number of sample plots was 571, of which 267 were in Pemba and 304 were in Unguja. The strata (18) are the LULC classes, which were visually delineated from 2012 RapidEye imagery.

The accuracy assessment not only provided a quantification of the map accuracy through the creation of error matrices but also it provided error-adjusted area estimates for the forest and deforestation classes. The results of land cover change accuracy assessment for Zanzibar are shown in Table 5.

Table 5: Land cover Change Accuracy Assessment for Zanzibar

No.	Change class	Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	Users Accuracy (%)
1	Forest - forest	444	326	310	70	95
2	Forest - non	32	118	27	84	23
3	Non - non	57	89	45	79	51
5	Wetland - wetland	1	1	0	0	0
Total		534	534	382	72	72

4.3.2 Reserved areas

Reserved areas in Tanzania constitute about half of the forest area of the country. Since they are formally managed, it is much easier to change the trend of emissions by interventions. The REDD+ activity, which is considered in this submission for the reserved areas, is deforestation only. Shape files for wildlife reserves were obtained from the United Nations Environment programme and shape files for nature forest reserve and forest reserves were obtained from Tanzania Forest Service Agency. The shapefiles polygons for the reserved areas were overlaid with land cover change maps of the entire Tanzania. The approach of obtaining activity data within the reserved areas with total area of 26,580,970 ha are therefore the same as the approach used to obtain Activity data for Mainland Tanzania or Zanzibar depending on the location of the reserved areas.

4.4 Emissions factors

Emission factors were obtained from NAFORMA and ZWBS. As pointed out in Chapter one, NAFORMA was carried out from 2009 to 2013 while ZWBS was carried out from 2012. NAFORMA was the first NFI for Mainland Tanzania, while the 2012 ZWBS was preceded by the previous inventory carried out in 1997.

Emission factors used in this submission were based on Land Cover Classification that is consistent with the Activity data. Three primary classes of land cover are identified namely, Forest, Non-Forest and Wetlands. Each primary class consists of several land cover sub-classes, which are based on the land cover classification used by NAFORMA and ZWBS. Each primary class and its corresponding land

cover sub-class for Mainland Tanzania and Zanzibar are presented in Tables 6 and 7 respectively.

Emission factors for the current FREL is defined as the difference between the total carbon densities (t/ha) before and after deforestation. The total carbon stock density (t/ha) is the sum of the carbon in the AGB, BGB and DW pools associated with the land cover primary classes from NAFORMA and ZWBS. It was assumed that the carbon density after deforestation would not be zero. Accordingly, after deforestation, carbon density was derived from non-forest land cover primary classes using NAFORMA and ZWBS data. Details of the NAFORMA are presented in MNRT (2015), available at http://www.tfs.go.tz/resources/view/naforma-report-2015 and those for ZWBS are presented in RGoZ (2013) available at http://www.indufor.fi/zanzibar-woody-biomass-survey-tanzania-2012-2013).

Table 6: Classification of land cover types in Mainland Tanzania

Land cover sub-class	Primary class
Bushland: Thicket	Forest
Bushland: Thicket with emergent trees	Forest
Woodland: Scattered cropland	Forest
Forest: Humid Montane	Forest
Forest: Lowland	Forest
Forest: Mangrove	Forest
Forest: Plantation	Forest
Woodland: Closed (>40%)	Forest
Woodland: Open (10-40%)	Forest
Bushland: Dense	Non forest
Bushland: Emergent trees (<10%)	Non forest
Bushland: Open	Non forest
Bushland: Scattered cultivation	Non forest
Grassland: Scattered cropland	Non forest
Cultivated land: Agro-forestry system	Non forest
Cultivated land: Wooded crops	Forest
Cultivated land: Herbaceous crops	Non forest
Cultivated land: Mixed tree cropping	Forest
Cultivated land: Grain crops	Non forest
Grassland: Wooded	Non forest
Grassland: Bushed	Non forest
Grassland: Open	Non forest
Open land: Bare soil	Non forest
Open land: Salt crusts	Non forest
Open land: Rock outcrops	Non forest
Other areas	Non forest
Water: Inland water	Wetland
Water: Swamp	Wetland

Table 7: Classification of land cover types in Zanzibar

Land cover sub-class	Primary class
Bush vegetation, crown cover >50% within coral rag	Forest
Bush and tall trees within coral rag	Forest
High forest	Forest
Riverine forests	Forest
Mangrove forest	Forest
Forest tree plantations: Rubber	Forest
Cloves plantations	Forest
Coconut	Forest
Mixed woody vegetation	Forest
Forest tree plantations Casuarina, Acacia, teak	Forest
Ferns, grass, individual trees or groups of trees within coral rag	Non-forest
Mixture of trees and agricultural crops	Non-forest
Large scale field assortments	Non-forest
Subsistence agriculture	Non-forest
Paddy/Sugar cane field	Non-forest
Built-up areas	Non-forest
Other built up areas	Non-forest
Bare land other than beach	Non-forest

Procedures used to estimate emission factors (EF) for the respective land cover classes are as follows:

i. Estimating the AGB and BGB values of each tree measured in the NAFORMA/ZWBS plots, using appropriate allometric equations, developed for different vegetation types in Tanzania and obtaining plot levels values scaled up to per ha level (Appendix 2 and see also Malimbwi et al., 2016).

   Biomass for dead wood was estimated as the product of volume and specific wood density. Volume was computed using Smalian formula (the average of the cross section area at the top and bottom of the dead wood log multiplied by its length). Species-specific wood density values from the Global Wood Density database (Chave et al., 2009; Zanne et al., 2009) were applied. For cases where species-specific wood density values were missing from the database, a default wood density value of 500 kg m^{-3} (MNRT, 2015) was applied. Irrespective of

species, a wood density reduction factor of 0.97 was used for solid woods and 0.45 was used for the more decayed wood (Harmon and Sexton, 1996 in IPCC, 2006);

ii. Stratifying the NAFORMA/ZWBS plots into appropriate land cover sub-classes which were further aggregated into primary land cover classes (Tables 1 and 2) that are consistent with activity data classification;

iii. Estimating the average biomass stock per unit area and the associated uncertainties for each of the land cover sub-class; and

iv. Estimating emission factors of each primary land cover class as a mean of the land cover sub-class estimates, which were weighted by their corresponding areas. The emission factor of a given primary land cover class was therefore computed using equation (1).

$$Y_i = \frac{\sum_{i=1}^{n}(X_i * a_i)}{\sum_{i=1}^{n} a_i} \quad \text{.......} \quad (1)$$

Where Y is the weighted estimate of AGB, BGB or DW per ha, *a* is the area of land cover sub-class *i*, X is AGB, BGB or DW per ha of the land cover sub-class and *n* is the number of land cover sub-classes in the primary land cover class.

v. Calculating Emission Factors for each primary land cover class as the sum of AGB, BGB and DW, and then multiplied by a factor of 0.47 to convert the biomass to carbon (IPCC, 2006). In this case, the quality of data and the method, which were used to obtain EF is high and correspond to Tier 3 (for details see Table 8).

Table 8: Emission factor for each primary land cover classes

Location	**Primary Land Cover Class**	**Carbon (t/ha)**
Mainland Tanzania	Forest	33.35
	Non forest	5.86
	Wetland	4.28
Zanzibar	Forest	12.26
	Non-forest	8.48

5. THE FREL CALCULATION AND RESULTS

The national FREL consists of two sub-national FRELs namely, Mainland Tanzania and Zanzibar (Fig. 1). Each sub-national FREL was computed as shown in Equation 2.

$$FREL = Area_{Activity}\, x\left(EF_{Forest} - EF_{Non-Forest}\right) \quad \text{..... (2)}$$

For reserved areas, Activity data were obtained as shown in section 4.3.4 and for the emission factor as shown in the procedure under section 4.4, and were estimated by applying Equation 2 for Mainland Tanzania or Zanzibar (See Tables 9 and 10). To obtain the carbon dioxide equivalent (tCO_2e) the activity data generated from FREL (Equation 2) was multiplied by a factor of 3.667.

Table 9: The Tanzanian Forest Reference Emission Level

Scope	**Annual Activity Data (ha/year)**	**Forest EF (t/ha)**	**Non-Forest EF (t/ha)**	**FREL (tCO_2e/year)**
Mainland Tanzania (Sub-National 1)	580,000	33.35	5.86	58,462,066.67
Zanzibar (Sub-National 2)	7,100	12.26	8.48	406.00
Total National FREL				**58,462,472.67**

Table 10: Activity data, Emission Factors and FREL for Reserved Areas

Scope	**Annual Activity Data (ha/year)**	**Forest EF (t/ha)**	**Non-Forest EF (t/ha)**	**FREL (tCO_2e/year)**
Mainland Tanzania (Sub-National 1)	319, 390.00	33.35	5.86	32,193,447.37
Zanzibar (Sub-National 2)	1,980.00	12.26	8.48	27,442.80
Total FREL				**32,220,890.17**

The current FREL for Tanzania is therefore estimated at 58,462,472 tCO_2e/year. This is about 0.92% of the total amount of 6,327,717,997 tCO_2 stock in the forested land of Tanzania (MNRT, 2015).

6. EXPECTED IMPROVEMENTS

Tanzania will take advantage of stepwise approach to improve the current FREL overtime by incorporating more REDD+ activities, better data, improved methodologies and, where appropriate, additional pools. Furthermore, Tanzania will update her FREL periodically incorporating new knowledge, trends, or any modification of scope and methodologies.

Repeated measurements from NAFORMA and ZWBS will provide data for forest degradation, enhancement and conservation of carbon stocks. These inventory data together with decreasing costs and availability of remote sensing data of higher spatial and temporal resolution will allow inclusion of the remaining REDD+ activities in future FREL. However, availability of data for sustainable forest management is still a challenge, which may be addressed in the distant future.

Soil data were partially collected and analyzed by NAFORMA and ZWBS and thus, they could not be used. Monitoring of soil organic carbon will be possible in the future when the analysis of soil data is completed and repeated measurement from NAFORMA and ZWBS made available.

Ideally, the number of data points should be sufficient to understand the dynamics and possible trends in historical emissions. This would enhance a country's capacity in identifying key national circumstances to be considered, and choose the most appropriate FREL/FRL construction approach. However, the choice of data points in this submission was constrained by availability of historical data. In the future, with availability of promising remote sensing sensors and ground re-measurement more data point will be included.

Tanzania has started the process of establishing her National Carbon Monitoring Centre (NCMC). This centre will harness human and technical capacity that will improve and implement a robust MRV system in order to improve the future FREL.

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APPENDICES

Appendix 1. The list of technical institutions, experts and stakeholders participated in the development of the FREL

Coordination and participants

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12.	Ms. Namkunda Johnson	National Carbon Monitoring Centre
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Appendix 2: Allometric biomass and volume equations for different vegetation types in Tanzania

Veg Type	**Species**	AGB	**Source**	BGB	**Source**	**Volume (m^3)**	**Source**
Forest: Humid Montane	All	$0.3571\times dbh^{1.744}\times ht^{0.4713}$	Mugasha et al., 2016a	AGB×0.25	MNRT, 2015	$0.000076 x dbh^{2.3488} x ht^{0.3848}$	Mugasha et al., 2016a
Forest: Lowland	All	$0.3571\times dbh^{1.744}\times ht^{0.4713}$	Mugasha et al., 2016a	AGB×0.25	MNRT, 2015	$0.000076 x dbh^{2.3488} x ht^{0.3848}$	Mugasha et al., 2016a
Forest: Mangrove	*Avicenia marina*	$0.25128\times dbh^{2.24351}$	Njana et al., 2016	$1.42040\times dbh^{1.44260}$	Njana et al., 2016	$0.000202\times dbh^{2.361854}$	Njana .2016
	Soneratia alba	$0.25128\times dbh^{2.21727}$	Njana et al., 2016	$1.42040\times dbh^{1.65760}$	Njana et al., 2016	$0.000202\times dbh^{2.361854}$	Njana. 2016
	Rhizophora mucronata	$0.25128\times dbh^{2.26026}$	Njana et al., 2016	$1.42040\times dbh^{1.68979}$	Njana et al., 2016	$0.000202\times dbh^{2.361854}$	Njana. 2016
	Others	$0.19633\times dbh^{2.010853}\times ht^{0.29654}$	Njana et al., 2016	$1.42040\times dbh^{1.59666}$	Njana et al., 2016	$0.000202\times dbh^{2.361854}$	Njana. 2016
Forest: Plantation	*Tectona grandis*	$0.1711\times dbh^{2.0047}\times ht^{0.3767}$	Zahabu et al., 2016a	$0.0279\times dbh^{1.7430}\times ht^{0.7689}$	Zahabu et al., 2016a	$0.00014\times(ht\times dbh^2)^{0.8793}$	Zahabu et al., 2016a
	Pinus patula	$0.0550\times dbh^{2.5968}$	Mugasha et al., 2016b	$0.0027\times dbh^{3.0579}$	Mugasha et al., 2016b	exp(-9.10398+2.106032xln(Dbh)+0.521077xln(Ht))	Malimbwi et al., 2016
	Eucalyptus spp	volume×843×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.000065\times dbh^{1.633} ht^{1.137}$	Malimbwi and Mbwambo, 1990
	Grevillea robusta	volume×609×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.000065\times dbh^{1.633} ht^{1.137}$	Malimbwi and Mbwambo, 1990
	Others	volume×500×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.5\times 3.14\times(0.01\times dbh/2)^2\times ht$	Haule and Munyuku, 1994
Woodland: Closed (>40%)	All	$0.0763\times dbh^{2.2046}\times ht^{0.4918}$	Mugasha et al., 2013	$0.1766\times dbh^{1.7844} ht^{0.3434}$	Mugasha et al., 2013	$0.00011\times dbh^{2.133} ht^{0.5758}$	Mauya et al., 2014
	Baobab	$2.234966\times dbh^{1.43543}$	Masota et al., 2016	AGB×0.25	MNRT, 2015	$0.005804\times dbh^{1.507423}$	Masota et al., 2016
	Dalbergia melanoxylon	Volume×1060×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.00023\times dbh^{2.231}$	Malimbwi, 2000
Woodland: Open (10-40%)	All	$0.0763\times dbh^{2.2046}\times ht^{0.4918}$	Mugasha et al., 2013	$0.1766\times dbh^{1.7844} ht^{0.3434}$	Mugasha et al., 2013	$0.00011\times dbh^{2.133} ht^{0.5758}$	Mauya et al., 2014
	Baobab	$2.234966\times dbh^{1.43543}$	Masota et al., 2016	AGB×0.25	Masota et al., 2016	$0.005804\times dbh^{1.507423}$	Masota et al., 2016

	Dalbergia melanoxylon	Volume×1060×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.00023\times dbh^{2.231}$	Malimbwi, 2000
Bushland: Thicket, dense	*Pseudoprosopis fischeri*	$0.4276\times dbh^{2.4053} st^{0.5290}$	Makero et al., 2016	$0.1442\times dbh^{4.1534} st^{0.4117}$	Makero et al., 2016	$0.00017\times dbh^{2.2177} ht^{0.5468} st^{0.7903}$	Makero et al., 2016
	Combretum celastroides	$0.7269\times dbh^{2.6710}\times ht^{0.5737} st^{0.2039}$	Makero et al., 2016	$0.1006\times dbh^{4.0062} st^{0.33499}$	Makero et al., 2016	$0.00023\times dbh^{2.4615} ht^{0.9089} st^{0.4534}$	Makero et al., 2016
	Baobab	$2.234966\times dbh^{1.43543}$	Masota et al., 2016	AGB×0.25	Masota et al., 2016	$0.005804\times dbh^{1.507423}$	Masota et al., 2016
Bushland: Emergent trees	All	$1.2013\times dbh^{1.5076}$	Makero et al., 2016	$1.3803\times dbh^{1.1671}$	Makero et al., 2016	$0.00042\times dbh^{1.5009} ht^{0.6419}$	Makero et al., 2016
Bushland: Thicket with emergent trees	All	$1.2013\times dbh^{1.5076}$	Makero et al., 2016	$1.3803\times dbh^{1.1671}$	Makero et al., 2016	$0.00042\times dbh^{1.5009} ht^{0.6419}$	Makero et al., 2016
Bushland: Open	others	$0.0763\times dbh^{2.2046}\times ht^{0.4918}$	Mugasha et al., 2013	$0.1766\times dbh^{1.7844} ht^{0.3434}$	Mugasha et al., 2013	$0.00011\times dbh^{2.133} ht^{0.5758}$	Mauya et al., 2014
	Acacia and Commiphora spp	$0.0292\times dbh^{2.0647}\times ht^{1.0146}$	Mugasha et al., 2016c	$0.0593\times dbh^{1.4481}\times ht^{1.0210}$	Mugasha et al., 2016c	$0.00009\times dbh^{2.0993}\times ht^{0.4914}$	Mugasha et al., 2016c
Grassland: Wooded	Others	$0.0763\times dbh^{2.2046}\times ht^{0.4918}$	Mugasha et al., 2013	$0.1766\times dbh^{1.7844} ht^{0.3434}$	Mugasha et al., 2013	$0.00011\times dbh^{2.133} ht^{0.5758}$	Mauya et al., 2014
	Acacia and Commiphora spp	$0.0292\times dbh^{2.0647}\times ht^{1.0146}$	Mugasha et al., 2016c	$0.0593\times dbh^{1.4481}\times ht^{1.0210}$	Mugasha et al., 2016c	$0.00009\times dbh^{2.0993}\times ht^{0.4914}$	Mugasha et al., 2016c
	Baobab	$2.234966\times dbh^{1.43543}$	Masota et al., 2016	AGB×0.25	Masota et al., 2016	$0.005804\times dbh^{1.507423}$	Masota et al., 2016
Grassland: Bushed Grassland: Open	Others	$0.0763\times dbh^{2.2046}\times ht^{0.4918}$	Mugasha et al., 2013	$0.1766\times dbh^{1.7844} ht^{0.3434}$	Mugasha et al., 2013	$0.00011\times dbh^{2.133} ht^{0.5758}$	Mauya et al., 2014
	Acacia and Commiphora spp	$0.0292\times dbh^{2.0647}\times ht^{1.0146}$	Mugasha et al., 2016c	$0.0593\times dbh^{1.4481}\times ht^{1.0210}$	Mugasha et al., 2016c	$0.00009\times dbh^{2.0993}\times ht^{0.4914}$	Mugasha et al., 2016c
	Baobab	$2.234966\times dbh^{1.43543}$	Masota et al., 2016	AGB×0.25	Masota et al., 2016	$0.005804\times dbh^{1.507423}$	Masota et al., 2016
Woodland: Scattered cropland (Unspecified	All	$0.0763\times dbh^{2.2046}\times ht^{0.4918}$	Mugasha et al., 2016	$0.1766\times dbh^{1.7844}\times ht^{0.3434}$	Mugasha et al., 2013	$0.00011\times dbh^{2.133} ht^{0.5758}$	Mauya et al., 2014
	Baobab	$2.234966\times dbh^{1.43543}$	Masota et	AGB×0.25	Masota et al., 2016	$0.005804\times dbh^{1.507423}$	Masota et al., 2016

density)			al., 2016				
Bushland: Scattered cultivation	All	$1.2013 \times dbh^{1.5076}$	Makero et al., 2016	$1.3803 \times dbh^{1.1671}$	Makero et al., 2016	$0.00042 \times dbh^{1.5009} ht^{0.6419}$	Makero et al., 2016
	Baobab	$2.234966 \times dbh^{1.43543}$	Masota et al., 2016	AGB×0.25	Masota et al., 2016	$0.005804 \times dbh^{1.507423}$	Masota et al., 2016
Grassland: Scattered cropland	All	$1.2013 \times dbh^{1.5076}$	Makero et al., 2016	$1.3803 \times dbh^{1.1671}$	Makero et al., 2016	$0.00042 \times dbh^{1.5009} ht^{0.6419}$	Makero et al., 2016
Cultivated land: Agro-forestry system	All	$0.051x(dbh^2xht)^{0.93}$	Henry et al., 2009	AGB×0.25	MNRT, 2015	$(0.051x(dbh^2xht)^{0.93})/(1.4x500)$	MNRT, 2015
Cultivated land: Wooded crops	Coconuts trees	$3.7964 \times ht^{1.8130}$	Zahabu et al., 2016b	$13.5961 \times ht^{0.6635}$	Zahabu et al., 2016b	$0.03470 \times ht^{1.1873}$	Zahabu et al., 2016b
	Cashewnuts	$0.3152 \times dbh^{1.7722} ht^{0.5003}$	Zahabu et al., 2016c	AGB×0.25	MNRT, 2015	$0.0000001 \times dbh^{2.6044}$	Zahabu et al., 2016c
	Others	$0.0763 \times dbh^{2.2046} \times ht^{0.4918}$	Mugasha et al., 2013	$0.1766 \times dbh^{1.7844} xht^{0.3434}$	Mugasha et al., 2013	$0.00011 \times dbh^{2.133} ht^{0.5758}$	Mauya et al., 2014
Cultivated land: Herbaceous crops	All	$0.051x(dbh^2xht)^{0.93}$	Henry et al., 2009	AGB×0.25	MNRT, 2015	$(0.051x(dbh^2xht)^{0.93})/(1.4x500)$	MNRT, 2015
Cultivated land: Mixed tree cropping	All	$0.051x(dbh^2xht)^{0.93}$	Henry et al., 2009	AGB×0.25	MNRT, 2015	$(0.051x(dbh^2xht)^{0.93})/(1.4x500)$	MNRT, 2015
Cultivated land: Grain crops	All	$0.051x(dbh^2xht)^{0.93}$	Henry et al., 2009	AGB×0.25	MNRT, 2015	$(0.051x(dbh^2xht)^{0.93})/(1.4x500)$	MNRT, 2015
Open land: Bare soil	All	volume×500×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.5 \times 3.14 \times (0.01 \times dbh/2)^2 \times ht$	Haule and Munyuku, 1994
Open land: Salt crusts	All	volume×500×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.5 \times 3.14 \times (0.01 \times dbh/2)^2 \times ht$	Haule and Munyuku, 1994
Open land: Rock outcrops	All	volume×500×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.5 \times 3.14 \times (0.01 \times dbh/2)^2 \times ht$	Haule and Munyuku, 1994
Water: Inland water	All	volume×500×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.5 \times 3.14 \times (0.01 \times dbh/2)^2 \times ht$	Haule and Munyuku, 1994
Water: Swamp	All	volume×500×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.5 \times 3.14 \times (0.01 \times dbh/2)^2 \times ht$	Haule and Munyuku, 1994
Other areas	All	volume×500×1.4	IPCC, 2006; MNRT, 2015	AGB×0.25	MNRT, 2015	$0.5 \times 3.14 \times (0.01 \times dbh/2)^2 \times ht$	Haule and Munyuku, 1994

Remarks:

For Thicket and dense bushland, the variable ST stands for number of stems in a clump. This variable should be “1”.