REPUBLIC OF ZAMBIA

FOREST REFERENCE EMISSIONS LEVEL (ZAMBIA)

Submission to the UNFCCC
January 2021

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List of Acronyms

AD	Activity Data
AFOLU	Agriculture Forestry and Other Land Use
AGB	Above Ground Biomass
BGB	Below Ground Biomass
CE	Collect Earth
CI	Confidence Interval
CO2	Carbon Dioxide
DBH	Diameter at breast height
DW	Dead Wood
EF	Emissions Factor
FRA	Forest Resources Assessment
FREL	Forest Reference Emissions Level
GHG	Greenhouse Gas Inventory
ILUA I	Integrated Land Use Assessment Phase I
ILUA II	Integrated Land Use Assessment Phase II
IPCC	Intergovernmental Panel on Climate Change
L	Litter
LULUCF	Land Use Land Use Change and Forestry
LUS	Land use / forest type sections
NFI	National Forest Inventory
NFMIS	National Forest Monitoring and Information Systems
NPE	National Policy on Environment
QA	Quality Assurance
QC	Quality Control
REDD+	Reducing emissions from deforestation and forest degradation
SeNDP	Seventh National Development Plan
SNC	Second National Communications
SoP	Standard Operating Procedures
TNC	Third National Communication
UNFCCC	United Nations Framework Convention on Climate Change
ZEMA	Zambia Environmental Management Agency
ZIFLP	Zambian Integrated Forest Landscapes Program

1. INTRODUCTION

Zambia welcomes the opportunity to submit a proposed Forest Reference Emissions Level (FREL) to the United Nations Framework Convention on Climate Change (UNFCCC) in response to Decision 1/CP.16 that requests developing country Parties intending to undertake REDD+ activities to develop a national FREL. The submission is presented voluntarily, and in accordance with Decision 12/CP.17 (Guidelines for Submissions of Information on Reference Levels), with a view that it will be technically assessed in the context of results-based payments in accordance with Decision 13/CP.19.

Zambia is adopting a "stepwise" approach to the development of its FREL, according to Decision 12/CP.17, and intends to make improvements over time by incorporating enhanced information, improved methodologies and additional carbon pools and activities. The proposed FREL in this document has been constructed with the best information available to Zambia at the time of submission. The data and information used in the FREL applies the most recent guidance and guidelines provided by the IPCC, notably the 2006 Guidelines.

The proposed FREL does not prejudge Zambia's Nationally Determined Contribution or Nationally Appropriate Mitigation Actions in the land and forestry sectors undertaken by Zambia. At this time, Zambia's objective in submitting a proposed FREL is to build capacity and to have a facilitated exchange with technical LULUCF experts from the UNFCCC roster of experts, and through such an effort, to improve the FREL as part of a stepwise approach.

Climate variability and change has become a major threat to sustainable development in Zambia. In response, the Government of Zambia has developed various climate change-related policies that include, among them, strategies and legal frameworks that provide a basis for generating positive results in the forest sector through improved land use planning and forest management. Among them are the National Policy on Environment (NPE, 2007); a new National Forestry Policy (2014); the National Energy Policy (2008); the National Agricultural Policy (2014); a National Strategy for Reducing Emissions from Deforestation and Forest Degradation (REDD+, 2015); a revision of the Forest Act No. 4 (2015); and passage of the Urban and Regional Planning Act No. 3 (2015). These policies, strategies, and laws are aligned with the Seventh National Development Plan and the Vision 2030 which promotes "A prosperous middle income country by 2030", both of which support development of a low carbon and climate-resilient development pathway.

Zambia has followed the guidelines for the submission of information on reference levels as per the Annex to Decision 12/CP.17. Therefore, the present submission has been developed and is structured accordingly, as follows:

a. Area covered by the FREL (section 3);
b. Activities, Pools and gases included as listed in decision 1/CP.16, paragraph 70, which have been included in the FREL and the reasons for omitting a pool and/or activity from the construction of the FREL, noting that significant pools and/or activities should not be excluded (section 4);
c. The forest definition used in the construction of the FREL (section 4.4);
d. Consistent with the national GHG inventory reporting, including methodological information, used at the time of construction of the FREL (section 4.5);
e. Information used in constructing the FREL (section 5);
f. Areas for improvement (section 7).

2. ESSENTIAL BACKGROUND

2.1. FREL Development Process

Since the submission of Zambia's first reference level in 2016 a number of activities have been undertaken to collect the necessary data to improve the transparency of the FREL as well as extend the scope of the activities reported on. The present iteration of the FREL has extended the reference period to run from 2009 till 2018 (10 years) while also including an additional REDD+ activity namely degradation and an additional pool namely litter. Emissions factors have also been updated following an analysis of the two most recent national inventories undertaken between 2005 and 2009 (Integrated Land Use Assessment Phase 1) and 2012 and 2016 (Integrated Land Use Assessment Phase 2). The additional analysis helped to produce robust emissions factors which better quantify the land use changes in typically found in Zambia. The updated emissions factors analysis began with a workshop in May of 2019 where colleagues from the United States Forest Service SilvaCarbon program met with Zambian Forestry Department staff as well as FAO staff to discuss the potential for updating Zambia's emissions factors. The collaboration on emissions factors development was complemented by a concurrent phase of work seeking to improve the activity data estimates first published in 2016. This work began in July 2019 with an initial land cover change assessment using a systematic grid of sample points (see section 5.1) and an improved data collection survey which allowed for the assessment of degradation and the disaggregation of emissions factors into relevant classes.

Work on the FREL construction began in early 2019 when key methodological decisions about the construction approach and the data sources were taken. Initial results from both the activity data and emissions factors work were first available. Facilitated by technical partners, the Zambian Forestry Department undertook a final assessment of both deforestation and degradation, collecting additional information required for the generation of robust estimates of forest cover change and degradation. Once complete the final emissions estimates for Zambia were produced in July 2020 which included estimates for each of the ten provinces, an internal validation process within the Zambian Forestry Department followed after which the FREL was presented to stakeholders via a virtual workshop in late 2020.

2.2. Technical Improvement beyond the first FREL submission

Zambia's updated FREL submission to the UNFCCC in 2020 has several technical improvements compared to the original reference level submission in 2016. Table 1 below compares the technical characteristics of the two submissions, notable differences are as follows. The reference period for the FREL update now runs from 2009 – 2018, the scale of the FREL remains national, however, the national FREL is calculated as the sum of the provincial FRELs which are also reported separately. The scope of the FREL now also includes degradation while both the emissions factors and the activity data have been updated through improved data analysis (Emissions Factors) and the collection of new land use change data (activity data). The basic approach to calculating the FREL has been improved and aligned to IPCC GHG inventory classes and all results presented in the FREL are now accompanied by uncertainty estimates calculated at the 90% confidence level.

Table 1 Technical specifications of Zambia's FRELs

	First FREL submission	**FREL update**
Reference period	2005-2014	2009-2018
Results period	-	2019-2023
Adjustment	No	No
Scale	National	National, but breaking out provinces
Scope of pools	AGB, BGB, DW	AGB, BGB, DW, L
Scope of gases	CO2	CO2
Scope of REDD+ activities	Deforestation	Deforestation and forest degradation
Forest definition	Crown cover >10%; area >0.5 ha; tree height >5 m, also factoring in information on land use	means any land with a tree canopy cover of more than 10% and area of more than 0.5 hectares and includes young stands that have not yet reached, but are expected to reach, a crown density of ten percent and tree height of 5 m that are temporarily under stocked areas
Key source of activity data	Data collected through stratified area estimation	Systematic area sampling
Key source of emission factors	ILUA II data	ILUA I and II data re-analyzed
Basic calculation approach	Gross-deforestation estimate based on forest / non-forest and neglecting post-deforestation land use	Calculation by IPCC GHG inventories categories, aggregated to REDD+ activities
Uncertainty analysis	Only partial assessment of AD done as part of stratified area estimation	Covers EF, AD and emission estimates

2.3. National Circumstances

Zambian forests are vulnerable to factors such as extensive practices of slash and burn shifting cultivation; ever-increasing demands for wood-based energy (firewood and charcoal); unsustainable commercial utilization of indigenous tree species; over-grazing; and to a lesser extent, forest fires. In particular, the low productivity of small scale agriculture and degraded agricultural soils create pressure to expand land use for agriculture in forested areas.

Zambia's population is 18.4 million (2019) and has increased more than 150 percent during last 37 years (United Nations, Department of Economic and Social Affairs, Population Division 2019). Currently 67 percent of Zambians are poor (National Population Policy. 2007. Ministry of Finance and National Planning. 18 p.). Rural poverty in Zambia is high, even by African standards: it is estimated that 83 percent of the rural population, mainly comprised of semi subsistence farmers, live in poverty. The correlation between poverty and deforestation and forest degradation is high in Zambia, especially in areas near urban centers, and is likely to occur in both directions: a scarce and dwindling natural resource base will be a major contributor to poverty in areas where this is an important element of people's livelihoods, and poverty may encourage activities that threaten the natural resource base.

A growing population has led to increased pressure for agricultural land in order to meet national and subsistence food requirements. Agricultural expansion is caused both by shifting subsistence cultivation and intensification of subsistence and commercial farming. The demand for timber has over the past few years been exacerbated by the expanding and intensifying construction activities in the country and international demand for valuable timber species existing in the country such as Pterocarpus chrysothrix, Pterocarpus angolensis Guibourtia coleosperma, Colophospermum mopane, and Baikiaea plurijuga which has contributed to illegal harvesting leading to Forest degradation.

Charcoal and firewood make up over 70% of the national energy consumption in Zambia as only about 32% of the population has access to electricity. Firewood is in high demand especially in rural areas for cooking and heating needs at household level and also among tobacco farmers especially those producing Virginia tobacco which requires smoke curing as well as for brick burning in the construction of houses in the rural and peri-urban areas of rural towns. It is also in high demand by fishing communities in rural areas for fish smoking to dry the fish. Electricity is mainly sourced by hydropower and low rainfall in the recent years, among other factors, has resulted in a shortage in electricity and subsequently an increase in the consumption of charcoal as alternative energy source which may have contributed to the increased forest loss in recent years. Charcoal extraction usually results in degradation but as it helps open up the forest for agriculture and thus the increased charcoal collection is expected to result in increased deforestation. Additional factors driving land use change include timber extraction, uncontrolled and late bushfires, mining and infrastructure development.

3. AREA COVERED BY THE FREL

The proposed FREL reports emissions at the provincial scale as well as the national scale. The national historical emissions are calculated as the sum of the historical emissions in the ten provinces. Subnational historical emissions estimates are very relevant as the Zambian REDD+ program is currently implementing its first provincial scale REDD+ program funded by the World Banks BioCarbon Fund. The Zambian Integrated Forest Landscapes Program (ZIFLP) is being implemented in the Eastern Province and is the first jurisdictional REDD+ program to be implemented in Zambia, the reference levels presented in this FREL will help to guide the development of provincial scale baselines for jurisdictional REDD+ activities.

4. SCOPE: ACTIVITIES, POOLS AND GASES INCLUDED

4.1. REDD+ activities in the FREL

Zambia's FREL includes emissions from deforestation and forest degradation only, the grey cells in Table 2 highlight the land use change transitions captured in the FREL as well as the REDD+ activities associated with these transitions.

Table 2 REDD+ Activities matrix

			From				
			Forest land		Cropland	Grassland	Settlement
			Intact forest	Degraded forest			
To	Forest land	Intact forest		conservation	enhancement	enhancement	enhancement
		Degraded forest	forest degradation				
	Cropland		deforestation				
	Grassland		deforestation				
	Settlement		deforestation				

Deforestation is defined as the conversion of forest land to non-forest land; where forest land is a piece of land covered by natural and exotic (plantation) forest area meeting the threshold with a tree canopy cover of more than 10% and area of more than 0.5 hectares and a tree height of 5 meters (see forest definition section). Non forest land is any other land below these thresholds.

Removals are not considered in the assessment due to the challenges associated with assessing forest regrowth with remote sensing, which is particularly challenging in the Zambian context due to the physiognomy of Zambia's native forest types. For this same reason, i.e. the complexity of assessing forest area gain, Zambia does not include enhancement of forest carbon stocks in this FREL.

Degradation is included in the FREL and is considered an improvement over the previous submission, in terms of the definition of degradation Zambia is using a three-class reduction in canopy cover (Siampale 2018) while maintaining a minimum canopy cover of 10% as per the definition of forests in section 4.4.

4.2. Carbon Pools in the FREL

Pools included in the estimates used in the FREL include above ground biomass (ABG), below ground biomass (BGB), standing/lying dead wood (DW) and litter (L).

These pools are selected because quality data have been collected on them through ground surveys as part of two National Forest Inventories (NFI) and, importantly, they are considered to represent the most significant pools in Zambia. The NFI's also collected information on litter/grass/twigs. Since this data has not yet been analyzed, IPCC default values are used for the present iteration of the FREL (Table 10).

Furthermore, the NFI collected information on soils, but its inclusion would require a more thorough analysis, including measurements of the soil pool in non-forest land and an improved understanding of soil carbon dynamics following degradation and deforestation in Zambia. The national forest inventory undertaken in support of this and other management activities in Zambia has conducted a comprehensive sample of soil characteristics including soil organic carbon, however, little is known of soil carbon dynamics in Zambia and as such it is unclear how soil organic carbon behaves within the deforestation activity chosen by Zambia. Given the lack of flux data associated with soils this FREL will not include this pool. The soil pool may be included in a future FREL iteration.

4.3. Gases in the FREL

Only CO_2 is included in the FREL at this time.

Emissions of non-CO_2 gases from the Zambian forests are mainly associated with forest fires. Many forest areas in Zambia are burnt annually (Matakala et al 2015) and one of the key features of the miombo eco-region is the frequent occurrence of dry season fires. Low herbivory, high carbon content in the plant biomass, seasonality in litter decomposition and a long dry season (5–7 months) interact to create conditions in which fire plays an important role in nutrient cycling. Annual fires tend to burn grass, leaves and woody litter (herbaceous materials) and therefore do not usually add much to the accumulation of carbon dioxide in the atmosphere as emissions are recaptured the following year by annual re-growth (Chidumayo et al., 2011). Therefore, for the proposed FREL, neither emissions from fire, nor regrowth following fire, are included.

Fire is considered a natural component of Zambia's forest ecology and trees are adapted to cope with regular burning. However, intensive late bushfires may impede and/or delay re-growth of forest as such affecting removals (Chidumayo, 1994). Current data does not yet allow for an accurate estimate of the emissions impact of this late burning; this could be included in future FRELs as data improves, as part of Zambia's stepwise approach.

4.4. Zambia's Forest Definition

The Forest Act (Commencement) Order, 2015 provides a definition of forest as below (page 7):

> *"forest" means **any land with a tree canopy cover of more than ten percent and area of more than zero point five hectares** and includes young stands that have not yet reached, but are expected to reach, a crown density of ten percent and **tree height of five metres** that are temporarily under stocked areas;*

In practice, the bolded part of the forest definition is used in measurement of forest cover and forest cover loss based on the minimum canopy cover, area and height thresholds provided in the Forest Act. This practice is consistent with the way in which estimates were generated for Zambia's most recent GHG inventory report, the Second National Communications (SNC), submitted December 2014, as well as to report forest and forest area changes to the FAO's 2020 Forest Resources Assessment (FRA).

4.5. Consistency with GHG Inventory Reporting

The Ministry of Lands and Natural Resources is the national regulator and reporter of the GHG inventory for Zambia through the compilation of the national communication reports submitted to the UNFCCC. The Zambian Environmental Management Agency (ZEMA) coordinates with a number of environmental sectors such as forestry, wildlife, agriculture (crop and livestock), water, fisheries and public health, to provide the required information for the regulator to compile and subsequently report on behalf of the country. This information normally improves with consistent updates as and when respective sectors collect more reliable information across the country.

It should be noted that there are currently observed information inconsistencies between the last National Communications and the information used to construct the FREL. The inconsistencies relate to the data used to compile previous communications and those used to compile the FREL. The first and second communication to the UNFCCC employed data collected between 2000 and 2004 while the FREL presented here makes use of data collected as part of two National Forest Inventories undertaken between 2004 and 2014. As such the FREL employs more up-to-date and accurate information than previous communications. The third national communication (TNC) has been prepared and submitted to the UNFCCC; this document makes use of ILUA II data, the same data source used for this FREL document.

5. ACTIVITY DATA AND EMISSION FACTORS

5.1. Activity Data

Zambia's second iteration of its Forest Reference Emissions Level makes use of a point-based approach to capturing and quantifying the land use change component (Activity Data) of its FREL. Sample, or point based approaches are considered less complex, easier to replicate, and provide more accurate results when compared to the traditional wall to wall mapping approaches used in the past.

The land cover classification scheme is aligned to recommendations made by the IPCC good practice guidelines including sub-divisions that are aligned to land use changes identified in Zambia. Quantifying land use change from Forest land to Non-Forest land (Cropland, Grassland, Settlement and Other land) was facilitated using open-source tools and freely available high-resolution satellite imagery hosted by the Google Earth Engine and Google Earth Pro.

A customized series of data collection cards were used to guide data collect activities and information on land use change in Zambia between 2009 and 2018. The team facilitating the collection of land use change data engaged in iterative quality control activities whereby point interpretations were reviewed by technical analysts while interpreters made use of interpretation keys to aid point classification.

Land cover change statistics were generated using proportional estimates of several land use change classes including forest land to cropland, forest land to grassland, forest land to settlement and forest land to other land. Land cover change statistics are reported at the provincial scale as well as the national scale.

5.1.1. Land Cover Classification Scheme

To facilitate national reporting to the United Nations Framework Convention for Climate Change (UNFCCC), Zambia utilized a country-specific version of a land representation framework recommended by the Intergovernmental Panel on Climate Change (IPCC) which outlines six main land use categories (Table 3).

Land use sub-categories indicate the conversions from the starting land use to the final land use for the period of interest. The year of change is significant for interpreting land use change dynamics and estimating emissions from land use change. Table 3 below provides national land cover descriptions for each of the land use classes assessed during the activity data collection and analyses.

Table 3: The main land use, land cover classification scheme (IPCC based)

Land cover categories	National land cover descriptions
1) Settlements	Land covered mainly by densely populated and organized or irregular settlement patterns surrounding cities, towns, chiefdoms and rural centers commonly referred to as urban and rural built-up areas.
2) Cropland	Land actively used to grow agriculture (annual and perennial) crops which may be irrigated or rain feed for commercial, peasant and small scale farms around urban and rural settlements
3) Grassland	Land that includes wooded rangeland that may be covered mainly by grasslands, plains, dambos, pans found along major river basins and water channels.
4) Forest land	This is land covered both by natural and planted forest meeting the threshold of 10% canopy cover growing over a minimum area of 0.5 ha with trees growing above 5m height and includes young stands that have not yet reached, but are expected to reach, a crown density of ten percent and tree height of five metres that are temporarily under stocked areas;

Land cover categories	National land cover descriptions
5) Wetlands	Land which is waterlogged, may be wooded such as marshland, perennial flooded plains and swampy areas (*surface water bodies included*).
6) Other land	Barren land covered by natural bare earth / soil such as sandy dunes, beach sand, rocky outcrops and may include old open quarry sites for mines and related infrastructure outside settlements.

The land cover classification scheme also includes the transition between classes as well as the dynamics associated with forest degradation. Zambia understands that forest degradation contributes to the annual emissions and should be captured as part of the present FREL submission. Degradation is defined within the context of this FREL submission as a reduction in crown cover within the presence of human disturbance. More detailed descriptions are provided in the relevant emissions factors and activity data sections. The present submission further notes that two different forest classes are used for deforestation and degradation emissions factors. Deforestation makes use of an All Forest class (see Table 8) which captures deforestation from both intact and secondary forests while degradation is derived from intact forests only. The split is required to capture accurate emissions from degradation. The overall land use classes remain largely the same in terms of the final land use.

5.1.2. Assessment Methodology

Zambia provides additional detailed Standard Operating Procedures (SoP) in the annex of this document outlining the sample design, response design, data collection and data analysis. The SoP documents are provided as a means of facilitating consistency in the reporting of land use change as well as REDD+ results.

5.1.2.1. Graphical User Interface

The open source Collect Earth image interpretation and data collection tool was developed under the auspices of the National Forest Monitoring and Information Systems (NFMIS) project which seeks to promote transparent and truthful REDD+ data collection and reporting. The application is a user-friendly, Java-based tool that draws upon a selection of other software to facilitate data collection. The training materials for the collect earth tool include guidance on the use of Collect (survey development) and Collect Earth (data collection) as well as most of its supporting software[1]. Documentation on the more technical

[1] www.openforis.org

components of the Collect Earth system (including SQLite and PostgreSQL) are available on the Collect Earth Github page[2].

5.1.2.2. Visualization of Satellite Imagery (Google Earth, Bing Maps and Google Earth Engine)

Collect Earth facilitates the interpretation of high and medium spatial resolution imagery in Google Earth, Bing Maps and Google Earth Engine. Google Earth's virtual globe, largely comprises of 30m resolution Landsat imagery, 10m Sentinel imagery and high resolution imagery from several other providers (Digital Global, Earth-Sat, First Base Solutions, GeoEye-1, Globe-Xplorer, IKONOS, Pictometry International, Spot Image, Aerometrex and Sinclair Knight Merz). Microsoft's Bing Maps presents imagery provided by Digital Globe ranging from 3m to 30cm resolution. Google Earth Engine's web-based platform facilitates access to United States Geological Survey 30m resolution Landsat imagery. Collect Earth synchronizes the view of each sampling point across all three platforms and facilitates consistent and transparent data collection practices.

The imagery used within Google Earth, Bing Maps and Google Earth Engine differ not only in their spatial resolution, but also in their temporal resolution. Collect Earth enables users to collect data regarding current and historical land use changes, the reference period for the present FREL covered 2009 – 2018 (10 years). The IPCC recommends a reference period of at least 10 years based on the amount of time needed for dead organic matter and soil carbon stocks to reach equilibrium following land-use conversion and to identify any trends in land use change. Most of the imagery available in Bing Maps and Google Earth has been acquired at very irregular intervals over the past 10 years.

5.1.2.3. Sampling Frame

Zambia has chosen to make use of a random systematic sampling frame consisting of point locations located approximately 8km apart. The systematic grid was assigned a random starting location within the border of Zambia after which the 8km by 8km grid was constructed (Figure 1). The grid covered the entire country with approximately 11,110 sample points where land cover and land cover change characteristics were recorded by 23 image interpreters for the period beginning in January 2009 and ending in December 2018.

[2] https://github.com/openforis/collect-earth

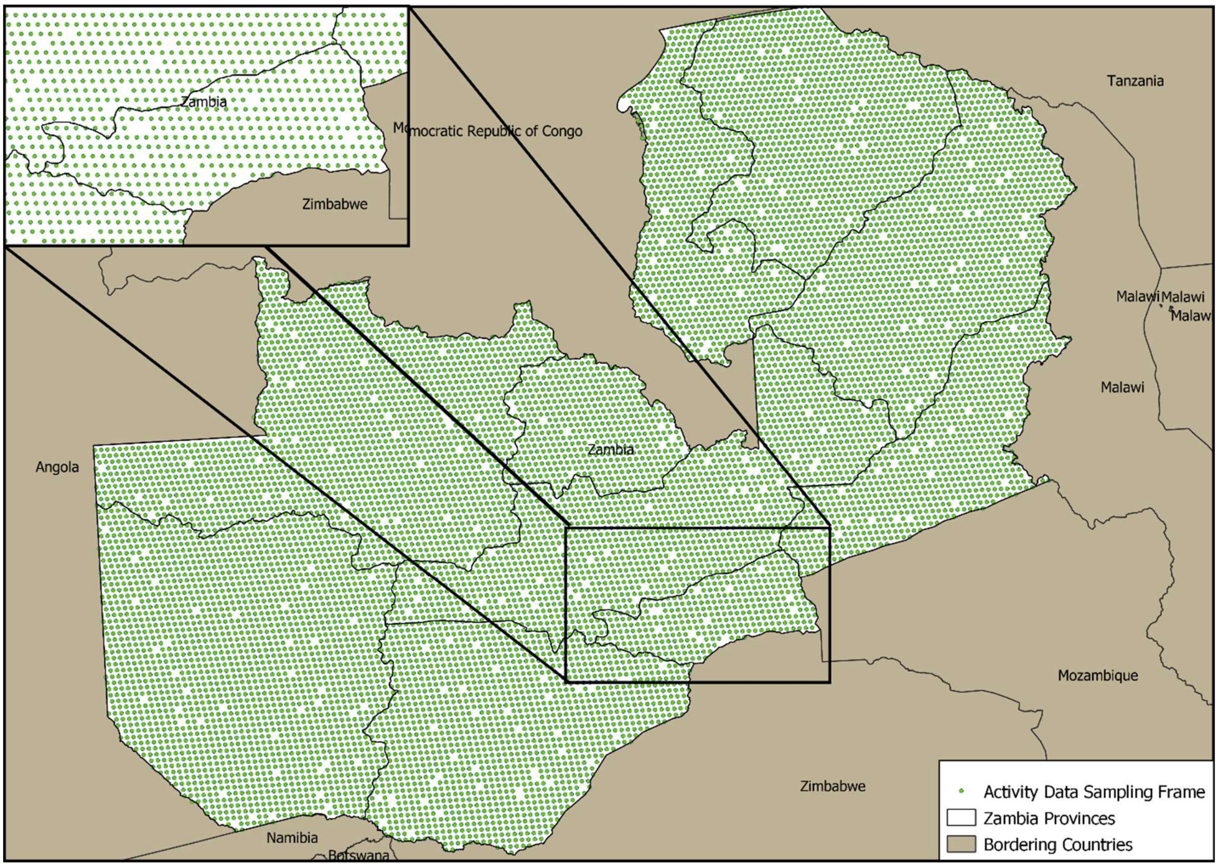


Figure 1 Zambia FREL sampling frame

Each sampling unit consisted of a square plot with a width and height of approximately 50 m resulting in a sample plot approximately 0.5 ha. Within the sample plot a square array of 49 sub-plot locations were used to determine the land cover present within the sample plot (Figure 2). This information was captured using the data collection cards discussed below.

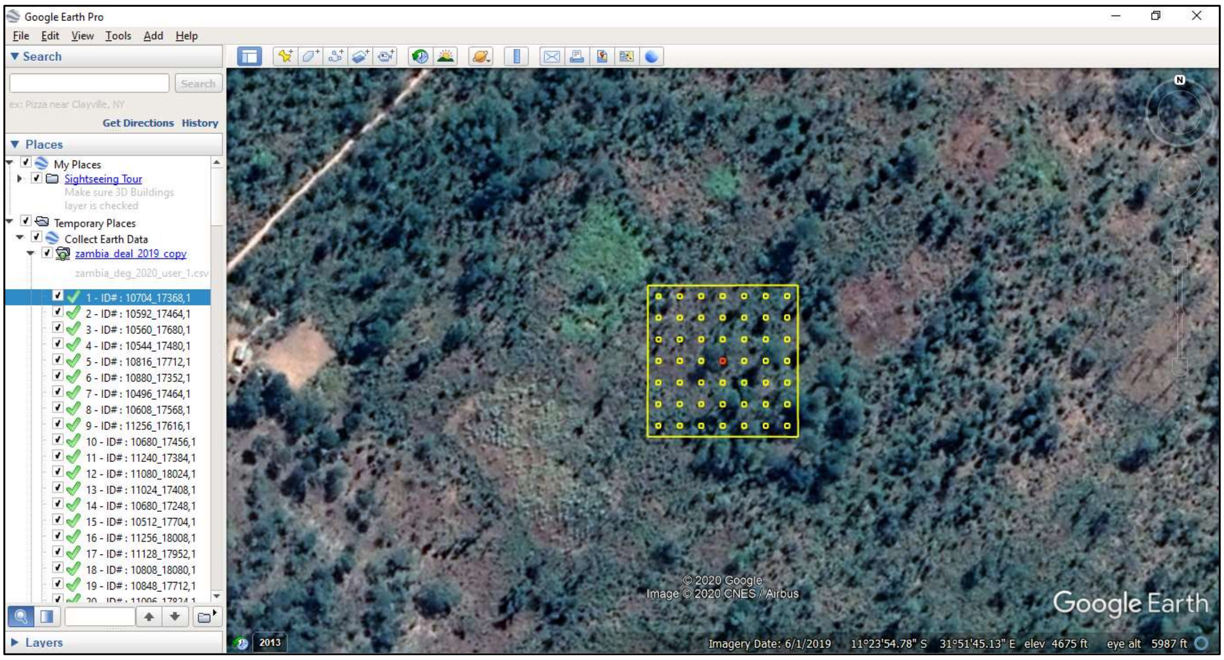


Figure 2 Sampling Unit (49 sub-plots)

5.1.2.4. Data Collection Cards

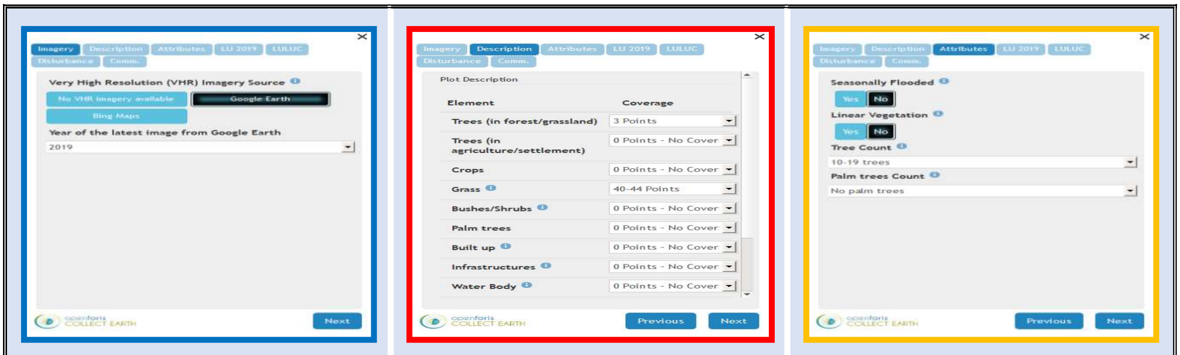
The CE point interpretation made use of seven (7) different data collection cards with unique functionalities. Each data collection card served a specific purpose interrelated to subsequent cards in order to enhance quality control and assurance in data entry from remote sensing interpretations. Table 4 and Figure 3 provide detailed information on the data collection process including all additional information collected for each of the points interpreted during the data collection process.

Table 4 Specific functionalities for data collection cards

Card name	Features	Functionalities
1) Imagery card	Available VHR imagery; Google earth and Bing maps	Used for selecting the best quality imagery and the year of observation
2) Description card	Plot descriptions in terms of subcategories associated with the location	Used to account for the elements of % cover for the land use type that best describes the plot under observation
3) Attributes card	Season flooding effects; any linear vegetation; aggregated tree and possible palm counts	Used for attaching additional attributes including aggregating the number of tree observed on this plot as described in the previous card.
4) LU 2019 card	Land use description currently according to the	Used for aligning the land use subcategories recorded and entered in Card

Card name	Features	Functionalities
	IPCC land categories using control points distributed in Card No:2	No. 2 to Six (6) main IPCC land use classes. It is expected that the plot descriptions should correspond to whether or not the plot observations are homogenous, distinct and overlapping
5) LULUC card	Land use, Land use Change; Current land use subdivisions changes and confidence of such changes; Associated grassland management if any	This card is used to indicate what land use, land use change is observed from the first entry to date; If YES – what subdivisions could have been there that may have changed to what currently (i.e. F>F, S>F, C>F, G>F, O>F); and to what confidence do you attribute such changes if any.
6) Disturbance card	Primary disturbances observed physically or detected from the MODIS graphical presentations	Used for recording qualitative disturbances observed in the plot associated with human activities over the plot. Disturbances maybe primary and or open forest depending which ones may be prominent or otherwise.
7) Comments card	Comments by the image interpreter	Used for the interpreter to recording general and technical comments that may be observed about the sample plot under review.

A hierarchical decision tree approach was used for data collection with information captured in the first four cards dictating the information collected in subsequent cards. For example, if a point was classified as cropland in 2019 (card 4), the survey would request additional information regarding the nature of the transition to cropland and if this transition occurred during the reference period (card 5), typically the change from forest to non-forest was captured in these two cards. Zambia has for the first time now also included degradation in its FREL.



Card 1 – Imagery Data Entry Card | **Card 2** – Quality Control Card | **Card 3** – Data Validation Card

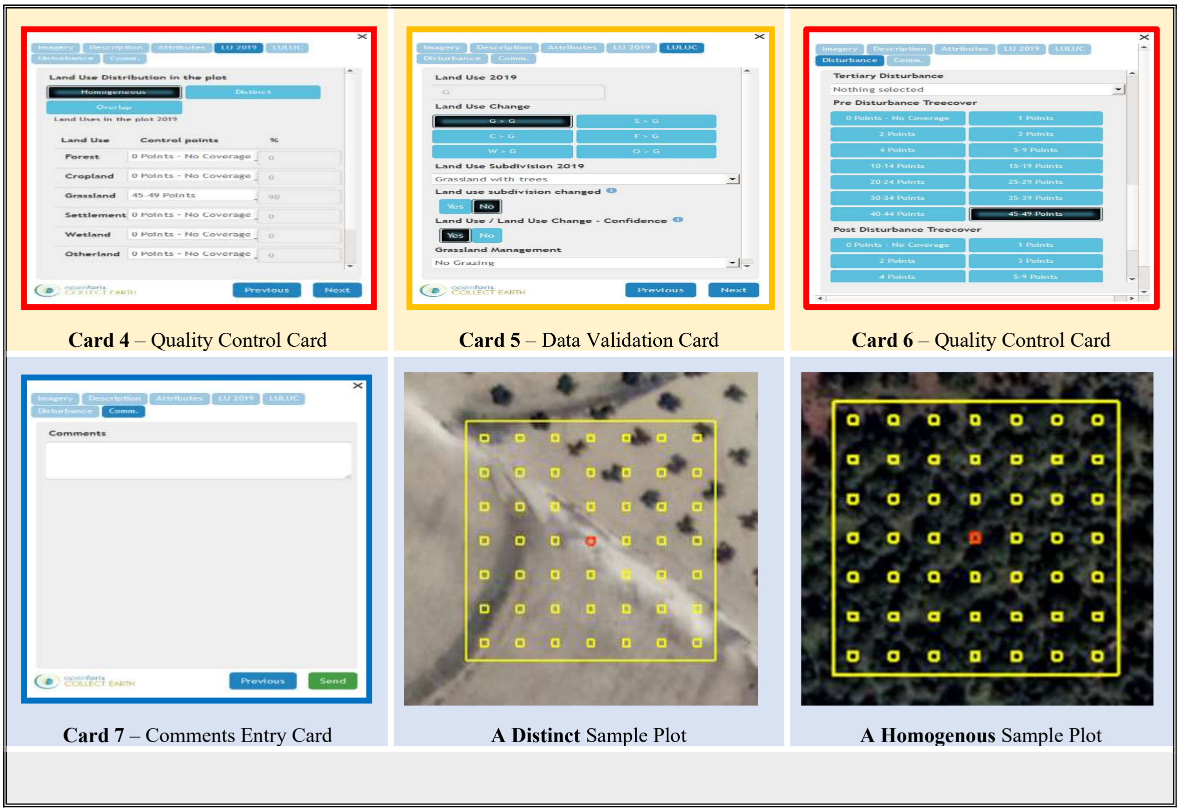


Figure 3 Thumbnails of the Data Collection Cards

5.1.2.5. Hierarchical Decision Tree

The flow chart presented in Figure 4 provides an overview of the process and decision making steps undertaken by each image interpreter during the analysis of the 11,110 sample points. An initial card determined the imagery used (card 1) for the assessment followed by a general description of the plot which allowed for the initial classification of the plot (card 2). Additional attributes such as flooding and the presence of palm trees followed (card 3) as well as an assessment of the land use in 2019, this card defines the final land use for each sample point (card 4). The fifth card was the key piece of information collection as the card sought to determine if the land use class of the point of interest had changed during the reference period, if there was no change then the class remained the same and the interpreter recorded the same classes for both the start and end of the reference period. If however the interpreters noticed that a change in land use had occurred, then the initial land use was recorded. For the purposes of the FREL only a change from forest to non-forest was recorded as these transitions are considered deforestation. An objective assessment was used for this transition whereby interpreters counted the number of sub points falling on tree canopies and determined if the sample point remained forest or was converted to another land use. All points that experienced a change from forest to non-forest were recorded.

The second REDD+ activity captured by the FREL is degradation, which is limited to those points which returned a land use of forest remaining forest. In the present survey if the interpreter noticed that a forest remaining forest point exhibited some form of minimal change (see Figure 5) driven by human activities they were asked to record the tree cover within the sample point before the disturbance as well as afterwards. Forest degradation was then identified based on a two class reduction in canopy cover between the start and end of the reference period. See section 4.2.3 and Table 7 for a review of the forest coverage classes, the same method for identifying degradation is used for both the Activity Data and Emissions Factor estimates and is based on the work undertaken by Domke et al (2019), Siampale (2018) and Vesa et al (2020).

To quantify degradation in sample points where disturbances were originally recorded, interpreters were asked to quantify forest cover before and after the disturbance event. Only those points which saw a significant class change (> 3 tree cover class change) between the start and end of the reference period and remained forest were identified as being degraded (see Table 7).

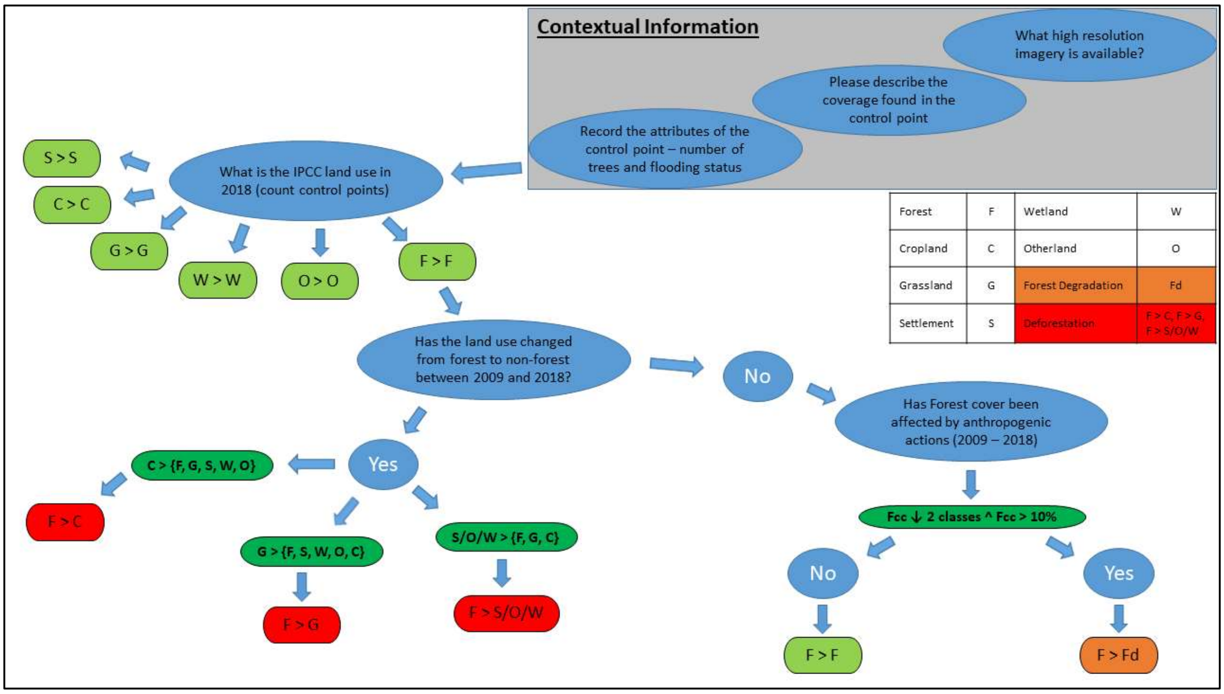


Figure 4 Point interpretation workflow

5.1.2.6. Quality Management

The process for quality control and quality assurance (QC/QA) was facilitated using built in validation controls and the data collection cards. In addition, image interpreters made use of interpretation keys as well as detailed standard operating procedures for the classification of sample points. Figure 5 provides an example of the interpretation key for a point sample returning forest degradation.

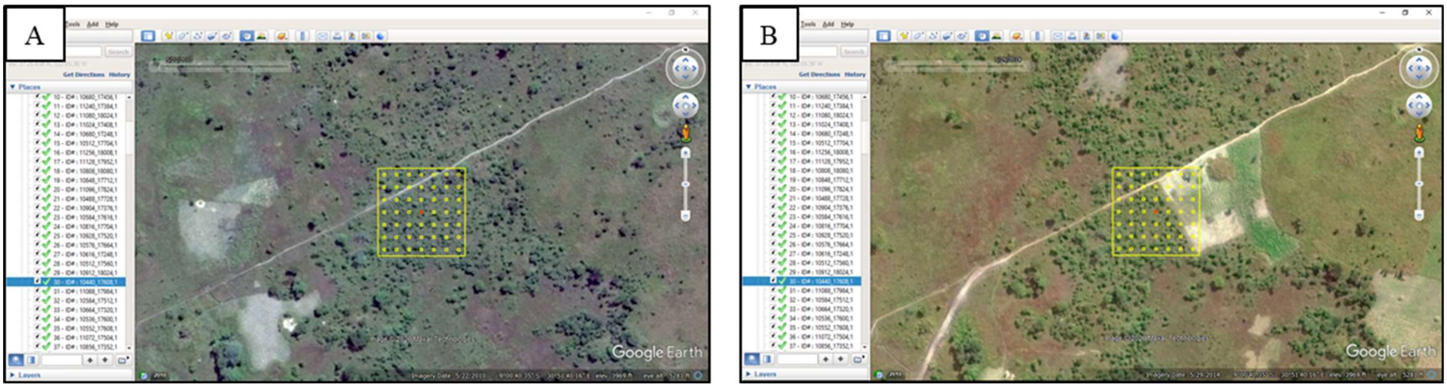


Figure 5 Degradation interpretation key (A: Pre Disturbance B: Post Disturbance)

Figure 6 provides an example of deforestation in Zambia with the transition from Forest land to Cropland clearly evident in the Google Earth Imagery.

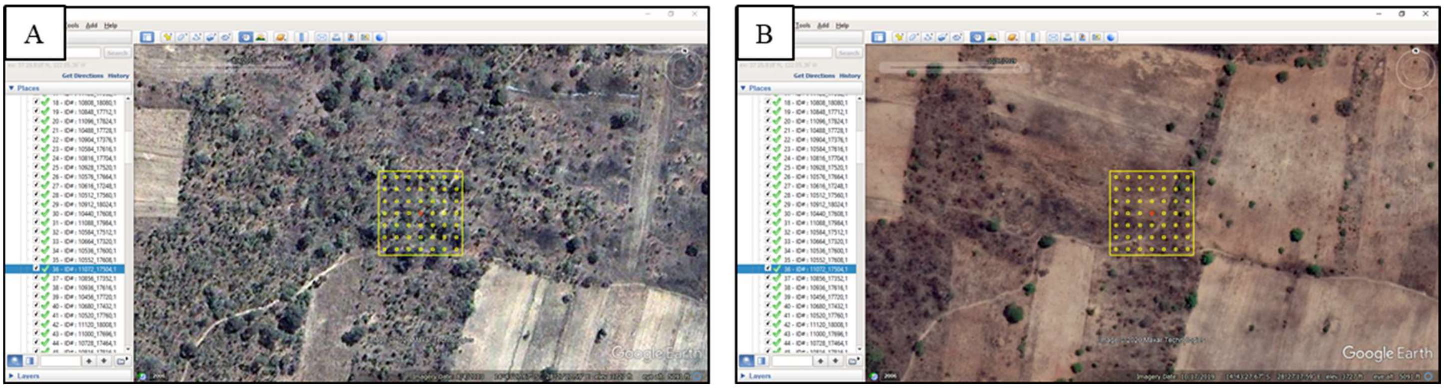


Figure 6 Deforestation interpretation key (A: Forest B: Non-Forest)

Additional quality assurance was attained through the review of all data entries by an experienced "Golden Operator" which ensured only high quality data entries were accepted for subsequent analysis. A comprehensive data checking for all data files by the facilitator was necessary to ensure that manual edits and screening of all entries was done. The facilitator has many years' experience in earth observation and image interpretation with additional field experience having taken part in both of the national forest inventories.

5.1.2.7. Data Management

The data entered in Collect Earth was automatically saved to a database. Collect Earth was configured for a single-user environment with a SQLite database and this arrangement is best for either individual users or for a geographically disperse team. The SQLite database automatically populates the Saiku Server which is an open source web-based software package distributed as part of the Collect Earth package. Saiku organizes the information and enabled users to run queries on the data and immediately view the results in tabular format or as graphs. Saiku allowed for the quick identification of trends and facilitated the preparation of inputs required for quantifying land use change in Zambia.

5.1.2.8. Data Analysis

Following completion of the point interpretation and the cleaning of the resulting assessments, area estimates for all of the change classes were generated. The systematic approach to the sampling design resulted in area estimates being calculated based on area proportions. IPCC 2006 Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 3, Section 3.33), recommend that the proportion of each land use change class is calculated by dividing the number of points located in the specific change class by the total number of points, and area estimates for each land use change category are obtained by multiplying the proportion of each category by the total area of interest. The following equation was used:

$$a_i = \left(\frac{S_i}{n}\right) \times A \qquad (1)$$

where

a_i = Area of the *ith* change class (ha)
S_i = Sample size for the *ith* change class (count)
n = Total number of samples in the area of interest (count)
A = Area of interest (ha)

The random systematic sampling approach is considered a more efficient method compared to the random sampling approaches and facilitates a simplified approach to future reassessments of land use change. The present approach to area estimation and uncertainty analysis follows the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 3, section 3.33 where the standard error of the area estimate is calculated as follows.

$$se_i = a_i \times \sqrt{\frac{P_i \times (1-P_i)}{n-1}} \quad (2)$$

where

se_i	=	Standard error of the *ith* change class (ha)
a_i	=	Area of the *ith* change class (ha)
P_i	=	Proportion of points in the *ith* land use change class (dimensionless)
n	=	Total number of samples in the area of interest (count)

Final uncertainty estimates were calculated at the 90% confidence intervals using the following equation:

$$CI_i = a_i \pm (se_i \times 1.65) \quad (3)$$

where

CI_i	=	Confidence Interval for the *ith* change class (90%)
a_i	=	Area of the *ith* change class (ha)
se_i	=	Standard error of the *ith* change class (ha)
1.65	=	1.65 standard deviations of the mean

5.1.3. Activity Data Results

Activity data reported in this FREL submission is disaggregated to the provincial level. Raw activity data is available for review in the attached excel spreadsheet. As part of the expanded scope of the reference level Zambia will report activity data estimates at the provincial scale for each of the following land use class transitions (Table 5).

Table 5 Zambia - Land use transitions

Starting Land Use		Final Land Use
Forest	To	Cropland
Forest	To	Grassland
Forest	To	Settlement
Intact Forest	To	Degraded Forest

Figure 7 and Table 6 provide the results from the activity data analyses. Figure 7 includes all transitions as well as the total deforestation for each province (green bar). Central province returns the highest deforestation for the reference period followed by Eastern and North-western provinces respectively. Lusaka province returns the lowest total deforestation with Luapula returning a slightly higher total deforestation. Total deforestation for the period 2009 till 2018 was approximately 1,915,962.27 90% CI [1,711,808.11, 2,120,116.43] hectares which translates into an annual average deforestation of 191,569.23 90% CI [171,180.81, 212,011.64] hectares across the country. Table 6 reports degradation in Zambia for the reference period as being 383,569 90% CI [272,703.36, 494,435.17] hectares or less than 40,000 hectares annually, the provinces with the highest degradation include Northern and Muchinga province followed by Central province. Once again Lusaka province returns the lowest degradation in Zambia.

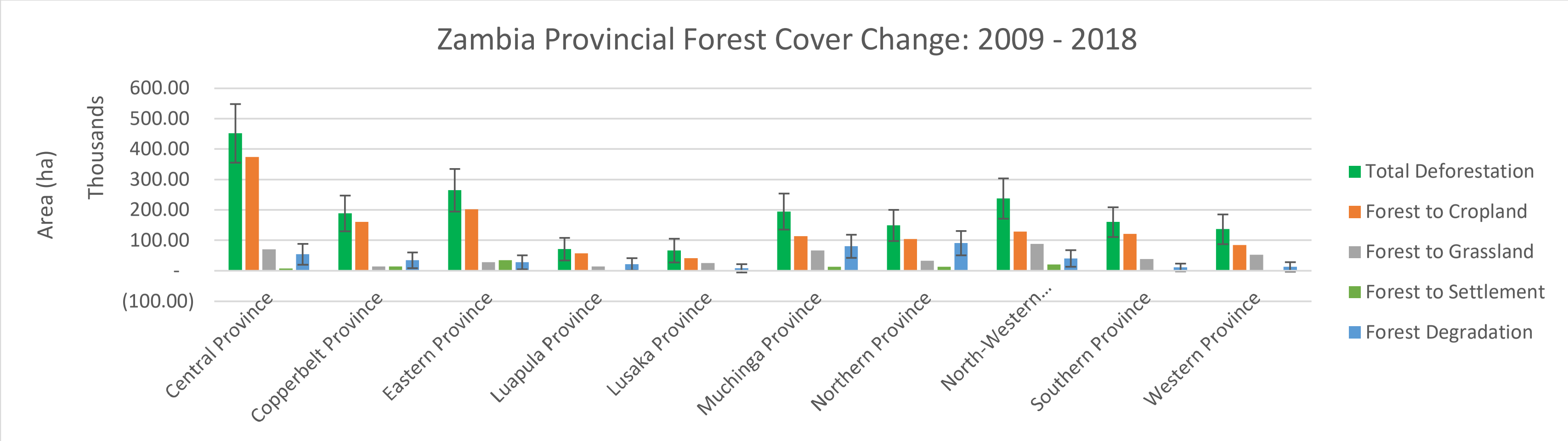


Figure 7 Provincial activity data

Table 6 Provincial activity data (all values in hectares over a ten-year period)

	Forest to Cropland	Forest to Grassland	Forest to Settlement	Total Deforestation	U (90% CI)	U ha (90% CI)	Forest Degradation	U (90% CI)	U ha (90% CI)
Central Province	374,037.76	70,132.08	7,792.45	451,962.29	21%	96,517.38	54,547.17	62%	33,945.47
Copperbelt Province	160,479.50	13,954.74	13,954.74	188,388.98	31%	58,546.84	34,886.85	73%	25,627.91
Eastern Province	202,229.85	27,893.77	34,867.22	264,990.84	26%	69,841.51	27,893.77	82%	22,965.03
Luapula Province	57,221.02	14,305.26	-	71,526.28	52%	37,167.07	21,457.88	95%	20,412.41
Lusaka Province	41,678.84	25,007.30	-	66,686.14	58%	38,694.41	8,335.77	165%	13,754.02
Muchinga Province	114,041.83	67,083.43	13,416.69	194,541.95	30%	59,317.11	80,500.12	47%	38,179.88
Northern Province	97,623.71	32,541.24	13,016.49	143,181.43	35%	50,143.15	91,115.46	44%	39,958.43
North-Western Province	129,087.53	88,323.05	20,382.24	237,792.82	28%	66,062.15	40,764.48	67%	27,422.24
Southern Province	121,495.11	38,657.53	-	160,152.64	30%	48,723.85	11,045.01	117%	12,881.28
Western Province	84,647.88	52,091.00	-	136,738.89	36%	49,105.87	13,022.75	117%	15,190.07
Totals	1,382,543.03	429,989.40	103,429.83	1,915,962.27	11%	204,154.16	383,569.27	29%	110,865.90

5.2. Emission Factors

5.2.1. Harmonizing Integrated Land Use Assessment I and II Data

Zambia's first national forest inventory commenced in 2005 and was known as the Integrated Land Use Assessment Phase One (ILUA 1). The main purpose of ILUA I was to "build up forest related land use resource inventories, support national planning capacity and contribute to formulating development policies". This project was initiated mainly to address increasing deforestation, the loss of biological diversity and the overexploitation of natural resources (Forestry Department, 2004). The ILUA I sampling design is best described as systematic with tracts selected along a grid at the intersection of every 30 minutes of latitude/longitude (Saket et al. 2006) for a total of 248 tracts. Each tract (1 km x 1 km) contained four field plots. The rectangular field plots (20 m wide and 250 m long) in the ILUA I were intended to be permanent (a marker was placed at the starting point of each plot and these points were georeferenced) and started at each corner of an inner 500 m square with plot 1 beginning in the southwest corner, plot 2 in the northwest corner, plot 3 in the north east corner, and plot 4 in the southeast corner (Figure 8).

Field plots were split into no more than four land use / forest type sections (LUS) where most of the variables related to forest conditions used in this analysis were collected. Each LUS was classified for the global assessments of forest and tree resources using country-specific land use classes. It was these classes, as defined in Saket et al. (2006), that were used to assign plots to land use categories within the Collect Earth – Activity Data Collection Card schema (Table 3). Measurements (e.g., species, location, diameter at breast height [dbh], total height) of standing live and dead trees (dbh ≥ 20 cm, or ≥ 7 cm for the trees outside forest) were taken on each plot and trees ≥ 7 cm dbh were measured on the first subplot on LUS classified as forest land.

The sampling intensity increased in ILUA II with the intent of improving the precision of estimates at sub-national scales. The plot design also changed with rectangular plots reduced to 20 m wide by 50 m long. Sampling of ecosystem attributes also expanded in the ILUA II. This included expanding measurements of live and standing dead trees with dbh ≥ 10 cm on the entire plot and trees on the subplot to 5 cm ≤ dbh < 10 cm. Further, there were changes in the health classification of individual trees in ILUA II where dead and dying trees were separated into unique classes whereas in ILUA I, standing dead and dying trees were combined into a single health class.

The ILUA I data were harmonized with ILUA II data by first relating tracts by their geographic location. Of the 248 tracts from the ILUA I, 179 of those were available and related to ILUA II tracts in this assessment. Within the 179 tracts, 550 ILUA I plots were related to ILUA II plots. The plot measurements from ILUA I were restricted to the first 50 m length to insure consistency with the plot design in the ILUA II. The tree records from the ILUA II data were restricted to stems ≥ 7 cm dbh to be consistent with the minimum diameter threshold used on the first subplot and LUS classified as non-forest.

The final step in harmonizing ILUA I and II data was to relate LUS to each plot and then compare these sections and the variables characterized for each LUS between ILUA I and II. Since land use classes, among other attributes, characterized in the LUS were needed to summarize emission factor estimates, plots and tracts were sorted so that the mapped area of each LUS on plots were consistent between ILUA I and II. This reduced the harmonized dataset to 174 tracts with 505 plots and all LUS were the same size (i.e., 1000 m2) on ILUA I and ILUA II plots.

Harmonizing data from ILUA I and ILUA II provided Zambia with the opportunity to derive biomass estimates of final land use plots where changes from dense forest to either degraded or non-forest were captured. Final land use biomass estimates therefore represent accurate estimates of residual biomass in environments where forests have been replaced with either cropland, grassland or settlements (otherland is combined with the settlement class). This approach to quantifying emissions factors is considered more transparent and accurate when compared to previous approaches.

5.2.2. ILUA Field Sampling of the IPCC Forest Carbon Pools

The IPCC (2006) Guidelines Chapter 4, AFOLU sector, identifies three main carbon pools which can be measured for quantifying carbon stock changes: Biomass, Dead organic matter and Soils. The Biomass pool consists of both Above (stems, stumps, branches, bark, seeds and foliage) and Below Ground Biomass (live roots) while Dead organic matter consists of Dead wood (non-living woody biomass not contained in litter) and Litter (non-living organic matter which does not fulfil the requirements for Dead wood). Finally Soils consist of soil organic matter that does not fulfil the requirements for below ground biomass (fine roots with a diameter of less than 2mm as well as decaying organic matter). The present inventory described in this document is based on FAO’s NFMA methodology. The details of the inventory can be found in the Biophysical Field Manual prepared in support of the ILUA II and published in 2014. All pools described below were measured as part of both ILUA I and ILUA II but not all pools are included in this Forest Reference Emissions Level.

5.2.2.1. *Above-ground Biomass*

AGB was measured in all plots selected during the harmonization of the ILUA I and ILUA II data. All trees located within the plots (20m wide and 50m long - see Figure 7) with a DBH of greater than 10 cm were sampled, where sampling consisted of measuring the height and diameter at breast height and recording the tree species. Trees with a DBH of between 5 and 10 cm were measured in a rectangular sub plot located in the first 10 m of the larger plot. Regeneration, trees with a DBH of less than 5 cm, were measured in a nested sub-plot within the rectangular sub-plot. Once again, height, DBH and species were recorded for each tree present.

5.2.2.2. *Below-ground Biomass*

Below Ground Biomass (BGB) was not measured directly, rather a root:shoot ratio was used to calculate BGB. The root: shoot ration of 0.28 was selected from Vesa (2016), see equation 7 below.

5.2.2.3. *Dead Wood*

Dead-wood data was recorded on all fallen dead logs and branches with a diameter equal to or above 10 cm and which were found in the plot area (regardless of where they originated). The minimum length of dead-wood to be measured was 1 meter. Combined broken parts (separately shorter than 1 m) from the same tree were counted and measured as one if total length of parts exceed 1 meter. The length and diameter at both ends of all pieces of fallen wood with diameter larger or equal to 10 cm within the plot area were measured. The standard wood density of 619 kg / m3 was used as per Chidumayo (2012) to convert the volume estimates created to biomass.

5.2.2.4. *Litter*

While litter data was collected during both ILUA I and ILUA II, this data is not yet suitable to be included in the 2020 FREL submission. In the interim Zambia will make use of a default value published by the IPCC and is available in chapter 2, volume 4 Generic Methodologies Applicable to Multiple Land-Use Categories of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[3]

[3] Generic Methodologies Applicable to Multiple Land-Use Categories

5.2.2.5. Soil Organic Matter

On specific clusters identified in the sampling plan and only part of the ILUA II survey, additional information was collected on soil. Soils required additional measurements which are briefly described below. The prescribed location of the soil pits is shown on Figure 8, however, this location was not always suitable and in some cases the location had to be modified. GPS location points were recorded for all soil pits dug.

At each soil pit site three types of soil samples were taken. Firstly, the undisturbed core ring sample was collected from the soil pit at 0–10, 10–20 and the 20–30 cm layers, respectively. Secondly, from the same layers in the soil pit, disturbed soil samples were collected for the measurement of soil organic carbon in the laboratory. Thirdly, composite soil samples were prepared having been collected using a soil auger targeting the top soil (0–10 cm), and sub soil (10–30 cm depths) from within the sampling plot (at the biophysical plot center and at 5m north, east, south and west).

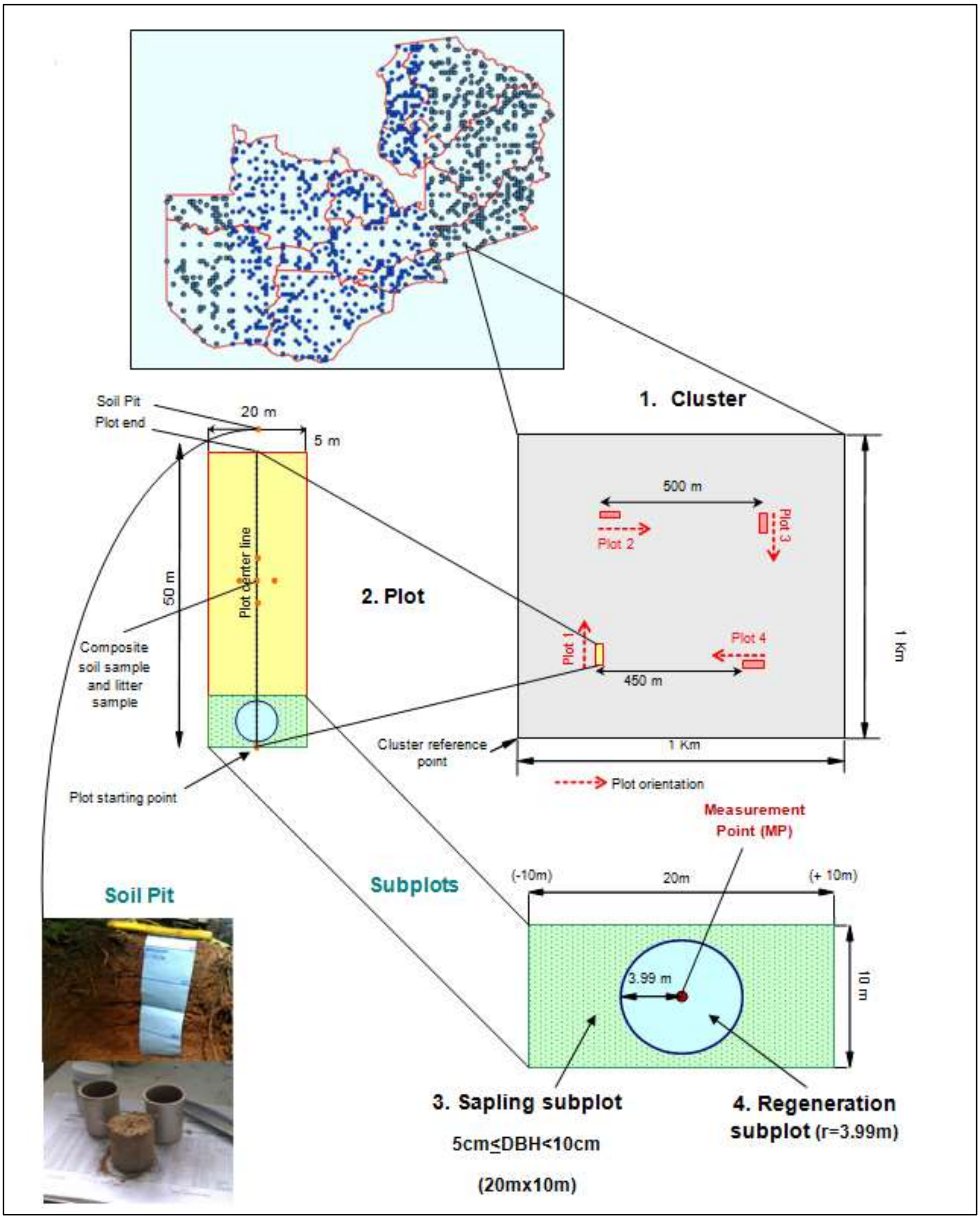


Figure 8 NFI Cluster & Plot Layout

5.2.3. Analysis of Collected NFI data

Individual tree measurements were used to estimate aboveground and belowground standing live and dead tree biomass and carbon. Tree dbh measurements were available for all trees in the harmonized dataset. In some cases, particularly in the Northwestern Province (NWP), tree heights were only measured on a subset of trees. In other provinces, all tree heights were recorded. When tree height measurements were missing, a height model was used (Mehtatalo et al. 2015) as follows:

$$h = \frac{dbh^2}{(a+b*dbh)^2} \tag{4}$$

where

H	=	estimated tree height (m)
Dbh	=	diameter at breast height (cm)
A	=	2.28355
B	=	0.22373

Note that a correction factor, 1.09915, was used as suggested to remove bias from the height estimate resulting from linearization. Once tree dbh and height measurements or estimates were populated for all trees in the harmonized dataset, two statistical models were used to estimate aboveground and belowground biomass. The first model was developed by Chidumayo (2012) and has been widely used throughout Zambia. The general model form only requires dbh from the inventories as follows:

$$AGB = \exp(2.342 * LN(dbh) - 2.059) \tag{5}$$

where

AGB	=	total aboveground biomass of live and standing dead trees (kg)
Dbh	=	diameter at breast height (cm).

This model was suggested in multiple ILUA documents as a generic approach to estimate standing live and dead biomass. Since there was a substantial investment in measuring tree height on most trees in the ILUA I and II and there was a well-established height model available to estimate tree height for trees lacking height measurements, a second aboveground biomass model which included tree height and wood specific gravity as predictor variables was identified. The second model, developed by Chave et al. (2014) has been widely used throughout tropical forest ecosystems and is expressed as follows:

$$AGB_{est} = 0.0673\ x\ (\rho D^2 H)^{0.976} \tag{6}$$

where

AGB_{est}	=	total aboveground biomass of live and standing dead trees (kg)
ρ	=	wood specific gravity (0.619 g km^{-1}; Chidumayo 2012)
D	=	diameter at breast height (cm)
H	=	total tree height (m).

To estimate belowground biomass for models 2 and 3, a root-shoot ratio was used from Vesa et al. (2016) as follows:

$$BGB\ or\ BGB_{est} = AGB\ or\ AGB_{est}\ x\ 0.28 \tag{7}$$

where

$AGB\ or\ AGB_{est}$	=	total aboveground biomass of live and standing dead trees (kg).

To convert live or standing dead aboveground and belowground biomass to carbon a carbon fraction of 0.49 was used following Vesa et al. (2016). Once live and standing dead tree biomass estimates were compiled for all trees in the harmonized data set, the estimates were summed over each LUS on each plot by incorporating the area of the LUS on each plot to expand above and belowground carbon estimates to carbon density estimates (tons/ha) using each biomass model (2, 3, and 4) as follows:

$$C_{density} = \sum(C_i\ x\ a_{exp})0.001 \tag{8}$$

where

$C_{density}$	=	carbon in aboveground or belowground live and standing dead trees per unit area (tons/ha)
C_i	=	carbon in the ith aboveground or belowground live and standing dead tree (kg) on a LUS
a_{exp}	=	area expansion (ha) based on the size of the LUS on each plot (e.g., 20 m wide x 50 m length = 1000 m^2).

5.2.4. Classification of Plots as intact or degraded forest

Plots which were classified as forest land at t_1 and t_2 were further disaggregated into forest and degraded forest. To characterize the forest land remaining forest land as degraded the canopy cover classes from ILUA I were related to the tree cover integers (converted to comparable ILUA I classes – Table 7) in ILUA II. If the tree cover class decreased by 3 or more classes (e.g., > 70% to 5-10% or 10-40% to no trees) from ILUA I to ILUA II the LUS on that plot was classified as degraded forest. Based on the definitions of degradation, this approach was deemed conservative, with sufficient forest land plots in both forest and degraded forest categories to obtain statistically robust estimates of carbon densities. In cases where canopy cover was recorded as < 10% in the ILUA I or ILUA II inventory but the Land Use classifications were recorded as forest land, it was assumed that, given the definition of forest in Siampale (2018) and the Forest Act No. 4 of 2015, these areas must be "young stands that have not yet reached, but are expected to reach, a crown density of ten percent and tree height of five meters that are temporarily under stocked areas". For these reasons, and following the definitions in Siampale (2018), the conservative approach for characterizing degradation was taken.

Table 7 Tree cover ground surface covered by the vertical projection of the tree canopies, expressed as percentage of the total ground area in the LUS (Saket et al. 2006).

Canopy Cover	Description/definition	Code
No trees	Not Forest	**0**
< 5%	Not Forest	**1**
5-10%	Forest Cover	**2**
10-40%	Forest Cover	**3**
40-70%	Forest Cover	**4**
>70%	Forest Cover	**5**

5.2.5. Results and Proposed Emissions Factors

The data found in Table 8 are all from plots that were deemed comparable between ILUA I and II. All values found in the table are carbon densities from ILUA II only. This information was used to derive emissions factors for the land use change classes of interest. As discussed above, the Chave *et al* (2014) model was utilized by Zambia as this model took advantage of the comprehensive tree height assessments in both ILUA I and ILUA II. Emissions factors for each of the land use change classes were based on the data contained in Table 8 and were calculated for the whole of Zambia and were from ILUA II only, however change classes were identified using data from both inventories. This choice was made as the final biomass estimates for these change classes were considered to be accurate estimates of the typical loss class associated with cropland, grassland and settlement / otherland. The emissions factors also included the degradation class which was derived through an assessment of the change in canopy coverage from ILUA I to ILUA II. The starting biomass estimates for the degradation class was intact forest as Zambia feels that the use of intact forest would preclude the incorporation of degraded forests into this class. Results highlighted in the table were used to derive the final emissions factors for each of the classes listed forest land to non-forest Land. The carbon density value for Forest Land was identified as All in the Forest Land class as it was not possible to determine the state of the initial forest type. This approach was deemed to be conservative.

Table 8 Carbon density estimates for aboveground (AGB) and belowground live tree biomass (BGB; tons carbon / ha) by land category and condition from the ILUA II

IPCC LU Category	LU Subdivison	ILUA 1 classification	ILUA 2 classification	Condition[4]	n	ILUA 2 AGB[2]	SE[3]	ILUA 2 BGB[2]	SE[3]
Forest Land remaining forest land	All	Forest	Forest	All	401	29.2	1.2	8.2	0.3
		Crown cover largely unchanged		Intact	307	33.7	1.5	9.4	0.4
		Crown cover reduced by three classes		D/D	94	14.5	1.3	4.1	0.4
Forest Land to Non-Forest Land	All	Forest	Grassland, cropland or settlement	All	44	10.1	1.4	2.8	0.4
	Forest Land to Grassland	Forest	Grassland	All	19	9.8	2.3	2.8	0.6
	Forest Land to Cropland	Forest	Cropland	All	20	9.6	1.6	2.7	0.5
	Forest Land to Settlement	Forest	Settlement	All	5	13.6	7.0	3.8	2.0

The harmonized ILUA I and ILUA II database also contained information relating to dead wood estimates per hectare. This information, along with the land use classes in Table 8 were used to derive the dead wood component of each land use class of interest. This information is provided below in Table 9.

Table 9 Carbon density estimates for deadwood

Dead Wood Group	n	Dead Wood (tC/ha)	Std Error (tC/ha)	U (90% CI)
Cropland	24	0.0965	0.0495	46%
Forest Land	422	1.7007	0.2442	19%
Grassland	24	0.3117	0.3117	62%
Settlement	34	0.5656	0.2805	45%
Forest Degradation	94	0.7076	0.1516	26%

Above and below ground biomass estimates from Table 8 were combined with deadwood estimates from Table 9 along with IPCC default values for litter to calculate a combined class total biomass including each of the carbon pools relevant for the land use class of interest. This information is provided in Table 10 along with the associated uncertainties calculated at the 90% confidence level. Uncertainties were combined and propagated using equation 3.2 approach 1 for addition and subtraction[4].

Table 10 Combined carbon densities of all carbon pools for land use classes of interest

Classes	AGB	U (90% CI)	BGB	U (90% CI)	DW	U (90% CI)	Litter	U (90% CI)	Biomass total	U (90% CI)
Unit	*t C / ha*	*t C / ha*	*t C / ha*	*t C / ha*	*t C / ha*	*t C / ha*	*t C / ha*	*t C / ha*	*t C / ha*	*t C / ha*
All Forest Land	29.2	6%	8.2	6%	1.70	19%	2.1	0%	41.20	5%
Intact Forest Land	33.7	7%	9.4	7%	1.70	19%	2.1	0%	46.90	9%
Degraded Forest Land	14.5	13%	4.10	14%	0.71	26%	2.1	0%	21.41	9%
Cropland	9.6	22%	2.70	23%	0.10	46%	0	0%	12.40	17%
Grassland	9.8	28%	2.80	26%	0.31	62%	0	0%	12.91	22%
Settlement	13.6	46%	3.8	46%	0.57	45%	0	0%	17.97	36%

Information contained in tables four, five and six were combined to derive emissions factors for the following land use change classes; Forest to Cropland, Forest to Grassland, Forest to Settlement, and finally Forest Degradation. Land use carbon density is represented by the Forest Land class from Table 10 while residual biomass estimates for the final land use class are represented by the Cropland, Grassland, and Settlement class respectively whose land use class in ILUA I was Forest Land and therefore represent biomass estimates of actual change classes. Degraded forest carbon densities are also captured in Table 10.

[4] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_3_Ch3_Uncertainties.pdf

Final emissions factors for each of the land use change classes including forest degradation are shown in Table 11 and are calculated by subtracting the initial land use from the final land use carbon density estimates. The difference between these classes is then converted to tons of CO2 equivalent by multiplying the difference by the ratio of the molecular weight of carbon dioxide and carbon[5]:

$$CO_2eq = Difference \cdot \frac{44}{12} \tag{9}$$

where

CO_2eq	=	CO2 equivalent
Difference	=	Carbon density difference between initial land use and final land use
44	=	Molecular mass of carbon dioxide
12	=	Molecular mass of carbon

The emissions factors for the land use change classes are provided in Table 11 along with the associated uncertainty estimates. In the past Zambia reported emissions factors based on generic carbon strata, the emissions factors presented here represent actual land use change class values, the benefit of harmonizing the ILUA I and LUA II inventory data is immediately evident and contributes to a more accurate, robust and transparent FREL submission.

Table 11 Zambian emissions factors

Land use classes	**Before (tC/ha)**	**After (tC/ha)**	**Difference (tC/ha)**	**Emission Factor tCO2eq/ha**	**U (90% CI)**
Deforestation: Forest to Cropland	41.20	12.40	28.80	105.62	10%
Deforestation: Forest to Grassland	41.20	12.91	28.29	103.73	12%
Deforestation: Forest to Settlement	41.20	17.97	23.24	85.20	29%
Forest degradation: Intact forest to degraded forest (D/D)	46.90	21.41	25.49	93.47	14%

[5] https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf

6. FOREST REFERENCE EMISSIONS LEVEL CALCULATION

6.1. Historical Emissions

Historical average emissions are computed based on the analysis of historical land use change (Forest to Cropland, Grassland, Settlements as well as forest degradation) which has been generated at the sub-national provincial scale (Section 5.1). The historical land use change classes are then combined with emissions factors (Section 5.2) derived from consecutive national forest inventories for the derivation of both national and sub-national provincial reference levels.

Table 12 provides a breakdown of the total emissions for each of Zambia's provinces as well as the average annual emissions. Central Province returns the highest annual emissions with a reference level of 5.25 90% CI [4.11, 6.39] $MtCO_2eq$ followed by Eastern (2.98 90% CI [2.19, 3.76] $MtCO_2eq$) and North-Western Province (2.83 90% CI [2.08, 3.58] $MtCO_2eq$). Lusaka and Luapula provinces return the lowest average annual emissions with reference levels below one million tons annually. Uncertainties for the annual estimates are provided in the table and range from 22% to over 55% and are reported at the 90% confidence level. Average annual estimates of emissions for each of the provinces are calculated by dividing the total provincial emissions (first column) by 10 years. Actual annual emissions are also provided in annex 1 for deforestation only as dates for degradation were not collected.

Table 12 Provincial level emissions

	Ten-year Emissions	U (90% CI)	U (90% CI)	Average Annual Emissions	U (90% CI)
	tCO2eq	%	tCO2eq	tCO2eq	tCO2eq
Central Province	52,541,336.76	22%	11,396,592.87	5,254,133.68	1,139,659.29
Copperbelt Province	22,846,494.84	30%	6,790,123.88	2,284,649.48	679,012.39
Eastern Province	29,829,784.92	26%	7,865,776.34	2,982,978.49	786,577.63
Luapula Province	9,533,023.44	46%	4,406,779.12	953,302.34	440,677.91
Lusaka Province	7,775,025.07	55%	4,293,977.43	777,502.51	429,397.74
Muchinga Province	27,670,667.43	27%	7,344,107.30	2,767,066.74	734,410.73
Northern Province	23,311,901.42	28%	6,604,771.01	2,331,190.14	660,477.10
North-Western Province	28,341,975.97	27%	7,536,294.26	2,834,197.60	753,629.43
Southern Province	17,873,980.20	30%	5,443,129.10	1,787,398.02	544,312.91
Western Province	15,560,622.24	35%	5,460,579.78	1,556,062.22	546,057.98
All Provinces	235,284,812.29	10%			

6.2. The Forest Reference Emission Level

Zambia's updated 2020 FREL is calculated using an historical average approach. It is calculated as the sum of the provincial average annual emissions and amounts to **23.52 MtCO_2eq** 90% CI [21.07, 25.98] per annum for the period 2009 till 2018.

6.3. Updating Frequency

The FREL is considered valid for a five-year period 2019-2023.

Zambia's initial FREL submission to the UNFCCC occurred in 2016 where the country noted that the FREL would be developed and updated based on three guiding goals and motivations. The first was for domestic purposes whereby Zambia makes use of the FREL to measure the impacts of policies and measures to protect forests. The second was to seek international finance within the context of results-based finance. Finally the third, Zambia sought to contribute to global mitigation activities.

Although this FREL is considered valid for a five-year period, the updating frequency will be determined based on how Zambia progress on forest monitoring. At present Zambia is able to submit an updated FREL as it has recently completed an improved round of data collection and analyses and is currently undertaking a provincial scale REDD+ project[6]. Future iterations may follow the same criteria whereby the reference level may be reassessed based on country needs and improved data access and analyses.

7. FUTURE IMPROVEMENTS

Zambia has chosen to develop its FREL using a stepwise approach which allows for iterative updates and improvements to the FREL as and when new data and or updated methods become available. The current submission makes use of updated analyses and data, it also seeks to expand the scope of the reference level to incorporate emissions from forest degradation. While the current FREL incorporates a number of improvements over the initial submission in 2016, the Zambian government recognizes the following areas where the FREL could be future improved in the future.

Including removals

Removals of carbon from forest area gains or from regrowth in existing forests have not been included in this FREL. Reliably quantifying removals is difficult at present. In the future Zambia will endeavor to

[6] http://ziflp.org.zm/

collect data that may be used for this and may also benefit from the development of advanced analytical tools and/or datasets that become available.

Additional pools

Within the present FREL the soil carbon pool is not included. Little is known about soil carbon dynamics following deforestation activities; as such the lack of empirical information on the losses from this pool makes it problematic to report accurate emissions. Soil data has however been collected throughout the country and additional soils analyses will be undertaken in the future. Once confidence in the data is improved, the pool will be included in future iterations of the FREL. Zambia will also seek to process the Litter data collected as part of ILUA I and ILUA II and generate a country specific emission factor for Litter.

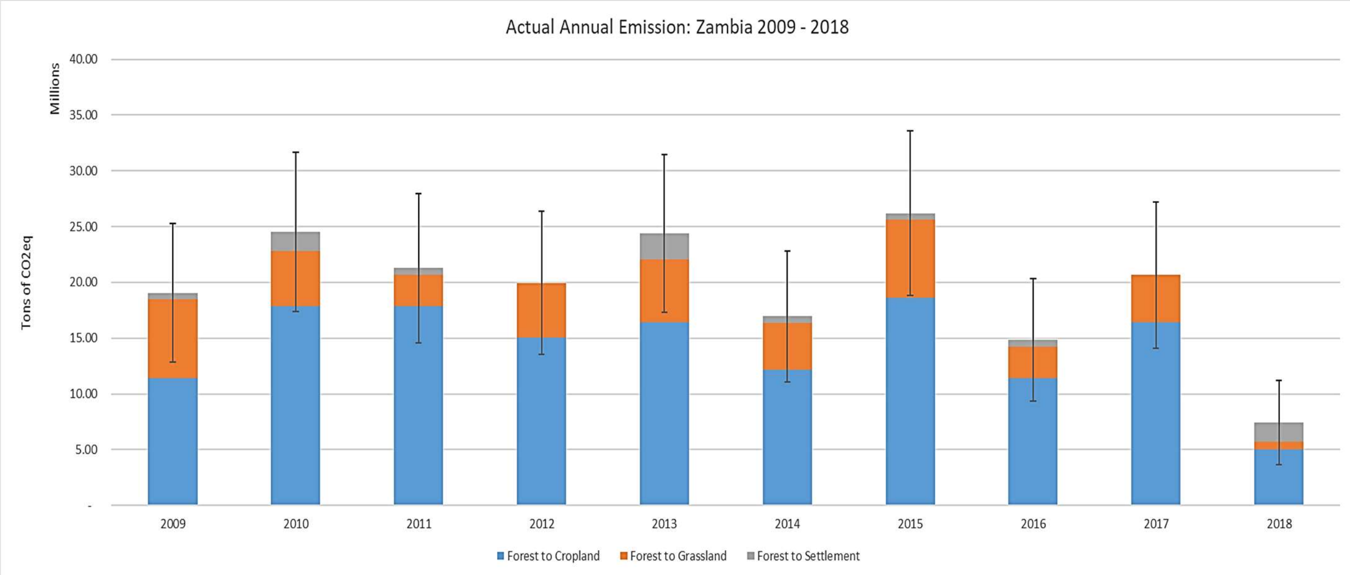
Including emissions from fires

Emissions associated with fires may be included in future iterations of this FREL. The quantification of these emissions is possible by combining spatial data capturing fire occurrence (MODIS Burn Scar Maps) with emissions factors data collected.

Improved degradation estimates

The present iteration of Zambia's FREL has included forest degradation as an additional REDD+ activity. The uncertainties associated with the provincial scale estimates indicate that Zambia should explore options for improving these estimates in future iterations. Zambia intends to develop improved support materials for assessing forest degradation as part of the activity data assessment along with methods for quantifying degradation with lower uncertainty values. Zambia will also review the definition of degradation and prepare detailed standard operating procedures to guide image interpreters during the activity data analyses.

8. ANNEX 1: ANNUAL EMISSIONS (DEFORESTATION ONLY)



Year	Total Annual Emissions	U tCO2eq (90% CI)	U (90% CI)
2009	19,045,973.81	6,218,225.75	33%
2010	24,529,902.64	7,121,334.73	29%
2011	21,268,532.38	6,664,023.86	31%
2012	19,937,911.33	6,421,685.16	32%
2013	24,378,817.98	7,070,776.42	29%
2014	16,951,346.77	5,864,762.47	35%
2015	26,198,639.31	7,397,352.68	28%
2016	14,831,133.43	5,477,745.79	37%
2017	20,665,971.03	6,559,944.24	32%
2018	7,440,264.36	3,784,448.56	51%

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