The Republic of Zimbabwe

Ministry of Environment, Climate, and Wildlife

Forest Reference Emission Level Submission to the UNFCCC

January 2024

Foreword

Zimbabwe has been continuously demonstrating her willingness to preserve the global climate for the good of the present and future generations. The country submitted Intended Nationally Determined Contribution (INDC) in 2015 which became the first NDC in 2017 when the country ratified the Paris Agreement. In 2021 Zimbabwe presented a revised Nationally Determined Contribution (NDC) which reported a 7% increase in emission reduction from 33% in the first NDC to 40% in this revised NDC. The forestry sector has been identified as one of the major contributors of Greenhouse Gas emissions in Zimbabwe and the country acknowledges the role of REDD+ in fostering atmospheric carbon sequestration and provision of alternative livelihoods to communities heavily dependent on forests.

At the moment, Zimbabwe is in the process of developing the relevant tools and documents required for REDD+ activities implementation, one of which is her first ever Forest Reference Emission Level (FREL). Having an assessed FREL in place is one of the requirements to be eligible for results-based payments in accordance with decision 9/CP.19. Developing countries aiming to implement REDD+ activities are invited to submit their FRELs to the secretariat, voluntarily, in a transparent manner, consistent with greenhouse gas inventory estimates and the guidance agreed upon by the Conference of Parties (CoP).

Zimbabwe has, therefore, developed her first FREL as the first of several upcoming iterations in a stepwise approach that will incorporate better data, improved methodologies, new knowledge, and new trends with time. Thus, the current FREL is not intended to prejudge Zimbabwe's Nationally Determined Contribution or any other mitigation actions but to serve as a benchmark for assessing the country's performance in implementing REDD+ activities.

The submission of this FREL is, therefore, a trendsetter in the country's quest to develop and finalize other REDD+-related documents required for results-based payment programs and carbon markets, including the National REDD+ Strategy (NRS), the Safeguard Information System (SIS), and the National Forest Monitoring System (NFMS) as prescribed by the Warsaw Framework.

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List of Acronyms

AD	Activity Data
AFOLU	Agriculture Forestry and Other Land Use
AGB	Above Ground Biomass
ALOS-PALSAR	Advanced Land Observing Satellite Phased Array L-band Synthetic Aperture Radar
BGB	Below Ground Biomass
CE	Collect Earth
CF	Carbon Fraction
CI	Confidence Interval
CNA	Country Needs Assessment
CO2	Carbon Dioxide
CO2e	Carbon Dioxide equivalent
CoP	Conference of the Parties
DBH	Diameter at breast height
DW	Dead Wood
EF	Emission Factor
EMA	Environmental Management Agency
ETM+	Enhanced Thematic Mapper Plus
ESA	European Space Agency
FAO	Food and Agriculture Organization of the United Nations
FC	Forestry Commission
FCBM	Forest Cover Benchmark Map
FNC	Fourth National Communication

FRA	Forest Resources Assessment
FREL	Forest Reference Emission Level
FREL	Forest Reference Emission Level
GDP	Gross Domestic Product
GFC	Global Forest Change
GFS	Global Forest Survey
GHG	Green House Gas(es)
GPG	Good Practice Guidance
GLCF	Global Land Cover Facility
Ha	hectare
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature and Natural Resources.
L	Litter
LCCM	Land Cover Change Mapping
LCCS	Land Cover Classification System
LULC	Land Use-Land Cover
LULCT	Landuse/landcover Change Transition
MRV	Measuring, Reporting, and Verification
NDA	National Designated Authority
NDC	Nationally Determined Contribution
NFI	National Forest Inventory
NFMS	National Forest Monitoring System
NICFI	Norway's International Climate and Forests Initiative
NRS	National REDD+ Strategy

QA	Quality Assurance
QC	Quality Control
REDD+	Reducing Emissions from Deforestation and forest Degradation; and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks.
SDG	Sustainable Development Goals
SEPAL	System for Earth Observation Data Access, Processing, and Analysis for Land Monitoring
SOC	Soil Organic Carbon
SoP	Standard Operating Procedures
tC	Tonnes of Carbon
tCO2e	Tonnes of CO2 equivalent
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation

Executive Summary

Zimbabwe is a medium forest cover country, with a naturally regenerating forest area of approximately 12.2 m Ha, which is about 31 % of the country's total land area. The deforestation rate assessed over a historic reference period of 2016-2021 has been estimated at 36,800 Ha per year, or 0.3 % of forest cover lost annually. The country has initiated a stepwise approach in developing and submitting her FREL. This FREL submission is the first stage of such a stepwise approach and aims at providing an objective benchmark that enhances the country's capacity to assess the performance of REDD+ activities countrywide.

The building blocks for this FREL are summarized below:

- Forest definition: an area of minimum 0.5 Ha extent with 10 % canopy cover from trees that are or capable of exceeding 5 m in height,
- Scale: National,
- Activities: Only deforestation is reported,
- Deforestation definition: the conversion of natural forest land to non-forest land. This excludes planned felling of plantation forests whether temporarily or permanently,
- Gases: Only CO_2 is covered,
- Pools: Aboveground biomass (ABG) and Belowground biomass (BGB),
- Emission Factors: Based on the National Forest Inventory (NFI) program data collected between 2017 and 2023 in combination with tier 1 data from IPCC Good Practice Guidance 2006 tables, refined in 2019,
- Historic Reference period: 2016-2021 (inclusive),
- Calculation Approach: Historical average of emissions associated with deforestation during the historic reference period,
- Validity period: 2022 - 2027 (inclusive).

The national scale FREL for the deforestation REDD+ activity has been estimated at **4,255,249.2 tCO_2e/ year** with a propagated uncertainty of **1,151,113.2 tCO_2e**, which is 27.1 % at the 95 % confidence interval. Future areas of improvement have been identified as: addition of more pools, addition of more REDD+ activities, addition of removals, further refinement of the NFI program and landcover mapping process to facilitate forest stratification and sampling of all land use classes, and overall strengthening of technical capacity.

1. Introduction

1.1.Background and context

Zimbabwe is renowned for its scenic landscapes comprising mosaics of vegetation types that provide critical wildlife habitat. About 75% of the country is semi-arid and experiences low and erratic rainfall. The forest sector contributes approximately 4 % of the country's GDP, with about 5.3 million people, largely in rural areas, dependent on forestry resources for their livelihoods[1]. As such, forests are vulnerable to land conversion activities: mainly slash and burn shifting cultivation, extraction of wood products for domestic energy (firewood) and construction, unsustainable commercial exploitation of indigenous wood products, unsustainable grazing practices, and wildfires. The Agriculture Forest and Other Land Use (AFOLU) sector has been the largest contributor to GHG emissions in Zimbabwe accounting for 54 % of GHG emissions as of 2017[2]. The ever-increasing demand for land for agriculture and settlement expansion, coupled with degrading agricultural soils constantly creates pressure on remnant forests. Furthermore, the expanding and intensifying construction activities in the country and international demand for valuable timber species existing in the country such as teak (*Baikiaea plurijuga*) and mahogany (*Afzelia quanzensis)* have contributed to illegal harvesting leading to forest degradation. As one of the world's biggest tobacco-farming countries in the world, the demand for tobacco-curing firewood has traditionally been a major cause of deforestation.

Zimbabwe has witnessed success in several economic and social development projects in the 21st century. Inevitably, such development comes in tandem with GHG emissions-related challenges. Despite the successful rural electrification program in the 21st century, the electricity is mainly supplied by the Kariba hydropower station, and thus, low rainfall patterns in recent years, among other factors, have resulted in a shortage of electricity and subsequently an increase in the consumption of fuelwood as the most accessible alternative energy source which therefore

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[1] Zimbabwe National Climate Policy, 2017

[2] https://unfccc.int/sites/default/files/NDC/2022-06/Zimbabwe%20Revised%20Nationally%20Determined%20Contribution%202021%20Final.pdf

has contributed to the increased forest loss of late. Additional factors driving land use change include late hot-season bushfires, mining, and overall infrastructure development.

1.2. REDD+ Progress in Zimbabwe

The Government of Zimbabwe identified REDD+ as a critical mechanism in fostering atmospheric carbon sequestration and provision of alternative livelihoods to communities heavily dependent on forests. In 2017, Zimbabwe submitted a country-level REDD+ country needs assessment (CNA) report to the UN-REDD programme as part of the preparation for REDD+ and the associated Monitoring, Reporting, and Verification (MRV). The CNA focused on the identification of national and sub-national stakeholders and their various roles in REDD+ issues as well as gaps and capacity development needs in institutional roles and mandates regarding REDD+. The CNA noted two critical impediments to the development of REDD+ in Zimbabwe as (1) lack of finance and (2) lack of technical know-how.

Through the Climate Change Management Department, Zimbabwe developed several policies and strategies, including the National Climate Policy, National Climate Change Response Strategy, and National Renewable Energy Policy, to mention a few. However, despite joining the UN-REDD programme in 2013 and the efforts henceforth to strengthen her policies and legislative framework to enhance climate action, the country still hasn’t complied with the Warsaw Framework for REDD+ and faces several challenges and remaining gaps, one of which is the nonexistence of critical national REDD program documents such as FRELs, REDD+ strategy, National Forest Monitoring System, and a Safeguard Information System.

1.3. FREL Development in Zimbabwe

In response to the challenges described above, the FAO Country office launched a project titled "*Strengthening Capacities of National Institutions for Sustainable Forest Management and Climate Change in Zimbabwe*," which is funded by FAO. One of the outcomes of this project was specified as Zimbabwe's first-ever FREL report. FAO forest resources assessment (FRA) experts from the Rome office worked with a national consultant (MRV expert) to build the capacity of the country's mapping and inventory experts to collect and process data that culminated in this FREL document subsequently reviewed and adopted by the country's National Designated Authority and submitted to UNFCCC. This FREL is submitted as the first iteration of several planned updates that will follow a stepwise approach informed by improvements in data availability and quality, country needs, and technological advancements. Zimbabwe's first-ever FREL ensures consistency with all prior, current, and future GHG inventory reporting procedures and is guided by IPCC's reporting principles of Transparency, Accuracy, Consistency, and Comparability.

1.4. Objective

The main purpose of developing this FREL is to provide an objective benchmark that enhances Zimbabwe's capacity to assess the performance of REDD+ activities within the country. The FREL is not intended to prejudge Zimbabwe's Nationally Determined Contribution or any other mitigation actions. This FREL submission is the first stage of a stepwise approach, that will be followed by future iterations informed by country needs and improvements in data availability and technologies.

1.5. Consistency with GHG Inventory Reporting

The Ministry of Environment, Climate, and Wildlife is responsible for the overall regulation and reporting of the GHG inventory for Zimbabwe to the UNFCCC. The climate change management department, a parastatal under this ministry is the national designated authority (NDA), mandated with promoting best practices in climate change adaptation and mitigation and coordinates with several departments and parastatals such as Forestry Commission, Environmental Management Agency, Zimbabwe Parks and Wildlife Authority, and other cross-ministry departments such as lands, agriculture, water, rural development, and health to provide the information required to compile and subsequently submit the reports for the country.

Zimbabwe's latest GHG inventory reports such as the Fourth National Communication (FNC) and the revised Nationally Determined Contributions (NDC), 2021 used default emission factors derived from the IPCC 2006 Good Practice Guidance (GPG) and emission factors database in calculating emissions. This FREL is a step-up improvement of the reporting process as it uses a hybrid of national forest inventory data collection between 2016 and 2022 for the forested areas and IPCC default values for other land covers where national inventory is not yet achieved. Therefore, the data used in this FREL development will benefit future national communications and the respective biennial updates.

2. Scale

Zimbabwe has decided to use the national scale for her first FREL so as to provide broad sectoral technical guidance to support REDD+ projects in the absence of a Jurisdictional REDD+ program. The decision is also greatly informed by the current national forest inventory program that uses a national grid. Depending on the yet-to-be-developed Jurisdictional nested REDD+ program, future FRELs may be developed at a different subnational scale such as the provincial scale.

The FREL excluded commercial plantation forests. The total present-day non-plantation forest area is ~12.2m Ha comprising reserved areas (gazetted forest reserves, national parks, safari areas), and private and communal forests. This constitutes ~32 % of the country's total land area. Reserved areas alone contribute ~25 % of the forested land, while their total extent (including non-forest) covers ~ 14 % of the total country's land area. The forest land comprises mostly dense and open woodlands. The woodlands, whether dense or open can be generally broken down into five subcategories: mopane woodlands (dominated by *Colophospermum mopane*), miombo woodlands (dominated by *Julbernadia globiflora, brachystegia boehmii,* and *Brachystegia spiciformis*), teak woodlands (dominated by *Baikiaea plurijuga*), and acacia woodlands (dominated by a mix of species in the *Vachellia*, *Terminalia*, and *Combretum* genera). However, a few patches of natural moist montane forests are also present, especially in the Eastern highlands of the country. Figure 2.1 below shows the country's forest cover probability, derived from the analysis of ALOS-PALSAR radar data as explained in section 4.3.

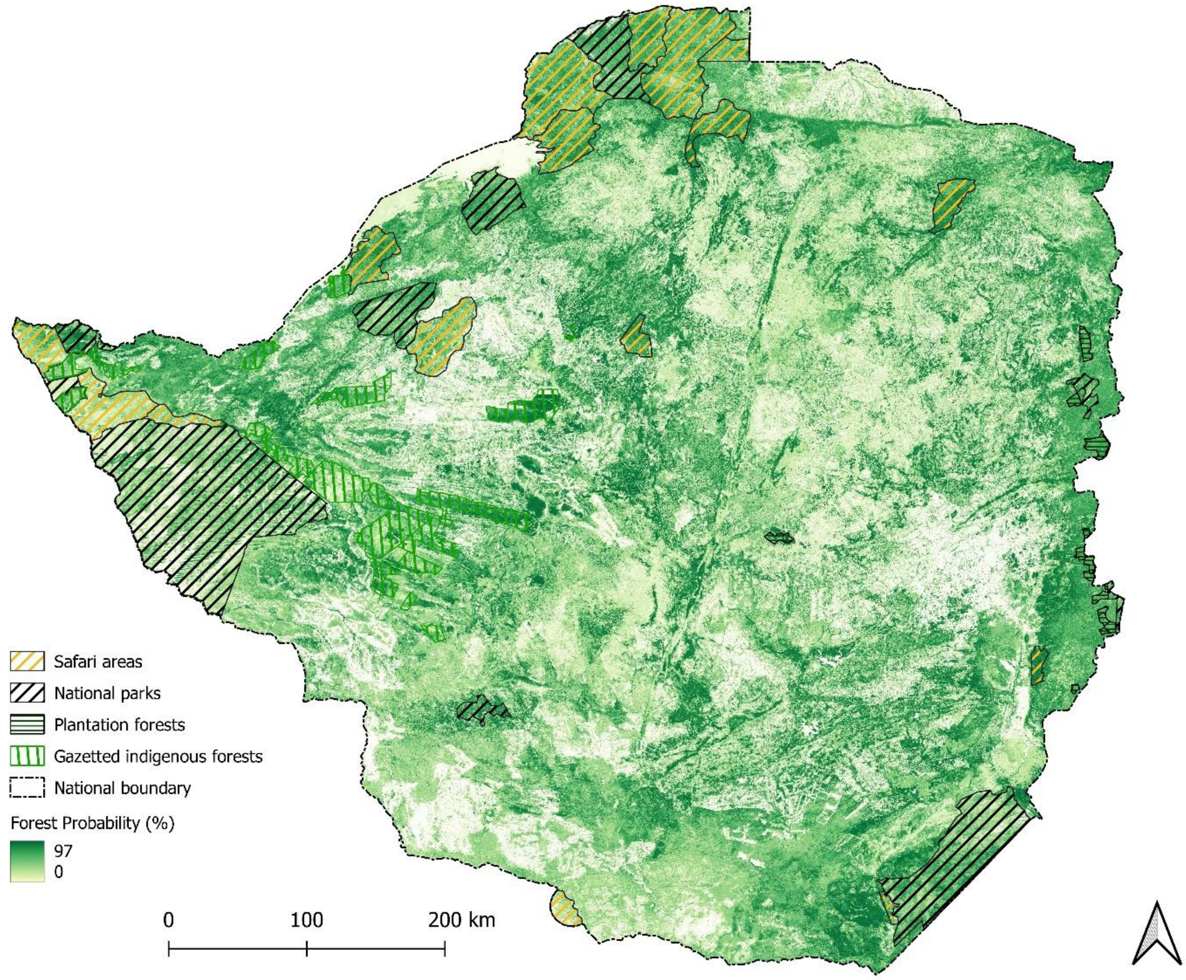

Figure 2.1. Zimbabwe forest cover probability benchmark map, 2022

3. Scope

3.1.REDD+ Activities

Zimbabwe's first FREL considers CO_2 emissions from deforestation only. The post-conversion land use/landcover (LULC) classes considered during the Activity Data analyses, following IPCC classification guidelines, are cropland, grassland, wetland, settlement, and other. Deforestation is defined as the conversion of natural forest land to non-forest land. This excludes planned felling of plantation forests whether temporarily or permanently.

Forest Degradation is defined as the reduction in crown cover, i.e. transition from dense forest to moderate and open canopy cover forest or from moderate canopy cover forest to open canopy cover forest due to natural or anthropogenic disturbances. However, while degradation areas were initially quantified during the activity data analyses, the corresponding carbon densities data was not available from the NFI data. Therefore, degradation is not included in the current FREL. Besides forest degradation, the 5 main deforestation activities analyzed during activity data assessments are:

1. Forest to Cropland
2. Forest to Grassland
3. Forest to Settlement
4. Forest to Wetland
5. Forest to other

However, the analyses of activity data showed that no forest areas were converted to wetlands or grasslands during the historic reference period. Zimbabwe also still lacks data on residual carbon densities and tier-1 data for these two LULC classes is scarce. It was, therefore, decided to exclude the Forest to Grassland and the Forest to Wetland activities from this FREL. The final activities reported in this FREL are, therefore, 3: **Forest to Cropland, Forest to Settlement,** and **Forest to Other.** Until the next update, any REDD+ activities that identify a conversion to grasslands can use the emission factor from the "Forest to Other" activity. Most of the conversion detected during activity data analyses was from intact forests, thus, to be conservative, deforestation for this FREL captures conversion from both forest classes (intact and degraded) as an average.

Zimbabwe acknowledges that forest cover dynamics within the country also involve removals in the form of enhancements, sustainable forest management activities, and forest conservation. However, at the moment, the country lacks the capacity to accurately report for this in a FREL, thus it is considered as a subject for future improvements.

3.2. Pools

The carbon pools reported in the current FREL submission are aboveground biomass (AGB) and belowground biomass (BGB) only. This is due to their significant contribution and availability of data and accuracy of estimation methods for these two pools and the lack of such for other pools like deadwood, litter, and soil organic carbon. Literature-based default values for these excluded pools could also not be used due to the high uncertainty associated with the data. However, as measurement resources and capacity continue to grow, Zimbabwe will consider including more pools in subsequent FREL submissions.

3.3. Gasses

The current FREL covers Carbon dioxide (CO_2) only as it is the main gas of concern and the one for which reliable spatial data is available. Nevertheless, anthropogenic sources such as wildfires, landfills, and agricultural activities result in the release of these other non-CO_2 gases such as Methane (CH_4) and Nitrous Oxide (N_2O), thus they may be considered in future FREL submissions. However, most of the dominant miombo woodlands in the forest cover category are known to be fire-adapted, thus further research will have to be conducted regarding the significance of the contribution of these other gases before they are actually reported in any FREL.

4. Procedure and Information Used (Building Blocks)

4.1. Definitions

For consistency purposes, the same FAO forest definition used in the Forest Resources Assessment (FRA) reports is adopted for this FREL. Forest is defined as a minimum of 0.5 Ha with 10% canopy cover from trees that are or capable of exceeding 5m in height. This definition is used in the national forest inventory program when assessing aboveground biomass in the forest land cover category. Exotic plantation forests, although meeting this definition, were excluded from the calculations of deforestation. Only natural forests are, therefore, included in the forest definition for the purposes of this FREL. The locations of these exotic plantation forests are known. They are mostly found in the Eastern Highlands and comprise mainly conifers (mostly pine) and eucalyptus species.

4.2. Historic Reference Period and Data

Zimbabwe decided to submit the Forest Reference Emission Level at a national scale using a 6-year reference period of 2016-2021 (inclusive). The selection of the reference period was mainly based on data availability and quality. Moderate-resolution optical and radar data from the EU's Copernicus program started to be available in 2015. (Sentinel-1 & 2) The first high-resolution planet mosaics, provided under the NICFI program, became available at the end of 2015 while ALOS-2 PALSAR-2 ScanSAR radar imagery is available from 2014.

After the visual inspection of the various available data sources and trial & error in the classification process, a set of 3 different layers for both 2016 and 2022 was selected. Red and Infrared bands from already pre-processed and analysis-ready annual reflectance data from the Landsat mission and available as part of the Global Forest Change dataset on Google's Earth Engine were used alongside the true color bands from annual composites of Planet NICFI data. The latter is processed on the fly using FAO's System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL) platform and creates an average image for all data available throughout the year of interest, applying additional cloud masking and advanced pixel selection. ALOS-2 PALSAR-2 analysis-ready data is available through Google Earth Engine. To take advantage of its capability to sense the Earth independent of clouds, all of the individual scenes were used to create yearly aggregates of the data, calculating the minimum, maximum, median, and standard deviation over each pixel. This process is also known as a timescan.

As part of the feature engineering process throughout the classification, further indices and ratios between various bands were added to improve the separability between forest and non-forest pixels. Sample point interpretation was done for the years 2016-2022 (both inclusive), but the area changes presented in the FREL calculation are only up to 2021. Due to the usage of annual composites in the stratification process, changes that occurred in 2022 would have been missed as the image composites do not coincide with the last day of the year, but rather represent a selection of best pixels that might occur at any time of the year. The consequence for the subsequent sampling is that omissions of change would either remain undetected and introduce a negative bias or fall into the stable strata and reduce the certainty of the estimate.

In light of the challenges posed by Zimbabwe's predominantly dry open forest landscape, obtaining precise and high-quality data for the construction of FRELs has proven to be a significant hurdle. The main issue is the seasonality that makes it difficult to tell apart a true change from seasonal changes, both for advanced remote sensing techniques as well as for visual interpretation. Annual composites are less prone to seasonal changes. Specifically, the radar timescan data is a valuable source that indirectly captures greening and leaf-off seasons independent of their timely occurrence due to the simple usage of minimum and maximum values. The Landsat data is composed of pixels selected during the greening, based on the underlying time series. Those characteristics make them more robust to the intra-annual variation and ease the process of separating forest and non-forest areas.

With regard to the visual interpretation, the scarcity of detailed temporal information on the selected sample plots hampers the ability to make informed decisions accurately for the same reason. Recognizing this impediment, Zimbabwe has opted to leverage Norway´s International Climate and Forest Initiative (NICFI) freely available, monthly Planet data throughout the interpretation process. This strategic decision facilitates a more streamlined data collection process, enabling the utilization of more recent, temporal dense, and thus more reliable information for the determination of forest and forest change, which ultimately improves the estimation process of the Forest Reference Emission Level.

4.3. Activity Data

4.3.1. Activity Data Methodology

Sampling grid

Zimbabwe is actively engaged in the Forest Resource Assessment (FRA) program conducted by FAO. Notably, it served as a pilot country during the initial FRA Remote Sensing Survey (FRA-RSS). As part of this initiative, a global, equal-area, hexagonal grid of 40 hectares was generated by the FRA team based on the DGGRID library (Sahr, 2019). Therefore, the country decided to use the same grid for both FRA and FREL assessments. This approach facilitates streamlined and cohesive data management.

The total population of this grid with its 987,556 points is huge. Therefore, a first spatially balanced subsample was drawn from it using every 4^{th} sample based on the approach of the space-filling curve (Lister & Scott, 2009). This step reduced the number of samples to 246,889 with an expansion factor of roughly 160 ha each.

Sampling approach

In the formulation of the FREL, a stratified area estimate methodology was employed in accordance with guidance principles of unbiased estimates of forest and forest change (GFOI MGD) document[3]. Initially, Landsat time series data for all 246,889 samples was extracted for

[3] https://www.reddcompass.org/mgd/resources/GFOI-MGD-3.1-en.pdf

the envisaged period. With this, various change algorithms (BFast, CCDC, CuSum, EWMA) were used to identify change, and additional information from relevant global data sets was added to each point location. Following data extraction, an analysis was conducted clustering the points by similarity using the *KMeans* algorithm. Each cluster was then subsampled to derive a set of training data points that included a wide variability of the different landscapes as well as locations of change. Ultimately, 1,000 training samples were selected. The visual interpretation of training data was executed using the Collect Earth tool from the Open Foris family, developed by FAO. Initially, the use of this ensemble of data sets and change algorithms was envisaged for creating a classification of change probability, using the results of the training data interpretation as predictors.

The result, to be used then for stratification of change, however, was not satisfactory, most likely due to the issue of seasonality within the prevailing dry forests, for which most of the change algorithms do not provide reliable results. Therefore, the decision to use annual, multi-sensor wall-to-wall composites for the classification of forest was taken to reduce the effect of seasonality. Traditional map comparisons of two categorical maps of Forest/Non-Forest in time have shown in other cases that errors add up and the resulting stratification is not sufficient for reliably estimating forest change. Zimbabwe therefore opted to use the underlying probabilities of the classification process and use their difference to derive a continuous layer that can be considered as the likelihood of forest change.

This approach is new but has certain advantages over other types of stratification of change. First, training data on change is actually not necessary, as only the knowledge about stable forest in the time of interest is necessary. As the occurrence of forest is abundant, the minimum number of samples for subsequent classification does not pose an issue. Another advantage is that the two classifications can come from any combination of sensors. This makes it future-proof, as new data sources can be easily integrated into classification without changing the main methodology. Moreover, a continuous proxy variable is available for stratification, and an optimal sample allocation based on Neyman is feasible, which optimizes the cost-benefit for visual interpretation. Further advantages of this way of creating a continuous variable are that by using an absolute value of change in forest probability both gain and losses could be detected, and the sensitivity should allow to detect degradation. Last but not least, the input data is easily created through the SEPAL platform, and it would be easy to derive other data-driven products for biomass or tree height for example.

Thus, following this simple, but innovative approach, forest probability maps for both time 1 (2016) and time 2 (2022) were generated using SEPAL. As outlined earlier, the input data for this process included annual composites from Planet NICFI monthly base mosaics, ALOS-2 PALSAR-2 Scansar Timescans, and Landsat annual mosaics. The training data collected in the preceding step was used in the supervised classification applied during this phase to predict Forest and Non-Forest. As a result, distinct forest probability maps were produced for the years 2016 and 2022. These 2 maps were then used to extract 2 layers that were relevant to the next steps. First is the maximum forest probability for each pixel, suitable to derive an omission-free forest mask. Secondly, the difference of both two maps (and clamped between 0 and 100) was considered a spatial proxy for forest loss, thus suitable for masking out no-change areas, as well as stratifying over the higher values.

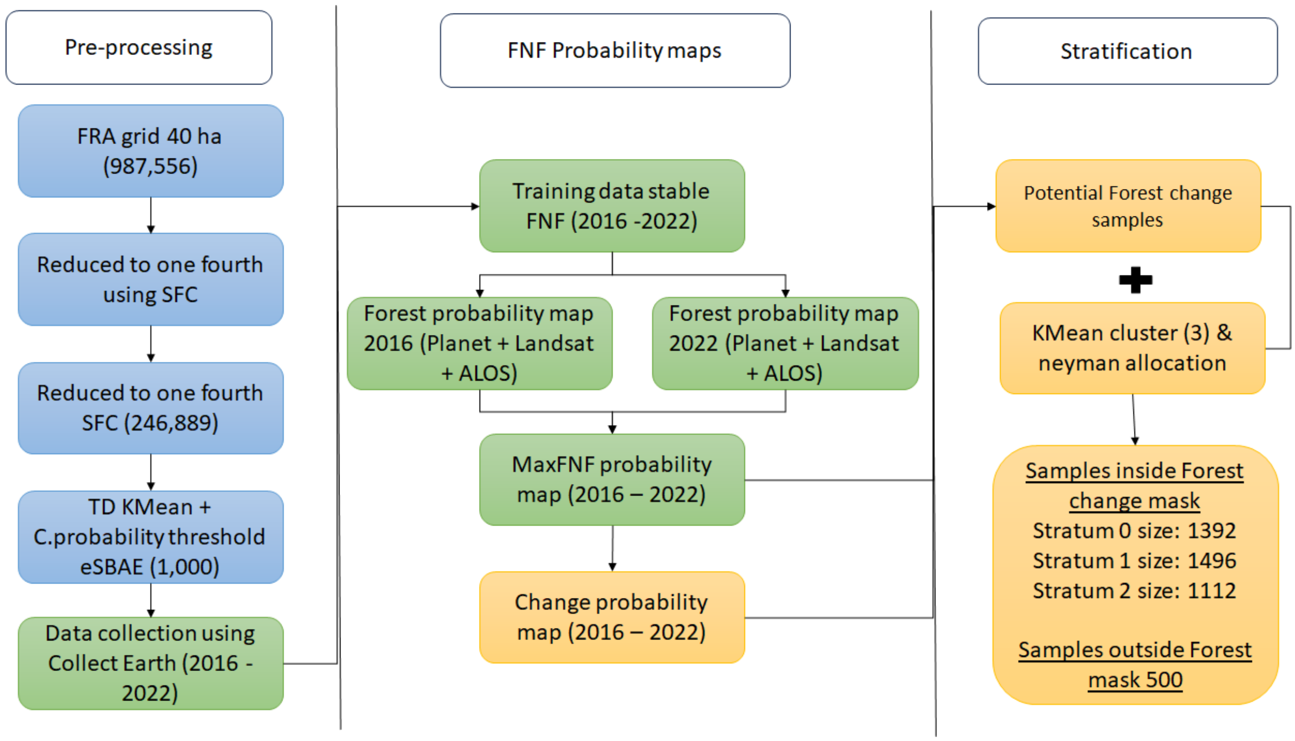

Figure 4.1. Workflow for activity data analyses

In order to reduce the total population of samples, and thus derive a higher proportion of change (beneficial for the uncertainty estimates), the maximum forest probability layer was used to mask out non-forest areas. A low probability threshold of 15 was chosen to ensure that all forest area was covered within the country. The reduced grid was superimposed on both the maximum forest and change probability layers, resulting in a total of 186,028 samples falling within the forest mask. Subsequently, an additional filter was implemented for change sample selection, again using a 15% threshold on the change probability layer, leading to a further reduction to 69,480 samples. This is basically a two-stage sample selection process. The Neyman allocation and *Kmeans* stratification were used to place the strata boundaries and Neyman allocation to place the optimal number of samples across three distinct strata, with a total of 4,000 samples. In addition, 500 samples for non-forest (below 15 % of forest probability) and 1,000 for stable forest (i.e. samples having more than 15% of probability being forest, but are lower than 15% of being change) were randomly selected from their respective layers. This meticulous stratification process ensured a representative and meaningful distribution of samples across different strata, optimizing for cost-benefit with regard to the uncertainty estimates.

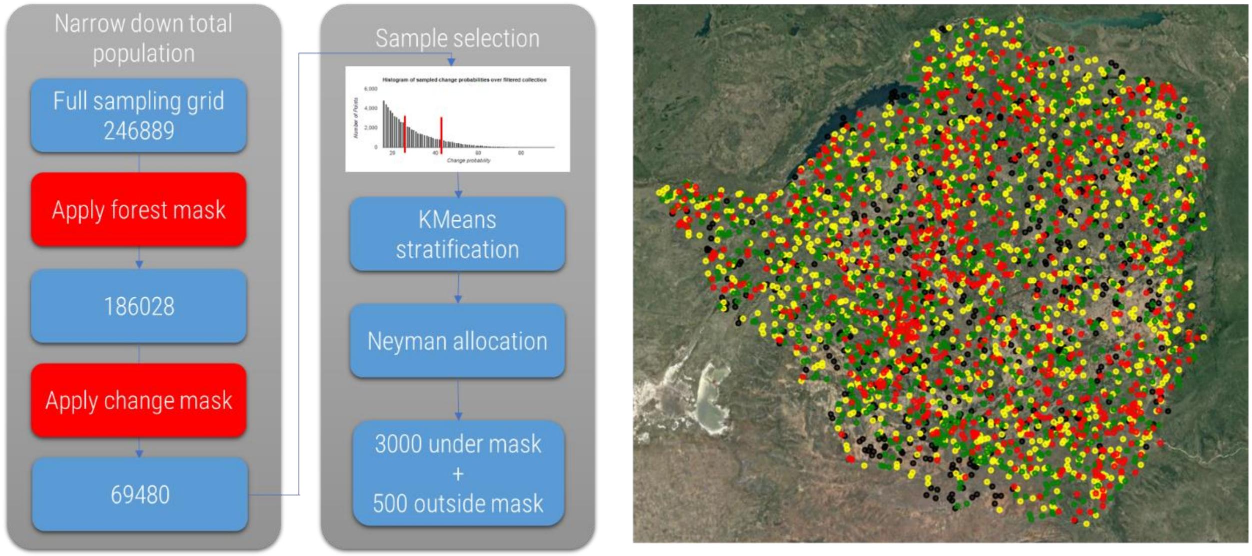

Figure 4.2. Explanation and spatial distribution of samples used in Activity Data analyses.

4.3.2. Data Collection

Data collection was conducted utilizing the Collect Earth tool, complemented by high-resolution satellite images sourced from Google Earth Pro and NICFI monthly composites. The exercise also incorporated Landsat and Sentinel-2 annual composites where needed for comprehensive data acquisition. The data collection approach is shown in Figure 4.3. Data was collected in a backward style, where first information about 2022 was collected. Then in case of change, further information about the year of change and the driver of change along with LULC class for the respective year was collected. Using this survey, interpreters were able to collect up to four maximum changes. As the reference period is small, no multiple changes were observed between 2016 and 2022.

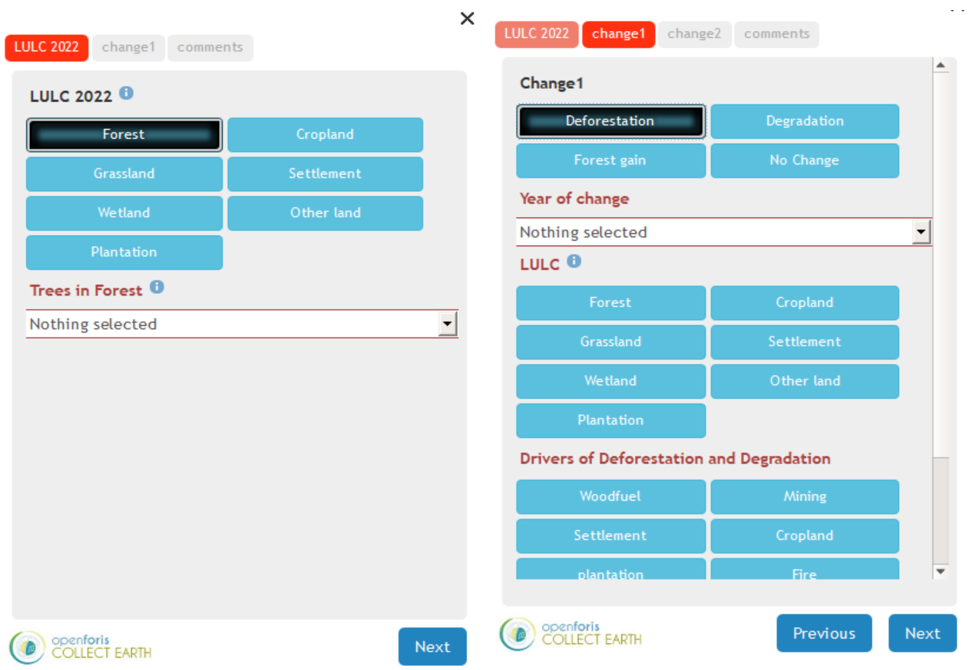

Figure 4.3. Survey card design used for data collection.

4.3.3. Results

Table 4.1 shows the forest change area estimates for the historic reference period of 2016-2021 (inclusive). As of now, Zimbabwe lacks nationally established definitions for deforestation and forest degradation. Therefore, a response design has been formulated, leveraging the IPCC classes. However, the country has opted to align with the FAO forest definition to maintain consistency with other concurrent projects. For a comprehensive understanding of the land cover classes, detailed definitions are provided in Appendix 9.3.

Table 4.1. Historic reference period forest change estimates

Change Type	**Change Area (Ha)**	**U (%)**	**95 % CI (Ha)**
Deforestation	220,823.7	21.1	46,643.9
Degradation	97,023.8	49.2	47,705.4

The drivers of deforestation and forest degradation identified during the Activity Data analyses are shown in Figure 4.4. These drivers were further grouped into 3 main activity classes according to the IPCC classification system: Cropland, Settlement, and Others.

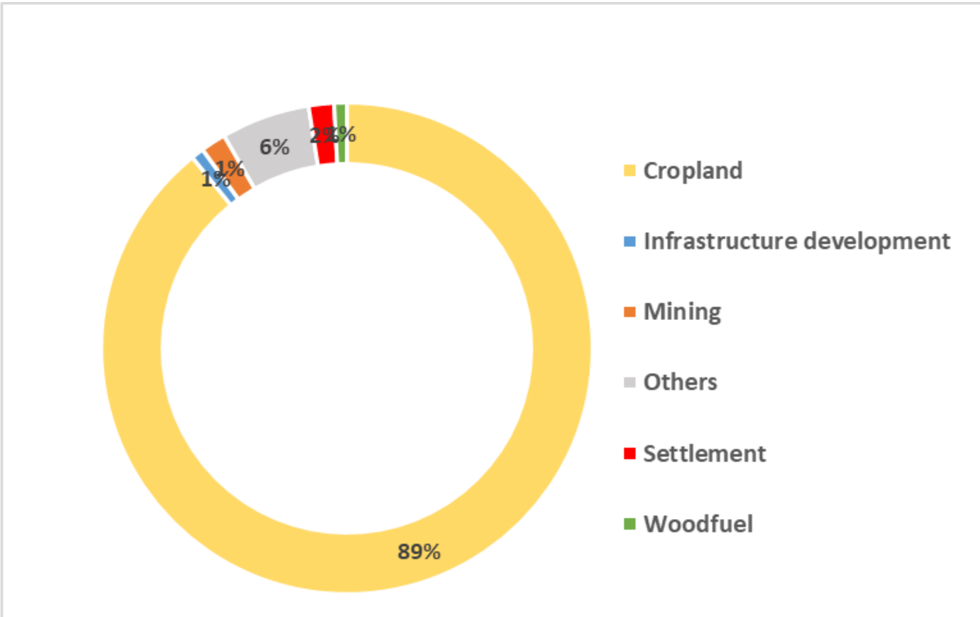

Figure 4.4. Historic reference period drivers of deforestation and forest degradation.

4.3.4. *Area Estimates for REDD+ Activities and Associated Uncertainty*

The results of the sample point interpretation were used to estimate the respective area of each REDD+ activity using a 2-step approach. First, estimators from the Neyman allocation were used to derive areas of change and their associated uncertainties for the 69k points falling under the change and forest mask. In parallel, standard estimators for stratified random allocation were used for the stable forest and the stable non-forest stratum. In the second step, areas and uncertainties from both estimation procedures were combined.

With some modifications, this follows the IPCC 2006 Guidelines for National Greenhouse Gas Inventories Chapter 3 and the IPCC Good Practice Guidance for LULUCF Chapter 5. According to the guidelines, it is efficient to estimate areas, and area changes, via assessment of proportions, since that procedure will result in the highest accuracy. Following these guidelines, 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 analyzed points. Area estimates for each land use change class are then obtained by multiplying the proportion of each change class by the total area. Equation 4.1 below was used to calculate the area of each land use change class:

$$a_i = \frac{s_i}{n} * A \tag{4.1}$$

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 = Total Stratum Area (ha)

The standard error for the change strata (reduced number of likely change points) was calculated using the Neyman equation 4.2 below.

$$(\hat{Y}_{opt}) = \frac{\left(\sum_{h=1}^{H} W_h S_h\right)^2}{n} - \frac{\sum_{h=1}^{H} W_h S_h^2}{N} \tag{4.2}$$

Where:

S = variance of the change strata

W = weight of the change strata

n = number of interpreted samples in the change strata

N = Number of total samples

The standard error for the stable forest and non-forest stratum was obtained using equation 4.3 from the guidelines mentioned above:

$$se_i = a_i * \sqrt{\frac{p_i * (1 - p_i)}{n - 1}} \qquad (4.3)$$

Where:

se_i = Standard error of the *ith* stratum (ha)

a_i = Area of the *ith* stratum (ha)

p_i = Proportion of points in the *ith* stratum (dimensionless)

n = Total number of samples in all strata (count)

The uncertainty for each land use change class at the 95% CI was then calculated as $se_i * 1.96$ while the combined uncertainty was estimated using Approach 1 of the guidelines mentioned above, i.e., equation 4.4 below.

$$U_{total} = \frac{\sqrt{(U_1 * x_1)^2 + (U_2 * x_2)^2 + \cdots + (U_n * x_n)^2}}{|x_1 + x_2 + \cdots + x_{\mathrm{n}}|} \qquad (4.4)$$

Where:

U_{total} = the percentage uncertainty in the sum of the quantities (half the 95 percent confidence interval divided by the total (i.e., mean) and expressed as a percentage). This term ‘uncertainty’ is thus based upon the 95 percent confidence interval.

x_i *and* U_i = the uncertain quantities and the percentage uncertainties associated with them, respectively.

Table 4.2. Area estimates of REDD+ activities.

Activity	**Area Estimate (Ha)**	**Uncertainty @ 95 % CI**
Forest to Cropland	191,046.0	23.4%
Forest to Settlement	16,943.4	62.6%
Forest to Other	12,834.3	44.0%
Total	**220,823.7**	**21.0%**

4.4. Emission Factors

Both tier 1 and tier 2 data were used to derive emission factors for the reported REDD+ activities. Carbon density (tCO_2e/Ha) in forested land was estimated from the national forest inventory data (tier 2) collected between 2017 and 2023. Residual carbon densities in the various post-conversion land uses were estimated using the IPCC 2006 Good Practice Guidance default values, refined in 2019[4] (tier 1).

4.4.1. Carbon densities in the forested land class

The following steps were taken to estimate carbon densities in the forested land class from field sample plots.

1. Calculation of single tree ABG biomass using an allometric equation
2. Calculation of single tree BGB biomass using a root-to-shoot ratio of 0.48 (IPCC default, GPG table 3A.1.8[5])
3. Calculation of total tree biomass (AGB+BGB)
4. Calculation of total plot biomass (Sum of all tree biomasses)
5. Calculation of total plot carbon by using a conversion factor of 0.5 (IPCC default[6])

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[4] https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html

[5] https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp3/Anx_3A_1_Data_Tables.pdf

[6] https://www.ipcc.ch/site/assets/uploads/2018/03/GPG_LULUCF_FULLEN.pdf

6. Calculation of plot carbon dioxide equivalent using the ratio of the molecular weight of carbon dioxide to that of carbon (44/12: IPCC default[7])
7. Calculation of carbon density (CO_2e/Ha) based on the ratio of plot size (area) to 1 hectare.

The national forest inventory program is based on the Global Forest Survey (GFS) methodology framework[8]. The framework establishes a multi-stage sampling approach to determine an efficient set of sites for fieldwork. A systematic grid of 5 km2 was laid out, resulting in 6500 potential field inventory plots. Per the framework, all the potential sites must be first surveyed using remote sensing techniques. In the Zimbabwe case, these potential sites were overlaid with the 2017 landcover map (Figure 4.5) to eliminate all non-forest sites. The landcover map was produced through a supervised classification of sentinel-2 multispectral imagery. In 2017, the Forestry Commission's national forest inventory team visited the forested sample sites to perform forest inventory as guided by the GFS framework. An attempt to visit all plots was made but inevitably some plots were discarded due to accessibility challenges. The team assessed each plot on site to evaluate its eligibility for classification as forested land, based on the forest definition presented in section 4.1. Sample sites that were identified to have been falsely classified as forests were also discarded.

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

[8] https://www.fao.org/3/ae346e/AE346E00.htm#TopOfPage

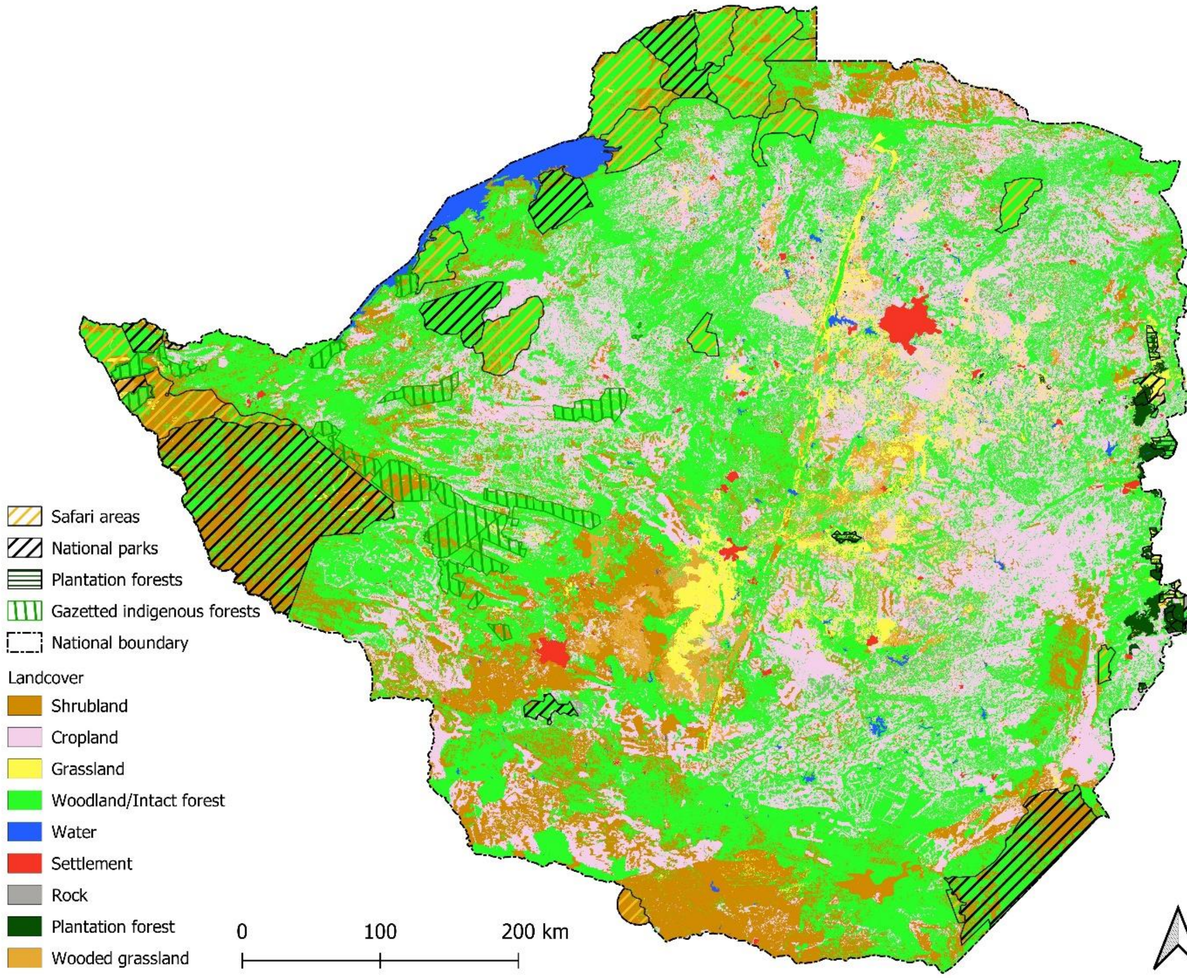

Figure 4.5 Zimbabwe landcover map for 2017

After the 2017 inventory, a decision was made to further refine the sample plots allocation per the GFS grid and move towards establishing permanent sample plots. Therefore, between 2017 and 2023, several iterations in the refinement of the sample plot allocation resulted in 3 main capacity-building exercises where forest plots were generated and visited for inventory. Further information is presented in the table below.

Table 4.3. Phases of improvement in the NFI program

Year	Exercise	Result
2018	Landcover mapping assessment, validating the 2017 landcover map	Concluded that crucial pockets of forested land, especially Mopane-dominated woodlands were omitted. 9 permanent sample plots were established and measured in 2021, 3 each in the miombo, mopane, and teak woodlands.
2023	Further training of the forest inventory team in the establishment of permanent sample plots	Miombo woodland pockets identified above were randomly assigned 12 sample plots and visited for inventory in 2023.
2023	Further refinement of the 2017 GFS grid based on updated landcover maps	48 additional plots were randomly allocated to both Mopane and Miombo woodlands.

The data that was used for the calculation of forest carbon densities is, therefore, an agglomeration of these 4 forest inventory exercises, with a total of 151 plots, that were confirmed as forested land upon visiting. This current sampling effort is low, hence the higher uncertainty in the results presented in section 4.4.2, and has been noted as a priority area of improvement.

4.4.2. Allometry

All of the NFI data contained diameter at breast height, while only 2 of these 4 exercises collected tree height in addition. For biomass calculations, it was decided to use DBH-only equations since it is the parameter that was the most accurately and consistently measured. Tree height data is prone to uncertainty since it is indirectly measured. Research has also shown that DBH alone explains more than 90% of the variability in aboveground biomass and that, even when accurately measured, tree height only explains about 2-5% more(Henry et al., 2011).

At the time of submission, the Zimbabwe NFI program does not have a national/standardized allometric equation for ABG calculation. Therefore, literature on allometric equations developed in similar miombo ecoregions was consulted. The following 10 DBH-only generic equations (Table 4.4) were evaluated on the entire dataset.

Table 4.4. Allometric equations evaluated for aboveground biomass calculations.

Author(s)	**Model**	**Development Site**
Mugasha et al. (2013)	$Y = 0.1027*DBH^{2.4798}$	Tanzania
Chidumayo (2016)	$Y = exp\{-2.059+2.342*ln9DBH)\}$	Zambia
Chidumayo (2013)	$Y = 0.0446*DBH^{2.765}$	Zambia
Guy. (1981); Henry et al. (2011)	$Y = 0.0549*DBH^{2.5101}$	Zimbabwe
GIZ (2012)	$Y = 0.1936*(DBH^{2}*3.1416/4)^{1.1654}$	Southern Africa
Ryan et al. (2011)	$Y = exp\{2.545*ln(DBH)\}-3.018$	Mozambique
Kachamba et al. (2016)	$Y = 0.2169*DBH^{2.3184}$	Malawi
Zahabu et al. (2004)	$Y = 0.0625*DBH^{2.553}$	Tanzania
Brown (1997)	$Y = exp\{-1.996+2.32*ln(DBH)\}$	Tropical dryland forests
Guedes et al. (2018)	$Y = 0.1754*DBH^{2.3238}$	Mozambique

It was found that the Ryan *et al*. (2011) model resulted in the lowest uncertainty (20.6 % at the 95% confidence interval) and was therefore selected for use in this FREL. The carbon density for the forest class was determined to be 35.6 tC/Ha = 130.5 tCO_2e/Ha. The carbon density value for the Forest class is considered as that of intact forest since it will, at this moment, not be possible to determine the state of an initial "degraded" forest type. This is a conservative approach compared to the uncertainty that would result from trying to compute the carbon density of an initial degraded forest class with limited data.

In the future, Zimbabwe is planning to improve the NFI program and perform some destructive, but objective sampling in order to derive her own national/standardized generic allometric model(s).

4.4.3. Residual carbon densities in post-conversion land use classes

Table 4.5 below shows the tier 1 carbon densities that were obtained from literature for all non-forest land use classes. These are derived from the IPCC good practice guidance tables from the relevant chapter of each land use category, as specified in the table.

Table 4.5. Post-conversion Carbon densities tier 1 data

Class	Value (tC/Ha)	Uncertainty	Source	Remark
Cropland	4.7	75%	Table 5.9: Chapter 5 of 2019 refinement	This is a value for annual croplands, 1 year after conversion. Most conservative approach.
Grassland	4.4	75%	Table 6.4: Chapter 6 of 2006	Total biomass is presented as 8.7 t/Ha, no refinement in 2019. This is a post-conversion value for tropical dry regions, i.e., the closest possible match.
Settlements	0	0	No Data	To be conservative, the extreme case scenario of 0 (zero) residual biomass is assumed.
Other	0	0	No Data	To be conservative, the extreme case scenario of 0 (zero) residual biomass is assumed.

4.4.4. Emission factor calculations

The Emission factors for each REDD+ activity (Table 4.6) were calculated as the Forest class carbon density minus the post-conversion class carbon density. Uncertainty was propagated using equation 4.4 presented above.

Table 4.6. Emission factors for REDD+ activities

Activity	Initial density		Post-conversion density		Emission Factor (tCO_2e/Ha)	
	Mean (tCO_2e/Ha)	**Uncertainty at 95% CI**	**Mean (tCO_2e/Ha)**	**Uncertainty at 95% CI**	**Mean (tCO_2e)**	**Uncertainty at 95% CI**
Forest to Cropland	130.5	20.7 %	17.2	75 %	113.3	20.3 %
Forest to Settlement	130.5	20.7 %	0	0 %	130.5	20.7 %
Forest to Other	130.5	20.7 %	0	0 %	130.5	20.7 %

5. FREL Calculation and Results

The FREL (Table 5.1) was calculated for each REDD+ activity and then summed up to obtain the total national FREL. The FREL for activity i was calculated based on the respective change area and emission factor (EF) using equation 5.1 below.

$$FREL_i = \text{Change Area}_{\text{Activity}_\text{i}} * EF_{Activity_i} \quad (5.1)$$

Total FREL was then calculated using equation 5.2.

$$FREL_{total} = \sum_{i=1}^{n} FREL_i \quad (5.2)$$

The uncertainty of the FREL was obtained by combining the uncertainties of the Emission Factors and Activity Data using approach 1 of the earlier mentioned IPCC guidelines for combining uncertainties when multiplying, equation 5.3 below.

$$U_{total} = \sqrt{U_1^2 + {U_2}^2 + \cdots + U_n^2} \quad (5.3)$$

Where:

U_{total} = the percentage uncertainty in the product of the quantities (half the 95 percent confidence interval divided by the total and expressed as a percentage);

U_i = the percentage uncertainties associated with each of the quantities.

Table 5.1. Zimbabwe Forest Reference Emission Level.

Activity	**Emissions (tCO_2e)**	**Uncertainty @ 95 % CI**
Forest to Cropland	21,645,513.2	31.0%
Forest to Settlement	2,211,111.7	66.0%
Forest to Other	1,674,870.1	48.6%
Total FREL	**25,531,495.0**	**27.1%**

The total emissions over the 6 years were, therefore, 25,531,495.0 tCO2e ± 27.1 %, which gives a FREL value of **4,255,249.2 ± 1,151,113.2 tCO_2e** per year.

6. Updating Frequency

The current FREL is technically valid for the projected 6-year period of 2022-2027 (inclusive). However, as explained in some sections, Zimbabwe is undergoing or has planned various improvements in the collection and processing of the data that make the building blocks for a FREL. Therefore, Zimbabwe expects to submit at least one updated/modified FREL before the 6 years lapse. The frequency of the updating will depend on the following main factors:

1. Availability of data for additional pools (deadwood, litter, and SOC).
2. Improvements in data collection and analysis, especially regarding the NFI program.
3. Launch of a Jurisdictional REDD+ program.
4. Need to align with any results-based financing programs or achievement of global mitigation goals.
5. Availability of reliable methods of quantifying degradation emission factors.

7. Expected Future Improvements

As emphasized in various sections, the submission of this FREL was the first stage in a stepwise approach that would see the submission of updated FRELs based on country needs, local and international goals, and improvement in the overall technical approach. Zimbabwe will be continuously working on the following components and submit an updated FREL when significant progress has been achieved in at least one of them, while also taking into consideration the factors mentioned above.

Forest degradation

The current FREL excluded the forest degradation REDD+ activity due to a lack of complete data. While SOPs are already developed and tested for the identification of forest degradation during activity data analysis, the corresponding residual carbon density data is not available. The Activity Data assessment process revealed that forest degradation occurred at a rate of 16,171 Ha per year, which accounts for 31 % of the emissions-related activities (deforestation+degradation). Forest degradation, is, therefore, an important source of emissions that the government of Zimbabwe is prioritizing as an area of improvement in FREL reporting. Parallel to the improvement of the NFI program to properly stratify and measure degradation carbon stocks, the current activity data analysis SOPs will also be refined based on past experience to minimize uncertainty in quantifying the degradation-related emissions. Once these improvements are made, the forest degradation activity will be included in future FREL submissions.

Emission factors

The NFI program will be improved to include sampling of all land use/ land cover strata. This will enable the calculation of inventory-based residual carbon densities for all non-forest land use classes. The plan is to match the activity data analyses sample grid to the NFI program sample grid to ensure data coherence. The use of tier 2 data is expected to minimize uncertainty compared to the use of tier 1 data (IPCC default) for all non-forest land use classes in this FREL. Another improvement expected in the NFI program is the development of local generic allometric equations for modeling aboveground biomass. When such models are available, carbon stocks will be calculated based on these rather than tier 1 models as in this FREL. The current NFI program uses only one class for forested land. Future planned improvements include the stratification of forest into intact forest and degraded forest to enable an accurate estimation of carbon densities in degraded forests.

Pools

The planned improvements in the NFI program include accurate collection and processing of deadwood carbon stocks. The litter pool is less likely going to be included in the near-future improvements of the NFI program, thus once deadwood data is available, default values may be evaluated and considered for that pool only. This is expected to result in a lower uncertainty than using tier 1 data for both deadwood and litter.

Removals (enhancement, sustainable forest management, and forest conservation)

Zimbabwe acknowledges that as the national efforts to promote forest conservation continue to yield results, recovery, and regrowth of forests will result in significant carbon removals. However, the country lacks the capacity to accurately collect and analyze this data at the national level. While not certain about timelines, efforts will be made to further improve the NFI program to include an accurate assessment of removals.

Emissions from fire

Wildfires are a common occurrence in Zimbabwe during the dry season. However, the dominant miombo woodlands are considered to be fire-shaped and some literature suggests that as long as the fires are sub-crown and non-destructive, the regrowth that comes soon after fire immediately offsets the emissions released during the fires. It is, therefore, not known yet whether fire contributes significant net emissions for it to be included in the FREL. The DNA will continue its collaboration with relevant parastatals such as the Environmental Management Agency (EMA) and academic and research institutes to improve the country's knowledge regarding fire emissions. When conclusive research results are available, a decision will be made on whether or not to include fire emissions in future FRELs.

Activity data analyses

Zimbabwe will keep building capacity in remote sensing data analysis to improve the forest cover dynamics mapping in the historic reference period and detection of REDD+ activities. Based on the current experience, areas of improvement noted are access to higher-resolution imagery and the collection of more field-based training and validation data points.

QAQC

For all subsequent FREL submissions, Zimbabwe will perform a thorough QAQC exercise to further refine both the identification of REDD+ activities and the estimation of land use change class areas.

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9. Appendices

9.1. FAO Forest change probability mapping procedure

Rough workflow for Zimbabwe

1. Create SEPAL Planet mosaic for 2016 (start: 31.12.2015, end: 1.1.2017)
2. Create SEPAL Planet mosaic for 2022 (start: 31.12.2021, end: 1.1.2023)
3. Create a SEPAL mask recipe with Hansen composite with Planet data as a mask for 2016

a. Input →EE asset: ee.Image('UMD/hansen/global_forest_change_2016_v1_4')

b. Planet Sepal recipe as mask

4. Create a mask recipe with Hansen composite and Planet data as mask for 2022 a. Input →EE asset: ee.Image('UMD/hansen/global_forest_change_2022_v1_10')

5. Create ALOS composites for 2016 and 2022 using this script:
https://code.earthengine.google.com/58ae9d002cb83d53e4f794c648d983f2
YOU CAN VISUALIZE ALL OF YOUR INPUT DATA HERE:
https://code.earthengine.google.com/9323acf937243b215fda1d8cb2944c91

6. Run SEPAL Classification recipe for 2016 with: a. Sepal recipe Planet 2016
b. Sepal recipe Masked Hansen 2016
c. ALOS EE Asset 2016
d. Legend to 0 and 1 (Non-Forest and Forest)
e. Stable FNF training data
f. `1500 trees in RF`

7. Run SEPAL Classification recipe for 2022 with: a. Sepal recipe Planet 2022
b. Sepal recipe Masked Hansen 2022
c. ALOS EE Asset 2022
d. Legend to 0 and 1 (Non-Forest and Forest)
e. Stable FNF training data
f. `1500 trees in RF`

`users/andreasvollrath/Zimbabwe/training_091123_stable`
NOTE: Classification recipe is buggy, just go through
`users/andreasvollrath/Zimbabwe/training_091123_stable`
the steps and export all layers, BE AWARE IT WONT SAVE THE RECIPE
8. SELECTION OF TRAINING DATA POINTS FOR REVISION
https://code.earthengine.google.com/1f0f16e4fddb9faabb95fdbe3e06c83d
9. REPEAT Steps 6 & 7 with revised points as training data and export the outputs with all layers
10. Create the absolute FNF probability difference layer and the maximum FNF probability layer and sample both + CCI biomass layer for all of the 240k points as in this script and export the samples with the probs sampled:
11. https://code.earthengine.google.com/e596551337ab94da3645b4c55798f529
12. Final step is to filter down and select the final samples to select:

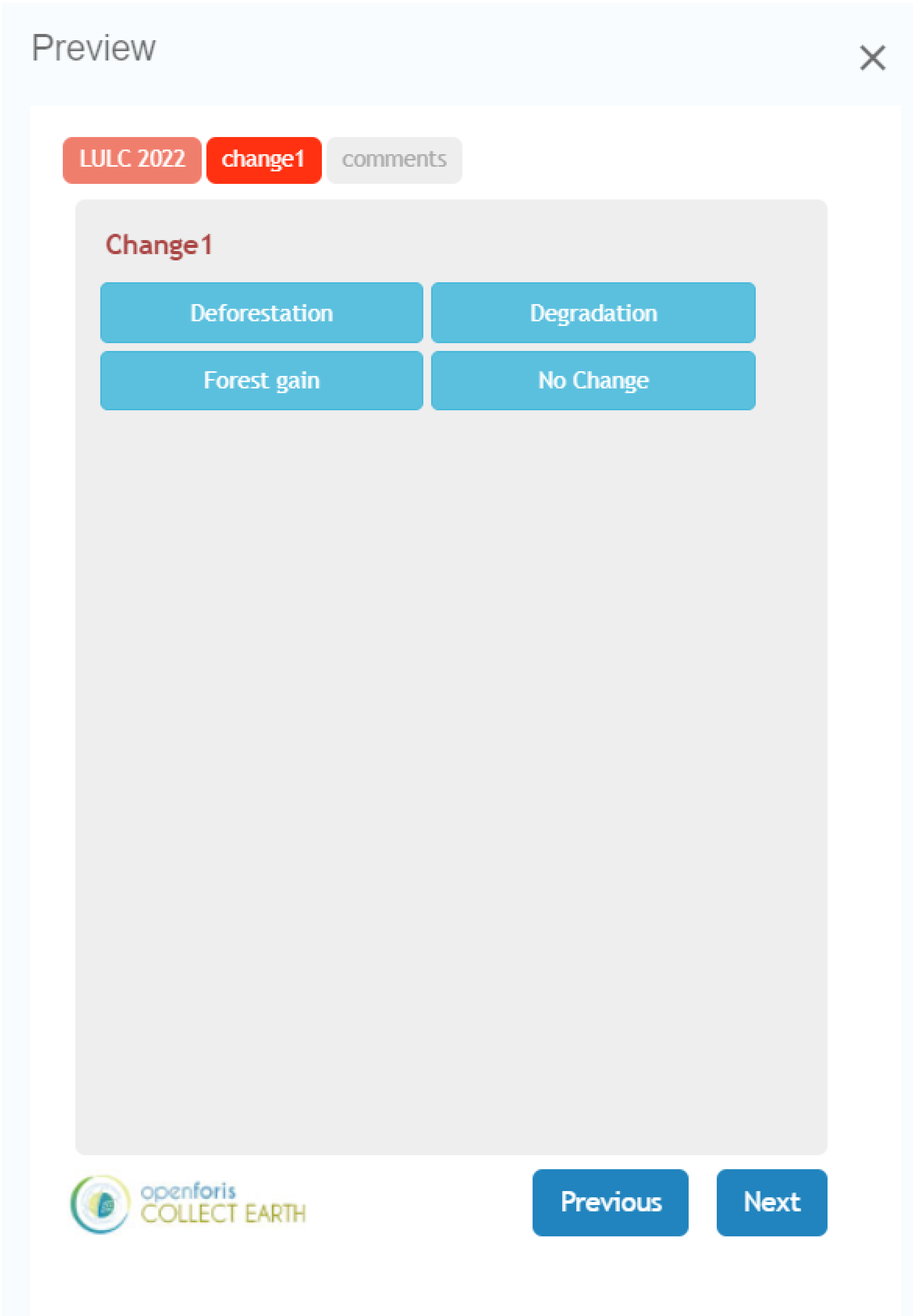
9.2.Activity Data collection cards

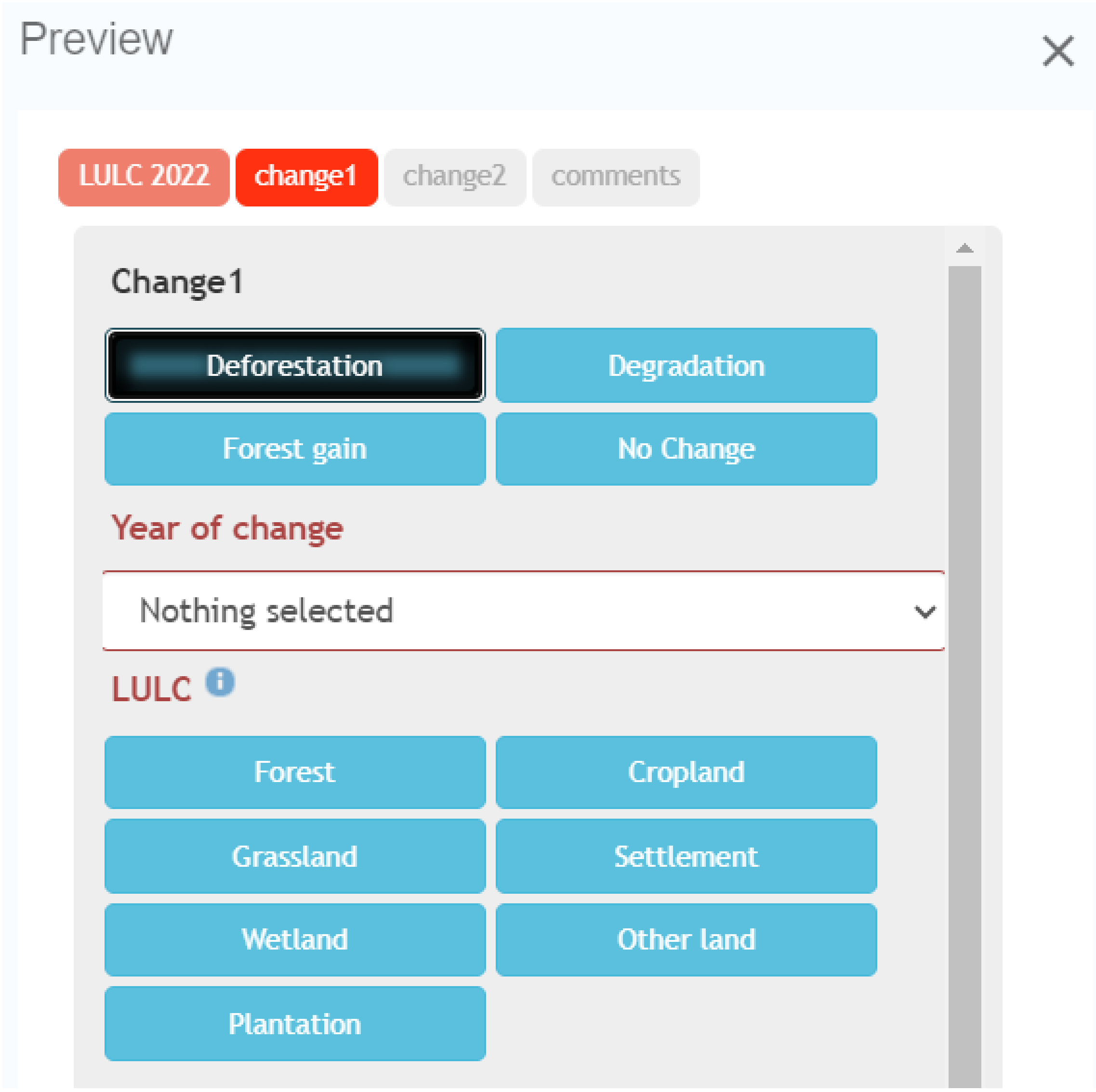
Reference Data collection survey card

Data is collected using collect earth open Foris tool.

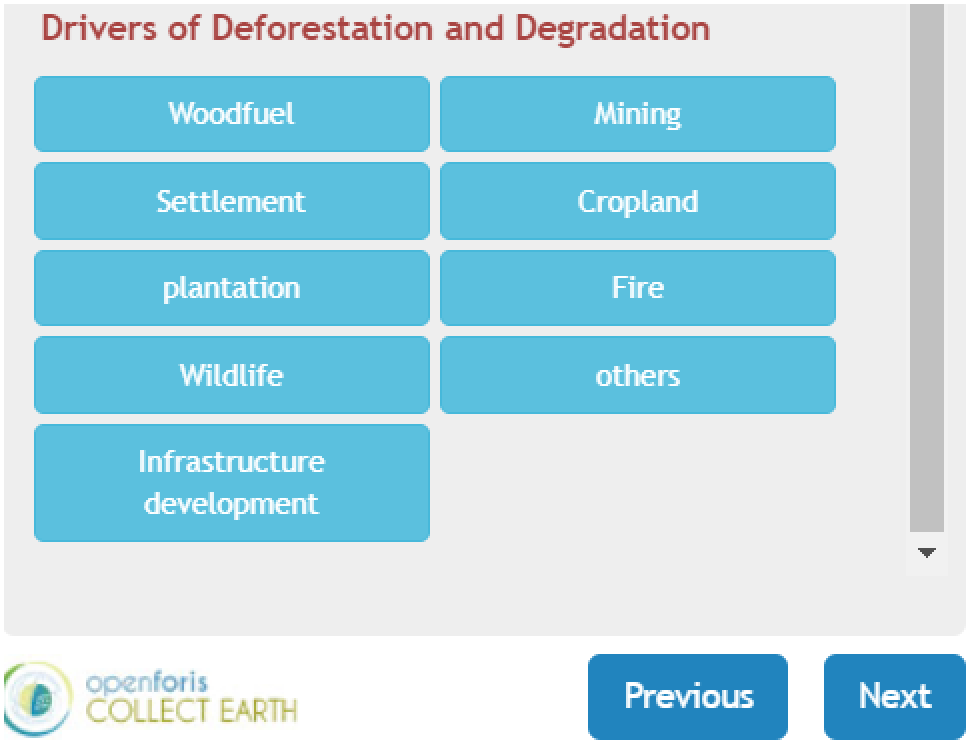
We are collecting data starting from 2022 LULC classes using IPCC classes but collecting information on plantations as well separately.

So going back from 2022 to up to 2000 for data collection, and recording multiple changes. This is to align with the FRA project. Although we will only use 2016- 2021 information for FREL.


Preview
LULC 2022
change1
comments
Change1
Deforestation
Degradation
Forest gain
No Change
openforis
COLLECT EARTH
Previous
Next



In case of deforestation interpreter will record the year of change and LULC information for that year and second question also appears on drivers of deforestation and forest degradation


Drivers of Deforestation and Degradation
Woodfuel
Mining
Settlement
Cropland
plantation
Fire
Wildlife
others
Infrastructure development
openforis
COLLECT EARTH
Previous
Next


Drivers of Deforestation and Degradation
Woodfuel
Mining
Settlement
Cropland
plantation
Fire
Wildlife
others
Infrastructure development
Species
Elephant
Others
openforis
COLLECT EARTH
Previous
Next

9.3. Activity Data response design and explanatory variables

Response Design and Explanatory variables Zimbabwe Activity Data

IPCC land cover classes [9]

Forestland

This category includes all land with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory, sub-divided into managed and unmanaged, and also by ecosystem type as specified in the IPCC Guidelines3. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category.

Land spanning more t**han 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent,** or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.

Explanatory variables

- It does not include land that is predominantly under agricultural or urban land use. Forest is determined both by the presence of trees and the absence of other predominant land uses.
- The trees should be able to reach a minimum height of 5 meters in situ.
- Is forest management site considered as forest, even unstocked.
- Includes forest roads, firebreaks, and other small open areas; forest in national parks, nature reserves, and other protected areas such as those of specific environmental, scientific, historical, cultural, or spiritual interest.
- It **includes** the plantation for restoration purposes. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10 percent or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes, but which are expected to revert to forest." (FAO/UNEP, 1999)
- **Excludes** tree stands in **agricultural production systems**, such as fruit tree plantations, oil palm plantations, olive orchards, and agroforestry systems when crops are grown under tree cover.
- Note: Some agroforestry systems such as the **"Taungya" system** where crops are grown only during the first years of the forest rotation should be classified as forest.

Cropland

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[9] https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp2/Chp2_Land_Areas.pdf

This category includes arable and tillage land, and agro-forestry systems where vegetation falls below the thresholds used for the forest land category, consistent with the selection of national definitions.

Explanatory variables

- Includes arable and tillable land, rice fields, and agroforestry systems where the vegetation structure falls below the thresholds used for the Forest Land category and is not expected to exceed those thresholds later.
- Cropland includes all annual and perennial crops.
- Annual crops include cereals, oils seeds, vegetables, root crops and forages.
- Perennial crops in combination with herbaceous
- crops (e.g., agroforestry) or as orchards, vineyards and plantations such as cocoa, coffee, tea,
- coconut, bananas
- Arable land, which is normally used for cultivation of annual crops, but which is temporarily used for forage crops or
- grazing as part of an annual crop-pasture rotation (mixed system) is included under cropland.
- Fellow land with and without trees

Grassland

This category includes **rangelands and pastureland** that is not considered as cropland. It also includes systems with vegetation that fall below the **threshold used in the forest land category and are not expected to exceed (trees less than 5 meter in height)**, without human intervention, the threshold used in the forest land category. The category also includes **all grassland from wild lands to recreational areas** as well as **silvi-pastural systems**, subdivided into **managed and unmanaged** consistent with national definitions.

Explanatory variables

Grasslands can vary greatly in their degree and intensity of management, from extensively managed rangelands and savannahs – where animal stocking rates and fire regimes are the main management variables – to intensively managed (e.g. with fertilization, irrigation, species changes) continuous pasture and hay land.

- Grasslands generally have a vegetation dominated by **perennial grasses**, with **grazing as the predominant land use**, and are distinguished from "forest" by having a **tree canopy cover of less than** 10 percent.
- **Grasslands includes rangelands and pastureland that not considered Cropland including systems with woody vegetation** and other **non-grass vegetation such as herbs and shrubs** (shrubs are tress where height is less than 5 meter).

Wetlands

This category includes land that is covered or **saturated by water for** all or part of the year (e.g., **peatland)** and that does not fall into the forest land, cropland, grassland or settlements categories. The category can be subdivided into managed and unmanaged according to national definitions. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged subdivisions.

Explanatory variables

- Guidance is restricted to **Managed Wetlands where the water table is artificially changed** (e.g., drained or raised) or wetlands created through human activity (i.e., damming a river)
- Reservoirs or impoundments, for energy production e.g., Dam
- irrigation, navigation, or recreation (Flooded Land)
- **All water bodies**, including seasonal water bodies, swamps.
- **Wetlands**
- **Natural or artificial ponds,**
- **Rivers, Lakes and streams, waterfalls**

Settlements

This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. This should be consistent with the selection of national definitions.

Explanatory variables

Settlements are defined includes **residential, transportation, commercial, and production (commercial, manufacturing) infrastructure of any size,** unless it is already included under other land-use categories.

- The land-use category Settlements includes soils, herbaceous perennial vegetation such as turf grass and garden plants, trees in rural settlements, homestead gardens and urban areas.
- Examples of settlements include land along **streets, roads in residential (rural and urban) and commercial lawns**, in **public and private gardens**, in **golf courses** and athletic fields, e.g., cricket field and in parks, provided such land is functionally or administratively associated with **cities, villages or other settlement types** and is not accounted for in another land-use category.
- Airports, factories

Other land

This category includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available. **Explanatory variables**

- Other Land includes **bare soil, rock, ice**, and all land areas that do not fall into any of the other five land-use categories.
- Other Land is often unmanaged, and in that case changes in carbon stocks and non-CO_2 emissions and removals are not estimated.
- Active Mine dump generally but also include the dumps if not active. **Plantation**
- Includes commercial plantation as well, pine, eucalyptus and others.

Tree cover Forest: please add the tree cover percentage in case of Forest by counting sub sample in the plot.

Deforestation

- Forest land changed to non-forest land during 2000 – 2022.
- This includes both changes in land use:
- Tree cover percentage reduce to less than 10% even no land use change.
- Even percentage tree cover is above 10% but land use change is observed as a major activity.

Examples

- Forest land converted to plantation.
- Forest land converted to settlement.
- Forest land converted to cropland.
- 2016 Tree cover was 70% but in 2022 reduced to 7%, will be deforestation.
- 2018 was a forest and in 2022 converted to cropland but percentage tree cover is 12 %, will be deforestation.

Forest degradation

- Forest remains Forest.
- Usually defined as reduction in canopy cover but still have percentage of forest cover as of forest definition. Examples percentage of canopy cover is reduced to 30% in 2017 from 90% in 2016

Forest gain

- When Non-Forest land converted to Forest land.
- Please remember the forest definition criteria to classify it as a gain/increased.