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The Ministry of Natural Resources, Energy and Mining

MALAWI REDD+ PROGRAM

National Forest Reference Level

FOREWORD

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ACRONYMS & ABBREVIATIONS

AD	Activity Data
AFOLU	Agriculture, Forestry, and Other Land Use
BAU	Business as Usual
BEST	Biomass Energy Strategy
CI	Confidence Interval
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COP	Conference of Parties
DMe	Dry Mass (Biomass) Equivalent
EF	Emission Factor
f_{NRB}	Fraction of Non-Renewable Biomass
FCPF	Forest Carbon Partnership Facility
GHG	Greenhouse Gas
GHG-IS	Greenhouse Gas Inventory System
GPG	Good Practice Guidance
HH	Household
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change, and Forestry
MRV	Monitoring, Reporting and Verification
NDC	Nationally Determined Contribution

NFMS	National Forest Monitoring System
PERFORM	Protecting Ecosystems and Restoring Forests in Malawi
REDD+	Reducing Emissions from Deforestation and Degradation
REL	Reference Emissions Level
RL	Reference Level
SE	Standard Error
SLMS	Satellite Land Monitoring System
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WISDOM	Wood Fuels Integrated Supply/Demand Overview Mapping

1.0 INTRODUCTION

In recognition of Decision 1/CP.16 adopted at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP) in 2010, identifying national Reference Emissions Levels (REL)/Reference Levels (RL) is an essential prerequisite for Parties aiming to undertake activities under the Reducing Emissions for Deforestation and forest Degradation (REDD+) program. This document serves as an interim Malawi National Forest Reference Level (FRL). Carefully adhering to existing guidance set forth by the UNFCCC and recognizing established precedents, the report explains in full detail Malawi's proposed FRL, including the historical time period it represents, the activities included, the methodologies applied for deriving the estimates, and key assumptions and rationalizations that underpin decisions made in the development of Malawi's FRL.

As detailed in the report, deforestation from 2006-2016 resulted in 1,236,631 tons of carbon dioxide equivalent (tCO_2e) of greenhouse gas emissions per year. This deforestation estimate was based on two data points so no trend was assessed. Enhancements driven by plantation management resulted in annual removals of 57,964 tCO_2e. Forest degradation by fuelwood extraction was modeled for 2016 and 2021 using a spatial and statistical modeling approach to develop a fraction-non-renewable biomass factor applied to fuel consumption trends. It has, therefore, been estimated that 2,991,058 tCO_2e in 2016, and rising to 4,645,844 tCO_2e by 2021 are emitted through fuelwood extraction. Thus degradation emissions are projected upward in the reference level. Because of Malawi's rapidly growing population and heavy continuing reliance on wood fuel for energy, this projection is highly realistic. The combined reference level for deforestation, degradation, and enhancements is presented in this report as 4,500,682 $tCO_2e\ y^{-1}$ in 2017 rising to 5,824,511 by 2021. In light of the high rate of demographic change it was determined there is insufficient basis to extend projections past 2021, and thus a five-year reference period is presented for the FRL.

This document also explains the role of Malawi's National Forest Monitoring System (NFMS), a system tasked with the responsibility of tracking and regularly reporting greenhouse gas emissions and removals from REDD+ activities, ensuring that accounting methods and procedures are compliant with Intergovernmental Panel on Climate Change (IPCC) principles of transparency, consistency, comparability, completeness and accuracy.

As a party to the UNFCCC and signatory to the Kyoto protocol, Malawi committed to monitoring levels of national greenhouse gas emissions and carbon sinking capacity, as well as implementing of various climate change related activities.

Malawi has submitted two national communications, the Initial and Second National Communication, and is currently working on the Third National Communication and First Biennial Update Report. The Government of Malawi (GoM) submits these reports to the COP of the UNFCCC as a commitment to contribute towards the global efforts to reverse the adverse effects and impacts of climate change.

Malawi established the Malawi REDD+ Program (MRP) in 2012 and has made tremendous progress including the development and endorsement of the Government of Malawi REDD+ Action Plan 2014 -2019. The REDD+ Action Plan defined a step-wise approach to achieving the REDD+ readiness phase. Malawi has made progress on all the four REDD+ pillars, namely the NFMS, Forest Reference Level (FRL), Safeguard Information System and finally the National REDD+ Strategy. Malawi has drafted the REDD+ Strategy which is expected to be endorsed in 2019.

In 2017, Malawi submitted its first Intended Nationally Determined Contribution (INDC) to the UNFCCC, outlining planned efforts for redirecting the country's emissions trajectory in support of the UNFCCC Paris Agreement to keep global surface temperature from rising more than 1.5°C. This document cites forestry and land use, agriculture, and energy sectors as the country's largest sources of greenhouse gas emissions. Unsustainable fuelwood and charcoal use, poor agricultural practices that result in high deforestation and degradation rates were also cited as major drivers of these emissions, and therefore, the country plans to take mitigation measures that directly target those activities. These efforts include the promotion and introduction of alternative renewable energy sources, more efficient cookstoves, promotion of sustainable forest management practices, and afforestation and reforestation (including woodlots).

Malawi's Nationally Determined Contributions (NDC) specifically cites the establishment of a Malawi REDD+ Program as the principal mechanism for lowering emissions in the forestry and other land use sector, in accordance with the Government of Malawi's REDD+ Action Plan. This Action Plan establishes protection and conservation of existing forests and afforestation as the primary REDD+ activities Malawi will seek to undertake.

Malawi's national FRL has been generated, ensuring that accounting methods and procedures are in full agreement with IPCC principles of transparency, consistency, comparability, completeness and accuracy.

1.1 The Context of Malawi

Rain-fed agriculture forms the foundation of Malawi's economy, making the country highly susceptible to risks associated with climate change. The increased intensity and frequency of drought events has devastated much of the country's economy, including the forestry sector, reducing biomass productivity in plantations, as well as increasing the incidences of forest fires (GoM 2011, SNC).

In addition, forest resources in Malawi have been dwindling in quality and quantity for decades as more than 97% of households in Malawi rely on illegally and unsustainably sourced biomass (charcoal and firewood) for domestic cooking and heating energy. Malawi's population is growing at 2.91% per year, and its dependency on wood fuels results in a high impact on forests, with downstream negative impacts on water availability, hydropower-generating capacity, biodiversity, and more broadly, the vulnerability of Malawians to climate change. The forestry sector has also been affected by the opening of new land from forest clearing activity for agriculture, upon which 80% of the Malawian population depends.

The forest resources of Malawi are classified into: (i) natural woodland, (ii) forestry plantations, and (iii) woodlots. The natural woodland comprises forest reserves (8,076 km^2), national parks and game reserves (9,680 km^2), and customary forests (8,843 km^2), totaling 26,428 km^2 of forest land (GoM 2011, SNC).

2.0 APPLICATION OF UNFCCC MODALITIES IN REFERENCE LEVEL

REDD+ REL or RLs are a fundamental component of REDD+ programs. They serve as the foundation for receiving international REDD+ results-based finance as they establish the key performance metrics and the benchmark against which a REDD+ program's success can be determined. Therefore, RELs or RLs can determine the amount of support that can be issued through financing mechanisms based on measured, reported, and verified emission reductions.

The creation of FRLs as benchmarks for assessing performance are guided by UNFCCC Conference of Parties (CoP) decisions, most notably decision 12/CP.17 and its Annex. Fundamentally, these modalities state FRLs should be established transparently, considering historical data and adjusting for national circumstances in accordance with relevant decisions of the COP. Given many countries lack capacity or data to comprehensively quantify emissions and/or carbon removals from all potential REDD+ activities, the UNFCCC guidance stipulates that a 'step-wise approach' is allowed whereby Parties may improve the FRL over time by incorporating better data, improved methodologies, and additional carbon pools.

FRLs are expressed in units of tons of CO_2 equivalent (tCO_2e) per year and represent emissions over a selected historical time-period. Parties must maintain consistency with a country's greenhouse gas inventory (according to 12/CP.17, Paragraph 8[1]). In response to the guidelines for submissions of FRLs provided in UNFCCC Decision 12/CP.17, a summary of Malawi's decisions on these modalities is given in Table 1.

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[1] https://unfccc.int/resource/docs/2011/cop17/eng/09a02.pdf

Table 1 | Malawi's Approach to Components of UNFCCC Decision 12/CP.17

Reference to Guidelines	Description	Malawi's Proposed Approach
Decision 12/CP.17, Paragraph 10	Allows for a stepwise approach	• Emissions from forest degradation caused by fire and logging have not been included in Malawi's RL as they do not present an opportunity for emission reductions in Malawi at this time. • Malawi's forests are naturally fire-adapted ecosystems. • Nevertheless, as new technologies and approaches emerge, Malawi will continue to seek opportunities to make its RL more complete by including this activity.
Decision 12/CP.17 Annex, paragraph (c)	Pools and gases included	Pools Deforestation: • Aboveground biomass is the most significant pool for forests • Belowground biomass is significant • Litter included for completeness • Deadwood included for completeness • Soil is a significant pool Degradation: • Aboveground biomass is the most significant pool for forests • Belowground biomass is significant Enhancements: • Aboveground biomass is the most significant pool for forests • Belowground biomass is significant • Other carbon pools not significant in plantations for the first 30-60 years Gases • CO_2 always accounted for emissions and removals • Fire CH_4 and N_2O accounted for fires that cause deforestation and degradation. All are converted into CO_2e.
Decision 12/CP.17 Annex, paragraph (c)	Activities included	• Deforestation • Forest degradation from wood fuel collection • Carbon stock enhancements from planted forests are included (timber plantations on customary lands managed by the GoM as well as Tobacco Estates)
Decision 12/CP.17 Annex, paragraph (d	Definition of forest used is same as that used in national GHG inventory	• 10% canopy cover, • minimum height of 5 meters • minimum area of 0.5 hectares

Decision 12/CP.17 Annex	The information should be guided by the most recent IPCC guidance and guidelines	GHG estimates were developed integrating 2006 IPCC Guidelines, Vol. 4 (AFOLU)
Decision 12/CP. 17 II. Paragraph 9	To submit information and rationale on the development of forest FRLs/FRELs, including details of national circumstances and on how the national circumstances were considered	Forest degradation and deforestation pose a significant threat to Malawi because forests provide a wide range of products and services which are central to Malawi's development and the well-being of Malawians. Deforestation has been a major contributor to climate change through CO_2 emissions in Malawi and globally. Therefore, Malawi will be a net emitter of CO_2 if it is unable to halt deforestation and forest degradation through addressing the energy challenges which contribute to deforestation and forest degradation. Malawi has therefore embraced REDD+ as a key strategy in its national development trajectory. Once effectively implemented, its REDD+ program will serve as an important pathway to maintain the ecological integrity of its forest cover whilst contributing to national efforts aimed at mitigating climate change. This FRL for Malawi will therefore provide the baseline that will enable a robust assessment of Malawi's efforts towards addressing emissions from the forestry sector.

Malawi submitted its Nationally Determined Contribution (NDC) to the UNFCCC in 2015 and is in the process of finalizing its Third National Communication, first Biennial Update Report, and fourth National Inventory Report for submission to the UNFCCC in 2019.

3.0 RATIONALE AND JUSTIFICATION FOR FOREST REFERENCE LEVEL

3.1 Scope of Activities

The most significant drivers of deforestation and forest degradation in Malawi are the expansion of agriculture and settlements, and unsustainable fuelwood extraction (Malawi 2016 National Forest Policy; Malawi 2017 INDC). Under its REDD+ program, the Government of Malawi is seeking to maximize potential emission reductions by implementing targeted measures and activities that will lower net emissions by:

1. lowering rates of **deforestation**
2. lowering rates of **forest degradation** from unsustainable fuelwood harvesting, and
3. **enhancing carbon stocks** through afforestation and reforestation.

To better evaluate and curb emissions from these activities and maximize potential emission reductions, an activity-based monitoring, reporting and verification (MRV) system has been established whereby each REDD+ activity is tracked and measured separately.

Unsustainable extraction of fuelwood is not the only driver of human-induced forest degradation in Malawi, but it is believed by the Malawi REDD+ program to be the most significant and thereby offers the greatest opportunity to lower emissions. In fact, the overwhelming majority of biomass extracted from natural forests in Malawi is used for heating and energy (Kerr 2005; Mauambeta 2010).

Fire is also likely a driver of forest degradation in some contexts, as it is sometimes used to clear land in customary landscape management activities, including hunting, pasture management, and land preparation for agriculture. At present, there is no approach available to reliably differentiate between fires driven by anthropogenic activities and those that occur naturally in Malawi. Given the role that fire plays in Malawi's natural forests and woodlands, as well as its use in traditional landscape management practices, opportunities to lower emissions from this activity (whether anthropogenic or naturally occurring) are limited. As such, emissions from this driver of forest degradation has been omitted in Malawi's REDD+ Program's FRL. Similarly, forest degradation from commercial timber extraction has also been omitted as it is not considered a significant cause of degradation.

3.2 Forest Definition

Forests are defined as land with woody vegetation (i.e., trees defined as a woody perennial plant with a life form that is a single well-defined stem and a more or less defined crown and includes palms, shrubs, bamboos, saplings and re-shoots of all ages and of all kinds and any part thereof) (Malawi Department of Forestry, 2017). The technical order forest definition further defines forest in terms of assessment context. For national mapping, the woody vegetation should be the dominant class in a minimum mapping area of 0.5 hectare; for all mapping the woody vegetation should be a minimum 10% crown closure and a potential height of 5 meters at maturity. For multiple time series data, an area of land that has the potential for woody vegetation in situ to exceed the minimum height of 5m at maturity should be considered as forest.

Malawi's forest definition does not include all trees, timber and non-timber, grown on cropland, as on cropland, the tree cover does not meet the definition of forest nor do windbreaks, shelter belts or roadside plantings less than 30 m in width.

The definition of forest in Malawi was adapted from international guidelines, including the Food and Agriculture Organization (FAO) (Global Land Cover Network land cover classification system), the IPCC (Good Practice Guidelines, 2003), and the UNFCCC (Guidelines for Reporting Greenhouse Gas Emissions). The definition also reflects the National Land Use and Land Cover Classification System. The definition was intended for natural resource management and biodiversity-related applications, as well as a practical definition for all forest users and managers.

Malawi also adopts the IPCC definition of forest land which "includes all land with woody vegetation consistent with thresholds used to define Forest Land in the national greenhouse gas inventory. It also includes systems with a vegetation structure that currently fall below, but in situ could potentially reach the threshold values used by a country to define the Forest Land category." On the basis of this definition, Malawi considers agroforestry systems (where shade trees meet the forest definition parameters) and early stage forest plantations (which are yet to meet the forest definition thresholds (e.g. 1–3 year old teak plantations) as forests.

3.3 Scale

The Malawi REDD+ Program is being developed at the national scale. As opposed to starting at the subnational level and gradually expanding, Malawi has opted to implement a national REDD+ program due to the country's largely centralized government structure and relatively small size.

3.4 Pools & Gases

3.4.1 Pools

All significant[2] pools and sinks for REDD+ activities under the Malawi's REDD+ Program have been included in the RL (Table 2). For deforestation, the only omitted carbon pool was harvested wood products because, as noted above, extracted timber is primarily sourced from plantations in Malawi, rather than from natural forests. For emissions from forest degradation from unsustainable fuelwood

[2] Defined as >10% of total forest-related emissions in the accounting area

collection, aboveground biomass pools are included. For carbon stock enhancement, only aboveground and belowground biomass pools are included as the other pools are not considered a significant source of additional removals (Pearson et al. 2005).

Table 2 | Carbon Pools Included in Each Activity of Malawi's Forest Reference Level

Activity	Aboveground Biomass (AGB)	Belowground Biomass (BGB)	Deadwood (DW)	Litter (L)	Soil Organic Carbon (SOC)
Deforestation	X	X	X	X	X
Degradation	X				
Carbon Stock Enhancements	X	X			

3.4.2 Gases

The FRL's selection of greenhouse gases focuses on CO_2. Emissions from nitrous oxide (N_2O) and methane (CH_4) are not included as these gases are only significant where fire is a significant driver of deforestation and degradation, and fire has been omitted from Malawi's RL (see Scope of Activities section above for justification).

3.5 Historical Time Period

The time period selected for the evaluation of historical emissions should be representative of what future emissions could be expected to be in the absence of a REDD+ program, though data availability can be a limited factor in some cases. The historical period for Malawi's national REDD+ RL is the 10-year period starting in 2006 and ending in 2016. This historical period is the most recent period for which data are readily available.

4.0 NATIONAL FOREST MONITORING SYSTEM

Malawi is in the process of developing its national forest monitoring system (NFMS), and has made significant progress since 2016 as it has completed a ground-based biomass survey, trialed a satellite-based land monitoring system, and developed a national Greenhouse Gas Inventory System (GHG-IS). The monitoring components have only been applied in a historical observation context, but form the basis for formalization into a more regularized NFMS.

Regarding the field-based carbon inventory, the Department of Forestry (DoF) has led several forest inventories since 2010. These past inventories have been site-based and used a variety of approaches driven by the Department's objectives at the time of design. As an important step to developing an NFMS, the DoF aggregated and harmonized these past inventories, and incorporated new measurement taken in 2018, to fill gaps and produce the first ever National Forest Inventory (NFI) (DoF 2019). This NFI effort lays the foundation for regularly conducted NFIs in the future.

Malawi has also taken steps to ensure consistency and efficiency in emissions accounting between its REDD+ program and the national efforts to regularly report greenhouse gas (GHG) emissions from all economic sectors to the United Nations Framework Convention on Climate Change (UNFCCC). Through a formal and integrated process, results from Malawi's annual forest monitoring efforts will be reported to staff at Malawi's Environmental Affairs Department (EAD) in the Ministry of Natural Resources, Energy and Mining, the Department responsible for managing the GHG-IS. This system, launched in 2019, has been designed to consistently and comprehensively estimate emissions and removals across the economic sectors defined by the Intergovernmental Panel on Climate Change (IPCC). Under the GHG-IS, EAD staff follow explicit and formal processes to gather and analyze necessary data from sectoral focal points in order to perform the GHG accounting analyses. These formal processes and procedures are articulated through standard operating procedures that include quality assurance and quality control measures which are designed to control systematic or random errors, as well as automated custom calculation tools that estimate emissions and removals in accordance with IPCC guidelines.

A satellite land monitoring system (SLMS) for tracking deforestation has not been formalized in Malawi. The approach used to generate historical activity data in this report instead relied on a sampling-based approach using Google Earth high-resolution satellite imagery. This a low-cost approach that the DoF and the University of Malawi has proven appropriate and sustainable. New technologies will always generate new opportunities for reevaluating this SLMS approach, but for the near term, a high resolution and visual sampling-based approach is an important component of Malawi's NFMS.

In the analysis presented in this document, degradation is estimated through a geospatial modeling technique that integrates maps and economic, demographic and behavior data captured through household surveys and census. There is not yet an agreed-upon strategy for monitoring emissions from degradation. The interim modeling approach relies heavily on outside technical assistance, but this could change with further capacity building of Malawian practitioners.

Enhancements are monitored primarily through management records on large GoM and private timber plantations. The government is developing standard data reporting tools for large plantations to aid in producing more reliable annual estimates of planted hectares and stand survival. While the DoF engages in extensive forest restoration and planting activities outside of timber plantations, either directly or through development partners and community-based organizations, there is not yet a systemized approach to monitoring these non-plantation enhancement activities and, as a result, non-plantation plantings have been omitted from the reference level.

The remainder of this section presents a more detailed description of the analytical approaches that were used to generate both activity data and emission factors for each of the three REDD+ activities.

4.1 Deforestation

4.1.1 Activity Data

Activity data for deforestation was estimated in hectares per year from 2006-2016 using a sample-based approach and with respect to the National Forest Definition's requirement of 10% canopy cover over 0.5 hectares. In the sample-based approach, deforestation was estimated for an entire landscape based on the proportion of visually-interpreted plots showing forest loss between the years 2006-2016.

Four thousand plots were randomly generated and numbered within the same sampling frame that was used in the 2018 National Forest Inventory. The sampling frame covered 26,128 km^2, or 22% of the land area of Malawi, and it focused on protected areas, forest reserves, and some highly forested customary lands, while excluding government timber plantations (Figure 1). The precision objective was to obtain a minimum of 2,000 complete records, taking into account the proportion of plots that would not offer a complete view for both 2006 and 2016. This number of plots translates to a sampling density of one plot per 13 km^2.

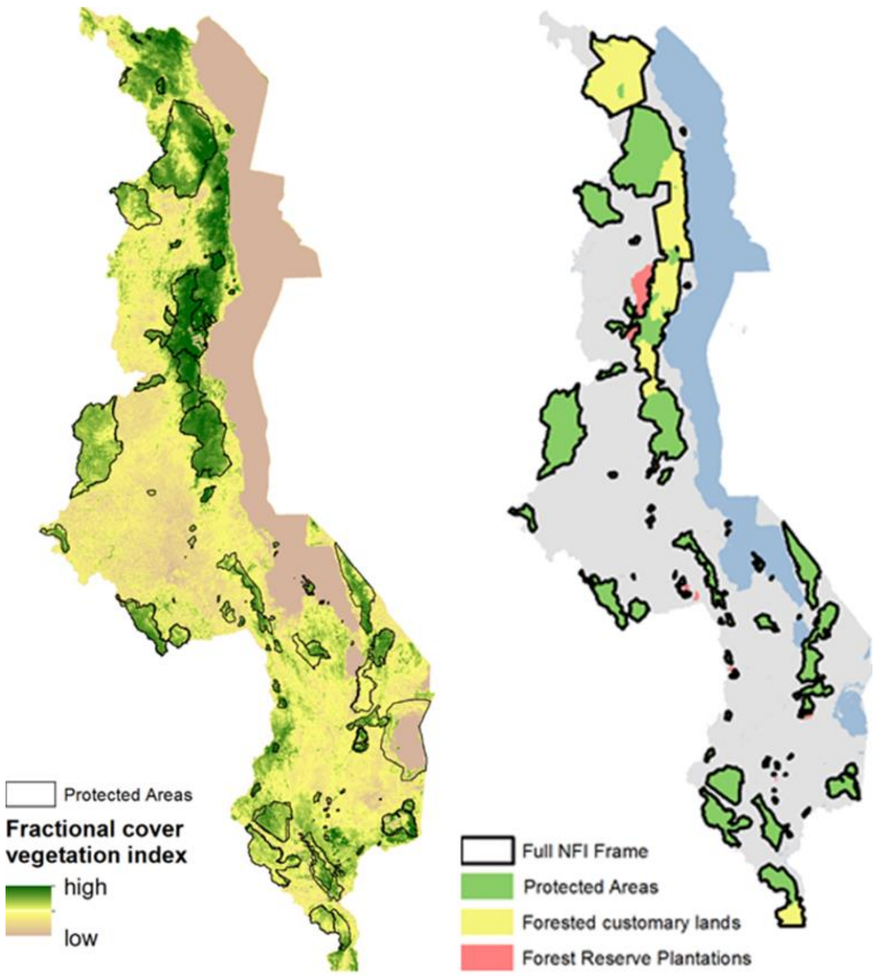

Figure 1 | Distribution of Fractional Cover Vegetation Index and Protected Areas in Malawi (Left); Sampling Frame for Generating REL Activity Data Adopted from the National Forest Inventory 2018 Sampling Frame

Observations were made by visually interpreting high-resolution images accessed through Google Earth, and with a 0.5 ha plot gridded into a 3x3 sub-grid configuration (Figure 2). Analysts recorded canopy cover for each of the nine sub grids within each plot as one of five options: 0%, 25%, 50%, 75%, and 100%. The result of each of nine sub-grid canopy cover responses for a plot was averaged to produce a single canopy cover estimate for the plot (Equation 1).

Equation 1 | Determination of Plot-Scale Canopy Cover

$$CC_{plot} = \frac{\sum CC_{subgrid}}{9}$$

Where:

CC_{plot}	Canopy cover aggregated to entire plot
$CC_{subplot}$	Canopy cover of each of nine sub-grids

This aggregated plot-level canopy cover value was used to classify plots as forest or non-forest based on the national definition's 10% canopy criteria. Records were made for both a 2016 and 2006-era image. Because imagery is not available for all years, analysts were given the flexibility to use images with dates up to 4 years either before or after the nominal years, meaning that 2006 could include 2002-2010 and 2016 could include 2012-2018. Analysts were instructed to choose the image with an actual date as close as possible to the nominal target whenever multiple alternatives existed. For 2006, 66% of observations were taken from 2005-2007, and for 2016, 87% were from 2015-2017.

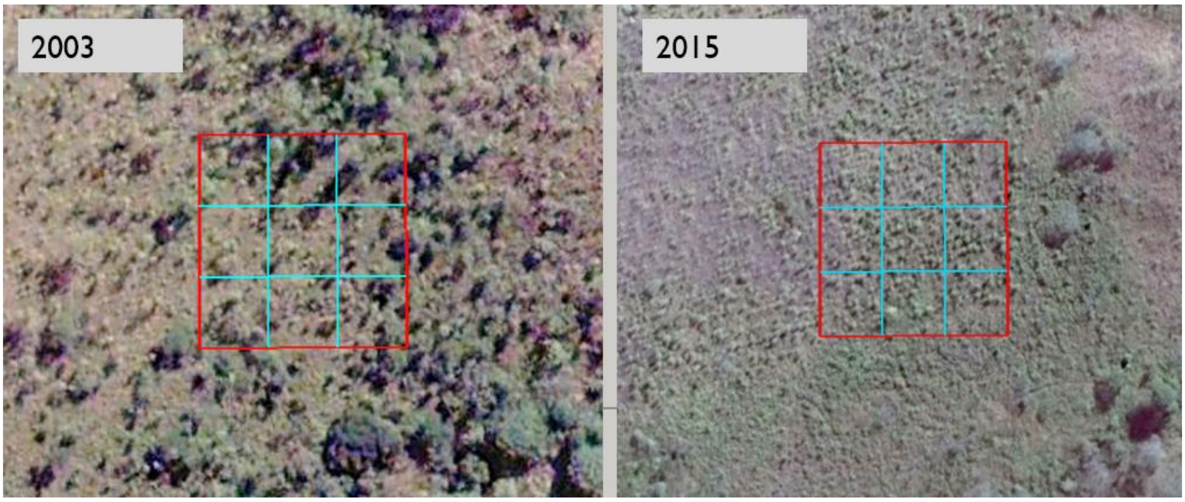

Figure 2 | Visual Comparison of a Single Plot over Two Time Periods in Google Earth, Showing a Reduction in Canopy Cover Over the Twelve-Year Period

The land cover interpreted at each plot for 2006 and 2016 were compared and a single determination was made for each plot whether it exhibited deforestation over the period (Table 3). The visual-based sampling approach did not produce sufficient information to categorize deforestation events by driver or post-deforestation land use. For this reason, a conservative principle was applied and the assumption was made that all deforestation was converted into grassland, as this category resulted in the lowest emissions per hectare when compared to the other IPCC categories of cropland, settlement, or wetland.

Table 3 | Determination of Deforestation by Land Cover Observations for 2006 and 2016

2006	2016	Transition
Forest	Forest	Not Deforestation
Forest	Non-Forest	Deforestation
Non-Forest	Non-Forest	Not Deforestation
Non-Forest	Forest	Not-Deforestation

Out of the 4,000 randomly generate plots, 3,495 were evaluated to reach the precision threshold of at least 2,000 complete plots that had useable imagery available for both 2006 and 2016. The final set contained 2,168 plots, and these were retained for further analysis. Plots with incomplete image coverage were discarded. The proportion of the sample experiencing deforestation was then estimated from the retained 2,168 plots (Equation 2).

Equation 2 | Proportion of Deforestation in the Sample

$$\hat{p}_{deforestation} = \frac{N_{adjusted-deforestation}}{N_{adjusted-total}}$$

Where:

$\hat{p}_{deforestation}$	Proportion of the sample that exhibits deforestation from 2006-2016
$N_{adjusted-deforestation}$	Count of deforestation observations adjusted to account for differences in dates of source imagery
$N_{adjusted-total}$	Count of all observations

Because the time period differences covered by each paired observation, it was necessary to normalize the results to reflect the 10-year reference (Equation 3). An observation from a shorter period was assigned a higher weight than one from a longer period. The actual recorded dataset had an average year of 2006.3 for 2006, and 2016.7 for 2016 (Figure 3). The average timespan covered by paired observations was 9.7 years.

Equation 3 | Normalization of Results to a 10-Year Period

$$N_{adjusted} = \sum_{i}^{N} \frac{10}{Y_{2016,i} - Y_{2006,i}}$$

Where:

$N_{adjusted}$	Count of complete observations adjusted to accounted for differences in time periods of each paired plot observation
N	Count of complete observations
$Y_{2006,i}$	Actual year of record for nominal 2006-era observation
$Y_{2016,i}$	Actual year of record for nominal 2016-era observation

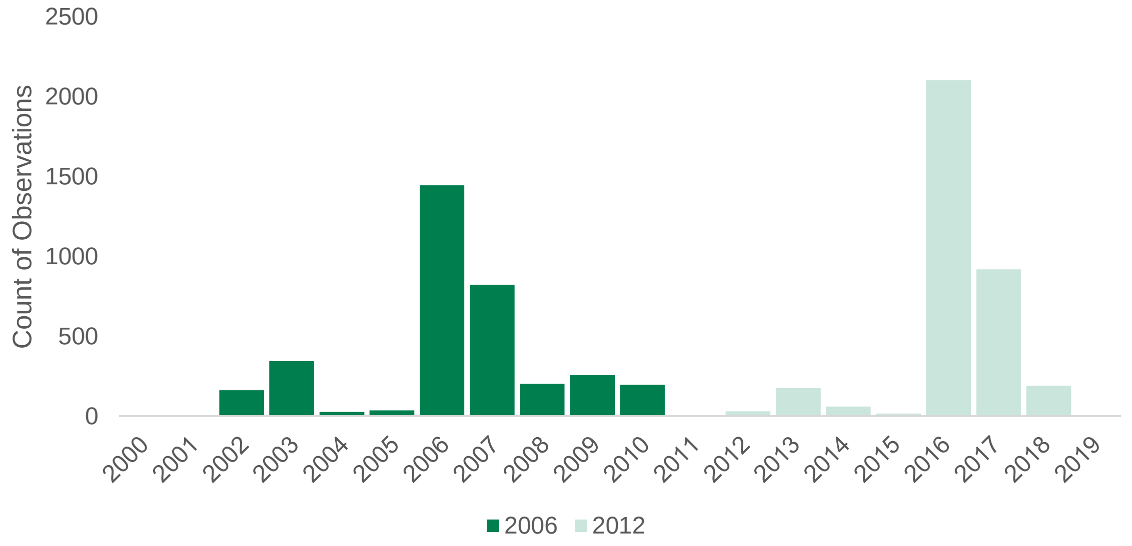

Figure 3 | Frequency of Observations by the Actual Year of Source Imagery, for Nominal 2006 and 2016 Years

Activity data in units of hectares per year were estimated by multiplying the period-adjusted proportion of deforestation in the sample by the total area of the sample frame (2,611,758 ha in this study), as shown in Equation 4.

Equation 4 | Annual Rate of Deforestation in Hectares

$$AD = \frac{\hat{p}_{deforestation} \times A}{10}$$

Where:

AD	Activity Data for deforestation (ha y^{-1})
A	Area of the sampling frame (ha)
$\hat{p}_{deforestation}$	Count of deforestation observations adjusted to account for differences in dates of source imagery

Quality control was conducted on observations by incorporating repeat measurements for a subset of plots and using a tiebreaking procedure for instances where the first and second records did not match. After all initial 2,168 complete observations were recorded, all plots exhibiting deforestation, and an equal number of plots randomly taken from the set not showing deforestation, were given blind review by an analyst not responsible for the initial records. Following this exercise, any plots that did not agree between the first and second viewings were given a third blind review by a designated tie-breaker analyst. The corrected observations following quality control were ultimately used in estimation of change statistics.

The reference level requires area of change estimation as activity data, and therefore determining percentage of forest loss was not a primary goal of this analysis. Nevertheless, due to strong public interest in this percent loss figure, a change value was also calculated, although the statistical uncertainty of this figure was not as thoroughly investigated as the hectare-based AD.

Percent deforestation was estimated by comparing the hectares of forest loss to the circa-2006 forest extent observed in the sample (Equation 5).

Equation 5 | Forest Loss Expressed as a Percent of 2006 Forest Area

$$deforestation\% = \frac{AD}{A \times \frac{N_{forest-2006}}{N_{total}}}$$

Where:

deforestation%	Percent of circa-2006 forest loss annually (% y^{-1})
AD	Activity Data for deforestation (ha y^{-1})
A	Area of the sampling frame (ha)
$N_{forest-2006}$	Count of observations showing forest land cover in 2006
N_{total}	Total count of observations

4.1.2 Emission Factors

Several forest inventories have been undertaken in Malawi over the past ten years by the Department of Forestry with the support of different international donors and actors, primarily to support the country's path toward REDD+ Readiness and to promote broader sustainable natural resource management goals. While many of these inventories have been implemented and executed, their scope has been limited to specific geographies, typically in protected areas and forest reserves.

With assistance from the USAID/Malawi-funded PERFORM project, a team comprised of the Malawi REDD+ Technical Working Group and the DoF worked to expand on existing NFI efforts to date and produce updated estimates of forest biomass stocks in Malawi. This work resulted in data collected from 116 plots in geographic areas where data were lacking from previous inventories. This effort was completed in 2018. Data collected in 2018 were combined with the results of existing inventories to produce an updated estimate of tree carbon stocks in the country. Results from the national NFI synthesis were presented for forests as a single stratum, and reported carbon stock for aboveground and belowground biomass.

This estimated forest biomass stock, calculated using the Kachamba et al. 2016 allometric equation specific to Malawi's forests, was applied to calculate live tree carbon stocks for Malawi's deforestation emission factor (EF). The value for aboveground biomass (ABG) was used as the basis for estimating belowground biomass (BGB) using the equation developed by Mokany et al. 2006 (Equation 6).

Equation 6 | BGB Equation, from Mokany et al. 2006

$$BGB_t = 0.489 * (AGB_t)^{0.89}$$

Where:

BGBt	Belowground biomass of the tree *t*; kg dry mass (d.m.)
AGB_t	Aboveground biomass of the tree *t*; kg dry mass (d.m.)

The total live tree biomass was then converted to tons of carbon (C) multiplying by 0.47 t C t^{-1} dry biomass matter, which was then multiplied by the molecular weight ratio of CO_2 to C (i.e., 44/12) to convert to CO_2e, following IPCC 2006 Guidelines.

Forest carbon stocks in the deadwood pool (standing and lying) were estimated by assuming dead biomass was equivalent to 6% of the total live biomass and litter biomass was equivalent to 1% of total live biomass[3]. Forest soil carbon stocks were obtained from Henry et al. 2008.

The sum of all pools (aboveground, belowground, deadwood, litter, and soil) resulted in the total forest carbon stock (following Equation 2.3 in the IPCC 2006 Guidelines, Volume 4). The final forest carbon stocks used in Malawi's deforestation reference level are presented in Table 4 below, along with values and sources of all carbon pools.

Table 4 | Stocks in Forest Carbon Pools Applied to Develop Malawi's Forest EF

	Total Live Tree Carbon Stocks (AGB & BGB)	Deadwood Carbon Stocks	Litter Carbon Stocks	∆SOC	Total Forest Carbon Stocks
Value	45.9	2.8	0.5	56.1	106.1
± error (half-width 90% CI)	4.4	0.3	0.04	-	4.10
Source	NFI 2018 Report	CDM AR-TOOL12	CDM AR-TOOL12	Henry et al. 2008	IPCC 2006

3 https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-12-v3.0.pdf

Deforestation emission factors were developed following the IPCC stock-difference approach (Equation 2.25 in the IPCC 2006 Guidelines, Volume 4), which estimates the difference between the pre-deforestation carbon stocks and post-deforestation carbon stocks for each stratum (Equation 7).

Equation 7 | Deforestation EF

$$EFdef = (Cbio.pre - Cbio.post + \Delta SOC) * 44/12$$

Where

EFdef	Emission factor for deforestation, t CO_2e ha^{-1}
Cbio.pre	Carbon stock in biomass, prior to deforestation, t C ha^{-1}
Cbio.post	Carbon stock in biomass, post-deforestation, t C ha^{-1}
ΔSOC	Change in soil carbon stock following deforestation, t C ha^{-1}
44/12	Conversion factor from carbon to CO_2

Equation 8 | Change in Soil Carbon Stock Following Deforestation

$$\Delta SOC = SOC.f * (1 - (FLU * FMG * FI))$$

Where

ΔSOC	Change in soil carbon stock following deforestation, t C ha^{-1}
SOC.f	Forest soil carbon stock prior to deforestation, t C ha^{-1}
F_{LU}	Stock change factor for land-use, dimensionless
F_{MG}	Stock change factor for management regime, dimensionless
F_I	Stock change factor for input of organic matter, dimensionless

The forest soil carbon stock (SOC.f) was obtained from Henry et al. 2008 (Table 4). The management coefficients listed in Equation 8 (FLU, FMG, and FI) used in the development of Malawi's deforestation EF development assume that cropland is a long-term, full-tillage, and low to medium inputs (Tables 5.5 and 5.9 in the IPCC 2006 Guidelines, Volume 4), while grassland assumes a moderately degraded management (Table 6.2 in the IPCC 2006 Guidelines, Volume 4). The soil management factors used are summarized in Table 5.

Table 5 | Soil Management Factors Used in Malawi's Deforestation EF

Forest Land Converted to Other Land Use	F_{LU}	F_{MG}	F_I
Cropland	0.48	1	0.96
Grassland	1	0.97	1
Settlement or Bare Land	1	1	1

The deforestation emission factor is based on biomass carbon stock difference for aboveground and belowground biomass, (Equation 9), with the addition of soil emissions which are calculated separately (Equation 8). The carbon stock in aboveground biomass (C.AGB) and belowground biomass (C.BGB) were obtained from Malawi's 2018 NFI Report. The rest of the carbon stocks (i.e. deadwood and litter) were obtained following the IPCC's guidance (Table 4).

Equation 9 | Carbon Stock in Total Forest Biomass, Prior to Deforestation, Used in Malawi's Deforestation EF

$$Cbio.pre = C.AGB + C.BGB + C.DW + C.LIT$$

Where

Cbio.pre	Carbon stock in forest biomass, prior to deforestation, t C ha^{-1}
C.AGB	Carbon stock in aboveground live tree biomass, t Cha^{-1}
C.BGB	Carbon stock in belowground live tree biomass, t C ha^{-1}
C.DW	Carbon stock in standing and lying deadwood pool, t C ha^{-1}
C.LIT	Carbon stock in litter, t C ha^{-1}

Table 6 | Emission Factors (t CO_2E ha^{-1}) for Deforestation Used in Malawi's RL, Indicating Land Use Forest Conversions Options

Forest Land Converted to Other Land Use	Deforestation EFS (tCO_2e ha^{-1})
Cropland	196.9
Grassland	139.8
Settlement or Bare Land	161.2

4.2 Degradation

Forest degradation (and associated emissions) in Malawi is driven in part by unsustainable fuelwood extraction. Degradation occurs wherever fuelwood is extracted faster than forest systems accumulate biomass, and results in diminishing forest carbon stocks over time. Malawi is highly dependent on fuelwood and charcoal for household energy for cooking, with up to 98% of rural households and 90% of urban households relying on this resource for domestic purposes (Integrated Household Survey, 2016). Fuelwood and charcoal are also important energy sources for small-scale industrial and commercial activities.

Estimating the degree to which fuelwood is unsustainably extracted requires an understanding of fuelwood demand, how much supply is produced by forest resources, and how that demand and supply are distributed geographically.

Under Malawi's REDD+ program, the Wood fuel Integrated Supply/Demand Overview Mapping (WISDOM)[4] methodology was adopted to estimate forest degradation emissions from this source. WISDOM offers a scientifically-credible modeling approach for producing spatially-explicit estimates of unsustainable harvesting of woody biomass for wood fuel production and the associated

[4] Detailed information about the WISDOM methodology available here: www.wisdomprojects.net/global

emissions. The WISDOM approach has already been applied in dozens of countries, including many of Malawi's neighbors (e.g. Mozambique, Tanzania) and was used to prepare Ghana's National REDD+ RL submitted to the UNFCCC[5] and Ghana's subnational REDD+ RL submitted to the World Bank's Forest Carbon Partnership Facility (FCPF)[6].

Outputs of the WISDOM analysis produced for Malawi include an evaluation of historical emissions from unsustainable fuelwood extraction as well as a projection of anticipated emissions under business as usual (BAU) conditions, in the absence of interventions to curb fuelwood extraction rates (USAID 2019). The following describes the data sources used to produce activity data and emission factor information that were developed through the WISDOM process.

4.2.1 Activity Data

Activity data for degradation by fuelwood extraction was calculated as tons of dry matter equivalent for two main fuel use categories (Table 7). Local wood collected for rural construction is also included in these data as it produces a similar impact as fuelwood collection on forest degradation.

Table 7 | Stratification of Fuel Use

Activity Data Category	Use Types
Household Fuelwood	Rural and urban households using wood as a cooking energy source
Other Wood Fuels	• All users of charcoal (household and industrial) • Industrial users of charcoal and wood • Household non-energy wood use (construction)

Table 8 | Per Capita Consumption of Biomass in Rural and Urban Malawi (KG DM E Consumed per Person per Year; BEST 2009)

Group	Fuel Type	Kg (Person^{-1} y^{-1}, 2009, all users)	Kg (Person^{-1} y^{-1}, 2009, main users only)	Kg (Person^{-1} y^{-1}, 2016, main users only)
Rural	Charcoal	7	371	315
Urban	Wood	601	632	537
Rural	Charcoal	293	209	177
Urban	Wood	94	721	613

[5] https://redd.unfccc.int/files/ghana__modified_frl_november_10_2017_clean.pdf
[6] https://www.forestcarbonpartnership.org/sites/fcp/files/2016/Nov/Ghana%20advanced%20draft%20ER-PD.pdf

Total consumption of fuelwood among households cannot feasibly be directly measured but can be estimated in reference to per-capita consumption, population, and household fuel penetration statistics.

The most recent per capita consumption study for Malawi is included in the Biomass Energy Strategy (BEST). Per capita consumption statistics from BEST averaged out main users, secondary users, and non-users (Table 8). Per capita consumption was modified using 2008 population data to report per capita use only for main users (households where this fuel is their primary energy source).

Conversion to dry matter equivalent (DMe) allows for comparing charcoal and wood in a single unit that relates to the amount of wood harvested. For wood, tons are equal to tons DMe. Tons of charcoal are converted to t DMe by dividing charcoal mass by an estimate of kiln yields. T DMe for charcoal is always larger than t charcoal. A 22.5% kiln yield was adapted from BEST (2009). After conversion to t DMe, charcoal and all wood uses except household energy are grouped, while household fuel use is kept separate (Figure 4).

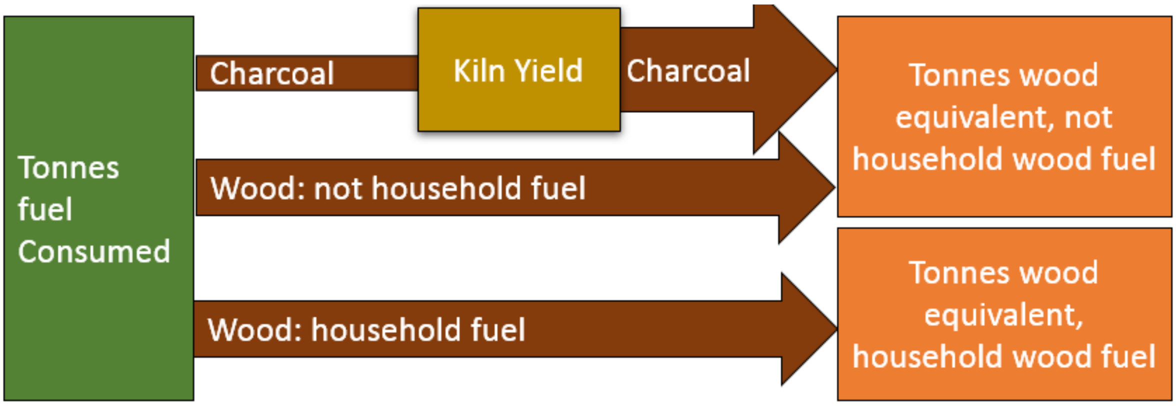

Figure 4 | Visual Representation of the Conversion of Tons of Fuel to t DMe

USAID (2019) projected out fuel penetration trends (Figure 5), population growth and trends in urbanization to 2021 to produce an estimate of what the fuelwood demand may be by that year.

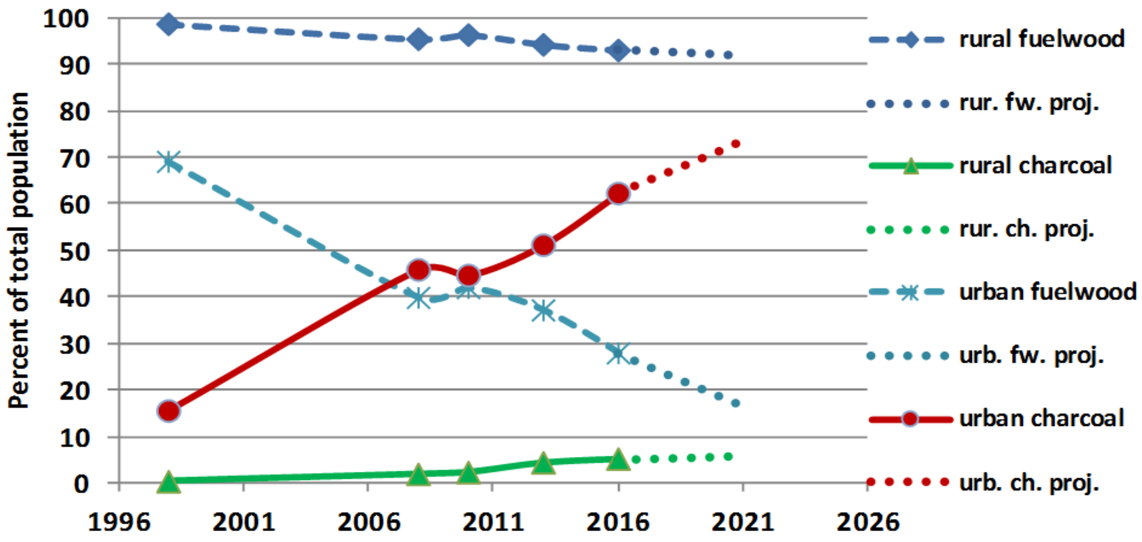

Figure 5 | Trends in Fuel Penetration – Primary Household Fuel by Rural and Urban Users

BEST 2009 estimated non-residential consumption of wood fuels. USAID 2019 reviewed and updated these estimates based on comparison to changes in demographic and industrial activity data since 2009. Estimates were made for 2016 and 2021 consumption for lime production, poultry industry, tobacco curing, brick making, fish drying, boarding schools, tea drying, and restaurants/resorts.

The full details of the process for developing these residential and non-residential estimates is presented in USAID 2019. The resulting activity data is shown in Table 9.

Table 9 | Activity Data for Wood Fuel Consumptionin Tons of DMe

Strata	Category	2016	2021
Household Fuelwood	Household Fuelwood (t DMe)	7,458	8,355
Other Wood Fuels	Household construction material demand	187	218
	Household charcoal	2,596	3,555
	Non-household demand (charcoal and fuelwood)	966	1,164

4.2.2 Emission Factors

Emission factors for fuelwood consumption are primarily the product of the fraction non-renewable biomass, or f_{NRB}, an estimate of wood carbon density, and a conversion from C to CO_2.

Equation 10 | Emission Factor for Degradation by Fuelwood Consumption

$$EF_i = f_{NRB,i} \times D \times \frac{44}{12}$$

Where:

EF_i	emission factor for fuel type *i I* (tCO_2e t DMe^{-1})
$f_{NRB,i}$	fraction non-renewable biomass fuel type *i*, (ratio)
D	Carbon density of wood (t C t DMe^{-1}). 0.47 used in this analysis

f_{NRB} is an abstract value that reports the proportion of wood harvesting that should be treated as unsustainable. It cannot be readily measured at a national scale, but is a fundamental requirement for estimating the emission reduction benefits of energy efficient cooking interventions and is widely used including in the UNFCCC Clean Development Mechanism (CDM).

USAID (2019) uses a WISDOM modeling framework to estimate the proportion of total wood fuel consumption that is unsustainable and is outstripping the ability of the source forests to regrow. USAID (2019) divides fuel into conventional and marginal categories. Conventional wood fuel consists of larger pieces of wood that are of sufficient quality for charcoal production or transporting to market. Non-conventional, also termed marginal fuelwood, are small sticks and twigs that are locally collected by households and do not generally result in long-term damage to the live tree stock.

For this analysis, two separate f_{NRB} values are generated, one that is applicable only to wood consumed by households for energy, and another that covers all applications that use only conventional sources, which are charcoal, construction, and non-household users.

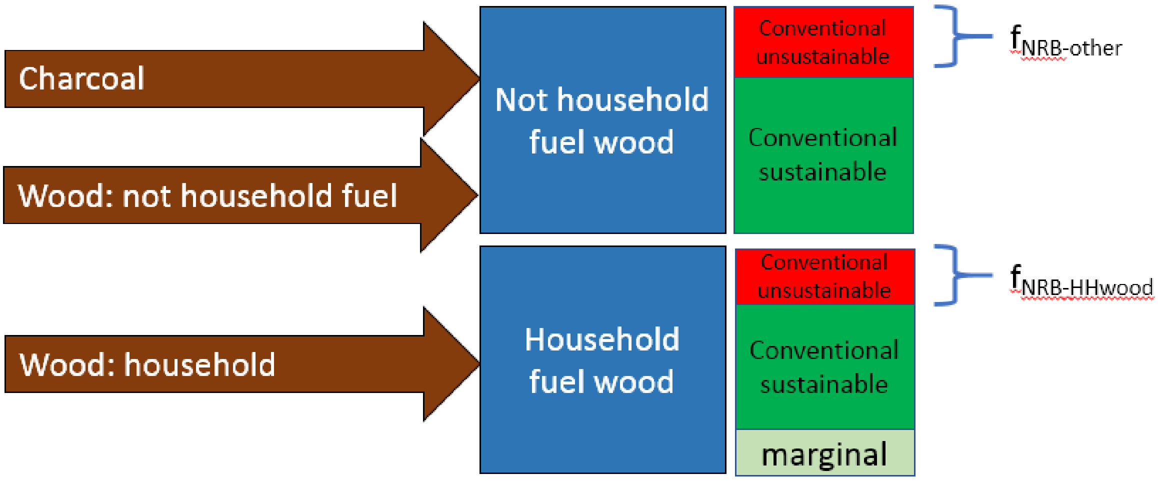

Figure 6 | Graphic Representation of Calculation Process to Obtain the Emission Factors (Tons of CO_2e per Ton of Wood Equivalent) from Biomass (t DMe) Consumed as Charcoal or Wood, to Estimate Forest Degradation Using the Wisdom Model

The estimation of f_{NRB} is presented in Equation 11.

Equation 11 | Fraction of Non-Renewable Biomass

$$f_{NRB,i} = \frac{NRB_i}{NRB_i + DRB_i}$$

Where:

$f_{NRB,i}$	fraction non-renewable biomass fuel type *i*, (ratio)
NRB_i	non-renewable biomass harvested, fuel type *i* (t DMe y^{-1})
DRB_i	Demonstrably renewable biomass harvested, fuel type *i* (t DMe y^{-1})

Results for calculating f_{NRB} values are presented in Table 10.

Table 10 | Results of F_{NRB} Calculation for 2016 and 2021

FUEL USAGE TYPE	FUEL TYPE	RENEWABLE (DRB)	2016 (T DME)	2021 (T DME)
Household Fuelwood (HHwood)	Conventional	No	987,000	1,396,000
		Yes	3,963,000	3,905,000
	Non-Conventional	Yes	2,508,000	3,052,000
Other Wood Fuels (Other)	Conventional	No	748,000	1,300,000
		Yes	3,001,000	3,637,000
$f_{NRB\text{-}HHwood}$			13.2%	16.7%
$f_{NRB\text{-}other}$			20.0%	26.3%

These f_{NRB} values, when used in Equation 10 produce the results presented in Table 11.

Table 11 | Wood Fuel Emission Factors for 2016 and 2021

Fuel Use Type	EF 2016 ($tCO_2e\ tDMe^{-1}$)	EF 2021 ($tCO_2e\ tDMe^{-1}$)
EF_{HHwood}	0.227	0.288
EF_{other}	0.343	0.453

4.3 Enhancements

Enhancement of carbon stocks has been included via the establishment and maintenance of timber plantations on customary lands managed by the GoM and tobacco companies. These planted forests remove (i.e., sequester) and store carbon dioxide from the atmosphere in their biomass, thereby increasing national carbon stocks. Accounting for carbon removals from these activities relies on data provided (in hectares) by plantation managers on the area of tree plantations established, as well as the composition of tree species planted and their harvest cycles. The following describes the activity data and carbon removal factors applied to estimate the carbon dioxide impact of carbon stock enhancement activities under Malawi's REDD+ program.

4.3.1 Activity Data

The number of hectares in which tree plantations are established is available through records submitted by plantation managers. As plantation activities are subject to failure due to natural or anthropogenic causes, annual plantation survival estimates (%) for each plantation are also obtained from plantation managers and applied to discount activity data accordingly.

Hectares planted per species group are summarized in Table 12. These numbers have been discounted according to the reported survival rates in each plantation, which are provided in full detail in the Annex of this report.

Table 12 | Wood Fuel Emission Factors for 2016 and 2021

Year	Eucalyptus spp. Plantations AD (ha)	Pinus spp. Plantation AD (ha)	Other Conifer spp. Plantations AD (ha)
2006	696	602	0
2007	696	736	0
2008	696	761	0
2009	696	567	0
2010	696	573	2
2011	696	545	0
2012	696	594	2
2013	696	596	2
2014	696	693	2
2015	696	661	2
2016	696	646	2

4.3.2 Removal Factors

The removal factors applied represent the carbon accumulation of planted tree species in both GoM and private plantations. The species, as indicated through plantation records, are comprised of eucalyptus species, pine species and, to a lesser extent, other conifer species (e.g., *Widdringtonia whytei*, native to Malawi). Table 13 describes the plantation areas as well as the species' typical harvest cycles, as reported by plantation managers.

Table 13 | Planted Species in Malawi and Rotation Cycles

Species	Average % of National Plantation Area	Rotation Cycle (Years)
Eucalyptus spp.	42.29%	14
Pinus spp.	47.62%	30
Widdringtonia spp.	0.23%	36

Removal factors were derived from the Global CO_2 Removals Database (Bernal et al. 2018), selecting tropical dry climate values specific to the species listed in Table 13. The Global Removals Database was selected over the IPCC defaults (2006 Guidelines, Volume 4) based on the availability of scientifically-validated data on the all three species of interest in Malawi offered by the database. The IPCC does not offer removal rates for conifers in tropical dry climates. Pursuant to a conservative approach, only accumulation in aboveground and belowground live tree biomass carbon pools were included under this activity. The growth curves used to derive removals factors for the three species groups included under this activity are shown in Figure 7, Figure 8, and Figure 9 below.

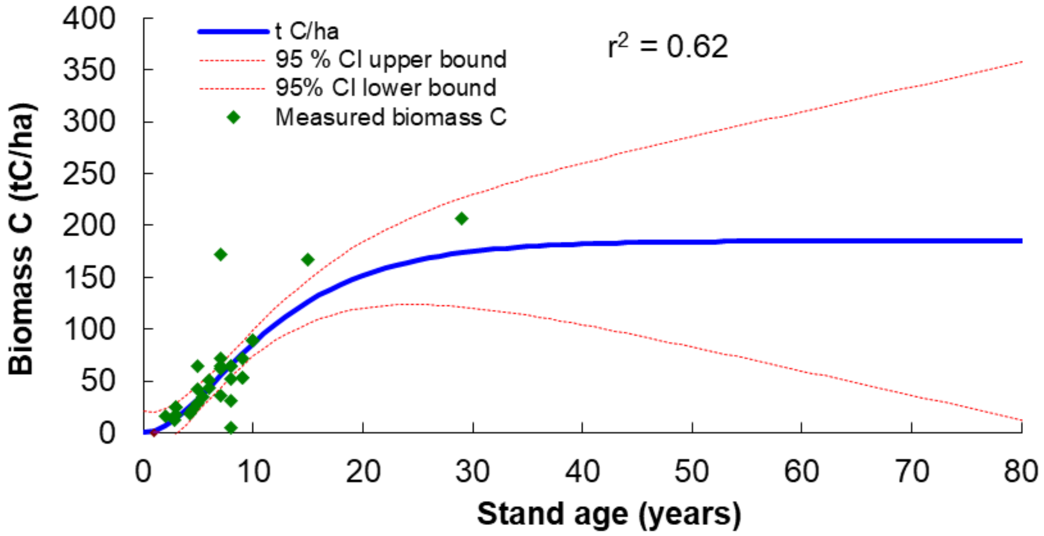

Figure 7 | *Eucalyptus* Spp. Growth Curve Used in Malawi's Enhancements Reference Levels

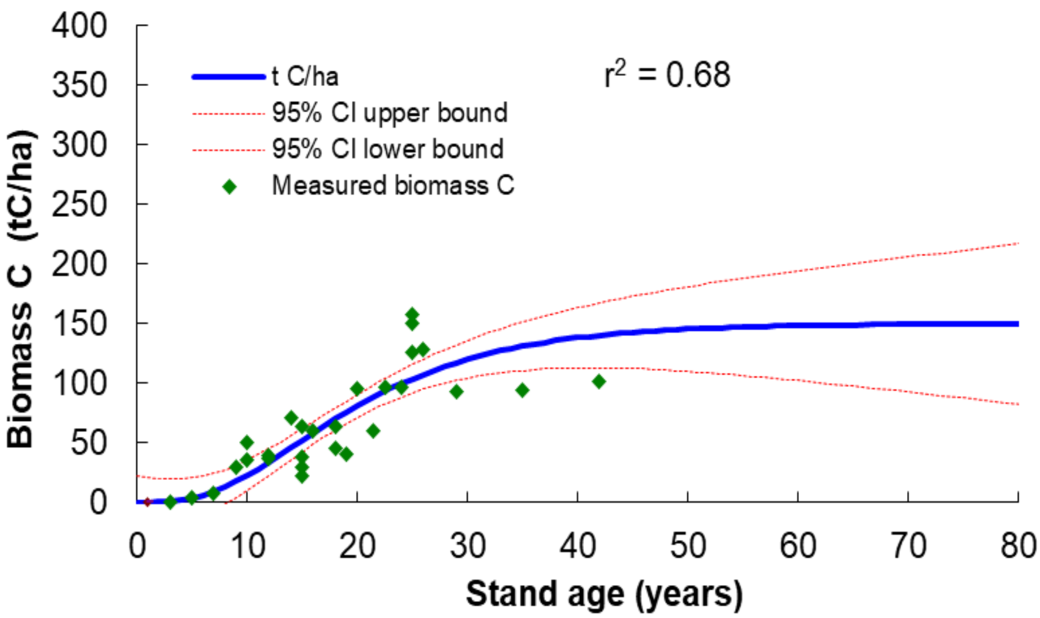

Figure 8 | *Pinus* Spp. Growth Curve Used in Malawi's Enhancements Reference Levels

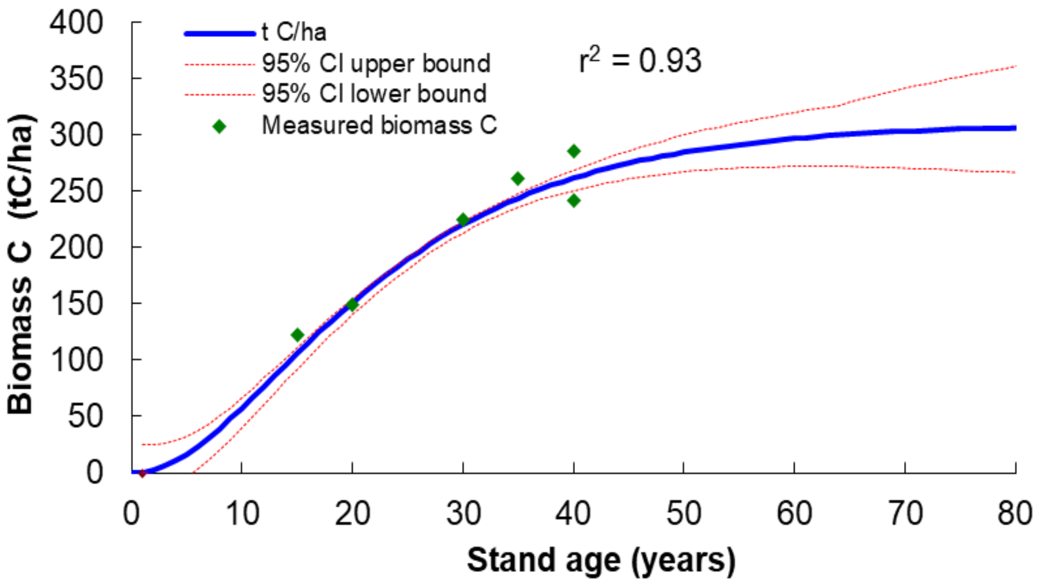

Figure 9 | Conifer (Non-*Pinus* Spp.) Growth Curve Used in Malawi's Enhancements Reference Level

To derive an annual removal rate, the total aboveground biomass carbon stocks for each of these species were divided by the length of their rotation (listed in Table 13). Aboveground biomass was then used to calculate total belowground biomass following Mokany et al. 2006, and the total tons of biomass per hectare per year (i.e. the removal factor) was calculated as the sum of aboveground and belowground biomass rates. Total biomass C was converted to CO_2e by applying the molecular weight ratio of CO_2 to C (i.e., 44/12). The final removal factors applied for each species planted in forest plantations included in Malawi's REDD+ program assume that each year the committed sequestration for an entire rotation length (listed in Table 13) is accounted for each year a new plantation area is planted. This entails taking the middle point of the maximum peak biomass at felling age and applying it as a removal factor for a plantation. These removal factors are shown in Table 14.

Table 14 | Removal Factors (t C ha^{-1} yr^{-1} and t CO_2e ha^{-1} yr^{-1}) Applied to Estimate the Enhancements Reference Level in Malawi

Plantation Species	Tons of Total Biomass (C ha^{-1} yr^{-1})	Tons of Total Biomass (CO_2e ha^{-1} yr^{-1})
Eucalyptus spp.	16.9 ± 1.4	61.8 ± 5.0
Pinus spp.	6.4 ± 0.5	23.5 ± 1.9
Conifer (Non-*pinus* spp.)	10.9 ± 0.1	39.8 ± 0.5

5.0 HISTORICAL EMISSIONS

5.1 Deforestation

The sampling-based land cover change analysis revealed that 88,474 ha were deforested in Malawi from 2006-2016, which equates to a rate of 8,847 ha y^{-1}. The analysis also showed that 54% of the study sampling frame, or 1.41 of 2.61m ha, was forested in 2006. In reference to 2006 forest cover, this per-hectare rate of changes is equivalent to a 0.63% annual rate of deforestation.

The methodology followed to obtain deforestation AD for Malawi in the 2006-2016 reference period did not allow for consistent assessment of post-deforestation land use. Expert opinion gathered from consultation with the DoF in the GoM concluded that most of the deforested land transitions to grassland in Malawi. Therefore, for conservative purposes, the grassland EF of 139.8 tCO_2e ha^{-1} (Table 6) was applied to the historical deforestation AD. This calculation resulted in a historical rate of emission from deforestation of 1,236,631 tCO_2e yr^{-1}. This historical emissions rate was projected into the monitoring period (2017-2021) on the basis of the historical average, producing a **deforestation reference emission level of 1,236,631 tCO_2e yr^{-1}**.

5.2 Degradation

Degradation emissions of the WISDOM scenario for the year 2016 indicates that Malawi emitted 2,991,058 tCO_2e ha^{-1} through forest degradation due to wood fuel harvesting. The WISDOM model projection resulted in **4,645,844 tCO_2e ha^{-1} emissions from forest degradation for the year 2021**. Both of these futures represent the medium variant or 'leading scenario' modeled by WISDOM as most plausible, but a high and low estimate is provided as well. A linear regression between 2016 and 2021 degradation emissions results in the continuous linear increase reflected on Table 15.

Table 15 | Projected Degradation Emissions for the Forest Degradation Reference Level in Malawi

Year	Projected Degradation Emissions (tCO_2e ha^{-1} yr^{-1})
2016	2,991,058
2017	3,322,015
2018	3,652,972
2019	3,983,930
2020	4,314,887
2021	4,645,844

5.3 Enhancements

The **average annual removals** from plantations in customary lands managed by Malawi's Government and by private tobacco companies during the reference period 2006-2016 were **57,964 t CO_2e yr^{-1}** (Figure 10). This average is therefore the enhancements reference level that Malawi would use from 2016 onwards. Over the reference period removals fluctuated from 57,054 tCO_2e to 60,907 t CO_2e.

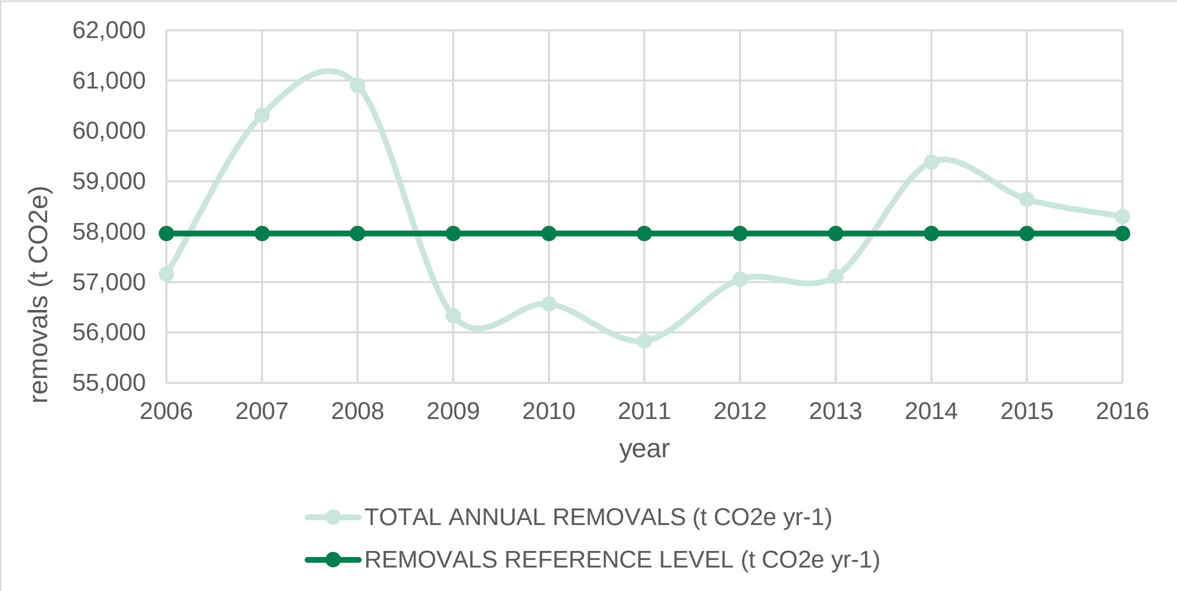

Figure 10 | Historic Removals (tCO_2e yr^{-1}) during the Reference Period (2006-2016) in Light Green and the Removals Reference Level (tCO_2e yr^{-1}) in Dark Green

6.0 REDD+ REFERENCE LEVEL PROPOSAL

The net emissions of Malawi's forest reference level during the 2006-2016 reference period are the sum of all emissions from deforestation, forest degradation, and emission removals from enhancements (plantations) each year (Table 16). However, because degradation was only assessed for 2016, this sum is only possible for 2016.

Table 16 | Forest Emissions (tCO_2e) for Deforestation, Degradation, Enhancements and Total (Net) Emissions during Reference Period (2006-2016)

Year	Deforestation	Degradation	Enhancements or Emissions Removals
2006	1,236,631	Not Evaluated	-57,156
2007	1,236,631	Not Evaluated	-60,314
2008	1,236,631	Not Evaluated	-60,907
2009	1,236,631	Not Evaluated	-56,332
2010	1,236,631	Not Evaluated	-56,569
2011	1,236,631	Not Evaluated	-55,831
2012	1,236,631	Not Evaluated	-57,054
2013	1,236,631	Not Evaluated	-57,115
2014	1,236,631	Not Evaluated	-59,381
2015	1,236,631	Not Evaluated	-58,644
2016	1,236,631	2,991,058	-58,299
Annual Average	1,236,631	Not Evaluated	-57,964

For deforestation and enhancements, the emissions and removals from the historical reference period are assumed to continue into the monitoring period. Degradation, because it is model- and projection-based, is taken directly from the WISDOM analysis, rather than as a continuation of an observed historical trend, and relies on a linear regression between 2016 and 2021 modeled results to produce estimates for each year from 2017-2021. The reference level is therefore different every year of the monitoring period. The final reference level is the sum of the three assessed activities, and is presented in in Table 17 as rising from 4,500,682 $tCO_2e\ y^{-1}$ in 2017 to 5,824,511 $tCO_2e\ y^{-1}$ in 2021.

Table 17 | Malawi's Proposed Forest Reference Level for the Period of 2017-2021

Year	Projected Degradation Emissions ($tCO_2e\ ha^{-1}\ yr^{-1}$)	Projected Deforestation Emissions ($tCO_2e\ ha^{-1}\ yr^{-1}$)	Projected Enhancements Removals ($tCO_2e\ ha^{-1}\ yr^{-1}$)	Total (Net) Forest Emissions ($tCO_2e\ ha^{-1}\ yr^{-1}$)
2017	3,322,015	1,236,631	-57,964	4,500,682
2018	3,652,972	1,236,631	-57,964	4,831,639
2019	3,983,930	1,236,631	-57,964	5,162,597
2020	4,314,887	1,236,631	-57,964	5,493,554
2021	4,645,844	1,236,631	-57,964	5,824,511

7.0 UNCERTAINTIES OF THE FOREST REFERENCE LEVEL

Potential sources of uncertainty of each of the REDD+ activities included in the Forest Reference Level (deforestation, degradation, and enhancements) are divided between the activity data and the emission factors used to estimate the reference level of each of the activities. The uncertainty of these REDD+ activities, in turn, determine the uncertainty of the proposed Forest Reference Level. The sections below describe the methodology followed to estimate the uncertainty of the three REDD+ activities and that of the final Forest Reference Level, with the uncertainty results reported at the end (Section 7.4).

7.1 Deforestation

Deforestation activity data is reported as a mean of the estimate ± a half-width of the 90% confidence interval (CI) of the mean. The CI of the activity data (area deforested during the 2006-2016 reference period) was calculated from the visual assessment and QA/QC process of forest transitioning to non-forest land from 2006 to 2016 using Google Earth imagery, as described in earlier in this report. The half CI of the resulting sample population proportion was calculated as the standard error (SE) of the deforested area multiplied by the z score, or the number of standard deviations away from the sample mean for the given value, corresponding to a 90% CI, as shown in Equation 12.

Equation 12 | Half-Width of 90% Confidence Interval of Deforestation Sample Used to Estimate Confidence of Deforestation Activity Data in the Deforestation Reference Level

$$E=z*\sqrt{(p*(1-p))/n}=z*SE$$

Where:

E	half-width of the 90% CI of the mean
z	z score, equal to 1.645 for a 90% confidence interval
p	deforestation sample proportion (% of the forest land that was deforested)
n	number of samples analyzed

The error of the forest carbon stocks used to estimate the deforestation EF (Equation 7 and Equation 9) are reported earlier in this report. The half-width 90% CI of the total forest carbon pool was calculated from the error propagation of the individual forest carbon pools following Equation 13 (from the Approach 1 of the IPCC 2006 Guidelines).

Equation 13 | Error Propogation

$$E\_total=\sqrt{(E\_1*x\_1)^2+\cdots+(E\_n*x\_n)^2}/(|x\_1+\cdots+x\_n|)$$

Where:

E_total	is the half-width of the total forest carbon stock 90% CI
En	is the half-width 90% CI of each forest carbon pool listed on Table 4
Xn	is the average value of the variables being added

The uncertainty of the deforestation reference level was estimated by combining the uncertainty of activity data and emission factors, employing Monte Carlo simulations following Approach 2 of the IPCC 2006 Guidelines, and reporting the uncertainties in terms of 90% confidence intervals. Monte Carlo simulations were run 10,000 times for the activity data and the emission factor and applied to the equation used to identify the final distributions of deforestation emissions using the SimVoi[7] statistical software for Microsoft Excel. The following assumptions were made about each value:

1. Each had a normal (i.e., Gaussian) distribution.
2. The estimated values are the means of the normal distributions.

The simulated distributions were truncated to prevent unrealistic values from being generated, i.e. distributions of parameters which the value could not be negative were truncated to a minimum value of 0 (zero). Based on the Monte Carlo simulations produced for emissions, the 90% CI of the final distribution is identified and divided by 2 to identify the margin of error of the distribution. The margin of error was then divided by the mean of the distribution and then multiplied by 100% to determine the percent uncertainty, following Equation 14.

Equation 14 | Annual Rate of Deforestation in Hectares

$$\%\,uncertainty = \frac{\frac{1}{2} \times Confidence\ interval\ width}{Mean}$$

7.2 Degradation

The unsustainable wood fuel harvest (f_{NRB}) for 2016 and 2021 was calculated using WISDOM to assess possible f_{NRB} values under a high, medium, and low modeled scenarios for both years. The EF for degradation was therefore the 'medium' or 'leading' scenario estimate, with the range being the high and the low estimates (Table 18). This range is not representative of a CI, and the CI of each f_{NRB} value is not known. This degradation reference level therefore reports the leading degradation emissions value and the plausible range of results.

[7] https://treeplan.com/simvoi/

Table 18 | Results for WISDOM Models Based on High (Pessimistic), Medium (Leading), and Low (Optimistic) Degradation Assumptions Made about Key Inputs Related to Supply and Accessibility, Non-Renewable Emissions in $tCO_2e\ yr^{-1}$

Model Variant	2016 f_{NRB}	2021 f_{NRB}	2016 tCO_2e	2021 tCO_2e
Low Degradation (Optimistic)	0.03	0.07	449,738	1,235,044
Medium Degradataion (Leading)	0.20	0.26	2,991,058	4,645,844
High Degradation (Pessimisti)	0.42	0.51	6,296,336	8,998,178

7.3 Enhancements

The annually planted hectares (activity data) were available as a single data point per year, equivalent to all new planted hectares during that year. The removal factors, on the other hand, were developed from the growth curves presented earlier, which used multiple data points and presented 90% CIs. These CIs were used to report the half-width 90% CI of the RFs reported in Table 14.

The uncertainty of the enhancements reference level was estimated following the same approach used in the deforestation reference level, i.e. employing Monte Carlo to simulate 10,000 times for the activity data and the emission factor values and applied to the equation used to identify the final distributions of removal estimates. The margin of error was estimated as the half-width of the 90% CI of the final distribution and used to calculate uncertainty of the estimate following Equation 14.

7.4 Reference Level Total Uncertainty

To combine the uncertainties of the deforestation and enhancement reference levels, the 10,000 simulated emissions and removals were used to calculate the corresponding 10,000 total forest reference level emissions. To estimate the half width of the 90% CI of these activities' simulations and of the net emissions, a Monte Carlo analysis using bootstrapping was used, the recommended approach over a simple uncertainty propagation of the REDD+ activities. The bootstrapping analysis was done using the R Studio statistical software[8] with the "resample" package. The bootstrapping was set to run 1,000 resamples of both REDD+ activities, from which the 90% CI was identified, and the uncertainty was calculated as in Equation 14. The uncertainty of the net emissions is listed in Table 19.

Table 19 | Uncertainty (%) of the REDD+ Activities Included in Malawi's Forest Reference Level, And Uncertainty of Total (Net) Forest Reference Level

Deforestation RL	Degradation RL	Enhancements RL	Total (Net) RL
1.15%	Not Applicable	0.95%	1.06%

Note: Total RL uncertainty does not include uncertainty of the degradation estimate.

[8] https://www.rstudio.com/

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9.0 ANNEX

9.1 Chongoni Timber Plantation Enhancements Activity Data

PLANTING YEAR	Ha	SPECIES	SURVIVAL %
2005	35.8	*P. oocarpa*	55.2
2006	32.4	*P.kesiya*	55.2
2007	261.44	*P.patula,oocarpa &kesiya*	86.2
2008	224.24	*P.patula,oocarpa &kesiya*	88.5
2009	135.59	*P.patula,oocarpa &kesiya*	90.4
2010	141.01	*P. kesiya & P. oocarpa*	88
2011	113.95	*P. kesiya & P. oocarpa*	91
2012	171.23	*P.oocarpa, kesiya &taeda*	88.2
2013	112.82	*P. kesiya & P. oocarpa*	93.2
2014	195	*P. kesiya & P. oocarpa*	91.2
2015	222.48	*P,kesiya & oocarpa*	97.5
2016	171.86	*P. kesiya & P. oocarpa*	98.6

9.2 Viphya Plantations Division Enhancements Activity Data

STATION	PLANTING YEAR	Ha	SPECIES	SURVIVAL % (assumed)[9]
Chikangawa	2005	4	P patula	60
Chikangawa	2006	28.3	P k	60
Kalungulu	2005	26.1		60
Kalungulu	2011	31.8		60
Kalungulu	2012	9.2	*E.tereticornis*	60
Kalungulu	2012	22.0	*P.kesiya*	60
Kalungulu	2012	10.8	*P.kesiya*	60
Kalungulu	2012	20.0	*P.kesiya & P.oocarpa*	60
Kalungulu	2012	20.7	*P.oocarpa & P.taeda*	60
Kalungulu	2012	18.1	*P.kesiya*	60
Mazamba	2005	10.0	*P.oocarpa*	60
Mazamba	2006	15.0	*P.oocarpa*	60
Mazamba	2007	15.0	*P.patula*	60
Mazamba	2008	20.0	*P.oocarpa*	60
Mazamba	2009	31.0	*P.oocarpa*	60

[9] Based on consultations with the Department of Forestry

Mazamba	2010	4.0	*P.oocarpa*	60
Mazamba	2010	2.0	*P.oocarpa*	60
Mazamba	2011	8.0	*P.oocarpa*	60
Mazamba	2012	16.0	*P.oocarpa*	60
Nthungwa	2000	188.6		60
Nthungwa	2005	177.0		60
Nthungwa	2009	13.5	*P. pseudostrobus*	60
Nthungwa	2009	13.9	*P.kesiya*	60
Nthungwa	2011	7.5	*P. kesiya*	60
Nthungwa	2011	30.0		60
Nthungwa	2012	17.9	*P.oocarpa*	60
Nthungwa	2012	21.0	*P.oocarpa*	60
Nthungwa	2012	21.3	*P.oocarpa*	60
Nthungwa	2012	29.3	*P.oocarpa*	60
Nthungwa	2012	21.8	*P.oocarpa*	60
Nthungwa	2012	23.8	*Pine mix*	60
Lusangazi	2005	87.2		60
Lusangazi	2011	25.2		60
Lusangazi	2012	47.5	*P.oocarpa*	60
Lusangazi	2012	21.9	*P.oocarpa*	60
Lusangazi	2012	5.6	*P.oocarpa*	60
Lusangazi	2012	16.0	*P.oocarpa & P.patula*	60
Lusangazi	2012	14.0	*P.patula*	60
Lusangazi	2012	15.0	*P.ooparpa*	60
Lusangazi	2012	59.17	*P.ooparpa*	60
Lusangazi	2012	9.7	*P. taeda*	60
Lusangazi	2012	42.5	*P.ooparpa*	60
Lusangazi	2012	18.0	*P.ooparpa*	60
Lusangazi	2012	41.5	*P.kesiya*	60
Lusangazi	2012	8.8	*P. oocarpa*	60
Lusangazi	2012	3.0	*P.oocarpa*	60
Lusangazi	2012	15.15	*P.oocarpa*	60
Lusangazi	2012	3.0	*P.oocarpa*	60
Lusangazi	2012	14.09		60
Luwawa	2005	1117.46		60
Luwawa	2006	1.9	*P.patula*	60
Luwawa	2007	4.0	*P.taeda*	60
Luwawa	2007	16.0	*P.ooparcarpa*	60
Luwawa	2007	1.41	*P.ooparcarpa*	60
Luwawa	2007	19.3	*E.grandis*	60
Luwawa	2007	20.84	*P.taeda*	60
Luwawa	2007	3.15	*P.taeda*	60
Luwawa	2007	2.02	*P.taeda*	60
Luwawa	2007	10.8	*E.grandis*	60
Luwawa	2007	4.3	*C.torulosa*	60

Luwawa	2007	16.79	*P.pseudostrobus*	60
Luwawa	2007	20.23	*P.ooparcarpa*	60
Luwawa	2007	5.4	*P.kesiya*	60
Luwawa	2007	9.3	*P.ooparcarpa*	60
Luwawa	2007	12.5	*P.patula*	60
Luwawa	2007	17.6	*P.insuralis*	60
Luwawa	2007	24.4	*P.insuralis*	60
Luwawa	2007	17.2	*P.ooparcarpa*	60
Luwawa	2007	21.0	*P.pseudostrobus & P.patula*	60
Luwawa	2008	13.6	*P.taeda*	60
Luwawa	2008	15.7	*P.pseudotrobus*	60
Luwawa	2008	9.3	*P.pseudostrobus/P.taeda*	60
Luwawa	2008	18.7	*P.pseudostrobus*	60
Luwawa	2008	3.1	*P.pseudotrobus*	60
Luwawa	2008	22.1	*P.elliotti & P.pseudo*	60
Luwawa	2008	10.1	*P.pseudo strobus*	60
Luwawa	2008	5.5	*P.pseudstrobus*	60
Luwawa	2010	3.1	*P.ooparcarpa*	60
Luwawa	2010	20.8	*P.ooparcarpa*	60
Luwawa	2010	8.1	*P.ooparcarpa*	60
Luwawa	2010	5.5	*P.ooparcarpa*	60
Luwawa	2010	2.4	*P.ooparcarpa*	60
Luwawa	2010	15.0	*P.patula*	60
Luwawa	2010	5.6	*P.kesiya*	60
Luwawa	2010	4.1	*P.elliotti*	60
Luwawa	2010	9.9	*P.patula & P.elliotti*	60
Luwawa	2011	3.0	*P.elliotti*	60
Luwawa	2011	2.1	*P.elliotti*	60
Luwawa	2012	11.0	*P.ooparcarpa*	60
Luwawa	2012	10.8	*P.patula*	60
Luwawa	2012	3.0	*P.patula*	60
Luwawa	2012	9.3	*P.patula*	60
Luwawa	2012	4.5	*P.patula*	60
Luwawa	2012	1.4	*P.patula*	60
Luwawa	2012	1.9	*P.patula*	60
Luwawa	2012	0.9	*Patula*	60
Luwawa	2012	1.2	*P.patula*	60
Luwawa	2012	1.4	*P.patula*	60
Luwawa	2012	4.1	*P.patula*	60
Luwawa	2012	4.5	*P.patula*	60
Luwawa	2012	0.3	*P.patula*	60
Luwawa	2012	0.4	*P.patula*	60
Luwawa	2012	1.2	*P.patula*	60
Luwawa	2012	9.0	*P.ooparcarpa*	60

Luwawa	2012	14.0	*P.patula & P.taeda*	60
Luwawa	2012	13.0	*P.patula*	60
Luwawa	2012	3.1	*P.patula*	60
Luwawa	2012	1.9	*P.patula*	60
Luwawa	2012	4.1	*p.kesiya*	60
Luwawa	2012	7.6	*P.oocarpa*	60
Luwawa	2012	9.4	*P.oocarpa*	60
Luwawa	2012	11.2	*P.oocarpa*	60
Luwawa	2012	5.5	*P.kesiya*	60
Luwawa	2012	99.5	*P.patula*	60
Luwawa	2012	86.8	*P.tecunumanni*	60
Luwawa	2012	80.0	*P.elliotti*	60
Luwawa	2012	39.6	*P.elliotti*	60
Luwawa	2012	82.5	*E.grandis & E.closiana*	60

9.3 Michiru Mountain Forest Reserve Enhancements Activity Data

PLANTING YEAR	HA	SPECIES	SURVIVAL %
2005	6.63	*P. Kesiya*	0
2005	12.88	*P. Kesiya*	0
2005	2.5	*P. Kesiya*	0
2005	1.24	*P. Kesiya*	0
2005	0.8	*P. Kesiya*	0
2005	9.2	*P. Oocarpa*	0
2005	1.48	*P. Oocarpa*	0
2005	1.28	*P. Oocarpa*	0
2006	2.84	*P. Kesiya*	0
2006	6.04	*P. Kesiya*	0
2006	3.16	*P. Kesiya*	0
2006	6.05	*P. Kesiya*	0
2006	0.32	*P. Kesiya*	0
2007	26.5	*P. Kesiya*	0
2007	8.3	*P. Kesiya*	0
2008	25	*p. Kesiya*	0
2008	18.44	*P. Kesiya*	0
2013	15.2	*P. Kesiya*	75
2014	5	*P. Kesiya*	0
2015	5	*P. Kesiya*	0

9.4 Dzonzi Mvai Timber Plantation Enhancements Activity Data

PLANTING YEAR	HA	SPECIES	SURVIVAL (%)
2005	12	*Kesiya*	46
2006	NIL	*NIL*	NIL
2007	3	*Kesiya & Ocapa*	71
2007	17.5	*Patula*	66
2008	2.2	*Kesiya*	17
2009	5	*Okapa*	18
2009	15.5	*Kesiya*	84
2010	6	*Kesiya*	57
2011	NIL	*NIL*	NIL
2012	15	*Kesiya*	74
2013	1	*Kesiya*	45
2013	7.3	*Kesiya*	75
2013	4	*Kesiya*	40
2013	3.8	*Kesiya*	60
2013	4.2	*Kesiya*	58
2014	3	*Kesiya*	63
2014	3	*Kesiya*	48
2015	22	*Kesiya*	90

9.5 Eastern Outer Slopes Enhancements Activity Data

PLANTING YEAR	HA	SPECIES	SURVIVAL %
2005	3.7	*P. kesiya & P. patula*	30
2006	2.8	*P.kesiya*	85
2007	1.5	*P.kesiya*	70
2008	13.9	*P.kesiya*	60
2009	10.9	*P.kesiya*	30
2010	4.4	*P.kesiya*	75
2011	6.4	*P.kesiya*	25
2012	5.5	*P.kesiya*	35
2013	10.5	*P.patula*	40
2014	11.4	*P.kesiya & E.grandis*	50
2015	6.6	*P.kesiya*	40

9.6 Chigumula Enhancements Activity Data

PLANTING YEAR	HA	SPECIES	SURVIVAL % (assumed)[10]
2012	27.79	*P. kesiya*	60
2012	18.43	*P. kesiya*	60
2016	13.93	*P. kesiya*	60
2016	19.51	*P. ocarpa*	60
2016	15	*P. kesiya*	60

9.7 Kaombe Plantation Enhancements Activity Data

PLANTING YEAR	HA	SPECIES	SURVIVAL %
2013	22	*Eucalyptus*	80
2013	28	*Eucalyptus*	80
2014	250	*Eucalyptus*	90
2015	130	*Eucalyptus*	90
2016	105	*Eucalyptus*	92
2017	100	*Albizia kebbeck*	90
2017	50	*Eucalyptus*	90
2018	103	*Eucalyptus*	91

9.8 Dedza Mountain Plantation Enhancements Activity Data

PLANTING YEAR	HA	SPECIES	SURVIVAL % (assumed)[11]
2005	85.26	*Pp, P. oorc*	60
2006	254.11	*Pp, P. oorc, Pk*	60
2007	132.3	*Pp, Pk*	60
2008	219.17	*P. oorc, Pp*	60
2009	21.19	*Pp*	60
2010	32.93	*Pp, P. oorc, Pk*	60
2011	17.12	*Pp, Pk*	60
2012	22.47	*Pp*	60
2013	103.2	*Pp, Pk*	60
2014	142.81	*Pp*	60
2015	25.38	*P. oorc*	60
2016	80	*P. oorc*	60

[10] Based on consultations with the Department of Forestry
[11] Based on consultations with the Department of Forestry

9.9 Fort Lister Plantation Enhancements Activity Data

PLANTING YEAR	HA	SPECIES	SURVIVAL %
2003	6.13	*Pinus kesiya*	0
2004	15.81	*Pinus kesiya*	90
2006	3.87	*Pinus kesiya*	50
2007	1.8	*Pinus kesiya*	50
2009	4.5	*Pinus kesiya*	0
2010	17.6	*Pinus oocarpa*	20
2010	5.5	*Widlingtonia whytei*	20
2011	7.54	*Pinus oocarpa*	10
2011	5.1	*Widlingtonia whytei*	0
2012	5.38	*Pinus Oocarpa*	20
2012	8.5	*Widlingtonia whytei*	0
2013	4.87	*Widlingtonia whytei*	0
2014	15.91	*Widlingtonia whytei*	0
2015	34.09	*Widlingtonia whytei*	0
2016	13.88	*Widlingtonia whytei*	90

9.10 Zomba Plantation Enhancements Activity Data

PLANTING YEAR	HA	SPECIES	SURVIVAL %
2005	1.9	*PPAT*	90
2006	4.2	*PKES*	11
2007	18.7	*PTAE*	98
2007	2.4	*PPAT*	72
2007	6.3	*POOC*	72
2008	6.3	*PMIX*	39
2008	0.05	*PPAT*	90
2008	7.7	*PTAE*	45
2009	22.9	*PMIX*	32
2009	17.8	*PKES*	21
2010	5	*MIX(INDIGENOUS)*	65
2010	8	*POOC*	82
2010	1	*K.ANTH*	75
2011	6	*PMIX*	78
2012	25.5	*MIXED*	81
2012	21.4	*PMIXED*	96
2012	13.1	*PMIXED*	71
2012	23.4	*PMIXED*	72

2012	18	*PMIX*	86
2013	21.3	*PPAT*	96
2014	6.9	*PPAT*	79
2014	40.3	*POOC*	94
2014	14.9	*PPAT*	0
2014	9.5	*PPAT*	75
2014	4.6	*PPAT*	79
2015	13	*PPAT*	84
2015	5	*PKES*	80
2015	8.4	*PPAT*	86
2015	20.5	*PKES*	88
2015	5	*PPAT*	75
2015	29.4	*PPAT*	66
2015	11.4	*PMIX*	78
2015	21	*POOC*	7
2015	9.3	*POOC*	11
2015	15.8	*PMIX*	56
2016	6.3	*PPAT*	70
2016	6.3	*PPAT*	75
2016	8.5	*PPAT*	78
2016	10	*PPAT*	86
2016	20.6	*PPAT*	83
2016	19.8	*PPAT*	90
2016	20.4	*POOC*	71
2016	16	*POOC*	78
2016	11.7	*POOC*	72
2016	1	*PPAT*	86
2016	5.5	*MIXED(INDIGENOUS)*	61
2016	0.4	*POOC*	77
2016	8.2	*POOC*	49
2016	3.4	*POOC*	34
2016	9.4	*PMIX*	95
2016	1.9	*PMIX*	75
2017	14.3	*PPAT*	82
2017	9.5	*PPAT*	85
2017	7.5	*PPAT*	65
2017	5.6	*PMIX*	48
2017	17	*POOC*	61
2017	3.6	*PMIX*	8
2017	11.3	*PMIX*	21
2017	9.9	*PMIX*	99

9.11 Dzalanyama Plantation Enhancements Activity Data

PLANTING YEAR	HECTARES	SPECIES	SURVIVAL %
2008	8.96	*Pinus kesiya*	98
2009	8.96	*Pinus kesiya*	90
2010	12.96	*Pinus kesiya*	96
2013	34.34	*Pinus kesiya*	95
2014	56.9	*Pinus kesiya*	85
2014	71.12	*Eucalyptus*	98
2015	66.35	*Pinus kesiya*	45
2015	68.3	*Eucalyptus*	87

9.12 Alliance One Tobacco Limited Enhancements Activity Data

PLANTING YEAR	HECTARES	SPECIES	SURVIVAL %
2013	34.5	*E.camadulensis*	78
2013	24.4	*E.Calmadulensis*	78
2013	29.52	*E.grandis, camaldulensis, maidenii*	74
2013	3.48	*E.grandis, camaldulensis*	71
2013	1.79	*E.grandis, E.calmadulesis*	78
2014	32.42	*e camaldu*	87
2014	19.93	*e camaldu*	79
2014	25.56	*e camaldu*	81
2014	49	*e camaldu*	83
2014	40	*E.camadulensis*	81
2014	114.49	*E .Calmadulensis*	83
2014	71.12	*E. camaldulensis*	87
2014	25	*E.grandis, camaldulensis*	84
2014	32.64	*E.grandis, E. camaldulesis*	84
2014	315.74	*E. grandiS; E. camaldulensis; E. tereticornis*	84
2014	29.36	*E.camadulensis*	82
2015	1	*e. grandis*	80
2015	1	*s. spectabilis*	85
2015	1	*S. siamea*	87
2015	80.61	*e camaldu*	84
2015	46.29	*E.camadulensis*	87
2015	69.99	*E.Calmadulensis*	88
2015	68.3	*E. camaldulensis*	88
2015	22.4	*E.grandis, camaldulensis, maidenii*	87
2015	79.32	*E.grandis, camaldulensis*	85

2015	64.5	*E.grandis, E. camaldulesis*	86
2015	18.1	*E. camaldulesis*	85
2015	123.51	*E. grandis*	86
2015	43.2	*E. grandis; E. europhylla*	88
2015	40.55	*E. grandis; E. europhylla*	90
2015	38.33	*E. camaldulensis*	88
2015	100.21	*E.camadulensis*	85
2016	8.6	*K.anthotheca*	67
2016	11	*m. azedirach*	84
2016	40.5	*A. polycantha*	87
2016	1.6	*E. medinnii*	78
2016	3	*India*	82
2016	4.5	*S. siamea*	86
2016	4	*s. spectabilis*	84
2016	17	*A. lebbeck*	88
2016	9	*A. galpinii*	87
2016	71.22	*e camaldu*	81
2016	12.11	*Apolyacantha*	93
2016	10	*A.species*	95
2016	18	*A.polyacantha/galpinii*	94
2016	13.61	*A.polyacantha*	93
2016	9.65	*A.lebbeck*	95
2016	7.65	*A.species /procera*	91
2016	3.7	*K.anthotheca*	67
2016	20	*Albizia Lebbeck*	94
2016	6.7	*Albizia Species*	97
2016	23.9	*E.Calmadulensis*	87
2016	18.06	*Acacia Polycathia*	92
2016	14.6	*A. lebbeck*	90
2016	87.8	*E.camaldulensis*	92
2016	5.2	*M.azedrack*	91
2016	64.77	*E. camaldulesis*	87
2016	5.9	*A. lebeck*	84
2016	10.87	*A.lebeck, M. azedirack*	87
2016	227.4	*E. grandis*	87
2016	127.9	*E.camadulensis*	93
2016	8	*Albizia lebbeck*	86
2017	29.1	*A. lebbeck*	88
2017	2	*Azadirachta indica*	64
2017	9	*m. azedirach*	84
2017	11.8	*A. polycantha*	89
2017	29.8	*e camaldu*	90
2017	11.1	*A.lebbeck*	95
2017	4.6	*A.Polyacantha*	94
2017	26.7	*A.lebbeck*	93

2017	2.6	*A.Polyacantha*	96
2017	52.7	*Albizia Lebbeck*	90
2017	28.19	*A.polycantha*	64
2017	49.23	*A.lebbeck*	38
2017	80.9	*M.azedrack*	30
2017	29.99	*M.azedirack*	87
2017	56.01	*A. polycantha*	90
2017	23.6	*A. lebeck*	88
2017	71.73	*Albizia lebeck*	89
2017	26.83	*Eucalyptus grandis*	87
2017	142.3	*E. grandis*	90
2017	26.83	*E.camadulensis*	91
2017	14.39	*E. saligna*	87
2017	93.02	*Albizia lebbeck*	86
2018	26.7	*A. polycantha*	91
2018	4.6	*A. lebbeck*	90
2018	8	*A. galpinii*	90
2018	110	*e camaldu*	85
2018	31.67	*A.lebbeck*	95
2018	2.46	*A. procera*	97
2018	3.3	*A. polycantha*	94
2018	3.62	*A. lebbeck*	89
2018	17.19	*A. polycantha*	91
2018	10.44	*E. camaldulesis*	93
2018	42.43	*M.azedrack*	97
2018	58.26	*A. polycantha*	95
2018	21.79	*A. lebbeck*	92
2018	2.01	E. camaldulensis	93
2018	28.8	*E. camaldulensis*	90
2018	26	*A. polyacantha/galpinii*	86
2018	25.5	*M.azedrack*	91
2018	18.8	*A. polycantha*	94
2018	2	*A. galpinii*	97
2018	25.2	*M.azedirack*	93
2018	5	*A. lebbeck*	90
2018	2	*E. camaldulensis*	88
2018	261.9	*E. grandis*	95
2018	3.1	*E. cloeziana*	90
2018	70.36	*Eucalyptus camadulensis*	93
2018	17.65	*Toona cilliata*	95
2018	8.12	*Albizia species*	90
2018	4.5	*Albizia lebeck*	91