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Report on the technical assessment of the proposed forest reference level of Malawi submitted in 2019

Summary

This report covers the technical assessment of the voluntary submission of Malawi on its proposed forest reference level (FRL) in accordance with decision 13/CP.19 and in the context of results-based payments. The subnational FRL proposed by Malawi covers the activities reducing emissions from deforestation, reducing emissions from forest degradation and enhancement of forest carbon stocks, which are among the activities included in decision 1/CP.16, paragraph 70. The FRL presented in the submission, which is the net emissions from the three activities, corresponds to 4,500,682, 4,831,639, 5,162,597, 5,493,554 and 5,824,511 tonnes of carbon dioxide equivalent per year for 2017, 2018, 2019, 2020 and 2021, respectively. The assessment team notes that the data and information used by Malawi in constructing its FRL are partially transparent and partially complete and thus in partial accordance with the guidelines contained in the annex to decision 12/CP.17. This report contains the assessed FRL and a few areas identified by the assessment team for future technical improvement in accordance with the provisions on the scope of the technical assessment contained in the annex to decision 13/CP.19.

Abbreviations and acronyms

AD	activity data
AT	assessment team
BUR	biennial update report
COP	Conference of the Parties
CO_2	carbon dioxide
CO_2 eq	carbon dioxide equivalent
EF	emission factor
FAO	Food and Agriculture Organization of the United Nations
FREL	forest reference emission level
FRL	forest reference level
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
NC	national communication
NFI	national forest inventory
REDD+	reducing emissions from deforestation; reducing emissions from forest degradation; conservation of forest carbon stocks; sustainable management of forests; and enhancement of forest carbon stocks (decision 1/CP.16, para. 70)
SOC	soil organic carbon
TA	technical assessment
WISDOM	Woodfuel Integrated Supply/Demand Overview Mapping
2006 IPCC Guidelines	*2006 IPCC Guidelines for National Greenhouse Gas Inventories*

I. Introduction and summary

A. Overview

1. This report covers the TA of the voluntary submission of Malawi on its proposed FRL,[1] submitted on 30 July 2019, in accordance with decisions 12/CP.17 and 13/CP.19. The remote TA[2] took place from 1 to 5 June 2020 and was coordinated by the secretariat.[3] The TA was conducted by two land use, land-use change and forestry experts from the UNFCCC roster of experts[4] (hereinafter referred to as the AT): Joana Brandao de Melo (Guinea-Bissau) and Till Neeff (Germany). In addition, Rehab Ahmed Hassan, an expert from the Consultative Group of Experts, participated as an observer[5] during the remote session. The TA was coordinated by Jenny Wong (secretariat).

2. In response to the invitation of the COP and in accordance with the provisions of decision 12/CP.17, paragraphs 7–15 and annex, Malawi submitted its proposed FRL on a voluntary basis. The proposed FRL is one of the elements[6] to be developed in implementing the activities referred to in decision 1/CP.16, paragraph 70. Pursuant to decision 13/CP.19, paragraphs 1–2, and decision 14/CP.19, paragraphs 7–8, the COP decided that each submission of a proposed FREL or FRL, as referred to in decision 12/CP.17, paragraph 13, shall be subject to a TA in the context of results-based payments.

3. The objective of the TA is to assess the degree to which the information provided by Malawi is in accordance with the guidelines for submissions of information on reference levels[7] and to offer a facilitative, non-intrusive, technical exchange of information on the construction of the FRL with a view to supporting the capacity of Malawi for the construction and future improvement of its FRL, as appropriate.[8]

4. The TA of the FRL submitted by Malawi was undertaken in accordance with the guidelines and procedures for the TA of submissions from Parties on proposed FRELs and/or FRLs.[9] This report on the TA was prepared by the AT following the same guidelines and procedures.

5. Following the process set out in those guidelines and procedures, a draft version of this report was communicated to the Government of Malawi. The facilitative exchange during the TA allowed Malawi to provide clarifications and additional information, which were considered by the AT in the preparation of this report.[10]

B. Proposed forest reference level

6. In decision 1/CP.16, paragraph 70, the COP encouraged developing country Parties to contribute to mitigation actions in the forest sector by undertaking a number of activities, as deemed appropriate by each Party and in accordance with their respective capabilities and national circumstances, in the context of providing adequate and predictable support. The FRL proposed by Malawi, on a voluntary basis for a TA in the context of results-based payments, covers the activities reducing emissions from deforestation, reducing emissions from forest degradation and enhancement of forest carbon stocks, which are three of the five activities referred to in that paragraph. Pursuant to paragraph 71(b) of the same decision, Malawi proposed a national FRL; however, the AT's finding was that the scale of the FRL

[1] The submission of Malawi is available at https://redd.unfccc.int/submissions.html?country=mwi.
[2] Owing to the circumstances related to the coronavirus disease 2019, the TAs of the FREL and FRL submissions of developing country Parties in 2020 had to be conducted remotely.
[3] As per decision 13/CP.19, annex, para. 7.
[4] As per decision 13/CP.19, annex, paras. 7 and 9.
[5] As per decision 13/CP.19, annex, para. 9.
[6] See decision 1/CP.16, para. 71(b).
[7] Decision 12/CP.17, annex.
[8] Decision 13/CP.19, annex, para. 1(a–b).
[9] Decision 13/CP.19, annex.
[10] As per decision 13/CP.19, annex, paras. 1(b), 13 and 14.

coverage is actually subnational (see para. 39 below). For its submission, Malawi applied a stepwise approach to developing its FRL in accordance with decision 12/CP.17, paragraph 10. The stepwise approach enables Parties to improve their FRELs or FRLs by incorporating better data, improved methodologies and, where appropriate, additional pools.

7. The FRL proposed by Malawi is the sum of expected emissions associated with three REDD+ activities for the period 2017–2021. For deforestation, historical emissions were estimated to be 1,236,631 t CO_2 eq/year on average for the historical reference period 2006–2016. For forest degradation, emissions amounting to 2,991,058 t CO_2 eq were estimated for 2016 only (see para. 12 below). These 2016 emissions were projected onto the monitoring period 2017–2021[11] by interpolating expected emission growth, and projected emissions ranged between 3,322,015 t CO_2 eq for 2017 and 4,645,844 t CO_2 eq for 2021 (see table 17 of the submission). For enhancement of forest carbon stocks, historical removals were 57,964 t CO_2/year on average for the period 2006–2016 (see table 16 of the submission for the fluctuation in values). The FRL presented in the submission, with the aim of accessing results-based payments for REDD+ activities for 2017–2021, corresponds to 4,500,682, 4,831,639, 5,162,597, 5,493,554 and 5,824,511 t CO_2 eq/year for 2017, 2018, 2019, 2020 and 2021, respectively.

8. The proposed FRL includes all carbon pools (i.e. above-ground and below-ground biomass, deadwood, litter and SOC) for the activity reducing emissions from deforestation, the above-ground biomass pool for the activity reducing emissions from forest degradation and the above-ground and below-ground biomass pools for the activity enhancement of forest carbon stocks. Regarding GHGs, the submission includes only CO_2. Non-CO_2 emissions (e.g. those resulting from fires) were omitted from the FRL.

II. Data, methodologies and procedures used in constructing the proposed forest reference level

How each element in the annex to decision 12/CP.17 was taken into account in constructing the forest reference level

1. Information used by the Party in constructing its forest reference level

9. For constructing its FRL, Malawi used the 2006 IPCC Guidelines as the basis for estimating carbon stock changes and emissions. Default values from these guidelines were used in developing the EFs. The AT noted that the treatment of SOC and of carbon accumulation in plantations was not fully in accordance with the 2006 IPCC Guidelines (see paras. 15, 26 and 32 below).

10. The estimation of emissions from deforestation focused on protected areas, forest reserves and some highly forested customary lands. Deforestation was identified by visual interpretation of satellite imagery available on Google Earth. Using a simple random sampling approach, approximately 4,000 sample plots covering an area of 26,128 km^2 or 22 per cent of the national territory were randomly generated. After excluding plots for which interpretation could not be undertaken, the final set of samples comprised 2,168 plots. Deforestation was determined on the basis of the proportion of plots showing forest loss between 2006 and 2016.

11. The EF for deforestation was estimated as the difference between carbon stocks before and after conversion. The carbon stocks before conversion, that is, the average forest carbon stock for the above-ground biomass pool, were based on a combination of sample plot measurements from five NFI campaigns undertaken since 2011 in different parts of the country. The carbon stocks after conversion were estimated under the assumption that all land that was deforested was converted to grassland (see the EF value in table 6 of the submission; see also para. 21 below), because sufficient information on post-deforestation land use was not available. Forest carbon stocks in below-ground biomass were estimated using root-to-shoot ratios (see para. 23 below). Forest carbon stocks in the deadwood pool

[11] The ‘monitoring period’ is here defined as the period of applicability of the FRL.

were estimated by assuming dead biomass to be equivalent to 6 per cent of total live biomass, and in the litter pool by assuming litter to be equivalent to 1 per cent of total live biomass (see para. 31 below). The post-deforestation carbon stocks in deadwood and litter were assumed to be zero. For estimating stocks in the SOC pool, a combination of data from the literature on forest SOC stocks (Henry et al., 2009) and default stock change factors from the 2006 IPCC Guidelines was used (see para. 32 below).

12. Emissions resulting from forest degradation were estimated on the basis of expected demand and supply of fuelwood determined using a common modelling framework known as WISDOM. This model establishes a balance between biomass loss (through harvesting of fuelwood) and biomass gains (through regrowth) by drawing on various biophysical and socioeconomic data sets. In cases where expected biomass harvesting exceeds regrowth, the harvesting is considered to come from non-renewable sources and therefore lead to forest degradation. The amount of non-renewable fuelwood harvested is then used to estimate emissions from forest degradation.

13. Carbon removals from timber plantations on customary lands managed by the Government of Malawi or tobacco companies were estimated for 2006–2016 and were based on growth of the tree species planted. Plantations were stratified as (1) *Eucalyptus*, (2) *Pinus* and (3) conifer species other than *Pinus*. During the TA, Malawi clarified that no new plantations had been established during 2006–2016; therefore, it was assumed that there had been no land-use changes. In addition, the Party clarified that the estimates do not capture carbon stock enhancements that may have occurred on tea estates. AD based on the number of hectares planted with specific species between 2006 and 2016 were provided by plantation managers. These values were later adjusted for annual plantation survival rates (i.e. survival percentage). Removal factors were derived from the Global CO_2 Emissions and Removals Database (see Bernal et al. (2018)[12] for the data sets generated and analysed) and from the growth curves for the above-mentioned three groups of species planted (see para. 26 below).

14. Malawi used the following reference periods and construction approaches for the three REDD+ activities covered by its FRL:

(a) For emissions from deforestation, a reference period of approximately ten years (2006–2016) was used. The specific start and end dates of the period were chosen to take into consideration data availability; that is, they correspond to the dates of satellite image pairs used for measuring AD. An average period, 9.7 years, was derived from all image pairs (see para. 18 below). The reference level is constructed as a historical average over the reference period;

(b) For emissions from forest degradation, a reference period could not easily be defined. Historical emissions were reported for only one year (2016) and were based on the modelling of diverse biophysical and socioeconomic data for that year. The reference level also relies on a projection of such biophysical and socioeconomic data for 2017–2021;

(c) For removals from carbon stock enhancement, the 10-year reference period 2006–2016 was used. Historical average removals across the period are reported as the reference level.

2. Transparency, completeness, consistency and accuracy of the information used in constructing the forest reference level

(a) Methodological information, including description of data sets, approaches and methods

15. Malawi estimated changes in forest carbon stocks, emissions and removals mostly in line with the 2006 IPCC Guidelines, with the exception of changes in the SOC pool and removals in land converted to forest land. The AT notes that Malawi deviated from the IPCC guidance for this pool and land-use change category. According to these guidelines, carbon stock changes in the SOC pool should consider a multi-year time frame (preferably 20 years), and removals in land converted to forest land should be estimated as annual removals

[12] The database for potential CO_2 removals from specific forest landscape restoration activities is available at https://infoflr.org/what-flr/global-emissions-and-removals-databases.

resulting from tree growth and not as 'committed removals' in the first year of the plantation cycle. The AT notes that moving towards a carbon quantification approach that is fully in line with the 2006 IPCC Guidelines is an area for future technical improvement.

16. The AT notes that Malawi did not maintain consistency in the methods, data and assumptions applied between its most recent national GHG inventory (included in its NC2) and the FRL, in accordance with decision 12/CP.17, paragraph 8. In its NC2, Malawi reported a forest loss of 50,000 ha/year, a value more than five times higher than the 8,847 ha/year reported in the FRL submission. Furthermore, emissions from forest conversion reported in the NC2 (2,088,310 t CO_2 eq for 2000) are almost double that of the emissions from deforestation estimated for the FRL (1,237,000 t CO_2 eq for 2006). The AT notes that Malawi's NC2, submitted in 2012, is based on earlier data than those on which the FRL is based. These latter data, which were made available to the AT, are from a recent NFI. During the TA, the Party clarified that the deforestation area reported in the NC2 was estimated using a combination of national data that are outdated and statistics from FAO that correspond to a different period (1995–2000), as well as using a different methodological approach. Malawi informed the AT that the national harmonization of forest information is an ongoing process and indicated that it plans to use the improved data and estimation methods implemented for the FRL for future submissions under the UNFCCC process. The AT, while commending Malawi on its efforts, considers the establishment of a GHG inventory system that generates consistent estimates to be both included in NCs and BURs and used for constructing FRLs as an area for future technical improvement.

17. With regard to AD for estimating emissions from deforestation, Malawi used a simple random sampling approach, without stratification, to estimate deforestation area. During the TA, the Party clarified that this approach was selected because it was the most affordable. The AT notes that even if the sampling strategy was not guided by stratification, post stratification could still have been carried out to reduce the variance in the estimation. The AT considers that introducing more efficient sampling approaches, including, potentially, post stratification, which would contribute to reducing uncertainties, is an area for future technical improvement.

18. Deforestation was assessed in satellite image pairs using 2006 and 2016 as the start and end years. However, not all locations had images available for both years. As a result, when imagery was not available for either 2006 or 2016, image interpreters were given the flexibility to interpret images up to four years before or after those years, that is, between 2002–2010 and 2012–2018. On average, image pairs were 9.7 years apart. The AT notes that, in some cases, deforestation events could have taken place after 2006 and regrowth could have occurred on those deforested lands before 2016. In such cases, the interpreter would not be able to identify the change in land use. Hence, the monitoring approach used likely underestimates areas deforested during the reference period. The AT considers that assessing the full time series of the reference period and recording the years of land-use change instead of assessing only the start and end years of the 10-year reference period, which could enhance the accuracy of the estimates, is an area for future technical improvement.

19. Malawi explained during the technical exchange that detection of deforestation was based on imagery available at Google Earth that has been captured by sensors with different spatial resolutions. The Party pointed out that details on the sensor type are not available, and also mentioned that medium-resolution remote sensing approaches (such as Landsat or Sentinel) have historically proven to be extremely unreliable for the country. The AT notes that, especially for earlier years of the reference period (e.g. 2006), the availability of high-resolution imagery at Google Earth is patchy for many regions of the world. The AT also notes that only 2,168 of the randomly generated 4,000 sample plots were retained for further analysis (54.2 per cent), which could have resulted in a lack of coverage, potentially adding uncertainty to the estimates. Malawi acknowledged the limitations of using Google Earth imagery and clarified that in developing its national forest monitoring system it would investigate tools such as Collect Earth[13] that might provide better access to imagery archives and better metadata. Malawi noted that it had intentionally planned to not rely on commercial imagery because lack of funding is a significant, ongoing threat to the sustainability of land-

[13] http://www.openforis.org/tools/collect-earth.html.

use monitoring. To address the reliability of its detection of deforestation, the Party has implemented quality assurance and quality control procedures during image interpretation, namely, interpretation of samples by several interpreters. During reinterpretation, approximately 60 per cent of plots initially classified as deforested have been reclassified – a figure that highlights the challenge faced by Malawi in this exercise. The AT, while commending Malawi on its efforts to reduce uncertainty in the interpretation of satellite imagery, notes that accessing a wide range of high-quality data to ensure accurate identification of forest-cover change is an area for future technical improvement.

20. Malawi presented a coherent set of EFs for deforestation in its submission. The five forest inventories (from which the EFs were derived) were conducted for different sub-areas and adequately represent 22 per cent of the country. Malawi used data from four site-based inventories (conducted in 2011–2016) that focused mainly on forest reserves. Malawi harmonized these inventories and filled data gaps with a fifth forest inventory completed in 2018. The AT commends Malawi on combining diverse data into a coherent data set. During the TA, the Party clarified that the data set does not adequately represent all of the country's forests because the data collection focused on only the 22 per cent of the country with forest landscapes that are intact and dense, including those in forest reserves and specific areas of land held in customary lands. Further to this point, the AT notes that given the forests that were not included in the consolidated fifth inventory (2018) are on average less densely stocked than the ones that were, the average carbon stock reported in the submission likely overestimates the country's average forest carbon stocks. In the AT's view, this is not problematic because Malawi reported deforestation emissions for a subnational area only.

21. Carbon stocks after deforestation were estimated under the assumption that in all cases, grassland is the land use after conversion. A default biomass stock for grassland for the tropical moist and wet climate zone from the 2006 IPCC Guidelines was used to estimate the post-deforestation biomass stock. The AT notes that Malawi did not include in the FRL submission a justification for its selection of this climate zone, and the AT is of the view that the country fits better in the tropical dry climate zone. Further, the AT notes that, if there were cases where post-deforestation land use was not grassland but, for example, cropland or settlements, this choice of default biomass stock could lead to bias when estimating emissions. The AT considers that providing more details on estimating post-deforestation carbon stocks, which could enhance the accuracy of the estimates, is an area for future technical improvement.

22. To convert tree measurements into carbon stock estimates, a country-specific allometric equation developed by Kachamba et al. (2016) was used.[14] The AT notes that while this study presented several allometric equations, Malawi used the simplest one, which is based on only the variable diameter at breast height. The AT considers that the error of tree biomass estimates would likely be smaller if the more complex equations that use both diameter at breast height and tree height as variables were to be used. Although most of the plot measurements included measurements of tree height, Malawi clarified during the TA that these measurements were often not made in a consistent manner. The AT notes the further analysis of plot-level data to maximize the use of all information from all plots is an area for future technical improvement.

23. To estimate below-ground biomass, Malawi used the model of Mokany et al. (2006) for relating root biomass to shoot biomass for forests and woodlands of all biomes. During the TA, the AT requested clarification on the reasons for choosing this model instead of a biome-specific root-to-shoot ratio developed by the same authors, which is available in the 2006 IPCC Guidelines (vol. 4, table 4.4). The AT noted that while the model used provides a good general description of the relationship between root and shoot biomass for forests and woodlands, individual root-to-shoot ratios for specific forest and woodland types provide a more accurate means of estimating root biomass. Malawi explained that the model was selected to maintain consistency across the activities covered by the FRL. The AT considers that the submission does not provide adequate quantitative information to support the selection, and notes that identifying the most appropriate equations for relating root biomass

[14] Kachamba et al. (2016) developed four models for the miombo woodlands of Malawi using a combination of three independent variables: diameter at breast height, tree height and wood density.

to shoot biomass, which could enhance the transparency of the below-ground biomass estimates, is an area for future technical improvement.

24. Malawi used WISDOM for estimating emissions from forest degradation. During the technical exchange, the AT raised several points related to the accuracy, transparency and time-series consistency of its use, as follows:

(a) Uncertainty of the estimates: the uncertainties in estimating forest degradation emissions using WISDOM are considerable and not easily quantified. On the supply side, fuelwood may originate from areas not considered forests (e.g. fallow land, grassland, cropland with remaining trees), and deforestation may generate fuelwood. Moreover, increment rates need to be estimated, and these often have high uncertainties. On the demand side, uncertainties are inherent in the socioeconomic data that underpin the modelling (e.g. population growth, cooking practices, kiln efficiency) as well as in the projection of those data. For example, a key parameter in the Party's calculations is population density, which was extrapolated from 2008 national census data to 2021. In the discussions with the AT during the TA on the sources of uncertainties, Malawi pointed out the FRL submission states that the confidence interval of emissions is not known. Rather than settling on one estimate of forest degradation emissions, Malawi decided to build scenarios of non-renewable biomass use and associated forest degradation emissions (low, medium or high) that would encompass the 'plausible' value for 2021. These emission estimates vary between 1,235 and 8,998 Mt CO_2 eq/year. The medium emissions scenario of 4,646 Mt CO_2 eq/year was characterized by Malawi as the 'best guess' scenario;

(b) Transparency of the estimates: the estimation of forest degradation emissions obtained using WISDOM is not fully transparent because it relies on diverse socioeconomic and biophysical data that are processed in a geographical information system, all of which the AT did not have access to so could not reconstruct the estimates. During the technical exchange, Malawi acknowledged the difficulty for third parties to replicate the calculations and obtain the same results with WISDOM;

(c) Time-series consistency: time-series consistency will be essential in monitoring changes in emission trends in the future. Malawi did not explain in its FRL submission or during the technical exchange how time-series consistency is ensured in the Party's approach to quantifying forest degradation emissions. The AT has concerns about the potential lack of robustness and the potentially high inter-annual variability of the estimates derived by using WISDOM. Malawi explained that no detailed plans have yet been made on how progress monitoring will be undertaken but acknowledged that WISDOM may not be suitable for this purpose.

25. On the basis of its assessment, the AT concludes that applying WISDOM to estimate forest degradation emissions may not fulfil the principles of transparency, accuracy and completeness guiding the estimation of emissions from REDD+ activities. The AT considers as an area for future technical improvement that Malawi move towards an approach for measuring forest degradation emissions that is transparent and facilitates reconstruction of the estimates. Such an approach should allow the quantification of uncertainties using standard statistical parameters, ensure time-series consistency and enable progress monitoring. The AT observes that Malawi has information available on crown cover trends from remote sensing measurements, and information on how crown cover correlates with forest biomass. The Party may therefore wish to consider exploring methods using direct measurement of crown cover trends to estimate forest degradation emissions, which has been done by several other countries, as part of its future technical improvements. During the TA, Malawi indicated that it would consider discarding the application of WISDOM for future FREL/FRL submissions, and instead apply more transparent and robust approaches, as proposed by the AT.

26. The FRL for removals from plantations was computed as the historical average of annual removals between 2006 and 2016. During the TA, Malawi clarified that none of the plantations was considered newly established, but some established plantations had undergone replanting – no land-use change was assumed for these plantations. The removal factors for each plantation stratum were calculated as the sum of above-ground and below-ground biomass (Mokany et al., 2006). In the FRL submission, Malawi stated that the

removal factors were estimated by taking the middle point of the maximum peak biomass at felling age obtained from growth curves that were developed using data from the Global CO_2 Emissions and Removals Database.[15] During the TA, the AT was not able to replicate the growth curves based on the data from the database. The FRL assumes a 'committed removals' approach wherein plantations reach their full biomass stock at the time of planting, effectively neglecting that biomass needs to accumulate over time. The AT pointed out that this approach is not consistent with the IPCC guidance and could lead to an overestimation of removals. Malawi clarified that because plantations experience numerous continuous harvesting cycles, overestimation and underestimation of carbon stocks will balance each other out over time. Further, the Party noted that by taking the middle point of a specific plantation's peak biomass, the removals are being estimated using best available country data. The AT views moving towards an approach that quantifies increases in carbon stocks in line with guidance provided by the 2006 IPCC Guidelines and estimates removals on a year-by-year basis as an area for future technical improvement.

27. Malawi undertook a partial analysis of uncertainties related to the estimation of historical emissions. The AT considers as an area for future technical improvement the provision by Malawi of an analysis of the uncertainties for all selected REDD+ activities, which would provide transparent information on the accuracy of estimates. The AT noted the following issues regarding the analysis of uncertainties in the FRL submission:

(a) For emissions from forest degradation, no uncertainty analysis was presented. Instead, Malawi provided a range of 'plausible' values to indicate the robustness of the model. For the medium emissions scenario, the reported estimate of emissions from forest degradation in 2016 of 2,991,058 t CO_2 eq/year lies in the range 449,738 to 6,296,336 t CO_2 eq/year. On the basis of the reported range, the AT concludes that emissions from forest degradation under the medium emissions scenario could amount to as little as 15 per cent of the value reported for 2016 or as much as 210 per cent;

(b) For deforestation and carbon stock enhancements, a Monte Carlo simulation was undertaken using SimVoi, an add-in for spreadsheet-based simulation.[16] The AT did not have access to this software package and therefore could not replicate the calculations. However, during the technical exchange, the Party provided the AT with details on the approach, including the SimVoi output and R code, enabling the AT to analyse it. The AT concludes that Malawi applied the Monte Carlo simulations incorrectly and that the reported uncertainties for historical deforestation emissions and removals for the activity enhancement of forest carbon stocks are in fact underestimated. Malawi's R code shows that the reported uncertainties reflect the uncertainties of the mean of the simulation results. However, it would have been correct to report the uncertainties of the simulation results themselves. While the FRL reports uncertainties of approximately 1.06 per cent of the mean at a 90 per cent confidence level, the AT notes that this value falls outside the range of uncertainties that other countries are able to achieve, which is on average 20–32 per cent of the mean (FAO, 2019, p.17);

(c) In deriving uncertainties of the average carbon stock estimates, the different area weights of the five NFI campaigns were neglected. Area weight is a variable that would have been considered in a more accurate analysis of uncertainties.

(b) Description of relevant policies and plans, as appropriate

28. Future changes to domestic policies and plans are briefly addressed in the FRL submission. Malawi's nationally determined contribution[17] includes the promotion or introduction of alternative renewable energy sources, more efficient cookstoves, sustainable forest management practices, and afforestation and reforestation.

[15] As footnote 12 above.

[16] SimVoi, which is commercially available, provides random number generator functions as inputs for a 'what if' spreadsheet model and automates Monte Carlo simulations.

[17] Available at https://www4.unfccc.int/sites/NDCStaging/pages/Party.aspx?party=MWI.

3. Pools, gases and activities included in constructing the forest reference level

29. According to decision 12/CP.17, annex, paragraph (c), reasons for omitting a pool or activity in constructing the FRL should be provided, noting that significant pools and activities should not be excluded.

30. Malawi included different carbon pools for each of the three activities that are covered by the FRL. For the activity reducing emissions from deforestation, Malawi included all carbon pools, that is, above-ground biomass, below-ground biomass, deadwood, litter and SOC. Only the above-ground biomass pool was included for the activity reducing emissions from forest degradation, while both above- and below-ground biomass pools were included in estimating removals from the activity enhancement of forest carbon stocks. The AT notes that although the submission states that all significant pools were included and that these pools represent greater than 10 per cent of total forest-related emissions included in the FRL, it does not include adequate transparent quantitative information justifying the exclusion of some pools. The AT considers below-ground biomass to be a significant pool for the estimation of emissions from forest degradation and that its exclusion could underestimate emissions by approximately 34 per cent (in calculating emissions from deforestation, the ratio between below-ground biomass and total living biomass was 3.0/8.8, or approximately 34 per cent). Hence, the AT notes that collecting more information on the relative contribution of all the pools to emissions and removals, working towards a more complete coverage of carbon pools and justifying transparently any exclusions are areas for future technical improvement.

31. Carbon stocks in deadwood and litter were estimated using data from a table included in an afforestation/reforestation methodological tool for estimating carbon stocks and change in carbon stocks in deadwood and litter in clean development mechanism project activities.[18] Malawi selected a value of 6 per cent as the conservative deadwood default factor (expressed as per cent of carbon stock in deadwood as a percentage of carbon stock in tree biomass) for the precipitation bracket above 1,600 mm per year. Referring to information on the World Bank's Climate Change Knowledge Portal,[19] the AT notes that only a few areas in Malawi have so much rainfall. Forests may be concentrated in high-precipitation areas, yet a considerable proportion of forest land is also in areas of lower rainfall. Using default factors that are not representative of average biophysical conditions could lead to an overestimation of average carbon stocks and, therefore, of deforestation emissions. The Party may wish to improve its estimation by choosing values for deadwood and litter biomass stocks that are more representative of the country's biophysical conditions. The AT notes this is an area for future technical improvement.

32. Emissions from SOC following deforestation were estimated using stock change factors. To estimate changes in SOC, forest SOC stocks from Henry et al. (2009)[20] were multiplied by the default stock change factors for grassland management from the 2006 IPCC Guidelines (vol. 4, table 6.2), assuming moderate degradation. Henry et al. (2009) aggregated soil profile data available from different soil databases by African ecoregion and by African country. Malawi selected the soil carbon stocks for the "tropical and subtropical moist broadleaf forests" ecoregion, and assumed all of the emissions from soil are released in the year of clearing. During the TA, the AT calculated the area of each forest type for the 14 ecoregions identified in Henry et al. (2009) and noticed that "tropical and subtropical grasslands, savannas and shrublands" occupy approximately 60 per cent of the national territory of Malawi, while "tropical and subtropical moist broadleaf forests" occupy an almost negligible area. In future submissions, Malawi may wish to consider using either the soil carbon stocks estimated for the ecoregion "tropical and subtropical grasslands, savannas and shrublands" or the aggregated soil carbon stocks for the entire national territory, which are also provided in Henry et al. (2009). Both options seem to be in better agreement with the range of IPCC default values for soil carbon stocks in the first 0–30 cm (depth) of tropical

[18] Available at https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-12-v3.0.pdf.

[19] https://climateknowledgeportal.worldbank.org/country/malawi/climate-data-historical.

[20] The authors aggregated available soil profile data from different soil databases (including the Harmonized World Soil Database) and linked derived interpretations of soil properties with the soil units on grid maps. Results are shown for each African country (table 2) and by ecoregion (table 3).

dry forests. The AT considers that providing adequate quantitative information to render the Party's selection of the most appropriate ecoregion and forest SOC stocks transparent is an area for future technical improvement.

33. The soil carbon stock change calculations in the FRL (see equation 8 in the submission) lack the time dependence variable and are therefore not in accordance with equation 2.25 in the 2006 IPCC Guidelines (vol. 4). During the TA, the AT noted that according to these guidelines, the annual rate of carbon stock change in soils is estimated as the difference in stocks at two points in time divided by the time dependence of the stock change factors (20 years is considered the default). Malawi acknowledged the AT's assessment and indicated that it would consider modifying its present 'committed' approach to an approach that takes into account the 10-year reference period. The AT considers moving from a 'committed' approach for SOC to annual estimates in order to avoid overestimating annual emissions and enhance the accuracy of the estimates is an area for future technical improvement.

34. The AT acknowledges that Malawi included the most significant activities, reducing emissions from deforestation, reducing emissions from forest degradation (from fuelwood harvesting) and enhancement of forest carbon stocks (from timber plantations), of the five activities identified in decision 1/CP.16, paragraph 70, in accordance with its national capabilities and circumstances. The AT points out, however, that for the latter two activities, only a portion of the emissions were covered in the FRL: for forest degradation, emissions not attributable to fuelwood collection (notably from fires or logging) were excluded; and for the enhancement of carbon stocks, removals in forest land remaining forest land and removals in lands converted to forests by natural regrowth were excluded, as were tree plantations not managed by the Government and by tobacco companies. The Party's submission does not include information on the other two REDD+ activities (i.e. conservation of forest carbon stocks and sustainable management of forests) or, notably, the reasons for excluding them. The AT notes that developing definitions for each of the REDD+ activities could facilitate the justification of their exclusion or inclusion and broaden the scope of the FRL, which in turn could enhance the transparency, comprehensiveness and accuracy of future FRL submissions, and considers this as an area for future technical improvement.

35. The submission includes only CO_2. Non-CO_2 gases are excluded owing to emissions from forest fires being omitted from Malawi's FRL.

4. Definition of forest

36. Malawi provided in its submission (chap. 3.2) the definition of forest used in constructing its FRL, which is based on the definition of forest of the Malawi Department of Forestry (2017). According to this definition, forest land is "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)". In addition, for national mapping purposes, woody vegetation should be the dominant class in a minimum mapping area of 0.5 ha and should have a minimum of 10 per cent crown cover and a potential height of 5 m at maturity. An area of land that has the potential for woody vegetation in situ and for such vegetation to exceed the minimum height of 5 m at maturity is considered as forest in mapping. Malawi also 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. one- to three-year-old teak plantations)) as forests. Furthermore, the FRL submission clarifies that Malawi's forest definition does not include all trees grown for timber and non-timber trees on cropland, particularly if the tree cover on cropland does not meet the definition of forest. Trees that are a part of windbreaks or shelter belts and roadside plantings of less than 30 m in width are also not included in the definition. According to Malawi, this definition of forest was adapted from international guidelines such as those of FAO and the IPCC.

37. The AT noted inconsistencies in the use of the forest definition in estimating both AD for deforestation and emissions from forest degradation. These inconsistencies largely pertain to the difficulty in separating cropland from forest land, especially with regard to customary

lands, agroforestry systems and cyclical agricultural systems in the fallow phase. The following issues in land-use monitoring were noted:

(a) When monitoring for deforestation in satellite imagery, the classification of agroforestry systems with tree cover above 10 per cent is difficult. Malawi explained that fallow clearings in shifting agriculture cycles were picked up as deforested areas in its monitoring approach. The Party clarified that customary lands are mostly classified under other land uses such as settlements and cropland, and hence are excluded from the construction of the FRL;

(b) The WISDOM model considers the supply of biomass across all landscapes and does not separate biomass that originates from forest land from biomass that originates from cropland or grassland. The AT notes that, according to information provided in Malawi's NC2, accessibility to protected areas and forest reserves is typically low; therefore, it is very likely that fuelwood is collected mostly from customary lands. This observation is supported by the finding that "over 50 per cent of the wood energy comes from customary land forests and woodlands, 36 per cent from forest reserves, 15 per cent from plantations, 14 per cent from crop residues and 22 per cent from other sources of biomass" (NC2, p.46). Following this rationale, the fuelwood included in the estimates likely comes from areas under land uses other than forest land, and hence would not constitute forest degradation.

38. Inconsistencies in implementing the forest definition could lead to the overestimation of emissions from deforestation and forest degradation. The AT notes that Malawi limited such overestimation by restricting the FRL for deforestation to a subnational area dominated by forest land for which data were available. However, the same subnational approach was not applied to forest degradation. The AT notes that moving towards a methodological approach that allows the forest definition to be applied to the quantification of emissions from deforestation and forest degradation is an area for future technical improvement.

39. The scale of coverage of the FRL differed among the three activities. Malawi estimated emissions from forest degradation at the national scale, removals from the enhancement of forest carbon stocks from timber plantations only, and emissions from deforestation for areas with the densest forest cover (an area equivalent to 22 per cent of the national territory comprising protected areas, forest reserves and some highly forested customary lands). The AT notes that the forest area in the remaining 78 per cent of the national territory can be considered significant on the basis of (1) a visual examination of maps included in Malawi's NFI 2018 report, which indicates that about half of this remaining territory is forest land and (2) globally available data sets at Global Forest Watch,[21] which indicate that in 2010, approximately 58 per cent of Malawi's territory had tree cover of more than 10 per cent. During the TA, in response to these observations, Malawi noted that the FRL does not attempt to include all the areas of land in the country that meet the forest definition; the areas outside the sampling frame are customary lands that are mainly under different land uses; and it was considered more conservative to estimate emissions from deforestation for only a portion of the country as this would result in an underestimation of such emissions. However, the AT is of the view that, first, arguing that customary lands are highly humanized and mostly under other land uses and therefore should not be included in deforestation estimates is inconsistent with the approach followed for emissions from forest degradation because degradation from fuelwood consumption includes fuelwood collection from these areas. Second, conservativeness is not a principle guiding the construction of FRLs. Moreover, the AT points out that an underestimation of historical emissions does not necessarily lead to an underestimation of emission reductions. In sum, the AT concludes that, since the Party's approach covers only a portion of the national territory for one REDD+ activity, Malawi's FRL is subnational, not national. The AT notes that collecting AD on deforestation for the whole country to allow a national scale estimation of emissions from deforestation is an area for future technical improvement.

40. With the FRL covering only a portion of the country's forest lands, there is a risk of the displacement of emissions from the area covered by the FRL to other forest areas of the country. Malawi's FRL submission does not discuss the drivers of deforestation or the risks of these drivers resulting in displacement. The AT considers that as long as the FRL remains

[21] https://www.globalforestwatch.org.

subnational, analysing drivers of deforestation and assessing the risk of emission displacement to areas not covered by the FRL is an area for future technical improvement.

III. Conclusions

41. The information used by Malawi in constructing its FRL for reducing emissions from deforestation, reducing emissions from forest degradation and enhancement of forest carbon stocks is partially transparent and partially complete and thereby in partial accordance with the guidelines for submissions of information on reference levels.

42. The FRL presented in the submission, for 2017–2021, corresponds to 1,236,631 t CO_2 eq/year for emissions from deforestation, a range of 3,322,015–4,645,844 t CO_2 eq/year for emissions from forest degradation and 57,964 t CO_2 eq/year for removals from the enhancement of forest carbon stocks. The historical reference period 2006–2016 applies to the emissions from deforestation and the removals from carbon stock enhancement. The emissions from forest degradation were estimated for 2016 only and these emissions were projected onto the monitoring period of 2017–2021.

43. The AT acknowledges that Malawi included in its FRL the most significant activities, the most important forest areas and the most significant pools in terms of emissions from forests. The AT considers that, in doing so, Malawi followed decision 1/CP.16, paragraph 70, on activities undertaken, and paragraph 71(b), on elaborating a subnational FRL as an interim measure, and decision 12/CP.17, paragraph 10, on applying the stepwise approach.

44. As a result of the facilitative interactions with the AT during the TA, Malawi expressed interest in submitting an improved FRL in the future that takes into consideration the technical feedback received during the TA.

45. The AT notes that, overall, the FRL does not maintain consistency, in terms of methods, data and assumptions applied, with the GHG inventory included in Malawi's NC2.[22] According to the Party, the inconsistency arose from its use of new, improved data for the FRL, which will be used for the next BUR submission to ensure consistency (see para. 16 above).

46. Pursuant to decision 13/CP.19, annex, paragraph 3, the AT identified the following areas for future technical improvement:

(a) Move towards a carbon quantification approach that is fully in line with the 2006 IPCC Guidelines and include the estimation of annual emissions from SOC and removals from living biomass (see paras. 15, 26 and 32 above);

(b) Establish a GHG inventory system that generates consistent estimates to be both included in NCs and BURs and used for constructing FRLs (see para. 16 above);

(c) Introduce more efficient sampling approaches for estimating AD, potentially including post stratification, which would contribute to reducing uncertainties (see para. 17 above);

(d) Assess the full time series when estimating AD and record dates of land-use change rather than only start and end dates of a 10-year reference period (see para. 18 above);

(e) Access a wide range of high-quality data to ensure accurate identification of forest-cover change (see para. 19 above);

(f) Include in the submission more details on estimating post-deforestation carbon stocks (see para. 21 above);

(g) Further analyse plot-level data to maximize the use of all information from all plots (see para. 22 above);

[22] In reference to the scope of the TA, as per decision 13/CP.19, annex, para. 2(a).

(h) Further clarify the reasons behind the choice of equations and default factors used for estimating changes in below-ground biomass, deadwood and litter, and the associated emissions (see paras. 23 and 31 above);

(i) Estimate forest degradation emissions with a more transparent approach that allows the reconstruction of the FRL and in which uncertainties can be quantified using standard statistical parameters and time-series consistency can be ensured (see para. 25 above);

(j) Provide a transparent analysis of uncertainties for all REDD+ activities covered by the FRL (see para. 27 above);

(k) Address the inconsistencies in the adopted national forest definition and its application in the FRL and move towards using a methodological approach that closely follows Malawi's forest definition in quantifying emissions from deforestation and forest degradation, thus avoiding overestimation (see paras. 37–38 above);

(l) Analyse the drivers of deforestation and assess the risk of emission displacement to areas not covered by the FRL (see para. 40 above).

47. Pursuant to decision 13/CP.19, annex, paragraph 3, the AT identified the following additional areas for future technical improvement regarding the exclusion of pools and gases from the FRL:

(a) Collection of more data on the relative contribution of the pools to emissions from forest degradation and removals from carbon stock enhancement, and transparent justification of any exclusions based on such data (see para. 30 above);

(b) Treatment of the carbon pools below-ground biomass, deadwood, litter and SOC in the estimation of emissions from forest degradation (see paras. 30–31 above);

(c) Treatment of removals from deadwood, litter and SOC for the activity enhancement of forest carbon stocks (see paras. 30–31 above);

(d) Treatment of non-CO_2 gases, particularly from forest fires (see para. 35 above).

48. The AT acknowledges and welcomes the Party's intention to address several of the above areas of improvement, as expressed during the technical exchange. Furthermore, Malawi noted its interest in improving its FRL estimates in a potential future submission, as part of the stepwise approach. A future submission could include a description of Malawi's plans for the future.

49. In conclusion, the AT commends Malawi for showing strong commitment to continuously improving its FRL estimates in line with the stepwise approach. A number of areas for the future technical improvement of Malawi's FRL have been identified in this report. At the same time, the AT acknowledges that such improvements are subject to national capabilities and policies and notes the importance of providing adequate and predictable support.[23] The AT also acknowledges that the TA was an opportunity for a rich, open, facilitative and constructive technical exchange of information with Malawi.

50. The table contained in annex I summarizes the main features of Malawi's proposed FRL.

[23] As per decisions 13/CP.19, annex, para. 1(b); and 12/CP.17, para. 10.

Annex I

Summary of the main features of the proposed forest reference level based on information provided by Malawi

Main features of the FRL		*Remarks*
Proposed FRL (t CO_2 eq/year)	Deforestation: 1 236 631 Forest degradation: 3 322 015 for 2017 3 652 972 for 2018 3 983 930 for 2019 4 314 887 for 2020 4 645 844 for 2021 Enhancement of forest carbon stocks: –57 964	The FRL for 2017–2021 includes emissions from deforestation, emissions from forest degradation (from fuelwood harvesting) and removals from the enhancement of forest carbon stocks (in established plantations) (see paras. 6–7 of this document)
Type and reference period of FRL	FRL deforestation and enhancement of forest carbon stocks = average of historical emissions/removals (using data from 2006–2016) FRL forest degradation = based on projections of 2016 emissions	Malawi constructed its FRL using the historical average emissions from deforestation and removals from established plantations during 2006–2016. Emissions from forest degradation from fuelwood consumption were modelled for 2017–2021. The period of applicability of the FRL is 2017–2021 (see para. 7 of this document)
Application of adjustment for national circumstances	No	
National/subnational	Subnational	The FRL is subnational. Although emissions from forest degradation are quantified for the entire country, deforestation emissions and carbon stock enhancements are quantified for only part of it. No information was provided on the drivers of deforestation that could result in the displacement of emissions (see paras. 6 and 39–40 of this document)
Activities included	Reducing emissions from deforestation Reducing emissions from forest degradation Enhancement of forest carbon stocks	Forest degradation is from fuelwood harvesting and carbon stock enhancements are carbon removals from timber plantations on customary lands (see paras. 6 and 34 of this document)
Pools included	Above-ground biomass Below-ground biomass (partly) Deadwood (partly) Litter (partly) SOC (partly)	The pools covered by the proposed FRL differ according to the activity. No justification was provided for the exclusion of some pools (see para. 30 of this document)
Gas included	CO_2	The FRL includes only CO_2 (see para. 35 of this document)
Forest definition	Included	Based on definition of forest of the Malawi Department of Forestry (2017) and adapted from international

Main features of the FRL		*Remarks*
		guidelines such as those of FAO and the IPCC. Inconsistencies in the use of the forest definition in estimating AD for deforestation and emissions from forest degradation were noted (see paras. 36–37 of this document)
Consistency with latest GHG inventory	Methods used for estimating the FRL are not consistent with those used for the latest GHG inventory (2012)	Malawi intends to apply the updated methods and data used for constructing its FRL to preparing its future NCs and BURs (see para. 16 of this document)
Description of relevant policies and plans	Included	See paragraph 28 of this document
Description of assumptions on future changes to domestic policies, if included in the construction of the FRL	Not applicable	
Description of changes to previous FRL	Not applicable	
Identification of future technical improvements	Included	Several areas for future technical improvements were identified (see paras. 46–47 of this document)

Annex II

Documents and information used during the technical assessment

A. Reference documents

FRL submission of Malawi. Available at https://redd.unfccc.int/submissions.html?country=mwi.

"Guidelines and procedures for the technical assessment of submissions from Parties on proposed forest reference emission levels and/or forest reference levels". Annex to decision 13/CP.19. Available at https://unfccc.int/sites/default/files/resource/docs/2013/cop19/eng/10a01.pdf#page=36.

"Guidelines for submissions of information on reference levels". Annex to decision 12/CP.17. Available at https://unfccc.int/sites/default/files/resource/docs/2011/cop17/eng/09a02.pdf#page=19.

IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. S Eggleston, L Buendia, K Miwa, et al. (eds.). Hayama, Japan: Institute for Global Environmental Strategies. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl.

NC2 of Malawi. Available at https://unfccc.int/documents/124583.

B. Other documents

The following references have been reproduced as received:

Accuracy assessment of land cover maps: Guidance and application for Malawi REDD+ reference level development. A working draft.

Bernal B, Murray LT and Pearson TRH. 2018. Global carbon dioxide removal rates from forest landscape restoration activities. *Carbon Balance and Management.* 13(22): pp.1–13. Available at: https://doi.org/10.1186/s13021-018-0110-8.

Excel worksheets containing the enhancements reference level tool with removal estimates from plantations; AD and removal factors and outcomes from calculations with the SimVoi software; estimation of AD on deforestation; the Malawi National Greenhouse Gas Information System: Emissions calculator: land cover change; data on fuelwood emissions; and results from the uncertainty analysis.

FAO. 2019. *From reference levels to results reporting: REDD+ under the United Nations Framework Convention on Climate Change. 2019 update.* Forestry Working Paper 9. Rome: FAO. Available at http://www.fao.org/3/ca6031en/ca6031en.pdf.

Henry M, Valentini R and Bernoux M. 2009. Soil carbon stocks in ecoregions of Africa. *Biogeosciences Discuss.* 6: pp.797–823. Available at: https://doi.org/10.5194/bgd-6-797-2009.

Kachamba D, Eid T and Gobakken T. 2016. Above- and belowground biomass models for trees in the Miombo woodlands of Malawi. *Forests.* 7(2): pp.38. Available at: https://doi.org/10.3390/f7020038.

Malawi Department of Forestry. 2017. *Technical Order – Definition of "Forest" in Malawi*. Available at: https://cepa.rmportal.net/Library/inbox/technical-order-forest-definition.

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Mokany K, Raison RJ and Prokushkin A. 2006. Critical analysis of root:shoot ratios in terrestrial biomes. *Global Change Biology*. 12(1): pp.84–96. Available at https://doi.org/10.1111/j.1365-2486.2005.001043.x.

Rudi Drigo, Winrock International. 2019. Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) Malawi: Analysis of woodfuel demand, supply and harvesting sustainability.