United Nations

FCCC/TAR/2021/GHA

Framework Convention on Climate Change

Distr.: General
22 December 2023

English only

Report on the technical assessment of the proposed forest reference emission level and forest reference level of Ghana submitted in 2021

Summary

This report covers the technical assessment of the voluntary submission of Ghana on its proposed forest reference emission level (FREL) and forest reference level (FRL) in accordance with decision 13/CP.19 and in the context of results-based payments. The FREL/FRL proposed by Ghana 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.

For its submission, Ghana developed a national FREL/FRL. The FREL/FRL presented in the original submission, for the reference period 2001–2015, corresponds to 1,526,457 tonnes of carbon dioxide equivalent per year. As a result of the facilitative process during the technical assessment, the FREL/FRL was modified to 19,659,303 tonnes of carbon dioxide equivalent per year.

The assessment team notes that the data and information used by Ghana in constructing its FREL/FRL are transparent, complete and in overall accordance with the guidelines contained in the annex to decision 12/CP.17. This report contains the assessed FREL/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

2006 IPCC Guidelines	*2006 IPCC Guidelines for National Greenhouse Gas Inventories*
2019 Refinement to the 2006 IPCC Guidelines	*2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*
AD	activity data
AT	assessment team
C	carbon
CH_4	methane
CO_2	carbon dioxide
CO_2 eq	carbon dioxide equivalent
COP	Conference of the Parties
dm	dry matter
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
LULUCF	land use, land-use change and forestry
N_2O	nitrous oxide
NIR	national inventory report
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)
TA	technical assessment

I. Introduction and summary

A. Overview

1. This report covers the TA of the voluntary submission of Ghana on its proposed FREL/FRL,[1] submitted on 14 January 2021, in accordance with decisions 12/CP.17 and 13/CP.19. The remote TA[2] took place from 19 to 23 April 2021 and was coordinated by the secretariat.[3] The TA was conducted by two LULUCF experts from the UNFCCC roster of experts[4] (hereinafter referred to as the AT): Joana Brandao de Melo (Guinea-Bissau) and Maria José Sanz-Sánchez (Spain). Although the Consultative Group of Experts was invited to participate as an observer[5] during the remote session, no expert was able to attend as a representative. 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, Ghana submitted its proposed FREL/FRL on a voluntary basis. The proposed FREL/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 and/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 Ghana 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 FREL/FRL with a view to supporting the capacity of Ghana to construct and improve its FREL and/or FRL in the future, as appropriate.[8]

4. The TA of the FREL/FRL submitted by Ghana 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 Ghana. The facilitative exchange during the TA allowed Ghana to provide clarifications and additional information, which were considered by the AT in the preparation of this report.[10] As a result of the facilitative interactions with the AT during the TA, Ghana provided a modified version of its submission on 9 February 2022, which took into consideration the technical input of the AT. The modifications improved the clarity and transparency of the submitted FREL/FRL without needing to alter the approach used to construct it. This TA report was prepared in the context of the modified FREL/FRL submission. The modified submission, containing the assessed FREL/FRL, and the original submission are available on the UNFCCC website.[11]

B. Proposed forest reference emission level and 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

[1] The submission of Ghana is available at https://redd.unfccc.int/submissions.html?country=gha.
[2] Owing to the circumstances related to the coronavirus disease 2019, the TAs of the FREL and FRL submissions of developing country Parties in 2021 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.
[11] https://redd.unfccc.int/submissions.html?country=gha.

national circumstances, in the context of providing adequate and predictable support. The FREL/FRL proposed by Ghana, 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, Ghana developed a national FREL/FRL that covers its entire territory (land area of 23.9 million ha), including all nine vegetation zones. For its submission, Ghana applied a stepwise approach to developing its reference levels 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 national FREL/FRL proposed by Ghana for the historical reference period 2001–2015 is the annual average of the net CO_2 eq emissions associated with all three activities: deforestation, forest degradation and enhancement of forest carbon stocks (see table 4 in the modified submission). The Party did not develop individual FRELs or FRLs for each of the selected activities; instead it developed an FREL for the activities reducing emissions from deforestation and reducing emissions from forest degradation and an FRL for the activity enhancement of forest carbon stocks, but then combined these values to present a single FREL/FRL covering the net emissions and removals for all three activities. The FREL/FRL presented in the modified submission corresponds to 19,659,303 t CO_2 eq/year[12] and will be used by Ghana as a benchmark for assessing net emission reductions for each year during 2016–2019.

8. The AD used in constructing the FREL/FRL were estimated on the basis of a stratified systematic sampling approach, including interpretation of sample units in Collect Earth[13] (approach 3 from the 2006 IPCC Guidelines). Ghana stratified forest land by vegetation zone: wet evergreen, moist evergreen, moist semideciduous (northwest and southeast subtypes), upland evergreen, dry semideciduous (fire zone and inner zone forest), savannah and southern marginal. For forest degradation, the AD derived from the sample units were complemented by expert judgment in order to assess areas subject to fire disturbances, and by data on industrial round wood and fuelwood harvesting provided by Ghana's Forestry Commission and Energy Commission. In estimating removals from the enhancement of forest carbon stocks in forest land remaining forest land, Ghana developed a harvest factor for each vegetation zone to distinguish between undisturbed forest and forest subject to logging activities.

9. The EFs used in constructing the FREL/FRL were provided by the Forestry Commission, which derived them on the basis of, inter alia, field plot data (on above- and below-ground biomass, deadwood and litter) and data from airborne light detection and ranging surveys under the Forest Preservation Programme. Although these data were collected at the subnational level, data samples were taken from all nine vegetation zones and then separated into open and closed forest categories, resulting in carbon stock estimates for 18 forest classes. The Forestry Commission also used relevant values from country-specific scientific publications and default values from the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines. For the soil organic carbon pool, the reference soil organic carbon stocks for all strata were obtained from the FAO Global Soil Organic Carbon Map[14] and the stock change factors from the 2006 IPCC Guidelines.

10. The proposed FREL/FRL includes the pools above-ground biomass, below-ground biomass, dead organic matter (litter and deadwood) and soil organic carbon. Harvested wood

[12] In its original submission, Ghana proposed a national FRL of 1,526,457 t CO_2 eq/year for 2001–2015. The difference between the original and the modified submission is due mostly to changes to the AD used (systematic sample grid was enhanced and an additional 7,563 units were analysed in the modified submission, with national data on wood removals and fuelwood used instead of just data from the sampling approach, as well as expert judgment on forest fires). In addition, the soil organic carbon pool was included in the modified submission.

[13] Collect Earth is an image visualization tool developed by Open Foris to facilitate the interpretation of high and medium spatial resolution imagery in Google Earth, Bing Maps and Google Earth Engine. Available at https://openforis.org/tools/collect-earth-online/.

[14] Available at https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/global-soil-organic-carbon-map-gsocmap/en/.

products were excluded. Regarding GHGs, the submission includes CO_2, CH_4 and N_2O. The non-CO_2 gases result from biomass burning in forest land.

11. The FREL/FRL proposed by Ghana is its second reference level submitted in the context of applying the stepwise approach in accordance with decision 12/CP.17, paragraph 10. Its previous modified national FRL was submitted on 3 January 2017 and was subject to a TA in March 2017;[15] it covered the same activities and the same reference period as the current submission. The previous assessed FRL corresponded to 60,670,197 t CO_2 eq/year and was therefore higher than the FREL/FRL proposed in the most recent submission. Ghana included in the executive summary of the modified most recent submission a table highlighting the differences between the first and second submissions.

12. During the TA, Ghana shared with the AT the calculation spreadsheets used in the construction of its FREL/FRL, as well as comprehensive background data and information on the steps involved in deriving its estimates. The spreadsheets enhanced the completeness and transparency of the Party's submission and enabled the AT to reconstruct the proposed FREL/FRL. The AT noted that all elements for the construction of the FREL/FRL could be reconstructed except the biomass calculations. Ghana also shared with the AT its AD collection protocol and a Forest Preservation Programme report (Pasco Corporation, 2013) containing the forest biomass estimates it used, which were not subject to the TA but enhanced the transparency of the submission.

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

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

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

13. For constructing its FREL/FRL, Ghana used the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines, applying the gain–loss method as the basis for estimating emissions and removals in forest land remaining forest land, forest land converted to other land and other land converted to forest land.

14. Land was categorized in accordance with the six IPCC land-use categories: forest land, cropland, grassland, wetlands, settlements and other land. Forest land was classified into nine vegetation zones (see para. 8 above) and, depending on canopy cover density, separated into either open forest (15–59 per cent canopy cover) or closed forest (60 per cent or more canopy cover) categories, resulting in 18 forest classes. In its submission, Ghana described each forest class or vegetation zone. Cropland was subcategorized into annual crops, perennial crops and fallow land, while grassland, wetlands, settlements and other land were not further subclassified.

15. Ghana defines deforestation as the conversion of natural forest to other IPCC land-use categories, and forest degradation as the process in which a forest is disturbed – due to illegal logging, fire, shifting cultivation, infrastructure or (livestock) grazing, resulting in loss of forest quality – but remains a forest. Forest carbon stock enhancement is defined as the creation or improvement of carbon pools and their capacity to store carbon, including as a result of the conversion of other land to forest land or the restoration or recovery of forest land subject to logging activities.

16. The AD for the activities reducing emissions from deforestation and enhancement of forest carbon stocks were derived by visually interpreting the loss of or gain in canopy cover, rather than the loss of or gain in biomass volume. Ghana used Collect Earth and the web-

[15] See document FCCC/TAR/2017/GHA.

based Google Earth Engine, which support the visual interpretation of medium- to very-high-resolution imagery. A stratified systematic sampling grid consisting of 18,009 square units covering the whole country was used with four different sampling designs: a 4 x 4 km grid with 0.5 and 1 ha units applied nationally; a 4 x 4 km grid with 0.5 ha units covering the Ghana Cocoa Forest REDD+ Programme and off-reserve areas; a 2 x 2 km grid with 0.5 ha units covering the high forest zone;[16] and a 1 x 1 km grid with 0.5 ha units covering forest reserves (see also table 14 and figures 5–6 and 22 in the modified submission). The land use of each plot was visually interpreted for each year of the reference period (2001–2015). Inside each plot, a grid containing 49 control points was used to estimate the percentage of coverage of a certain land use within the plot during the reference period. In order to be classified as a certain land use, a plot needed to contain at least 20 per cent of a given land use, following the hierarchical order of the IPCC land-use categories: settlements, cropland, forest, grassland, wetlands and other land. For example, if settlements accounted for 20 per cent of a plot containing forest cover, it was labelled under "settlements". The AD for estimating forest degradation due to forest fires were based on expert judgment. Ghana assumed that 1–5 per cent of the total area of forest as identified by the Collect Earth analysis was disturbed by fire each year. The percentage of fire disturbance for each vegetation zone was determined by expert judgment (see table 27 of modified submission). The annual volume of wood removals (planned and unplanned harvest) and fuelwood removals was sourced from the Forestry and Energy Commissions.

17. Under the Forest Preservation Programme, field plot measurements were taken in pilot sites and the destructive sampling of 116 individual trees and 58 tree roots undertaken to develop allometric equations for estimating above- and below-ground biomass in the 18 forest classes. The field plots were paired with airborne light detection and ranging data strips in order to develop a biomass model. Mean above-ground biomass densities used in the FREL/FRL were obtained from a Forest Preservation Programme report (Pasco Corporation, 2013) for each vegetation zone; these were not available for assessment by the AT. Biomass estimates for the deadwood and litter pools were also provided by the Forestry Commission, derived from field measurements of 252 field plots. Ghana estimated the net emissions from the conversion of forest land to other land, assuming the instantaneous oxidation of all forest carbon stocks in the year of transition. Scientific literature, the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines were used to obtain carbon stocks for the cropland and grassland categories as post-deforestation land uses, including for the above- and below-ground biomass and the annual above-ground biomass accumulation rates. Deadwood and litter pools were assumed to be zero. For forest conversions to wetlands and other land, the post-deforestation carbon stock was assumed to be zero. Soil organic carbon estimates for forest (stratified by vegetation zones), cropland and grassland classes were derived from the Global Soil Organic Carbon Map by extracting the value from the map for each sample of the systematic grid. The growth in forest land remaining forest land was assumed to be linear over a 20-year period and the annual growth rate was derived by dividing above-ground biomass stocks by 20, but the annual growth of undisturbed forest was not included.

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

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

18. The FREL/FRL proposed by Ghana is its second reference level submitted in the context of applying the stepwise approach in accordance with decision 12/CP.17, paragraph 10. The previous FRL submission was subject to a TA in 2017.[17] In its most recent submission, Ghana described changes from previously submitted information in accordance

[16] The high forest zone is located in the southwestern part of the country, consists of rainforest and deciduous forests, is considered a biodiversity hotspot and has the highest precipitation level in the country.

[17] See document FCCC/TAR/2017/GHA.

with decision 12/CP.17, annex, paragraph (b). The Party described the following changes (see also the relevant table in the executive summary of the modified submission):

(a) Landsat satellite imagery was used to generate AD on deforestation for the previous submission, while for the most recent submission AD were generated by interpreting sample units in a systematic grid across the country in Collect Earth;

(b) For the previous submission, AD on forest degradation were based on timber extraction statistics provided by the Forestry Commission, illegal logging data from a peer-reviewed paper, burned areas from the Moderate Resolution Imaging Spectroradiometer Burned Area product, and fuelwood from the Woodfuel Integrated Supply/Demand Overview Mapping methodology; for the most recent submission, national data on wood removals and fuelwood were provided by the Forestry Commission in tabular format, while information on forest fires was obtained from Collect Earth and adjusted on the basis of expert judgment;

(c) AD on areas with enhancement of forest carbon stocks were derived from national statistics on planted areas for the previous submission, and from interpretation of the sample units in Collect Earth and expert judgment for the most recent submission.

19. During the TA, the AT identified the following additional differences in methods and data used between Ghana's previous and most recent submission:

(a) The FREL/FRL was based on an annual average of emissions and removals in the most recent submission, as opposed to a linear projection of emissions in the previous submission;

(b) Harvested wood products were included in the previous submission but excluded from the most recent;

(c) The activity enhancement of forest carbon stocks included only removals from plantations in the previous submission, while the most recent submission included annual increments in areas of forest land subject to harvest, estimated as a proportion of total forest land remaining forest land, and removals from the conversion of non-forest land to forest land.

20. The AT noted the FREL/FRL proposed in the most recent modified submission, of 19,659,303 t CO_2 eq/year, is a third of the FRL of 60,670,197 t CO_2 eq/year proposed in the 2017 submission for the same reference period. The AD values for deforestation differed considerably: 311,880 ha/year in the previous submission compared with approximately 13,000 ha/year in the most recent. In an attempt to understand this large difference, the AT compared the country-specific estimates of deforestation of both FREL/FRLs submitted by Ghana with the independent estimate of tree cover loss provided for Ghana's territory in the Global Forest Watch portal,[18] assuming a tree cover threshold of 15 per cent. The estimate from the portal is approximately 60,000 ha/year between 2001 and 2015. The AT acknowledges that the estimates from a global product are not fully comparable with the country data (e.g. different forest definitions), and this comparison is not a judgment on the quality of the country-specific data in the FREL/FRLs in either submission. Nevertheless, the AT considers that, given the large differences between the estimates in the two submissions (and the independent estimate derived from global satellite-based Earth observation products), additional measures of accuracy would improve confidence in the FREL/FRL estimates. The AT considers including an assessment of the impacts of using different AD sources and methods for constructing the FREL/FRL and the performance of an AD uncertainty analysis as areas for future technical improvement.

21. Ghana submitted its fifth NIR in 2022, covering 1990–2019, and its third biennial update report in 2021.[19] The AT noted that the methods used for developing the FREL/FRL are not consistent with those used for the latest GHG inventory, such as the Party's approach to deriving AD. For the GHG inventory, the Party applied a post-classification change-detection technique to its land-use maps for 1990, 2000, 2010, 2013 and 2019 and used data on fire disturbances from the Moderate Resolution Imaging Spectroradiometer satellite.

[18] Available at https://gfw.global/3jedDy1.
[19] Available at https://unfccc.int/BURs.

During the TA, Ghana expressed its intention to work towards ensuring full consistency between the methods used for developing its FREL/FRL and GHG inventory in the future. The AT also sought clarification as to the different time periods used. Ghana explained that a shorter reference period was applied for constructing the FREL/FRL in order to better reflect the current national circumstances, including pressures on its national forests. The AT acknowledges Ghana's clarifications and commends the Party for its plan to ensure consistency between the FREL/FRL and the GHG inventory.

22. When inspecting the sample units containing information collected from Collect Earth (obtained from the AD database shared with the AT), the AT noted that 42 per cent of the sample units did not contain very-high-resolution imagery or information on the source of the imagery used in the interpretation. Ghana clarified that the interpretation team relied on Planet,[20] which provides data with a spatial resolution of 3–10 m from the RapidEye and PlanetScope satellites starting in 2009 or Sentinel-2 data starting in 2015. As Planet data are only available from 2009 or 2015, for earlier years Ghana used Landsat imagery with a spatial resolution of 30 m. The AT noted the importance of ensuring the consistency of data and methods applied over time. Comparing Landsat data with a spatial resolution of 30 m at the beginning of the reference period with PlanetScope data with a spatial resolution of 3 m at the end of the reference period will inevitably lead to classification errors, particularly in the event of subtle changes in land use. The AT also noted that any such errors were not quantified by the Party. The AT considers that adding quantitative information on the proportion of sample units that rely on high-resolution imagery, on which data source and spatial resolution were used and on the associated errors would enhance the transparency, accuracy and comprehensiveness of the FREL/FRL, and identifies this as an area for future technical improvement.

23. The AT sought clarification on the four different sampling designs applied (see para. 16 above) and asked why smaller grids were used in certain areas but not others. Ghana explained that deforestation and forest degradation were expected to be higher in more forested areas, noting that in the case of the upland evergreen vegetation zone, which covers a very small area, denser sampling was undertaken (a 1 x 1 km grid) in order to ensure a statistically relevant estimate. In the modified submission, Ghana changed its national grid from 8 x 8 km to 4 x 4 km and adjusted the expansion factors accordingly. The AT commends Ghana for its efforts to collect additional data and for increasing the sampling size to ensure better representation of its national territory. In response to a question by the AT, Ghana confirmed that there were no overlaps or duplicate sample units resulting from the transition between different sampling intensities.

24. The Party applied three levels to classify land: the six IPCC land-use categories are considered as level 1 and further subcategories are classified as levels 2–3. These levels were applied in the Collect Earth analysis to identify land use, land-use changes and forest disturbances (see table 8 in the modified submission). The AT noted that fallow land (in level 2) is included in the IPCC land-use category cropland (level 1). However, shifting agriculture (classified in levels 2 and 3 for fire disturbance) is classified as a disturbance in forest land (level 1). The AT sought clarification on the classification of shifting agriculture and asked how the interpreters (i.e. the technical team visually interpreting satellite imagery) ensured consistency in the classification. Ghana responded that, if the land use is forest, shifting agriculture is classified as deforestation. In addition, Ghana shared with the AT its AD collection protocol and further explained that, as part of the quality assurance/quality control procedures, if an interpreter identifies shifting agriculture land, they notify the entire group of interpreters, who then decide on the actual land use and/or land-use change category. The AT commends the Party for the clarifications provided and for sharing the AD collection protocol. However, the AT noted that, in the AD collection protocol, shifting agriculture is described under forest disturbances and not identified as a transient land-use conversion to cropland or deforestation, as mentioned by Ghana during the TA. The AT considers that providing a clear description of shifting agriculture cycles and how the Party ensures consistency in the classification of shifting agriculture would improve the transparency of the FREL/FRL and facilitate the reproducibility of the AD over time and by different teams.

[20] See https://www.planet.com/.

The AT considers the development of a clear protocol for classifying shifting agriculture as an area for future technical improvement.

25. The AT sought additional clarifications on the operationalization of the national forest definition, namely how the land-use categories grassland and cropland are distinguished from forest land, and in which cases the forest definition is not met but has the potential to be. Ghana clarified that the interpreters decide whether the definition of a forest is met according to the location of the sample. For example, land with less than 15 per cent tree cover is classified as a forest if it is located within a forest reserve and there is no evidence of annual or perennial cultivation; by contrast, if the sample is an off-reserve area, the risk factors associated with forest loss are taken into consideration, it is assumed that the area will not be left to regrow to reach the thresholds for a forest, and the sample is classified as either grassland or cropland. The AT acknowledged Ghana's clarifications, which improved the transparency of the FREL/FRL.

26. In interpreting the sample units, Ghana applied a hierarchical classification system based on percentages of land use within the sample (see para. 16 above). The AT noted that, according to IPCC guidance, it is good practice to clearly document the country-specific rules applied to ensure the consistent derivation of land use from land cover information. In response, Ghana shared with the AT its AD collection protocol, which contained useful information on this matter, including examples of how it is applied. However, the AT noted that some important elements required to ensure the consistent classification of land are missing. For example, according to the protocol, transitions from forest land to any other land (cropland, grassland, settlements and other land) are defined by the complete removal of all forest within the unit, which is inconsistent with the hierarchical rules. According to the hierarchical classification system, a unit can be classified as a conversion from forest land to settlements if there is a change from 100 per cent forest to 80 per cent forest and 20 per cent settlement. Further, there are no clear rules in the protocol for distinguishing between forest and perennial tree crops or fallow land according to tree cover. The AT considers that having a protocol with clear, detailed rules and examples, including specific illustrations as supplementary information, in relation to translating land cover information to land use would enhance the transparency of the FREL/FRL and ensure the consistent classification of land over time, and thus notes it as an area for future technical improvement.

27. During the TA, the AT noted that the size of the sample unit used to identify land use and land-use change was 0.5 ha, which differs from the 1.0 ha minimum mapping unit in the national definition of forest. The AT noted that identifying forest land in 0.5 ha samples could result in the number of forest areas, and thus areas of deforestation, being overestimated. In response, Ghana assessed the impact of using sample units of 0.5 ha compared with 1.0 ha to derive deforestation estimates and confirmed that more areas of deforestation were detected when the 0.5 ha sample units were used. In the modified submission, Ghana increased the intensity of its sampling by an additional 7,563 sample units, each 1.0 ha in size. The AT commends Ghana for the information on this matter and notes the Party's efforts to adhere to IPCC guidance. However, the AT is of the view that ensuring consistency in the methodology used in terms of both space and time is more important than the size of the sample units, and notes that, in future submissions, Ghana could provide information showing how the differing sample unit sizes and their distribution in the different forest classes affect the accuracy of the estimates. The AT identifies this as an area for future technical improvement.

28. In the original submission, as part of the Collect Earth land-use classification exercise, Ghana identified burned areas in forest land and converted forest land. During the TA, the AT noted that the calculation spreadsheets shared with it did not show any fire occurrences in forest land converted to other land-use categories. Given the frequency with which fires occur in African savannahs and the rapid recovery of vegetation thereafter, the AT noted that if fires were only identified through Google Earth imagery (and thus at low temporal resolution), it is very likely that the amount of burned areas was underestimated in the submission. Ghana informed the AT that it is planning to use a variety of remote sensing sensors coupled with field-based data to assess fires in the country in the future. In the modified submission, the Party modified its approach to quantifying fire disturbances by applying an expansion factor to areas identified as burned. The percentage of areas burned

per forest stratum was derived from expert judgment communicated by the Forestry Commission. The AT found little information in the submission and accompanying spreadsheets on this expert judgment procedure and considers that Ghana may wish to include such information in future submissions to enhance transparency, noting this as an area for future technical improvement. The AT welcomes Ghana's intention to explore ways of quantifying forest areas affected by fire and also notes this as an area for future technical improvement.

29. The AT noted that, in addition to the nine vegetation zones, an additional class (mangroves) was mentioned in the submission. Ghana clarified that since mangroves are a unique ecosystem, they were categorized as a separate forest cover type during the data-collection process. It also clarified that no plots were measured in mangrove areas, however, and mangroves are not considered as a vegetation zone, with mangroves that met the forest definition being classified as forest. The AT acknowledges this information, which enhances the transparency of the submission. The AT considers ensuring full coverage of all forest zones, including mangroves, as an area for future technical improvement.

30. Above-ground biomass data for forest classes were sourced from a Forest Preservation Programme report (Pasco Corporation, 2013). The AT noted that the pilot area, in which 20 x 20 m field plots were established and systematic light detection and ranging strips collected, corresponds to approximately 7 per cent of the national territory and may not be entirely representative of the national forests. The AT also compared the above-ground biomass estimates for the nine vegetation zones with IPCC default values.[21] The above-ground biomass estimates for the zones moist semideciduous northwest (83.9 t dm/ha), dry semideciduous fire zone (32.3 t dm/ha), inner zone (47.8 t dm/ha), savannah (36.5 t dm/ha) and southern marginal (22.13 t dm/ha) are lower than the default values in the 2006 IPCC Guidelines of 260 (160–430) t dm/ha for tropical moist deciduous forest and 120 (120–130) t dm/ha for tropical dry forest. Nevertheless, they are within the ranges of the updated default values in the 2019 Refinement to the 2006 IPCC Guidelines of 69.6 (±47.5) t dm/ha and 48.4 (±45.8) t dm/ha) respectively, and are also consistent with the value of 37.5 t dm/ha for Ghana's national territory based on independent estimates from the Global Ecosystem Dynamics Investigation light detection and ranging mission (as detailed in the report by Dubayah et al., 2022). Ghana acknowledged that its field sampling intensity is extremely low for producing accurate plot-based mean values. However, the Party considers that using country-specific data is still preferable to using IPCC default values. Furthermore, it clarified that, although the pilot area only corresponds to 7 per cent of the national territory, it covers all nine vegetation zones and is representative of the diversity of the national landscape. The AT is of the view that the transparency of the submission would be enhanced if Ghana included further information justifying the application of data measured at the subnational level to the entire national territory. Such information would improve the accuracy of the estimates at the national level, and the AT considers this as an area for future technical improvement.

31. Although a short description of the Forest Preservation Programme is included in the submission, the AT is of the view that highlighting the components of the Programme used in constructing the FREL/FRL would enhance the transparency of the submission. For example, on inspecting the biomass data provided under the Programme, the AT noted that some forest types have either no or insufficient plot data from which to derive above-ground biomass. The AT sought clarification from Ghana as to how carbon stocks were derived for those forest classes. In response, Ghana shared a Forest Preservation Programme report (Pasco Corporation, 2013), which contained above-ground biomass values, enabling the AT to link the estimates to those in the spreadsheet used for constructing the FREL/FRL. The AT noted that the above-ground biomass values used were not from the field plots but from a light detection and ranging model developed during the Forest Preservation Programme period. During the TA, Ghana confirmed that light detection and ranging footprints were used in combination with destructive and ground sampling to derive mean above-ground biomass values and confidence intervals for the forest classes for each vegetation zone. Ghana ensured that the approach was robust, transparent and easy to replicate. The AT commends Ghana for

[21] See table 4.7 in vol. 4, chap. 4, of the 2006 IPCC Guidelines and the updated table in the 2019 Refinement to the 2006 IPCC Guidelines.

providing this additional information. The AT is of the view that the transparency of future submissions could be enhanced by clearly documenting the underlying sources of data and describing the methodology used to develop the models for biomass estimation, and identified this as an area for future technical improvement. It noted that such documentation could include a description of the model and information on whether the average biomass stocks stem from the model applied at the pilot site or were extrapolated to apply to the national level; the rationale for using light detection and ranging strips; a description of the methodology for calibrating information obtained from the strips with the measurements from the sample plots; and a description of how the model was validated and uncertainty measured.

32. Annual biomass increments were only included in the submission for forest subject to logging, while undisturbed forest was not included in the forest biomass gain estimates. As the statistics on harvested logs used by Ghana are not spatially explicit, Ghana developed a harvest factor for each vegetation zone using the Collect Earth reference data set and expert judgment. This factor (ranging from 2 to 35 per cent) was multiplied by the total area of forest remaining forest in each stratum (i.e. AD) and then by the corresponding annual growth factor. This means that, depending on the zone, 2–35 per cent of the area could be considered as disturbed forest and the corresponding annual biomass growth of that area included in the forest biomass gains. The annual biomass growth was calculated for each zone using the weighted average of open and closed forests, and derived by dividing the above-ground biomass stock provided by the Forest Preservation Programme by 20 (owing to the assumption that stability is reached at 20 years). The AT noted that the annual growth values used by Ghana are higher than the IPCC default values for annual above-ground biomass growth.[22] For example, the weighted average biomass growth for the wet evergreen vegetation zone used by the Party was 12.94 t dm/ha/year, while the IPCC default for African tropical rainforests is 7.6 t dm/ha/year for secondary forests less than 20 years old. This value is also higher than those used in Ghana's fifth NIR (1.6 t dm/ha/year). The AT also noted that applying an annual biomass increment for young forests (under 20 years old) to the area subject to harvesting may result in removals being overestimated. The AT considers the justification of the annual biomass growth parameters selected for forest land remaining forest land as an area for future technical improvement.

33. During the TA, the AT noted a discrepancy between the values pertaining to annual cropland growth reported in one of the literature sources and those used in the calculations. In response, Ghana clarified that there was no discrepancy, but that the biomass obtained from the literature was divided by years of crop maturity in order to obtain an annual increment. For example, the above-ground biomass value for cocoa obtained from Feuer (2013) is 76.2 t C/ha and the Party divided this value by 30 (number of years) to obtain an annual increment (2.54 t C/ha or 5 t dm/ha). Ghana also clarified that in forest land converted to perennial crops or left as fallow land, the biomass increment is applied in the year of conversion and every year thereafter until the maximum stock is reached (20 years for perennial and 5 years for fallow land). The AT acknowledges this information, which enhanced the transparency and completeness of the submission.

34. In the original submission, the average values from Adu-Bredu et al. (2008) were used for above-ground biomass in fallow land. The AT noted that the value of 66.3 t C/ha (or 132.60 t dm/ha) was more than 10 times greater than the default IPCC value for above-ground biomass for one-year-old fallow land (12 t dm/ha). The AT also noted that the values from Adu-Bredu et al. (2008) appear to be for total carbon stocks and include herbaceous and woody biomass, litter and soil (at depths of 0–20 and 20–40 cm). Although the authors did not include information on the age of the fallow land, Ghana assumed that the carbon stocks corresponded to a five-year accumulation. In the modified submission, Ghana replaced the five-year accumulated biomass stock from Adu-Bredu et al. (2008) with the default values from the 2019 Refinement to the 2006 IPCC Guidelines, which show the biomass stock immediately after conversion. The AT commends Ghana for its efforts to increase the accuracy of the estimates.

[22] See table 4.9 in vol. 4, chap. 4, of the 2006 IPCC Guidelines.

35. The IPCC definition of good practice requires that emissions and removals be neither overestimated nor underestimated, with uncertainties reduced as far as practicable. The AT noted that Ghana did not quantify the bias of the FREL/FRL estimates or identify the different sources of bias. The AT acknowledges the Party's efforts to reduce bias in the AD estimates by using more interpreters and including quality control measures in the calculation spreadsheet. However, the AT is of the view that, since Ghana uses a systematic probability sampling design approach to derive AD, this bias could have been quantified. In response, Ghana informed the AT during the TA that its interpreters were in agreement 79 per cent of the time during the visual interpretation procedure and shared diagrams demonstrating examples of agreement between different interpreters. The AT considers that this information enhances the transparency of the submission and advises Ghana to consider including such information in future submissions. The AT identifies quantifying the classification bias and uncertainty of the AD estimates, as well as including measures of uncertainty of the estimates from the field biomass plot and of the model derived from remotely sensed light detection and ranging data as areas for future technical improvement.

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

36. In its submission (chap. 5, table 3), Ghana referred to its well-established range of laws, regulations and policies governing or having an impact on its forest sector, including several relating to climate change, implementation of climate action, sustainable management of forest and land, and development of national tree crops, in particular in the cocoa sector.

37. Ghana also noted in its submission that, to address the issue of rapidly diminishing forest resources, the Government has introduced a forestry policy involving the compulsory reforestation of cutover areas, the more accurate measurement of exploitable timber and rates of extraction and regeneration, and a ban on the export of round logs.

38. In addition, Ghana mentioned the provision of support by the World Bank for its work under the subnational cocoa forest REDD+ programme; technical support received from the Coalition for Rainforest Nations for the scaling up of subnational REDD+ estimation methodologies for use at the national level; and support from FAO for building the capacity of the in-country technical team to operate the Collect Earth tool.

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

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

40. The pools included in the Party's FREL/FRL are above-ground and below-ground biomass, deadwood, litter and soil organic carbon.

41. The carbon stocks in the above- and below-ground biomass pools for all forest strata were derived from information under the Forest Preservation Programme. Under the Programme, allometric equations were developed in order to estimate above- and below-ground biomass values. As the equations applied were not published, the AT considers that the transparency of the submission could be enhanced if Ghana provided more information on the sampling size used to derive the equations and the ranges of dendrometric variables used, such as the minimum and maximum diameters at breast height derived from the destructive samples collected. The AT considers providing such information in future submissions as an area for future technical improvement.

42. In the original submission, the AT noted that the reference source for below-ground biomass was inconsistent and unclear. During the technical assessment, Ghana clarified that the relevant tables in the original submission were mislabelled and the below-ground biomass values per forest stratum used were estimated using the root-to-shoot data developed by the Forest Preservation Programme, which used field plot measurements. The AT was able to confirm from the calculation spreadsheet that below-ground biomass equalled zero in the forest classes with no field plot biomass measurements (dry semideciduous fire zone forest, closed forest and savannah closed forest) (see table 28 in the modified submission). However,

the AT found an exception in the wet evergreen open forest class. This class had no measured plots but included a below-ground biomass estimate calculated from the root-to-shoot ratio. The AT commends Ghana for correcting the relevant references and table titles in the modified submission and for the clarifications provided. Ghana may want to include in future submissions a more detailed description of the below-ground biomass calculation, in particular the root-to-shoot ratio applied for the wet evergreen open forest class.

43. With regard to emissions and removals in forest land remaining forest land in the deadwood and litter pools, Ghana assumed that the carbon stocks did not change over time. Thus, the carbon lost in the biomass pool due to forest disturbance was assumed to be released immediately into the atmosphere in the year of the event and not move between pools. Carbon stock estimates for the deadwood and litter pools were provided by the Forestry Commission and derived from field measurements for each of the nine vegetation zones, without being disaggregated into open and closed forest. The AT found these estimates to be high. According to IPCC good practice, the maximum bound for carbon in deadwood is 25 per cent of that in live biomass pools. However, the AT noted that for five of the nine vegetation zones, the estimated stocks are higher than the above-ground biomass stocks within the same zone. For example, for upland evergreen, the above-ground biomass was 69.45 t C/ha, while the carbon stock in the deadwood pool was 195.38 t C/ha (see table 36 in the modified submission). The AT commends Ghana for including all significant pools and using national data in constructing its FREL/FRL, but identifies assessing the accuracy of national estimates of carbon stocks in the deadwood pool as an area for future technical improvement.

44. Ghana extracted soil organic carbon reference values from the FAO Global Soil Organic Carbon Map for each sample unit (from the Collect Earth exercise) and then computed average soil organic carbon values by vegetation zone. The AT noted that insufficient information is given on how the Map was constructed, in which year and whether national soil surveys were taken into account in its development. The AT also noted that the reference soil organic carbon values obtained from the Map range between 31.65 and 55.62 t C/ha, which is consistent with the IPCC default values for the tropical dry and tropical moist climate zones of 31–65 t C/ha. Following the 2006 IPCC Guidelines, Ghana applied an annual increment covering a period of 20 years after the conversion of non-forest land to forest land. For all other land-use conversions, the Party assumed that emissions from soils following conversion occurred exclusively in the year of conversion. The AT noted that the same methodological choice was made in the 2017 modified FRL. The AT considers providing further information on the methodological decisions taken when reporting reductions or increments in the soil organic carbon pool over a period of 20 years after land conversion as an area for future technical improvement.

45. The spreadsheet that accompanied the original submission did not contain sufficient information on biomass to allow the reconstruction of the EFs. During the TA, Ghana shared another spreadsheet with the AT, which provided an analysis of its plot measurements. In that spreadsheet, the AT identified an error in the deadwood stock conversion from t C/ha to t CO_2/ha. In response, Ghana corrected the values and explained that the error was a transpositional error that occurred when entering values into the spreadsheet, but noted that it did not affect the computation of the totals. The AT commends Ghana for correcting the values and checking whether this error had any impact on subsequent calculations.

46. Ghana included both CO_2 and non-CO_2 emissions (CH_4 and N_2O) in the construction of the FREL/FRL. Non-CO_2 gases were included in the estimates as emissions from forest fires (resulting in forest degradation). The fuel available was derived as a fraction (based on expert judgment) of biomass in the above-ground biomass, deadwood and litter pools, and default values from the 2006 IPCC Guidelines were used for the EFs in the equation for estimating annual carbon losses from fire disturbances.

47. The AT acknowledges that Ghana included in its FREL/FRL the most significant activities reducing emissions from deforestation, reducing emissions from forest degradation and enhancement of forest carbon stocks of the five activities identified in decision 1/CP.16, paragraph 70, in accordance with its national capabilities and circumstances. The AT acknowledges the Party's intention to improve future FREL and/or FRL submissions when new and adequate data and better information become available as part of the stepwise approach.

4. Definition of forest

48. Ghana provided in its submission the definition of forest used in constructing the FREL/FRL: minimum area of 1 ha with trees that have the potential to reach a minimum height of 5 m at maturity. Forest canopy cover is defined differently for open and closed forest, with closed forest having a canopy cover of greater than 60 per cent and open forest with a canopy cover between 15–59 per cent. The term forest also includes systems with a vegetation structure that currently fall below this threshold but may reach the national threshold. Timber tree plantations are considered as forest under the national forest definition but agricultural trees, including cocoa, citrus, oil palm (in smallholder or estate plantations) and rubber plantations, are excluded. These definitions are the same as those used by the Party for its national GHG inventory in the fifth NIR and its reporting to FAO for the Global Forest Resources Assessment.

III. Conclusions

49. The information used by Ghana in constructing its FREL/FRL for the activities reducing emissions from deforestation, reducing emissions from forest degradation and enhancement of forest carbon stocks is transparent, complete[23] and in overall accordance with the guidelines for submissions of information on reference levels.

50. The reference level presented in the submission is Ghana's second reference level. The previous FRL was submitted on January 2017 and was subject to a TA in the same year; it covered the activities reducing emissions from deforestation, reducing emissions from forest degradation and enhancement of forest carbon stocks for 2001–2015.

51. The FREL/FRL presented in the most recent modified submission, for the reference period 2001–2015, corresponds to 19,659,303 t CO_2 eq/year.

52. The AT acknowledges that Ghana included in its FREL/FRL the most significant activities, the most important forest classes and the most significant pools in terms of emissions and removals from forests. The AT considers that, in doing so, Ghana followed decision 1/CP.16, paragraph 70, on activities undertaken and decision 12/CP.17, paragraph 10, on applying the stepwise approach. The AT commends Ghana for providing information on its ongoing work to improve data and information on mapping, sampling, AD and EFs and broaden the scope of future FRELs and/or FRLs to include other activities as part of the stepwise approach towards constructing a national FREL and/or FRL.

53. As a result of the facilitative interactions with the AT during the TA, Ghana provided a modified submission that took into consideration the technical input of the AT. The AT notes that the transparency and completeness of the information provided were significantly improved in the modified FREL/FRL submission and commends Ghana on its efforts. The new information provided in the modified submission increased the reproducibility of the reference level calculations.

54. The AT notes that, overall, Ghana did not maintain consistency, in terms of sources of AD and EFs used for its FREL/FRL, with those used for the GHG inventory included in its third biennial update report and fifth NIR.[24]

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

(a) Including an AD uncertainty analysis and an assessment of the impacts of the changes in AD sources and methods used between submissions (see para. 20 above);

(b) Including quantitative information on the proportion of sample units with very-high-resolution imagery, the types of data sources and the spatial resolution used and associated errors (see para. 22 above);

[23] To the extent permitted by available national data (i.e. excluding the biomass calculations provided by the Forest Preservation Programme for the FREL/FRL (see paras. 30–32 above) but not available for the reconstruction of the FREL/FRL by the AT).

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

(c) Developing a clear protocol for ensuring the consistent classification of shifting agriculture (see para. 24 above);

(d) Developing a protocol with clear rules in order to translate land cover information to land use, using specific illustrations as supplementary information (see para. 26 above);

(e) Ensuring spatial and temporal consistency in the sample units and providing an assessment of the impacts of selecting different sample sizes (see para. 27 above);

(f) Explaining the expert judgment procedure for quantifying AD on fire disturbances and including such information in future submissions (see para. 28 above);

(g) Considering including mangroves as an additional forest class (see para. 29 above);

(h) Justifying the application of EFs derived from subnational data and working to use representative EFs in future submissions (see para. 30 above);

(i) Clearly documenting the underlying sources of data and describing the methodology used to develop biomass estimation models (see para. 31 above);

(j) Justifying the selection of annual biomass growth parameters for estimating gains in forest land remaining forest land in future submissions (see para. 32 above);

(k) Quantifying the classification bias associated with estimating AD using a systematic sampling approach as well as including measures of uncertainty of the estimates from field biomass plots and of the model derived from remotely sensed light detection and ranging data (see para. 35 above).

56. Pursuant to decision 13/CP.19, annex, paragraph 3, the AT identified the following additional areas for future technical improvement regarding pools and gases included in the FREL/FRL:

(a) Provision of more information on the sampling size used to derive the allometric equations for estimating above- and below-ground biomass and the ranges of dendrometric variables used, derived from the destructive samples collected (see para. 41 above);

(b) Assessment of the accuracy of national estimates of carbon stocks in the deadwood pool (see para. 43 above);

(c) Provision of further information on methodological decisions taken when reporting reductions or increments in the soil organic carbon pool over a period of 20 years after land conversion (see para. 44 above).

57. The AT acknowledges and welcomes the Party’s intention to:

(a) Improve the accuracy and precision of its AD estimates by adding more sample units and changing the sample unit size to 1 ha for consistency with the minimum area that constitutes forest land in the national forest definition;

(b) Increase the accuracy of its fire disturbance estimates in order to complement the expert judgment approach applied (see para. 28 above);

(c) Include an AD uncertainty analysis;

(d) Increase the accuracy of the EFs used by reviewing the data produced under the Forest Preservation Programme and complementing those data with additional studies;

(e) Broaden the scope of the FREL/FRL by including the activity sustainable management of forests;

(f) Improve the accuracy of national wall-to-wall land cover maps and use them for stratification purposes in the AD sampling design.

58. In conclusion, the AT commends Ghana for showing strong commitment to continuously improving its FREL/FRL estimates in line with the stepwise approach. A number of areas for the future technical improvement of Ghana’s FREL/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.[25] The AT also acknowledges that the TA was an opportunity for a rich, open, facilitative and constructive technical exchange of information with Ghana.

59. The table contained in annex I summarizes the main features of Ghana's proposed FREL/FRL.

[25] 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 emission level and forest reference level based on information provided by Ghana

Main features of the FREL/FRL		*Remarks*
Proposed FREL/FRL	19 659 303 t CO_2 eq/year	The FREL/FRL includes net emissions from three activities (deforestation, forest degradation and enhancement of forest carbon stocks) (see para. 7 of this document)
Type and reference period of FREL/FRL	FREL and FRL = average of historical emissions and removals in 2001–2015	See paragraphs 6–7 of this document
Application of adjustment for national circumstances	No	
National/subnational	National	The scope of the FREL/FRL is national and all land in the national territory is included (see para. 6 of this document)
Activities included	Reducing emissions from deforestation Reducing emissions from forest degradation Enhancement of forest carbon stocks	Ghana included emissions from forest land remaining forest land and removals from areas of forest subject to logging, net emissions from the conversion of forest land to a new land use, and removals from the conversion of non-forest land to forest land (see paras. 6–7 of this document)
Pools included	Above-ground biomass Below-ground biomass Deadwood Litter Soil organic carbon	See paragraph 10 of this document
Gases included	CO_2, CH_4, N_2O	The non-CO_2 emissions stem mainly from biomass burning in forest land (see paras. 10 and 46 of this document)
Forest definition	Included	Minimum canopy cover of 15 per cent, minimum height of 5 m and minimum area of 1 ha (see para. 48 of this document)
Consistency with latest GHG inventory	Methods used for estimating the FREL/FRL are not consistent with those used for the latest GHG inventory (2022)	Ghana stated its intention to work towards ensuring consistency between the methods used for the FREL/FRL and the GHG inventory (see para. 21 of this document)
Description of relevant policies and plans	Included	See paragraphs 36–38 of this document

Main features of the FREL/FRL		*Remarks*
Description of assumptions on future changes to domestic policy, if included in constructing the FRL	Not applicable	–
Description of changes to previous FRL	Included	See paragraphs 18–19 of this document
Identification of future technical improvements	Included	Several areas for future technical improvement have been identified (see paras. 55–56 of this document)

Annex II

Reference documents

A. Reports of the Intergovernmental Panel on Climate Change

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.

IPCC. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. E Calvo Buendia, K Tanabe, A Kranjc, et al. (eds.). Geneva: IPCC. Available at https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html.

B. UNFCCC documents

First original and modified FRL submissions and second original and modified FREL/FRL submission of Ghana. Available at https://redd.unfccc.int/submissions.html?country=GHA.

"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.

Report on the TA of the proposed FRL of Ghana submitted in 2017. FCCC/TAR/2017/GHA. Available at https://redd.unfccc.int/submissions.html?country=GHA.

C. Other documents

The following references may not conform to UNFCCC editorial style as some have been reproduced as received or as cited in the submission:

Adu-Bredu S, Abekoe MK, Tachie-Obeng E and Tschakert P. 2008. "Carbon stock under four land-use systems in three varied ecological zones in Ghana." *Proceedings of the Open Science Conference on "Africa and Carbon Cycle: The Carbon Africa project". Accra, Ghana 25–27 November 2008*. In: *World Soil Resources Reports 105 (Africa and the Carbon Cycle)*, 2011. Bombelli A and Valentini R (Eds.). Rome: Food and Agriculture Organization of the United Nations.

PASCO Corporation, Japan. 2013. Forest Preservation Programme Report on Mapping of Forest Cover and Carbon Stock in Ghana. In collaboration with FC-RMSC, CSIR-FORIG and CSIR-SRI, Ghana.

Protocol for Activity Data Collection (shared by Ghana with the AT).

Feuer M. 2013. *Land use systems in Ghana's Central Region and their potential for REDD+*. Bachelor Thesis. Zollikofen, Switzerland: School of Agricultural, Forest and Food Sciences, Bern University of Applied Sciences.

Dubayah R, Armston J, Healey SP, et. al. 2022. GEDI launches a new era of biomass inference from space. *Environ. Res. Lett.* 17(9). https://dx.doi.org/10.1088/1748-9326/ac8694.