Draft Afforestation and reforestation baseline methodology AR-AM000X

"Afforestation and Reforestation of Land Currently Under Agricultural or Pastoral Use"

Source

This methodology is based on the draft CDM-AR-PDD "Chocó-Manabí Corridor Reforestation and Conservation Carbon Project" whose baseline study, monitoring and verification plan and project design document were prepared by EcoSecurities Consult, Britain; Joanneum Research, Austria; Conservation International, USA; and EcoDecision. For more information regarding the proposal and its consideration by the Executive Board please refer to case ARNM0021-rev: "Chocó-Manabí Corridor Reforestation and Conservation Carbon Project" at: http://cdm.unfccc.int/methodologies/ARmethodologies/process?OpenRound=11&OpenNM=ARNM0021-rev&cases=B#ARNM0021-rev

Section I. Summary and applicability of the baseline and monitoring methodologies

1. Selected baseline approach from paragraph 22 of the CDM A/R modalities and procedures

"Existing or historical, as applicable, changes in carbon stocks in the carbon pools within the project boundary"

2. Applicability

This methodology is applicable to the following project activities:

- Afforestation or reforestation activities undertaken on pasture, agricultural land or abandoned lands; land use change is allowed in the baseline scenario.

The conditions under which this methodology is applicable to A/R CDM project activities are:

1. Lands to be afforested or reforested are currently pasture or agricultural land or abandoned lands.
2. Environmental conditions, human-caused degradation or ongoing human activities do not permit the spontaneous encroachment of natural forest vegetation.
3. The application of the procedure for determining the baseline scenario in section II.4 leads to the conclusion that the baseline approach 22(a) (existing or historical changes in carbon stocks in the carbon pools with the project boundary) is the most appropriate choice for determination of the baseline scenario. This implies that only land uses that currently form part of the land use pattern within the analyzed area are plausible alternative land uses for the baseline scenario.
4. Biomass of non-tree vegetation is in a steady-state or decreasing for all baseline land uses; for rotational land-use systems, peak biomass over the rotation has to be constant or decreasing over several rotations.
5. Lands will be afforested or reforested by direct planting and/or seeding.
6. Site preparation does not cause significant longer term net decreases of soil carbon stocks or increases of non-CO_2 emissions from soil carbon. In particular, soil disturbance is insignificant, so that CO_2 and non CO_2-greenhouse gas emissions from these activities can be neglected. Soil drainage is not permitted.
7. Flooding irrigation is not permitted.
8. Greenhouse gas emissions from denitrification due to the use of nitrogen-fixing species are not significant.
9. Plantation may be harvested with either short or long rotation and will be regenerated either by

direct planting, sowing, coppicing or assisted natural regeneration

10. For each of the alternative land uses being part of the baseline scenario, carbon stocks in soil-organic carbon can be expected to decrease more or increase less in the absence of the project activity, relative to the project scenario.
11. All of the plausible land use changes being part of the baseline scenario shall lead only to such changes in soil organic carbon stocks that the stocks can be expected to decrease more or increase less, relative to afforestation/reforestation of the project area.
12. This methodology does not account for displacement of landowners that lose their farms due to the project activity. If this leakage occurs, this methodology is not applicable.
13. The project proponents have the managerial power to stop pre-project activities without shifting them to the outside of the project boundary. Upon project start, the pasture and agricultural activities are terminated. This does not only mean, that they end on the project sites, but also that there is no continuation of these activities to new areas outside the project boundaries. Pre-project livestock shall not be displaced somewhere else, but slaughtered or sold to be slaughtered.
14. There are sufficient areas where the land is used below its sustainable capacity in the vicinity to the project area, within the same market area. These areas are sufficiently large to absorb the possible displacement of pre-project productive capacities due to market effects.

The use of a Geographical Information System (GIS) platform and the use of Global Positioning System receivers are recommended.

3. Selected carbon pools:

Table 1: Selection and justification of carbon pools

Carbon pools	Selected (answer with Yes or No)	Justification / Explanation of choice
Above ground	Yes	Major carbon pool subjected to the project activity
Below ground	Yes	Major carbon pool subjected to the project activity
Deadwood	Yes	Major carbon pool subjected to the project activity
Litter	Yes	Major carbon pool subjected to the project activity
Soil organic carbon	No	Excluded. Conservative approach under applicability conditions

4. Summary of baseline and monitoring methodologies

<u>Baseline methodology steps</u>

The baseline methodology is structured into the following steps:

Step 1: Demonstrate the applicability of the methodology to the specific project activity.

Step 2: The project boundary is defined for all discrete parcels of land to be afforested or reforested and that are under the control of the project participants at the starting date of the project activity. The methodology also provides rules for including in the project area discrete parcels of land not yet under the control of the project participants at the starting date of the proposed A/R CDM project activity but expected to become under the control of the project participants during the crediting period.

Step 3: The eligibility of land for an A/R CDM project activity is demonstrated based on definitions provided in p33aragraph 1 of the annex to the decision 16/CMP.1 ("Land use, land-use change and forestry"), as requested by decision 5/CMP.1 ("Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol"), until new procedures to demonstrate the eligibility of lands for afforestation and reforestation project activities under the clean development mechanism are approved by the Board.

Step 4: Stratification of the A/R CDM project area is based on local site classification map/table, the most updated land-use / land-cover maps, satellite image, soil map, vegetation map, landform map as well as supplementary surveys, and the baseline land-use / land-cover is determined separately for each stratum.

a) Sub-step 1. Stratification according to the baseline projections.
b) Sub-step 2. Stratification according to the project scenario.
c) Sub-step 3. Final ex-ante stratification

Step 5: This methodology applies approach 22(a), taking into account historical land use/cover changes, national, local and sectoral policies that influence land use within the boundary of the proposed A/R CDM project activity, economic attractiveness of the project relative to the baseline, and barriers for implementing project activities in absence of CDM finance. The baseline approach 22(a) is applied to extrapolate past land use change trends into the future over the crediting period.
The baseline scenario is determined by the following steps:

a) Identify and list plausible alternative land uses on the project lands
b) Map current and historical land use
c) Derive land-use change trends
d) Extrapolate the observed past trends into the future.

Step 6: Determination of baseline carbon stock changes. The baseline carbon-stock changes are estimated based on the identified baseline land-use scenario (step 5).
For strata without growing trees or woody perennials, this methodology assumes that the carbon stock in above-ground and below-ground biomass, as well as deadwood and litter would remain constant in the absence of the project activity, i.e., the baseline net GHG removals by sinks are assumed to be zero.
For strata with a few growing trees or woody perennials, the baseline net GHG removals by sinks are estimated based on the carbon stock changes in above-ground and below-ground biomass (in living trees), litter and deadwood.
To estimate carbon stock decreases due to land preparation for planting, this methodology conservatively estimates the highest carbon stock in above-ground and below-ground living biomass, as well as deadwood and litter that exists through the current land use cycle.
The loss of non-tree living biomass on the site due to competition from planted trees or site preparation is accounted as a carbon stock decrease within the project boundary, in a conservative manner.
The omission of the soil organic matter can considered to be conservative if it can be justified that this pool would decrease more or increase less in the absence of the proposed A/R CDM project activity, relative to the project scenario. This assumption has to be demonstrated through pre-project measurements in representative pastures, agricultural lands and forest areas, or alternatively based on scientific literature.

Step 7: *Ex ante* actual net GHG removal by sinks are estimated for each type of stand to be created with the A/R CDM project activity. Stand types are represented by a description of the species planted or regenerated and the management prescribed (species, fertilization, thinning, harvesting, etc.). Carbon stock changes and the increase of GHG emissions resulting from fertilization, site preparation (biomass burning) and fossil fuel consumption are estimated using methods developed in IPCC GPG-LULUCF (IPCC 2003)[1] and IPCC (1997)[2].

Step 8: This methodology uses the latest version of the *"Tool for the demonstration and assessment of additionality for afforestation and reforestation CDM project activities"* approved by the CDM Executive Board[3].

Step 9: Leakage emissions, including carbon stock decreases outside the project boundary, are accounted for the following sources: fossil fuels consumption for transport of staff, products and services; displacement of the former employees on the lands, leakage from the increased use of wood posts for fencing and from the displacement of fuel-wood collection.

Monitoring methodology steps

This methodology includes the following elements:
Step 1: The overall performance of the proposed A/R CDM project activity is monitored, including the integrity of the project boundary and the success of forest establishment and forest management activities.

Step 2: Stratification of the project area is monitored periodically as the boundary of the strata may have to be adjusted to account for unexpected disturbances, changes in forest establishment and management, or because two different strata may become similar enough in terms of carbon to justify their merging.

Step 3: Baseline net GHG removals by sinks are not monitored in this methodology. The ex-ante estimate is "frozen" on a per area-unit basis for the entire crediting period.

Step 4: The calculation of ex-post actual net GHG removals by sinks is based on data obtained from permanent sample plots and methods developed in IPCC GPG-LULUCF to estimate carbon stock changes in the carbon pools and increase of project emissions due to fossil fuel consumption and nitrogen fertilization.

Step 5: Leakage due to vehicle use for transportation of staff, seedlings, timber and non-forest products, as a result of the implementation of the proposed A/R CDM project activities is monitored.

Step 6: Leakage due to displacement of employees from the project area to other areas, the increased use of wood posts for fencing and the displacement of fuel-wood collection outside the project boundary is monitored.

Step 7: A Quality Assurance/Quality Control plan, including field measurements, data collection verification, data entry and archiving, as an integral part of the monitoring plan of the proposed A/R CDM project activity, to ensure the integrity of data collected and improve the monitoring efficiency.

---

[1] IPCC (2003): Good practice guidance for land use, land-use change and forestry. Institute for Global Environmental Strategies (IGES), Hayama.
[2] IPCC (1997): Revised 1996 IPCC guidelines for national greenhouse gas inventories; Volume 3: Greenhouse gas inventory reference manual, http://www.ipcc-nggip.iges.or.jp/public/gl/invs6.htm
[3] Throughout this document, "A/R additionality tool" refers to the document approved by the Executive Board of the CDM and available at the following URL: http://cdm.unfccc.int/EB/Meetings/021/eb21repan16.pdf.

The baseline net GHG removals by sinks do not need to be measured and monitored over time. However, the methodology checks and re-assesses the baseline assumptions if a renewable crediting period is chosen.

This methodology uses permanent sample plots to monitor carbon stock changes in living tree biomass pools. The methodology first determines the number of plots needed in each stratum/sub-stratum to reach the targeted precision level of ±10% of the mean at the 95% confidence level. GPS is used to locate plots.

Section II. Baseline methodology description

1. Project boundary

This methodology demonstrates eligibility of A/R CDM project activities based on definitions provided in paragraph 1 of the annex to the decision 16/CMP.1 ("Land use, land-use change and forestry"), as requested by decision 5/CMP.1 ("Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol"), until new procedures to demonstrate the eligibility of lands for afforestation and reforestation project activities under the clean development mechanism are approved by the Board.

The boundary of the proposed A/R CDM project activity shall be defined as follows:

Step 1: The project boundary shall geographically delineate and encompass all anthropogenic GHG emissions by sources and removals by sinks on lands under the control of the project participants that are significant and reasonably attributable to the proposed A/R CDM project activity. An A/R CDM project activity may contain more than one discrete parcel of land. Each discrete parcel of land shall have a unique geographical identification. The boundary shall be defined for each discrete parcel and shall not include the areas in between these discrete parcels of lands. The discrete parcels of lands are usually defined by polygons. To make the boundary geographically verifiable and transparent, the coordinates for all corners of the polygons shall be measured (using GPS, analysis of geo-referenced spatial data, or other appropriate techniques and data sources, e.g. maps, aerial photos, cadastral information, etc.), recorded, archived and listed in the CDM-AR-PDD of the proposed A/R CDM project activity.

The sources and gases included in this methodology are listed in Table 1 below.

Table 1: Emissions sources included in or excluded from the project boundary

Sources	Gas	Included	Justification / Explanation of choice
Use of fertilizers	CO_2	No	Not applicable
	CH_4	No	Not applicable
	N_2O	Yes	Main gas of this source
Combustion of fossil fuels e.g.,on-site and/or offsite use of vehicles	CO_2	Yes	Main gas of this source
	CH_4	No	Potential emission is negligibly small
	N_2O	No	Potential emission is negligibly small
Burning of biomass	CO_2	No	However, carbon stock decreases due to burning are accounted as a carbon stock change
	CH_4	Yes	Non-CO_2 gas emitted from biomass burning
	N_2O	Yes	Non-CO_2 gas emitted from biomass burning

Step 2: Discrete parcels of land not under the control of the project participants at the start date of the proposed A/R CDM project activity but expected to come under the control of the project participants

during the crediting period may be included within the project boundary if all of the following conditions are met:

- The total area (hectares) of these parcels of land not yet under the control of the project participants is clearly defined in the CDM-AR-PDD;
- A justification of why these parcels of land are not yet but will come under the control of the project participants is provided in the CDM-AR-PDD;
- The candidate land areas among which the particular parcels of land will be chosen have been identified and are unambiguously identified in the CDM-AR-PDD with coordinates and maps;
- All candidate land areas have been included in the baseline assessment and it can be shown that they are not different from the land areas already under the control of the project participants at the start of the proposed A/R CDM project activity in terms of land eligibility, baseline net greenhouse gas removal by sinks, actual net greenhouse gas removal by sinks, leakage, socio-economic and environmental impacts.
- To avoid shifting of pre-project activities from such lands before the project proponents have gained control over such parcels, the project proponents have to describe in the PDD how they will assure that pre-project activities are stopped without shifting them to outside the project boundary in line with applicability condition 13.

2. Ex-ante stratification

Stratification of the project area into relatively homogenous units will increase the accuracy of the estimation of baseline and actual carbon stock changes. In this methodology, stratification is achieved in three steps. Step 1 stratifies the project area according to pre-existing natural conditions and baseline projections in m_{BL} strata; Step 2 stratifies the project area according to projected A/R CDM project activities in m_{PS} strata; and Step 3 achieves the final *ex ante* stratification by combining the results of Step 1 with those of Step 2[4]:

Step 1: Stratification according to pre-existing conditions:

1. Define the factors influencing carbon stock changes, especially in above-ground and below-ground biomass pools. These factors may include soil, climate, previous land use, existing vegetation type, degree of anthropogenic pressure in the baseline scenario, etc.
2. Collect local site classification maps/tables, the most updated land use/cover maps, satellite images, soil maps, vegetation maps, landform maps, and literature reviews of site information concerning key factors identified above.
3. Do a preliminary stratification based on the collected information.
4. Carry out supplementary sampling for site specifications for each stratum, including as appropriate:
   a) Area cover for herbaceous plants and crown cover, height and DBH for shrubs and trees (preferably species or cohort specific), respectively;
   b) Events that have resulted in deforestation, and their timing;
   c) Likely land use in the absence of an A/R CDM project activity;
   d) Present/potential vegetation types, alternatively, site and soil factors: soil type, soil depth, slope gradient, slope face, underground water level, etc.;
   e) Animal pressure, e.g. grazing.
5. Do the final stratification of the baseline scenario based on supplementary information collected from point 4 above. Distinct strata should differ significantly in terms of their baseline net green-

4 Baseline and actual net GHG removal by sinks are expected to be significantly different. Accordingly, different stratifications may be required for the baseline scenario (step 1) and for the project scenario (step 2) to achieve optimal accuracy of the estimates of net GHG removal by sinks.

house gas removals by sinks. For example, separate strata could consist of sites: totally deprived of trees or shrubs; with some trees or shrubs already present; subject to intensive collection of fuel wood or grazing. On the other hand, site and soil factors may not warrant a separate stratum as long as all lands have a baseline of continued degradation.

The stratification of the baseline scenario does not need to coincide with the areas that are covered by the various land-use types. One stratum can contain many different land-use types. On the other hand, one land-use type may occur in different strata, and different rates of land-use change may be observed in different strata. Therefore, when determining the baseline land-use scenario in the following sections, areas of the land-use types are tracked stratum by stratum.

Step 2: Stratification according to the planned A/R CDM project activity:

(1) Define the project scenario to be implemented in the project area by specifying:
   a) The species or species combination to be planted together in one single location and at the same date to create a "stand".
   b) The growths assumptions for each species, combination of species in the stand type.
   c) Planting, fertilization, thinning, harvesting, coppicing, and replanting cycle scheduled for each stand type, by specifying:
      - The age class when the above management activities will be implemented.
      - The quantities and types of fertilizers to be applied.
      - The volumes to be thinned or harvested.
      - The volumes to be left on site (harvest residues becoming deadwood) or extracted.

(2) Define the establishment timing of each stand by specifying:
   a) The planting date.
   b) The area to be planted (ha).
   c) The geographical location for each stand.

(3) Stratify the project area according to the above specifications. Distinct strata should differ significantly from each other in terms of their actual net greenhouse gas removals by sinks. On the other hand, species and management (thinning, harvesting and replanting) and other factors of the project scenario may not warrant a separate stratum as long as all lands have similar actual stock changes in the carbon pools.

Step 3: Final ex-ante stratification:

(1) Verifiably delineate the boundary of each stratum as defined in steps 1 and 2 using GPS, analysis of geo-referenced spatial data, or other appropriate techniques. Check consistency with the overall project boundary. Coordinates may be obtained from GPS field surveys and/or analysis of geo-referenced spatial data, including remotely sensed images, using a Geographical Information System (GIS).

(2) Preferably, project participants shall build geo-referenced spatial data bases in a GIS platform for each parameter used for stratification of the project area under the baseline and the project scenario. This will facilitate consistency with the project boundary, precise overlay of baseline and project scenario strata, transparent monitoring and ex-post stratification.

<u>Note</u>: In the equations used in this methodology, the letter i is used to represent a stratum and the letter m for the total number of strata. m_{BL} is the number of ex-ante defined baseline strata as determined with step 1; m_{BL} remains fixed for the entire crediting period. m_{PS} is the number of strata in the project scenario as determined ex-ante with step 2. Ex-post adjustments of the strata in the project scenario (ex-post stratification) may be needed if unexpected disturbances occur during the crediting period (e.g. due to fire, pests or disease outbreaks), affecting differently different parts of an originally homogeneous

stratum or stand, or when forest management (planting, thinning, harvesting, replanting) occurs at different intensities, dates and spatial locations than originally planned.

3. Procedure for selection of most plausible baseline scenario

Summary explanation of the approach

This methodology allows setting a baseline land-use scenario according to approach 22(a) as the continuation of past land-use change trends. If past trends are assumed to continue and if these past trends entailed land-use change, then the baseline scenario will also show the expected land-use change. This methodology therefore provides a procedure for quantifying past land-use change trends. It also provides a procedure for extrapolating these past land-use change trends into the future.

This methodology quantifies the annual land-use change as an area that a land-use type changes by. Land-use change trends are quantified as "hectares changing, per year" of a given land-use type. The area-based approach is linear, and conceptually straightforward, given that commonly land-use data are only available for a limited number (two) of discrete points in time (two satellite images). This methodology, therefore, opts for the linear, area-based approach in identification past land-use change trends and extrapolating them into the future.

This section identifies land-use changes by tracking the areas of land-use types. Baseline GHG removals by sinks are then determined as a function of land-use changes between years.

Step-by-step description of the approach

Project participants shall determine the most plausible baseline scenario ***for each of the identified ex-ante strata*** with the steps 1-8 described below.

In line with applicability condition 3, this methodology is not applicable if project proponents can not clearly show in the application of Steps 1 to 8 that, the baseline approach 22(a) (existing or historical changes in carbon stocks in the carbon pools with the project boundary) is the most appropriate plausible baseline scenario.

The following procedure determines the baseline land use on a stratum-by-stratum basis. If it is possible to broaden the analysis to a representative vicinity of the project area, i.e. if the land-use drivers in this representative vicinity are representative for the project area and its baseline strata, then this should be done. Consistently with the distinction between different strata, the representative vicinity of a stratum is defined by the baseline-stratification criteria (see step 1 in section II.2). The reference area for the determination of baseline land-use changes in a stratum shall be determined as follows:

a) All areas of a stratum shall be considered that fall within the project boundaries.
b) Additional areas in the project vicinity shall be considered that fall outside the project boundaries if these are representative for the stratum within the project area. For this purpose the project vicinity comprises all areas that fall inside a buffer zone of 5 km from the project boundaries for all discrete parcels of land.

To ensure transparency all information used in the analysis and demonstration shall be archived and verifiable.

Step 1: Identify and list plausible alternative land uses on the project lands for all strata

Plausible alternative land uses including alternative future public or private activities on the project lands, include any similar A/R activity undertaken not as CDM activity or any other feasible land development activities, considering relevant national and/or sectoral land-use policies that would impact the proposed project area and/or, if applicable, its representative vicinity. This should be carried out using selected available sources of data, including as appropriate archives, maps and/or satellite images, as well as supplementary field investigation, land-owner interviews, and/or other appropriate sources.

In line with applicability condition 3, this analysis should demonstrate that only land uses that currently form part of the land use pattern within the analyzed area are plausible alternative land uses for the baseline scenario. If any other land uses (e.g. land uses that would be (re-)introduced) are identified as plausible alternatives, this methodology is not applicable.

In the case of rotational land-use systems, all phases of such systems shall be grouped in only one land-use class, and they shall not be treated separately. The later derivation of the baseline carbon stocks treats those land-use types with cyclical management in an appropriate manner when considering the carbon releases and uptakes upon land-use change to correspond to the average carbon stock over the rotational cycle[5]. It shall be substantiated that the vegetation does not meet the country's forestry definition even at the most advanced phase of the cyclical land-use system hence, the A/R activities over the project lands are eligible A/R CDM project activities as demonstrated based on definitions provided in paragraph 1 of the annex to the decision 16/CMP.1 ("Land use, land-use change and forestry"), as requested by decision 5/CMP.1 ("Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol"), until new procedures to demonstrate the eligibility of lands for afforestation and reforestation project activities under the clean development mechanism are approved by the Board.

The level of detail to which age classes of land-use types need to be distinguished depends on the carbon stocks of those land-use types.

a) In all land uses without woody perennials (e.g., grazing land, cropland), it is not necessary to account for the age of the possibly present other vegetation.
b) In all land uses that contain woody perennials (e.g., regeneration, reforestation, coffee plantations, oil-palm plantations, agroforestry systems, etc.), age of the vegetation shall be accounted for.
c) The phases of rotational systems (such as shifting cultivation and fallow agriculture systems) shall be treated as one vegetation class and shall not be distinguished as to where they are in the cycle. The later derivation of the baseline removals treats those land-use types with various cyclical phases with an average carbon stock over the entire rotational cycle.

Step 2: Map current and historical land use at least two reference dates for all strata

The land use in the project region and (if applicable) its representative vicinity shall be mapped for two reference dates. The classification legend for land-use mapping shall correspond to the alternative land uses identified in step 1. An analysis of land-use changes between these dates shall be carried out. This

[5] It is important that the carbon-stock estimates for the cyclical land-use systems correspond to the average carbon stock that these systems typically contain across the land-use cycle. One way of determining the average is to carry out a land-use inventory before project start that estimates the average carbon stock in those systems for the time point of the inventory and disregarding the phases. If the land-use sample is representative for the phases of the land-use cycle, the resulting average carbon stock will correspond to the average across the rotation cycle.

multi-temporal analysis of satellite images will later be used for the identification of land-use change trends (step 3). In order to ensure rigor in the identification of land-use change trends, this methodology has detailed provisions for the selecting of reference dates and the reference area. As appropriate, the project proponents may complement satellite images with other data sources, including as appropriate archives, maps of land use/cover, as well as supplementary field investigation, land owner interviews, and/or other appropriate sources, if necessary.

In selecting the reference dates, the project proponents shall use satellite images from dates that can also be used for demonstrating eligibility of lands (if possible). The following provisions shall be followed:

a) The project proponents shall consider a date that is (if possible) earlier than and as close as feasible to the 31.12.1989 for the earlier image and a date that is reasonably close to the project start for the later image.
b) It is possible to base the multi-temporal analysis on a later date if land-use trends were not representative for the current land-use trends during the entire period since 1990. In this case, the project proponents shall substantiate that using the later date leads to the identification of a representative land-use trend.

In selecting the reference area, the project proponents shall follow the above provisions as to the representative vicinities of strata.

Step 3: Represent land-use change through tabular forms for each of the strata and the representative vicinities

Project proponents shall derive land-use change tabular representations from the multi-temporal analysis of land use based on data on area of each historical land use that changed into each current land use between the two reference dates.

The land-use change data shall list areas (in ha) for each stratum and its representative vicinity in the following tabular way:

Table 2: Land-use change tabular representation of the stratum and its representative vicinity

[name of the stratum]				
	[later year]			
[earlier year]	[LU#1]	[LU#2]	[LU#n]	Sum
[LU#1]	[area where LU#1 remains]	[area converted from LU#1 to LU#2]	[area converted from LU#1 to LU#n]	[total area of LU#1 in the earlier year]
[LU#2]	[area converted from LU#2 to LU#1]	[area where LU#2 remains]	[area converted from LU#2 to LU#n]	[total area of LU#2 in the earlier year]
[LU#n] [1]	[area converted from LU#n to LU#1]	[area converted from LU#n to LU#2]	[area where LU#n remains]	[total area of LU#n in the earlier year]
Sum	[total area of LU#1 in the later year]	[total area of LU#2 in the later year]	[total area of LU#n in the later year]	[overall total area]

[1] LU#n is name of the stratum n

As the land-use change tabular representations identified in step 3 represent the past land-use changes of the stratum's representative vicinity, they may also contain deforestation. In order to be conservative, the past land-use changes corresponding to deforestation shall be nullified. This is achieved by deleting the row representing forest land use in Table 2.
Note: the column representing forest land use shall be kept in order to represent reforestation/ afforestation.

Step 4: Plausibility check and correction for singular events

The land-use change tabular representation indicates the way of change of land uses. Under this step it is checked if these trends are biased by possible singular events. It may happen that a singular land-use change event occurred during the reference period and is not likely to be repeated in the future. The observed past land-use changes shall therefore be subjected to a plausibility-check in order to avoid bias from singular events. If a land-use change event can be considered singular, the land-use change tabular representation for the larger vicinity of the project area (step 3) shall be corrected.

For the plausibility-check of the land-use change , it shall be demonstrated for the observed area changes for each land use individually between the two reference dates (e.g., the conversion of pastures into secondary forests) that the most plausible baseline scenario is either of the following two:

- Continuation of the identified historical area change during the crediting period in absence of the project activity; or
- Continuation of the previous land-use type, and the change observed in the past is not likely to repeat. This shall be done by demonstrating that, considering relevant national and/or sectoral land-use policies, either the past land-use change trend for the respective land use does not apply any longer (i.e. it was caused by impacts that ceased to exist), or that the land-use change was not part of any trend, but an isolated, singular event.

If the continuation of the current land use (rather than the continuation of the past change trend) is identified as the most plausible baseline scenario, the land-use change tabular representation shall be adjusted. The adjustment shall allow continuation of the the respective land-use type.. Correspondingly, the areas contained in some cells of the land-use change tabular representation need to be moved to its diagonal. For instance, if the land-use change from LU#1 to LU#2 was identified as a singular event then the corresponding area needs to be moved to the cell that expresses remaining area of LU#1 (i.e. diagonal - see Table 3).

Table 3: Adjustment of the land-use change tabular representation by excluding singular past events of the stratum and its representative vicinity (in the grey cells)

[name of the stratum]				
	[later year]			
[earlier year]	[LU#1]	[LU#2]	[LU#n]	Sum
[LU#1]	[area where LU#1 remains] + [area converted from LU#1 to LU#2 as a result of singular event] [1]	0^2	[area converted from LU#1 to LU#n]	[total area of LU#1 in the earlier year]
[LU#2]	[area converted from LU#2 to LU#1]	[area where LU#2 remains]	[area converted from LU#2 to LU#n]	[total area of LU#2 in the earlier year]
[LU#n]	[area converted from LU#n to LU#1]	[area converted from LU#n to LU#2]	[area where LU#n remains]	[total area of LU#n in the earlier year]
Sum	[total area of LU#1 in the later year]	[total area of LU#2 in the later year]	[total area of LU#n in the later year]	[overall total area]

[1] The areas in this cell on the diagonal have been increased in order to correct for singular events.
[2] This must be zero in consequence of the correction, because the areas that used to be in this cell were moved to the next cell to diagonal. The land use change from LU#1 to LU#2 was a result of singular event.

Step 5: Derive land-use change trends using the land-use change tabular representation for each stratum

The following sub-steps shall be applied to the land-use change tabular representation of each stratum:

Sub-step 5.1: Derive per-ha and per-year changes for each entry

The land-use change tabular representation shall be transformed to list values per area unit and per year. In order to do so, those cells of the above tabular representation that show area changes need to be divided by the duration of the reference period and by the total area covered by the respective land-use type at start of the reference period.

For instance, over a reference period of 15 years croplands were converted into grazing lands on an area of 15 ha, while 85 ha of croplands remained unchanged. Since, the total area of croplands amounted to 100 ha before the change, the conversion needs to be quantified as 15 ha of change per 100 ha of existing croplands. The annual change of cropland into grazing land then amounts to 1 ha change / yr / 100 ha cropland.

The results shall be listed in the following manner:

Table 4: Land-use changes (per ha and per year) of the stratum and its representative vicinity (unit of the entries: yr^{-1})

[name of the stratum]			
	[LU#1]	[LU#2]	[LU#n]
[LU#1]	-[1]	[area converted from LU#1 to LU#2] / ([later year] – [earlier year]) / [total area of LU#1 in the earlier year]	[area converted from LU#1 to LU#n] / ([later year] – [earlier year]) / [total area of LU#1 in the earlier year]
[LU#2]	[area converted from LU#2 to LU#1] / ([later year] – [earlier year]) / [total area of LU#2 in the earlier year]	-[1]	[area converted from LU#2 to LU#n] / ([later year] – [earlier year]) / [total area of LU#2 in the earlier year]
[LU#n]	[area converted from LU#n to LU#1] / ([later year] – [earlier year]) / [total area of LU#n in the earlier year]	[area converted from LU#n to LU#2] / ([later year] – [earlier year]) / [total area of LU#n in the earlier year]	-[1]

[1] These cells is empty, because this table only tracks changes and not unchanged areas.

Sub-step 5.2: Determine starting land use for the project area

List the areas covered by the land uses inside the stratum, inside the project boundary at project start. This will be the starting land use situation to extrapolate future baseline land use from.
List the areas of the land-use types in the stratum at project start in the following way:

Table 5: Pre-project land use in a stratum at project start (unit of the entries: ha)

[name of the stratum]	
[LU#1]	[total stratum area LU#1]
[LU#2]	[total stratum area LU#2]
[LU#n]	[total stratum area LU#n]
Sum	[total stratum area]

Sub-step 5.3: Relate the land-use change tabular representation from the larger vicinity to the project area for each stratum

In order to relate the trends observed for a larger area to the smaller project area, the results of sub-step 5.1 and sub-step 5.2 shall be combined. The per-ha and per-year changes from the stratum and its representative vicinity shall be multiplied with the stratum's starting land use in order to derive the stratum's per-year changes. The results reflect the annual changes to be expected for the stratum. The results shall be presented in the following way:

Table 6: Baseline land-use changes (per-year) for the stratum (unit of the entries: ha * yr^{-1})

[name of the stratum]				
	[LU#1]	[LU#2]	[LU#n]	Sum
[LU#1]	-[1]	[area converted from LU#1 to LU#2] / ([later year] – [earlier year]) / [total area of LU#1 in the earlier year] * [total stratum area LU#1]	[area converted from LU#1 to LU#n] / ([later year] – [earlier year]) / [total area of LU#1 in the earlier year] * [total stratum area LU#1]	[stratum area decreases LU#1]
[LU#2]	[area converted from LU#2 to LU#1] / ([later year] – [earlier year]) / [total area of LU#2 in the earlier year] * [total stratum area LU#2]	-[1]	[area converted from LU#2 to LU#n] / ([later year] – [earlier year]) / [total area of LU#2 in the earlier year] * [total stratum area LU#2]	[stratum area decreases LU#2]
[LU#n]	[area converted from LU#n to LU#1] / ([later year] – [earlier year]) / [total area of LU#n in the earlier year] * [total stratum area LU#n]	[area converted from LU#n to LU#2] / ([later year] – [earlier year]) / [total area of LU#n in the earlier year] * [total stratum area LU#n]	-[1]	[stratum area decreases LU#n]
Sum	[stratum area increases LU#1]	[stratum area increases LU#2]	[stratum area increases LU#n]	

[1] These cells must be empty, because this table only tracks changes and not unchanged areas.

Sub-step 5.4: Derive the annual land-use change trends for the stratum

The annual land-use change trends by land-use type for the stratum shall be derived as the difference between increases and decreases as derived in sub-step 5.3. The annual change trends shall be presented in the following way:

Table 7: Annual baseline land-use change trends for the stratum (unit of the entries: ha * yr^{-1})

[name of the stratum]	
[LU#1]	[LU#1 net change] = [stratum area increases LU#1] – [stratum area decreases LU#1]
[LU#2]	[LU#2 net change] = [stratum area increases LU#2] – [stratum area decreases LU#2]
[LU#n]	[LU#n net change] = [stratum area increases LU#n] – [stratum area decreases LU#n]
Sum	0

Step 6: Extrapolate the observed past trends into the future for each stratum

The most plausible baseline scenario shall be identified by extrapolating the historical area change trends in land use identified in Step 5 above into the future. For each year of the crediting period, the project proponents shall assign an expected area to each of the land-use types that are part of the baseline (identified in Step 1).

The following procedure shall be applied for extrapolating past land-use change trends as identified in step 5 into the future:

a) The baseline land use in year 1 corresponds to the pre-project land use (sub-step 5.2).
b) The baseline area that a land-use type covers in any subsequent year corresponds to the sum of the area covered by the land-use type in the previous year and annual baseline land-use change trend for the stratum (read from the Table 7). For instance, the baseline area that a land-use type covers in year 2 corresponds to the sum of the area covered by the land-use type in the pre-project land use situation (sub-step 5.2) and the area by which the respective land use is expected to change (sub-step 5.4).

The baseline land-use scenario shall be listed for each stratum *i* by specifying the areas A_{ijt} that all land uses *j* cover in each year *t*:

Table 8: Extrapolated baseline land-use changes (per-year) for the stratum (unit of the entries: ha)

[name of the stratum *i*]				
	Land use *j* = [LU#1]	Land use *j* = [LU#2]	Land use *j* = [LU#n]	Sum
Year *t*=1	$A_{i\,j=1\,t=1}$ = area covered by land use 1 in stratum *i* in year 1	$A_{i\,j=2\,t=1}$ = area covered by land use 2 in stratum *i* in year 1	$A_{i\,j=n\,t=1}$ = area covered by land use n in stratum *i* in year 1	[total stratum area]
Year *t*=2	$A_{i\,j=1\,t=2}$ = area covered by land use 1 in stratum *i* in year 2	$A_{i\,j=2\,t=2}$ = area covered by land use 2 in stratum *i* in year 2	$A_{i\,j=n\,t=2}$ = area covered by land use n in stratum *i* in year 2	[total stratum area]
Year *t*=*tx*	$A_{i\,j=1\,t=tx}$ = area covered by land use 1 in stratum *i* in year *tx*	$A_{i\,j=2\,t=tx}$ = area covered by land use 2 in stratum *i* in year *tx*	$A_{i\,j=n\,t=tx}$ = area covered by land use n in stratum *i* in year *tx*	[total stratum area]

Step 7 (if necessary): Guidance on how to treat cessation of land uses within the project duration as a result of extrapolating land use changes

While extrapolating negative net annual changes for a land use type, this land use type could cease to exist within the project duration. In this case, the land use change trend cannot be extrapolated beyond the time at which the land use area reaches zero. The year, in which one (or more) of the areas of all land uses reach(es) zero, can be determined by the following procedure for land use LU#n:

- if [LU#n net annual change] = [stratum area increases LU#n] – [stratum area decreases LU#n] < 0, and
- if [initial area LU#n] / [LU#n net annual change] < project duration

then, the year *tx*, = [initial area [LU#n]] / [LU#n net annual change]

Where:

tx year in which the area of a land use reaches zero within the project duration

For the extrapolation following this year, the following steps need to be carried out instead of further applying the land-use change trend:

In

Table 6 in sub-step 5.3 all land-use changes shall be eliminated that involve the land-use type, the area of which reaches 0. For instance, if for certain *tx* the area of land-use type LU#2 becomes 0, then *for each t>tx* all land-use changes of LU#2 into other land-use types shall be 0, as well as all land-use changes of other land-use types into LU#2 shall be 0. That is, all cells in the respective row and the respective column of

a) Table 6 shall be zeros.
b) Repeat sub-step 5.4 with the updated land-use changes and derive the adjusted net-annual land-use change trends for the stratum.
c) Continue applying step 6 with the updated annual land-use change trends.

For the determination of further land uses ceasing to exist while applying the updated annual land-use change trends, the reference period for the calculations outlined below is the time span between the year the last land use ceased to exist and the end of the project:

- if [updated LU#n net annual change] = [updated stratum area increases LU#n] – [updated stratum area decreases LU#n] < 0, and
- if [area LU#n at the year the last land use ceased to exist] / [updated LU#n net annual change] < project duration – years since the start of the project until the year the last land use ceased to exist

then, the year *tx*, in which the next area of a land use reaches zero within project duration, = [area LU#n at the year the last land use ceased to exist] / [updated LU#n net annual change]

If further land uses cease to exist, the same procedure applies as outlined above.

Step 8: Estimate baseline net GHG removals by sinks from the baseline scenario for each stratum

The application of steps 1-7 results in a yearly record of areas that all baseline land uses cover for each year of the crediting period in each stratum. The following section uses this early record to establish the baseline net GHG removals by sinks.

4. Additionality

This methodology uses the latest version of the *"Tool for the demonstration and assessment of additionality for afforestation and reforestation CDM project activities"* approved by the CDM Executive Board[6].

When applying the additionality tool, the project proponents shall consider applicability conditions and include the justification required in Annex 19, EB24:

- In demonstrating the additionality of the project, it needs to be taken into account that the baseline could also include afforestation and reforestation. According to the provisions of Annex 19 to the

[6] Hereinafter referred as "A/R additionality tool". Please refer to <http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html>

report from the 24th meeting of the Executive Board, "the assessment of additionality shall include justification that the increased rate of afforestation / reforestation would not occur in the absence of the project activity and results from direct intervention by project participants."

- In line with applicability condition 3, only land uses that currently form part of the land use pattern within the analyzed area are plausible alternative land uses for the baseline scenario. If any other land uses (e.g. land uses that would be (re-)introduced) are identified as plausible alternatives this methodology is not applicable.

5. Estimation of baseline net GHG removals by sinks

5.1 Summary explanation of the approach

This methodology allows for land-use change in the baseline scenario. The dynamic baseline scenario with respect to the areas that land-use types cover over the crediting period (described in section 3) requires a particular way of tracking carbon stock changes that remaining and changing land-use changes entail (described in this section).

This methodology quantifies for each land-use type within a stratum (and year-by-year) the areas that continue to be covered by the respective land-use type. It also quantifies area changes: land-use types can either increase or decrease. Most other methodologies do not account for land-use change; therefore they only deal with areas that continue to be covered by the respective land-use types.

For *areas that remain*, i.e., that continue to be covered by the same land-use type, the same approach as in most other methodologies is applied. If the areas have woody perennials, carbon stock changes are estimated as a function of their growth rates. Alternatively, if the areas do not have woody perennials, it is assumed that carbon-stocks remain constant.

For *areas that undergo land-use change*, i.e. where the area of a land-use type increases or decreases, a new approach is proposed. Land-use change is considered as increases and decreases of areas covered by the respective land-use types. For instance, the change of sugar cane to pasture is considered a decrease of sugar cane together with an increase of pasture.

Looking at the sum of decreases and increases for determining carbon stock changes from land-use change is mathematically equivalent to the difference of carbon stocks before and after the change. For instance, the change of sugar cane (8 t C per ha) to pasture (5 t C per ha) will lead to a carbon stock change of -3 t C per ha. It is mathematically equivalent to calculate:
[carbon stock after the change, i.e., 5 t C per ha] – [carbon stock before the change, i.e. 8 t C per ha],
or to calculate:
[carbon stock decrease from decreasing area of sugar cane, i.e. -8 t C per ha] + [carbon stock increase from increasing area of pasture, i.e. +5 t C per ha].

The methodology assigns carbon stock changes to the decreases and increases of areas of land-use types. The carbon stock changes from land-use change are assigned in a conservative manner, as the methodology prescribes that when areas of land-use types increase the carbon-stocks are overestimated, and when areas of land-use types decrease the carbon-stocks are underestimated.

5.2 Step-by-step description of the approach

To determine the baseline net GHG removals by sinks, the following steps are necessary to be carried out ***for every year*** of the crediting period and ***for each stratum*** of the project area:

(1) Determination of the areas that each land-use type will cover following the procedures outlined in section II.2 and II.3. This step results in the table listed in step 5 of section II.3.

(2) Determine the areas of the land-use types expected to remain and expected to change.

a) Determine the area of each land-use type that is expected to remain unchanged between two given years. Following the notation in the table listed in step 5 of section II.3, the area of a land-use type *j*=LU#n expected to remain between a given year $t=tx$ and the subsequent year $t=tx+1$ is denoted as $A_{Remain\ i\ j=n\ t=tx}$. The area of each land-use type that is expected to remain corresponds to the smaller area of those that the land-use types cover before and after the change.

$$A_{Remain\ i\ j=n\ t=tx} = min\ \{\ A_{i\ j=n\ t=tx},\ A_{i\ j=n\ t=tx+1}\ \} \qquad (1)$$

Where:

$A_{Remain\ ijt}$	area of the species (= land-use type) *j* [7] that is expected to remain, in stratum *i*, between year *tx* and *tx*+1; ha
tx	starting year of a land-use change
A_{ijt}	area of stratum *i*, species (= land-use type) *j*, at time *tx*; ha

<u>Note:</u> The use of the minimum function is an easy way of determining areas that do not undergo changes between two years; . For instance, if a land-use type has 8 ha in year 1 and 13 ha in year 2, then the lesser (namely 8 ha), correspond to the areas that remained without change between the years.

b) Determine the area of each land-use type that is expected to change between two given years. This analysis does not track changes between land-use types, but is limited to increases in areas and decreases in areas. The sum of all changes for all land-use types must be 0 for each year. Following the notation in the table listed in step 5 of section II.3, the area of a land-use type *j*=LU#n expected to change between a given year $t=tx$ and the subsequent year $t=tx+1$ is denoted as $A_{Change\ i\ j=n\ t=tx}$. The area that is expected to change corresponds to the difference in areas that the land-use type covers before and after the change.

$$A_{Change\ i\ j=n\ t=tx} = A_{i\ j=n\ t=tx+1} - A_{i\ j=n\ t=tx}, \qquad (2)$$

Where:

$A_{Change\ ijt}$	area of the species (= land-use type) *j* that is expected to change, in stratum *i*, between the year $t=tx$ and $t=tx+1$; ha
tx	starting year of a land-use change
A_{ijt}	area of stratum *i*, species (= land-use type) *j*, at time *tx*; ha

(3) Determine the sum of carbon-stock changes for the area expected to remain from step 2a for each land-use type (ΔC_{Remain} in Equation 3 and $\Delta C_{LB} + \Delta C_{DW} + \Delta C_{LI}$ in Equation 7):

a) For those land-use types without growing trees or woody perennials, the sum of carbon stock changes in above-ground and below-ground biomass, deadwood and litter is set as zero.

b) For those land-use types with growing trees or woody perennials, the sum of carbon stock

[7] In the estimation of carbon-stock changes from land uses that change, the equations distinguish between land uses. This distinction may or may not coincide with the distinction between species. Later, when estimating carbon-stock changes from land uses that remain, the equations distinguish between species. For reasons of consistency with equations in the subsequent part of the methodology, the notation names species as well as land-use types. See also footnote 15.

changes in above-ground and below-ground biomass of living trees, deadwood and litter is determined based on Equations 8, 24, and 31.

c) For shifting cultivation and fallow agriculture systems with various phases, the sum of carbon-stock changes is set as zero.

(4) Determine the sum of carbon-stock changes from areas that change from step 2b (ΔC_{Change} in Equation 3). The carbon-stock changes from land-use change correspond to the sum of the carbon-stock changes from decreases and increases thanks to area-changes of the individual land uses.

(5) Sum the baseline net GHG removals by sinks across all strata.

The baseline is determined ex-ante and remains fixed on per ha basis during the subsequent crediting period. Thus the baseline is not monitored.

This baseline methodology accounts for all carbon pools, except soil organic carbon.
Therefore, the baseline net greenhouse gas removals by sinks can be calculated by the following equation[8]:

$$C_{BSL} = \Delta C_{Remain} + \Delta C_{Change} \tag{3}$$

Where:

C_{BSL}	baseline net greenhouse gas removals by sinks; t CO_2-e.
ΔC_{Remain}	sum of the changes in the stocks of all biomass pools from land uses that remain; t CO_2-e.
ΔC_{Change}	sum of the changes in the stocks of all biomass pools from land uses that change; t CO_2-e.

Note: In this methodology Equation 3 is used to estimate baseline net greenhouse gas removal by sinks for the period of time elapsed between project start (*t=1*) and the year *t=t**, *t** being the year for which baseline net greenhouse gas removals by sinks are estimated.

5.3 Estimation of baseline carbon stock changes from land uses that change

The sum of the changes in all biomass stocks from land uses that change shall be estimated by:

$$\Delta C_{Change} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{BL}} \sum_{j=1}^{s_{BL}} (C_{decrease\ ijt} + C_{increase\ ijt}) \cdot MW_{CO2\text{-}C} \tag{4}$$

Where:

ΔC_{Change}	sum of the carbon-stock changes in all biomass pools from land uses that change; t CO_2-e.
$C_{increase\ ijt}$	increases in carbon stock in all biomass pools due to increasing areas for stratum *i*, species (= land-use type) *j*, calculated at time *t*; t C
$C_{decrease\ ijt}$	decreases in carbon stock in all biomass pools due to decreasing areas for stratum *I*, species (= land-use type) *j*, at time *t*; t C
i	1, 2, 3, ... m_{BL} baseline strata

[8] In this determination, biomass-stock changes in land uses without growing trees or woody perennials are ignored, as long as the land use does not change. Carbon-stock changes when land use changes are calculated in a conservative manner for both land-use with and without growing trees or woody perennials.

j	1, 2, 3, … s_{BL} baseline species (= land-use types) Note: j is termed "species" in most of this methodology; however, it really means "baseline vegetation" of "woody and non-woody species". In concordance with this provision and for the purpose of Equation 4, we are looking at baseline land uses that are significantly different categories in terms of expected carbon stocks and carbon-stock changes in the carbon pools.
t	1, 2, 3, ... t^* years elapsed since the start of the A/R CDM project activity
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); t CO_2 (t C)$^{-1}$

Note: $C_{increase\ ijt}$ is always greater or equal to 0. $C_{decrease\ ijt}$ is always less or equal to 0. In a given year and a given stratum, and for a specific land-use type, only one of the two can be different from 0, because one land-use type can only either increase or decrease but never both.

Note: The carbon stock change resulting from land-use change at a specific site is considered the sum of two components. For instance, 1 ha of sugar cane (8 t C per ha) is converted into 1 ha of pasture (5 t C per ha). The conversion entails a decrease of the carbon stock of sugar cane in the specific stratum and the specific year, and an increase of the carbon stock of pasture in the specific stratum and the specific year. The resulting carbon-stock change is the sum of a decrease of - 8 t C and an increase of + 5 t C, that is, the overall carbon-stock change corresponds to -3 t C.

In order to be conservative, the carbon stock of a land use shall be determined in a different yet parallel way for areas with increasing area ($C_{increase\ ijt}$) and for land uses with decreasing area ($C_{decrease\ ijt}$).

If $A_{Change\ ijt} > 0$ (i.e., according to Equation 2, $A_{i\,j\,t=tx+1} > A_{i\,j=n\,t=tx}$), then:

$$C_{increase\ ijt} = A_{Change\ ijt} \cdot B_{ijt} \cdot CF \qquad (5)$$

If $A_{Change\ ijt} < 0$ (i.e., according to Equation 2, $A_{i\,j\,t=tx+1} < A_{i\,j=n\,t=tx}$), then:

$$C_{decrease\ ijt} = A_{Change\ ijt} \cdot B_{ijt} \cdot CF \qquad (6)$$

Where:

$C_{increase\ ijt}$	increases in carbon stock in all biomass pools due to increasing areas for stratum i, species (= land-use type) j, calculated at time t; t C
$C_{decrease\ ijt}$	decreases in carbon stock in all biomass pools due to decreasing areas for stratum i, species (= land-use type) j, at time t; t C
$A_{Change\ ijt}$	area of a species (= land-use type) j expected to change between a given year t and the subsequent year t+1 in stratum i; ha Note: $A_{Change\ ijt}$ is less than 0 if the area decreases and greater than 0 if the area increases. If $A_{Change\ ijt}$ equals 0, the area remains, and the equations further below in this section must be applied.
B_{ijt}	average biomass stock on land before or after the land-use change for stratum i, species (= land-use type) j, time t; t d.m. ha^{-1} Note: this value will be different if the land use's area decreases or increases.
CF	carbon fraction of dry biomass in tree or non-tree vegetation, as appropriate; t C (t d.m.)$^{-1}$

The biomass stocks of areas that change (B_{ijt}) shall be determined by the below provisions (a-c). If carbon stocks are expected to increase due to land-use change to a land use type without trees or woody perennials, this methodology assumes conservatively that the carbon-stock changes occur instantly upon land-use change, whereas in reality they only occur over various years when carbon stocks approach a new equilibrium after the land-use change.

This does, however, not apply when an area changes to a land use with trees or woody perennials, in which case it is assumed that in the year of land-use change the carbon stocks change to those of a recently transformed area (for example a newly reforested area). Then, in the following years the carbon stocks increase over time according to the growth-based equations given further below in this methodology.

a) For each of the land-use types without trees or woody perennials, determine biomass stocks at maturity. The biomass stocks can be determined either based on local or national or IPCC default parameters, or based on local inventories.
   - If the area of the land-use type is expected to increase then assume for those areas that are added an instant growth to the biomass stock at maturity. This is a conservative provision, because the time it would take to reach stocks at maturity is not taken into consideration.
   - If the area of the land-use type is expected to decrease then assume for those areas that are subtracted that their biomass is removed fully upon conversion. This is a conservative provision, because the biomass on the land use after conversion is assumed to grow to maturity upon conversion as well. This is based on the assumption that any residual carbon stocks in the litter pool from the previous land use, that could realistically remain after land conversion, will be smaller than the carbon stocks at maturity of the new land use, which is a safe assumption to make.

b) For each of the land uses with growing trees or woody perennials:.
   - If the area of the land-use type is expected to increase then assume for those areas that are added the biomass stock for a recently transformed area. This is a realistic provision. In following years these areas will then be treated as areas without land-use change, and the growth-based equations below are applied.
   - If the area of the land-use type is expected to decrease then assume for those areas that are subtracted that they contained the biomass stock of the youngest areas covered by the land-use types in the given baseline year, if applicable. This is a conservative provision, because it likely underestimates the carbon-stock decrease. Note: If the land-use type corresponds to "forest", then the area of the land-use type is not expected to decrease, since the land-use change tabular representation excludes any land-use change events corresponding to deforestation. This methodology excludes the possibility of deforestation in the baseline. Therefore, this rule only applies to non-forest land with woody perennials of which the age is known.

c) For shifting cultivation / fallow agriculture systems, the carbon stocks can be determined either based on local or national or IPCC default parameters, based on local inventories, and (as appropriate) based on regional surveys about management practices.
   - If the area of the land-use type is expected to increase use the average stock over the fallow cycle. This is a reasonable provision, because it adequately represents an average carbon stock.
   - If the area of the land-use type is expected to decrease use the average stock over the fallow cycle. This is a reasonable provision, because it adequately represents an average carbon stock.

5.4. Estimation of baseline carbon-stock changes from land uses that remain[9]

The sum of the changes in all biomass stocks from land uses that remain shall be estimated in the individual biomass pools by the following provisions[10]:

$$\Delta C_{Remain} = C_{LB} + \Delta C_{DW} + \Delta C_{LI} \quad (7)$$

Where:

ΔC_{Remain}	sum of the changes in the stocks of the biomass pools from land uses that remain; t CO_2-e.
ΔC_{LB}	sum of the changes in biomass carbon stocks of living trees (above- and below-ground) of land uses that remain; t CO_2-e.
ΔC_{DW}	sum of the changes in deadwood carbon stocks of land uses that remain; t CO_2-e.
ΔC_{LI}	sum of the changes in litter carbon stocks of land uses that remain; t CO_2-e.

5.4.1 Estimation of baseline ΔC_{LB} (changes in biomass carbon stocks of living trees):

$$\Delta C_{LB} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{BL}}\sum_{j=1}^{s_{BL}} \Delta C_{LB\ ijt} \quad (8)$$

Where:

ΔC_{LB}	sum of the changes in biomass carbon stocks of living trees (above- and below-ground); t CO_2-e.
$\Delta C_{LB\ ijt}$	annual carbon stock change in living biomass of trees for stratum *i,* species *j*, time *t*; t CO_2-e. yr^{-1}
i	1, 2, 3, ... m_{BL} baseline strata
j	1, 2, 3, … s_{BL} baseline tree species[11]
t	1, 2, 3, …t^* years elapsed since the start of the A/R CDM project activity

For those strata without growing trees or woody perennials, $\Delta C_{LB\ ijt} = 0$. For those strata with a few growing trees, $\Delta C_{LB\ ijt}$ is estimated using one of following two methods that can be chosen based on the availability of data.

<u>Method 1 (Carbon gain-loss method)</u>[12]

$$\Delta C_{LB\ ijt} = \Delta C_{G,\ ijt} - \Delta C_{L,\ ijt} \quad (9)$$

[9] The remainder of this section deals with areas that continue to be covered by the same land-use type (=species) between years. Consistently with the above notation, this is A_{Remain}, where A_{Change} denotes changing areas, and A represents the total area, including both changing and remaining areas. Other methodologies only deal with areas that continue to be covered by the same land-use type (=species). What other methodologies denote A_{ijt}, this methodology denotes $A_{Remain\ ijt}$.

[10] Following GPG-LULUCF Equation 3.2.1

[11] The baseline vegetation in stratum *i* may include one or more woody and non-woody species. Project proponents shall identify the individual species, group of species or vegetation cohorts – in the equations of this methodology referred to with the letter *j* ("tree species") - that represent homogeneous and significantly different categories in terms of expected carbon stock changes in the carbon pools. See also footnote 11.

[12] GPG-LULUCF Equation 3.2.2, Equation 3.2.4 and Equation 3.2.5

Where:

$\Delta C_{LB\ ijt}$	annual carbon stock change in living biomass of trees for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$\Delta C_{G,\ ijt}$	annual increase in carbon *stock* due to biomass growth of trees for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$\Delta C_{L,\ ijt}$	annual decrease in carbon *stock* due to biomass loss of trees for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}

$$\Delta C_{G,\ ijt} = A_{Remain\ ijt} \cdot G_{TOTAL,\ ijt} \cdot CF_j \cdot MW_{CO2\text{-}C} \quad (10)$$

Where:

$\Delta C_{G,\ ijt}$	annual increase in carbon stock due to biomass growth of trees for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$A_{Remain\ ijt}$	area of the species *j* that is expected to remain, in stratum *i,* between year *t* and *t*+1; ha
$G_{TOTAL,ijt}$	annual average increment rate in total biomass of trees in units of dry matter for stratum *i*, species *j*, at time *t*; t d.m ha^{-1} yr^{-1} Note: $G_{TOTALijt}$ can be estimated as a constant annual average value.
CF_j	the carbon fraction for species *j*; t C (t d.m)$^{-1}$
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); t CO_2 (t C)$^{-1}$

$$G_{TOTAL,ijt} = G_{w,ijt} \cdot (1+R_j) \quad (11)$$

$$G_{w,ijt} = I_{v,\ ijt} \cdot D_j \cdot BEF_{1,\ j} \quad (12)$$

Where:

$G_{TOTAL,ijt}$	annual average increment rate in total biomass of living trees in units of dry matter for stratum *i,* species *j*, at time *t*; t d.m ha^{-1} yr^{-1}
$G_{w,ijt}$	average annual aboveground dry biomass increment of living trees for stratum *i*, species *j*, at time *t*; t d.m ha^{-1} yr^{-1}
R_j	root-shoot ratio appropriate to increments for tree species *j*; dimensionless Note: Care should be taken that the root-shoot ratio may change as a function of the above-ground biomass present at time (*t*) (see IPCC GPG, 2003, Annex 3.A1, Table 3A1.8)
$I_{v,ijt}$	average annual increment in merchantable volume for stratum *i*, species *j*; m^3 ha^{-1} yr^{-1} Note: I_{vijt} is estimated as "current annual increment – CAI". The "mean annual incremente" – MAI in the forestry jargon – can only be used if its use leads to conservative estimates.
D_j	basic wood density for species *j*; t d.m. m^{-3}
$BEF_{1,j}$	biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total aboveground biomass increment for tree species *j*, dimensionless

The following equations shall be used to calculate the average annual decrease in carbon stocks due to biomass loss of living trees.[13] [14]

[13] It is more likely that these equations will be used for estimating the project-scenario verifiable changes in the stocks of the carbon pools than for estimating the baseline net GHG removals. Nevertheless, this methodology includes them here already for reasons of consistency.
[14] Refers to GPG-LULUCF Equation 3.2.6, Equation 3.2.7, Equation 3.2.8 and Equation 3.2.9

$$\Delta C_{L,\,ijt} = L_{hr,\,ijt} + L_{fw,\,ijt} + L_{ot,\,ijt} \tag{13}$$

Where:

$\Delta C_{L,\,ijt}$	average annual decrease in carbon stocks due to biomass loss of living trees for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$L_{hr,\,ijt}$	annual carbon loss of living trees due to commercial harvesting for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$L_{fw,\,ijt}$	annual carbon loss of living trees due to fuel wood gathering for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$L_{ot,\,ijt}$	annual natural carbon losses (mortality) of of living trees for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}

$$L_{hr,\,ijt} = H_{ijt} \cdot D_j \cdot BEF_{2,\,j} \cdot CF_j \cdot A_{Remain\ ijt} \cdot MW_{CO2\text{-}C} \tag{14}$$

$$L_{fw,\,ijt} = FG_{ijt} \cdot D_j \cdot BEF_{2,\,j} \cdot CF_j \cdot A_{Remain\ ijt} \cdot MW_{CO2\text{-}C} \tag{15}$$

$$L_{ot,\,ijt} = B_{w,ijt} \cdot M_{ijt} \cdot CF_j \cdot Adist_{ijt} \cdot MW_{CO2\text{-}C} \tag{16}$$

Where:

$L_{hr,\,ijt}$	annual carbon loss due to commercial harvesting for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$L_{fw,\,ijt}$	annual carbon loss due to fuel wood gathering for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$L_{ot,\,ijt}$	annual natural losses (mortality) of carbon for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
H_{ijt}	annually extracted merchantable volume for stratum *i*, species *j*, time *t*; m^3 ha^{-1} yr^{-1} Note: The time notation *t* is given here assuming that in most cases project participants are able to define a harvesting schedule (volumes and years of harvesting). A constant average annual harvesting volume should be used only under particular circumstances and should be justified in the PDD.
D_j	basic wood density for species *j*; t d.m. m^{-3} merchantable volume
$BEF_{2,j}$	biomass expansion factor for converting merchantable volumes of extracted roundwood to total aboveground biomass (including bark) for tree species *j*, dimensionless
CF_j	carbon fraction of dry matter for species *j*; t C $(t\ d.m.)^{-1}$
$A_{Remain\ ijt}$	area of the species *j* that is expected to remain, in stratum *i,* between year *t* and *t*+1; ha
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); t CO_2 $(t\ C)^{-1}$
FG_{ijt}	annual volume of fuel wood harvesting of living trees for stratum *i*, species *j*, time *t*; m^3 yr^{-1} Note: See note made for H_{ijt}.
$Adist_{ijt}$	forest areas affected by disturbances in stratum *i*, species *j*, time *t*; ha yr^{-1}
$B_{w,\,ijt}$	average above-ground biomass stock of living trees for stratum *i*, species *j*, time *t*; t d.m. ha^{-1}

The choices of methods and parameters shall be made in the same ways as described in section II.5.

This methodology allows assuming no disturbances in the ex-ante[15] estimation of actual net GHG removals by sinks, which implies that $Adist_{ijt}$ is set as zero and therefore $L_{ot,ijt} = 0$. This assumption can be made in project circumstances where expected disturbances (e.g. fire, pest and disease outbreaks) are of low frequency and intensity. However, the factor $Adist_{ijt}$ should be estimated when natural tree mortality due to competition and/or disturbances is likely to result in significant carbon losses. In such cases, $Adist_{ijt}$ can be estimated as an average annual percentage of A_{ijt} to express a yearly mortality percentage due to competition (usually between 0% and 2% of A_{ijt}) and/or disturbances.

Method 2 (stock change method)[16]

$$\Delta C_{LB\ ijt} = (C_{LB\ ijt\ 2} - C_{LB\ ijt\ 1})/T \cdot MW_{CO2\text{-}C} \tag{17}$$

$$C_{LB\ ijt} = C_{AB,\ ijt} + C_{BB,\ ijt} \tag{18}$$

$$C_{AB,\ ijt} = A_{Remain\ ijt} \cdot V_{ijt} \cdot D_j \cdot BEF_{2,\ j} \cdot CF_j \tag{19}$$

$$C_{BB,\ ijt} = C_{AB,\ ijt} \cdot R_j \tag{20}$$

Where:

$\Delta C_{LB\ ijt}$	total carbon-stock change in living biomass of trees for stratum *i*, species *j*, at time *t*; t CO_2 -e year^{-1}
$C_{LB\ ijt}$	total carbon stock in living biomass of trees for stratum *i*, species *j*, at time *t*; t C
$C_{LB\ ijt2}$	total carbon stock in living biomass of trees for stratum *i*, species *j*, calculated at time $t=t_2$; t C
$C_{LB\ ijt1}$	total carbon stock in living biomass of trees for stratum *i*, species *j*, calculated at time $t=t_1$; t C
T	number of years between times t_2 and t_1 $(T = t_2-t_1)$; years
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); t CO_2 (t C)$^{-1}$
$A_{Remain\ ijt}$	area of the species *j* that is expected to remain, in stratum *i,* between year *t* and *t*+1; ha
$C_{AB,ijt}$	carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, at time *t*; t C
$C_{BB,ijt}$	carbon stock in belowground biomass of living trees for stratum *i*, species *j*, at time *t*; t C
V_{ijt}	average merchantable volume of stratum *i*, species *j*, at time *t*; m^3 ha^{-1}
D_j	basic wood density for species *j*; t d.m. m^{-3} merchantable volume
$BEF_{2,j}$	biomass expansion factor for conversion of merchantable volume to aboveground tree biomass for species *j*; dimensionless
CF_j	the carbon fraction for species *j*; t C (t d.m)$^{-1}$
R_j	root-shoot ratio species *j*; dimensionless

The time points 1 and 2, for which the stock are estimated taken to determine the $\Delta C_{LB\ ijt}$ must be broadly representative of the typical age of the trees under the baseline scenario during the crediting period.

---

[15] The baseline methodology assumes that a monitoring methodology will be used for ex-post mandatory accounting of disturbances.

[16] GPG-LULUCF Equation 3.2.3

The combinations of strata and species shall be developed and presented in the PDD in a way that the values of V_{ijt} (average merchantable volume of stratum *i*, species *j*, at time *t*) used in Equation 21 represent the actual average merchantable volume of stratum *i*, species *j*, at time *t* after deduction of harvested volumes and mortality[17]:

$$V_{ijt2} = V_{ijt1} \cdot (1 - Mf_{ijT}) + (I_{v,\,ijT} - H_{ijT} - FG_{ijT}) \cdot T \qquad (21)$$

$$Mf_{ijT} = Adist_{ijT} / A_{ijT} \qquad (22)$$

Where:

V_{ijt2}	average merchantable volume of stratum *i*, species *j*, at time $t = t_2$; $m^3\ ha^{-1}$
V_{ijt1}	average merchantable volume of stratum *i*, species *j*, at time $t = t_1$; $m^3\ ha^{-1}$
Mf_{ijT}	mortality factor = fraction of V_{ijt1} died during the period *T*; dimensionless
$I_{v,ijT}$	average annual net increment in merchantable volume for stratum *i*, species *j* during the period *T*; $m^3\ ha^{-1}\ yr^{-1}$
H_{ijT}	average annually harvested merchantable volume for stratum *i*, species *j* during the period *T*; $m^3\ ha^{-1}\ yr^{-1}$
FG_{ijT}	average annual volume of fuel wood harvested for stratum *i*, species *j*, during the period *T*; $m^3\ ha^{-1}\ yr^{-1}$
T	number of years between times t_2 and t_1 $(T = t_2 - t_1)$; years
$Adist_{ijT}$	average annual area affected by disturbances for stratum *i*, species *j*, during the period *T*; $hayr^{-1}$
A_{ijT}	average annual area for stratum *i*, species *j*, during the period *T*; $ha\ yr^{-1}$

An alternative way of estimating $C_{AB,ijt}$ is to use allometric equations which are also considered to be good practice by the IPCC and other recognized experts in the field of forestry.

$$C_{AB,\,ijt} = A_{Remain\ ijt} \cdot nTr_{ijt} \cdot CF_j \cdot f_j(DBH_t,\, H_t) \qquad (23)$$

Where:

$C_{AB,ijt}$	carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, at time *t*; t C
$A_{Remain\ ijt}$	area of the species *j* that is expected to remain, in stratum *i,* between year *t* and *t*+1; ha
nTR_{ijt}	number of trees in stratum *i*, species *j*, at time *t*; ha^{-1}
CF_j	carbon fraction for species *j*; t C $(t\ d.m)^{-1}$
$f_j(DBH_t,H_t)$	allometric equation linking above-ground biomass of living trees (d.m ha^{-1}) to mean diameter at breast height (DBH_t) and possibly mean tree height (H_t) for species *j*; t d.m. ha^{-1} Note: Mean DBH and H values should be estimated for stratum *i*, species *j*, at time *t* using a growth model or yield table that gives the expected tree dimensions as a function of tree age. The allometric relationship between above-ground biomass of trees and DBH and possibly H is a function of the species considered. However, when several species or groups of species are present in a vegetation category or in a planted stand, allometric equations can also be developed for a group of species or for

[17] It is more likely that these equations will be used for estimating the project-scenario verifiable changes in the stocks of the carbon pools than for estimating the baseline net GHG removals. Nevertheless, this methodology includes them here already for reasons of consistency.

the dominant species to represent a particular species mix or vegetation cohort.

For the choice of methods 1 or 2 above, there is no priority in terms of transparency and conservativeness. The choice should mainly depend on the kind of parameters available. V_{ijt} and $I_{v,ij}$ shall be estimated based on number of trees and national/local growth curve/table that usually can be obtained from national/local forestry inventory. D_j, $BEF_{1,j}$, $BEF_{2,j}$, CF_j and R_j are regional and species specific and shall be chosen with priority from higher to lower order as follows:

1. Locally-derived species-specific information, if sufficiently accurate and comprehensive data are available
2. Species-specific information from regional datasets, or species-specific information extracted from national datasets for sites with similar soil and climatic conditions
3. Species-specific information extracted from nationally-derived datasets avoiding only sites with very different soil and climate conditions
4. Locally-, regionally-, or nationally-derived information for similar species
5. Default values provided by the IPCC (e.g. IPCC 2003, Annex 3A.1, Annex 4A.2) or other scientific sources

When choosing from global or national databases because local data are limited, it shall be confirmed with any available local data that the chosen values for the baseline are not a significant underestimate of the baseline net removals by sinks, as far as can be judged. Local data used for confirmation may be drawn from the literature and local forestry inventory, or measured directly by project participants especially for BEF and root-shoot ratios that are age- and species- dependent.

5.4.2. Estimation of baseline ΔC_{DW} (changes in deadwood carbon stocks)

Baseline deadwood carbon stocks increase due to the mortality of living biomass of trees and the accumulation of residues from harvesting operations remaining on the ground, and decreases due to partial harvesting (e.g. fuel wood collection) and wood decomposition:

$$\Delta C_{DW} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{BL}} \sum_{j=1}^{s_{BL}} \Delta C_{DW\,ijt} \qquad (24)$$

Where:

ΔC_{DW}	sum of the changes in deadwood carbon stocks; t CO_2-e. (as per Equation 3)
$\Delta C_{DW\,ijt}$	annual carbon stock change in deadwood for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
i	1, 2, 3, … m_{BL} baseline strata
j	1, 2, 3, … s_{BL} baseline tree species
t	1, 2, 3, … *t** years elapsed since the start of the A/R CDM project activity

<u>Method 1 (Carbon gain-loss method)</u>

$$\Delta C_{DW\,ijt} = \Delta Cmlb_{DW\,ijt} + \Delta Chr_{DW\,ijt} - \Delta Cfw_{DW\,ijt} - \Delta Cdesc_{DW\,ijt} \qquad (25)$$

Where:

$\Delta C_{DW\,ijt}$	annual carbon stock change in the deadwood carbon pool for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$\Delta Cmlb_{DW\,ijt}$	annual increase of carbon stock in the deadwood carbon pool due to mortality of the

living biomass of trees for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}

$\Delta Chr_{DW\,ijt}$	annual increase of carbon stock in the deadwood carbon pool due to harvesting residues not collected for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$\Delta Cfw_{DW\,ijt}$	annual decrease of carbon stock in the deadwood carbon pool due to harvesting of deadwood for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$\Delta Cdesc_{DW\,ijt}$	annual decrease of carbon stock in the deadwood carbon pool due to deadwood decomposition for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}

The following equations shall be used:

$$\Delta Cmlb_{DW\,ijt} = V_{ijt} \cdot Mf_{ijt} \cdot Dw_j \cdot BEF_{2,j} \cdot CF_j \cdot A_{Remain\,ijt} \cdot MW_{CO2\text{-}C} \quad (26)$$

$$\Delta Chr_{DW\,ijt} = H_{ijt} \cdot Hf_{ijt} \cdot Dw_j \cdot BEF_{2,j} \cdot CF_j \cdot A_{Remain\,ijt} \cdot MW_{CO2\text{-}C} \quad (27)$$

$$\Delta Cfw_{DW\,ijt} = Fwf_{ijt} \cdot C_{DW\,ij,t-1} \quad (28)$$

$$\Delta Cdesc_{DW\,ijt} = DC \cdot C_{DW\,ij,t-1} \quad (29)$$

Where:

$\Delta Cmlb_{DW\,ijt}$	annual increase of carbon stock in the deadwood carbon pool due to mortality of the living biomass of trees for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}.
V_{ijt}	average merchantable volume of stratum *i*, species *j*, at time *t*; m^3 ha^{-1}
Mf_{ijt}	mortality factor = fraction of V_{ijt} dying at time *t*; dimensionless
Dw_j	intermediate[18] deadwood density for species *j*; t d.m. m^{-3} merchantable volume
$BEF_{2,j}$	biomass expansion factor for converting merchantable volumes of extracted round wood to total above-ground biomass (including bark) for stratum *i*, species *j*, time *t*; dimensionless
CF_j	carbon fraction of dry matter for species *j*; t C $(t\ d.m)^{-1}$
$A_{Remain\,ijt}$	area of the species *j* that is expected to remain, in stratum *i,* between year *t* and *t*+1; ha
H_{ijt}	average annually harvested merchantable volume for stratum *i*, species *j*, time *t*; m^3 ha^{-1} yr^{-1}
$\Delta Chr_{DW\,ijt}$	annual increase of carbon stock in the deadwood carbon pool due to harvesting residues not collected for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
Hf_{ijt}	fraction of annually harvested merchantable volume not extracted and left on the ground as harvesting residue for stratum *i*, species *j*, time *t*; dimensionless
$\Delta Cfw_{DW\,ijt}$	annual decrease of carbon stock in the deadwood carbon pool due to harvesting of deadwood for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
Fwf_{ijt}	fraction of annually harvested deadwood carbon stock harvested as fuel wood for stratum *i*, species *j*, time *t*; dimensionless
$C_{DWij,t-1}$	carbon stock in the deadwood carbon pool in stratum *i*, species *j*, time *t* = *t*-1 year; t CO_2-e.
$\Delta Cdesc_{DW\,ijt}$	annual decrease of carbon stock in the deadwood carbon pool due to deadwood

[18] Each deadwood piece should be assigned to one of three density states – sound, intermediate, and rotten –(Warren, W.G. and Olsen, P.F. 1964. A line transects technique for assessing logging waste. *Forest Science* 10: 267-276). In absence of ex-ante data, intermediate densities should be assumed.

	decomposition for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
DC	decomposition rate (% carbon stock in total deadwood stock decomposed annually); dimensionless
MW_{CO2-C}	ratio of molecular weights of CO_2 and C (44/12); t CO_2 $(t\ C)^{-1}$

Project proponents shall make conservative estimates of the parameters used in Equations 26 to 29 using the best information available to them. If these equations are used for monitoring, the parameters shall be updated, once data from monitoring will become available. The values used for the variables (e.g. V_{ijt}, Mf_{ijt} and H_{ijt}) shall be consistent with the values used in Equations 14 to 16.

Method 2 (stock change method)

$$\Delta C_{DW\,ijt} = (C_{DW\,ijt\,2} - C_{DW\,ijt\,1})/T \cdot MW_{CO2-C} \tag{30}$$

Where:

$\Delta C_{DW\,ijt}$	annual carbon stock change in the deadwood carbon pool for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$C_{DW\,ijt2}$	total carbon stock in deadwood for stratum *i*, species *j*, calculated at time $t=t_2$; t C
$C_{DW\,ijt1}$	total carbon stock in deadwood for stratum *i*, species *j*, calculated at time $t=t_1$; t C
T	number of years between times t_2 and t_1 $(T = t_2-t_1)$; years
MW_{CO2-C}	ratio of molecular weights of CO_2 and C (44/12); t CO_2 $(t\ C)^{-1}$

5.4.3. Estimation of baseline ΔC_{LI} (changes in litter carbon stocks)

Baseline litter carbon stocks increase due to the mortality of living biomass and the accumulation of residues from harvesting operations remaining on the ground, and decreases due to partial harvesting (e.g. fuel wood collection) and wood decomposition:

$$\Delta C_{LI} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{BL}}\sum_{j=1}^{s_{BL}} \Delta C_{LI\,ijt} \tag{31}$$

Where:

ΔC_{LI}	sum of the changes in litter carbon stocks; t CO_2-e. (as per Equation 3)
$\Delta C_{LI\,ijt}$	annual carbon stock change in litter for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
i	1, 2, 3, ... m_{BL} strata in the baseline
j	1, 2, 3, … s_{PS} tree species in the project scenario
t	1, 2, 3, ...t^* years elapsed since the start of the A/R CDM project activity

Method 1 (Carbon gain-loss method)

$$\Delta C_{LI\,ijt} = \Delta Cmlb_{LI\,ijt} + \Delta Chr_{LI\,ijt} - \Delta Cfw_{LI\,ijt} - \Delta Cdesc_{LI\,ijt} \tag{32}$$

Where:

$\Delta C_{LI\,ijt}$	annual carbon stock change in the litter carbon pool for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$\Delta Cmlb_{LI\,ijt}$	annual increase of carbon stock in the litter carbon pool due to mortality of the living biomass of trees for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$\Delta Chr_{LI\,ijt}$	annual increase of carbon stock in the litter carbon pool due to harvesting residues not collected for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$\Delta Cfw_{LI\,ijt}$	annual decrease of carbon stock in the litter carbon pool due to harvesting of litter for

stratum i, species j, time t; t CO_2-e. yr^{-1}

$\Delta Cdesc_{LI\ ijt}$	annual decrease of carbon stock in the litter carbon pool due to litter decomposition for stratum i, species j, time t; t CO_2-e. yr^{-1}

Method 2 (stock change method)

$$\Delta C_{LI\ ijt} = (C_{LI\ ijt\ 2} - C_{LI\ ijt\ 1})/T \cdot MW_{CO2\text{-}C} \quad (33)$$

$\Delta C_{LI\ ijt}$	annual carbon stock change in the litter carbon pool for stratum i, species j, time t; t CO_2-e. yr^{-1}
$C_{LI\ ijt2}$	total carbon stock in litter for stratum i, species j, calculated at time $t=t_2$; t C
$C_{LI\ ijt1}$	total carbon stock in litter for stratum i, species j, calculated at time $t=t_1$, t C
T	number of years between times t_2 and t_1 $(T = t_2\text{-}t_1)$
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); t CO_2 $(t\ C)^{-1}$

6. Ex ante actual net GHG removals by sinks

In choosing parameters and making assumptions project participants should retain a conservative approach, i.e. if different values for a parameter are plausible, a value that does not lead to an overestimation of the actual net GHG removals by sinks or underestimation of the baseline bet GHG removals by sinks should be applied.

The actual net greenhouse gas removals by sinks represent the sum of the verifiable changes in carbon stocks in the carbon pools within the project boundary, minus the increase in non-CO_2 GHG emissions measured in CO_2 equivalents by sources that are increased as a result of the implementation of an A/R CDM project activity, while avoiding double counting, within the project boundary, attributable to the A/R CDM project activity. Therefore,

$$C_{ACTUAL} = \Delta C_{LB} + \Delta C_{DW} + \Delta C_{LI} - E_{Biomassloss} - GHG_E \quad (34)$$

Where:

C_{ACTUAL}	actual net greenhouse gas removals by sinks; t CO_2-e.
ΔC_{LB}	sum of the changes in living biomass carbon stocks of trees (above- and below-ground); t CO_2-e.
ΔC_{DW}	sum of the changes in deadwood carbon stocks; t CO_2-e.
ΔC_{LI}	sum of the changes in litter carbon stocks; t CO_2-e.
GHG_E	sum of the increases in GHG emissions by sources within the project boundary as a result of the implementation of an A/R CDM project activity; t CO_2-e.
$E_{biomassloss}$	decrease in the carbon stock in the tree and non-tree living biomass, deadwood and litter carbon pools of pre-existing vegetation in the year of site preparation up to time t^*; t CO_2-e.

Note: In this methodology Equation 34 is used to estimate actual net greenhouse gas removal by sinks for the period of time elapsed between project start ($t=1$) and the year $t=t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are estimated.

Note: In Equation 34, ΔC_{LB} does not distinguish between pre-existing vegetation and trees planted under the project activity, but ΔC_{LB} includes both. This is possible, because the project initially takes a discount for the biomass stored in pre-existing vegetation with $E_{Biomassloss.}$. The 100% decrease in the carbon stocks of the pre-existing vegetation is an initial loss, and therefore accounted for only once upfront as part of the first monitoring interval, not per year. Later, remainders of pre-existing vegetation are accounted for along with the project vegetation.

6.1. Verifiable changes in the carbon stocks in the carbon pools

6.1.1. Treatment of pre-existing vegetation

The methodology considers the two following possible situations:

a) The carbon stocks in the tree and non-tree living biomass, deadwood and litter of pre-existing vegetation are not significant (i.e., they are not likely to represent more than 2% of the anticipated actual net GHG removals by sinks):
   - Carbon stock changes in the tree and non-tree living biomass of pre-existing vegetation, deadwood and litter are not included in the *ex ante* calculation of actual carbon stock changes, regardless if the pre-existing vegetation is left standing, burnt for land preparation, or is harvested.
   - If the pre-existing vegetation is burned for land preparation before planting, non-CO_2 emissions are estimated from the tree and non-tree above-ground biomass, deadwood and litter (details in section 2 below) and included in the calculation of actual net GHG removal by sinks if they are significant (> 2% of actual net GHG removals by sinks).
   - To be realistic, the biomass of the pre-existing vegetation would be set as the average biomass over a slash and burn/fallow cycle.

b) The carbon stocks in the tree and non-tree living biomass, deadwood and litter of pre-existing vegetation are significant.

If the carbon stocks in the pre-existing vegetation are significant, i.e., they are likely to represent more than 2% of the anticipated actual net GHG removals by sinks, the following methodology procedure is applied:

- If the baseline is shifting agriculture or another form of agriculture/fallow cycle, it is a realistic approach to set the baseline stock to be equal to the average stock over the cycle. It is assumed all this stock will be removed in the year of site preparation. The stocks are assumed to be burned:
  - ✓ Non-CO_2 emissions are calculated from the carbon stock in the tree and non-tree above-ground biomass, deadwood and litter (details in section II.6.2) below).
  - ✓ 100% carbon stock loss in the above-ground and below-ground biomass, deadwood and litter is assumed and estimated using Eq. 35 for both the non-tree component and the young trees.
- Otherwise if for land preparation before planting non-tree and tree vegetation is burned (and not harvested) then:
  - ✓ Non-CO_2 emissions are calculated from the carbon stock in the tree and non-tree above-ground biomass, deadwood and litter (details in section II.7.2) below).
  - ✓ 100% carbon stock loss in the above-ground and below-ground biomass, deadwood and litter is assumed and estimated using the methods outlined in Eq. 36 below for the tree component and deadwood and litter and Eq. 35 for the non-tree component.
- Or, if the tree vegetation is partially or totally harvested before burning then:
  - ✓ The carbon stock decrease in the harvested above-ground and below-ground tree biomass is estimated using the methods outlined below.

- ✓ The above-ground biomass of the harvested trees is subtracted from the biomass estimate (including tree and non-tree above-ground biomass, deadwood and litter) used for the calculation of non-CO_2 emissions from burning.
- ✓ Carbon stock changes in the tree and non-tree living biomass, deadwood and litter of pre-existing vegetation (e.g., trees that are left standing) are not included in the *ex ante* and *ex post* calculation of actual carbon stock changes. This is a conservative assumption because the trees will continue to grow.

All pre-existing tree and non-tree vegetation as well as all deadwood and litter can be assumed to be removed in the year of site preparation, to account for slash and burn or future competition from planted trees. This is a conservative assumption because there will be some non-tree vegetation in the project scenario. Some vegetation may re-grow even if all non-tree vegetation is removed during the site preparation (overall site burning). Moreover, this is a conservative assumption, because some trees may not be removed during site preparation, or slash and burn may not occur at all.

The carbon stock decrease is estimated as follows:

$$E_{biomassloss} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{BL}} \sum_{j=1}^{S_{PS}} A_{ijt} * B_{pre\ ijt} * CF_{pre} * MW_{CO2\text{-}C} \tag{35}$$

Where:

$E_{biomassloss}$	decrease in the carbon stock in the tree and non-tree living biomass, deadwood and litter carbon pools of pre-existing vegetation in the year of site preparation up to time t^*; t CO_2-e.
A_{ijt}	area of stratum i, species j, time t; ha
$B_{pre,ijt}$	average pre-existing stock of pre-project biomass in the tree and non-tree living biomass, deadwood and litter carbon pools on land to be planted before the start of a proposed A/R CDM project activity for baseline stratum i, species j, time t; t d.m. ha^{-1}
CF_{pre}	the carbon fraction of dry biomass in pre-existing vegetation, t C (t d.m.)$^{-1}$
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and carbon; t CO_2-e. (t C)$^{-1}$
i	1, 2, 3, ... m_{BL} strata in the baseline
j	1, 2, 3, … s_{PS} tree species in the project scenario
t	1, 2, 3, ... t^* years elapsed since the start of the A/R CDM project activity

The methodology and equations for estimating ex-ante actual changes in the living biomass carbon stocks of trees are similar to the ones used for the estimation of baseline changes in the living biomass carbon stocks of trees:

$$\Delta C_{LB} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{PS}} \sum_{j=1}^{s_{PS}} \Delta C_{LBijt} \tag{36}$$

Where:

ΔC_{LB}	sum of the changes in living biomass carbon stocks of trees (above- and below-ground); t CO_2-e.
$\Delta C_{LB\ ijt}$	annual carbon stock change in living biomass of trees for stratum i, species j, time t; t CO_2-e. yr^{-1}
i	1, 2, 3, … m_{PS} strata in the project scenario
j	1, 2, 3, … s_{PS} tree species in the project scenario

t 1, 2, 3, … t^* years elapsed since the start of the A/R CDM project activity

The average annual carbon stock change in aboveground biomass and belowground biomass in living trees between two monitoring events at time t, for stratum i, species j ($\Delta C_{LB\,ijt}$) shall be estimated using one of the two methods described in section II.5.4.1, i.e., Equations 8 to 23.

6.1.2. Estimation of actual ΔC_{DW} (changes in deadwood carbon stocks)

As in the case of the living biomass, carbon stock changes in the deadwood carbon pools can be estimated using a carbon gain-loss method or a stock change method.

$$\Delta C_{DW} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{PS}}\sum_{j=1}^{s_{PS}} \Delta C_{DW\,ijt} \tag{37}$$

Where:

ΔC_{DW}	sum of the changes in deadwood carbon stocks; t CO_2-e. (as per Equation 34)
$\Delta C_{DW\,ijt}$	annual carbon stock change in deadwood for stratum i, species j, time t; t CO_2-e. yr^{-1}
i	1, 2, 3, … m_{PS} strata in the project scenario
j	1, 2, 3, … s_{PS} tree species in the project scenario
t	1, 2, 3, … t^* years elapsed since the start of the A/R CDM project activity

The average annual carbon stock change in deadwood at time t, for stratum i, species j ($\Delta C_{DW\,ijt}$) shall be estimated using one of the two methods described in section II.5.4.2, i.e., Equations 24 to 30.

6.1.3. Estimation of actual ΔC_{LI} (changes in litter carbon stocks)

As in the case of the living biomass, carbon stock changes in the litter carbon pools can be estimated using a carbon gain-loss method or a stock change method.

$$\Delta C_{LI} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{PS}}\sum_{j=1}^{s_{PS}} \Delta C_{LI\,ijt} \tag{38}$$

Where:

ΔC_{LI}	sum of the changes in litter carbon stocks; t CO_2-e. (as per Equation 34)
$\Delta C_{LI\,ijt}$	annual carbon stock change in litter for stratum i, species j, time t; t CO_2-e. yr^{-1}
i	1, 2, 3, … m_{PS} strata in the project scenario
j	1, 2, 3, … s_{PS} tree species in the project scenario
t	1, 2, 3, … t^* years elapsed since the start of the A/R CDM project activity

The average annual carbon stock change in litter between two monitoring events at time t, for stratum i, species j ($\Delta C_{LI\,ijt}$) shall be estimated using one of the two methods described in section II.5.4.3, i.e., Equations 31 to 33.

6.2. GHG emissions by sources

An A/R CDM project activity may increase GHG emissions, in particular CO_2, CH_4 and N_2O. The list below contains factors that may be attributable to the increase of GHG emissions[19]:

[19] Refer to Box 4.3.1 and Box 4.3.4 in IPCC GPG-LULUCF

- Emissions of greenhouse gases from combustion of fossil fuels for site preparation, thinning and logging;
- Emissions of non-CO_2 greenhouse gases from biomass burning for site preparation (slash and burn activity);
- N_2O emissions caused by nitrogen fertilization application.

The increase in GHG emission as a result of the implementation of the proposed A/R CDM project activity within the project boundary can be estimated by:

$$GHG_E = E_{FuelBurn} + E_{Non\text{-}CO2,\ BiomassBurn} + N_2O_{direct\text{-}Nfertilizer} \quad (39)$$

Where:

GHG_E	increase in GHG emissions as a result of the implementation of the A/R CDM project activity within the project boundary, t CO_2-e. yr^{-1}
$E_{FuelBurn}$	total GHG emissions due to fossil fuel combustion from vehicles; t CO_2-e. yr
$E_{Non\text{-}CO2,\ BiomassBurn}$	non-CO_2 emission as a result of biomass burning within the project boundary; t CO_2-e. yr^{-1}
$N_2O_{direct\text{-}Nfertilizer}$	increase in N_2O emission as a result of direct nitrogen application within the project boundary; t CO_2-e. yr^{-1}

Note: In this methodology Equation 39 is used to estimate the increase in GHG emission for the period of time elapsed between project start (*t=1*) and the year *t=t**, *t** being the year for which actual net greenhouse gas removals by sinks are estimated.

6.2.1. Estimation of $E_{FuelBurn}$ (GHG emissions from burning of fossil fuels)

GHG emissions from the burning of fossil fuels could result from the use of machinery during site preparation and logging. These emissions can be calculated as:

$$E_{FuelBurn} = E_{Vehicle,CO_2} \quad (40)$$

and:

$$E_{Vehicle,CO_2} = \sum_{t=1}^{t^*}\sum_{x}\sum_{y}(EF_{xy} \cdot FuelConsumption_{xyt}) \quad (41)$$

$$FuelConsumption_{xyt} = n_{xyt} \cdot k_{xyt} \cdot e_{xyt} \quad (42)$$

Where:

$E_{FuelBurn}$	total GHG emissions due to fossil fuel combustion from vehicles; t CO_2-e. yr
$E_{Vehicle,CO2}$	total CO_2 emissions due to fossil fuel combustion from vehicles; t CO_2-e. yr^{-1}
EF_{xy}	CO_2 emission factor for vehicle type *x* with fuel type *y;* dimensionless
$FuelConsumption_{xyt}$	recorded consumption of fuel type *y* of vehicle type *x* at time *t*; liters
n_{xyt}	number of vehicles
k_{xyt}	kilometers traveled by each of vehicle type *x* with fuel type *y* at time *t*; km
e_{xyt}	fuel efficiency of vehicle type *x* with fuel type *y* at time *t*; liters km^{-1}
x	vehicle type

y	fuel type
t	1, 2, 3, … *t** years elapsed since the start of the A/R CDM project activity

The country-specific emission factors shall be used. There are three possible sources of emission factors:

- National emission factors: These emission factors may be developed by national programmes such as national GHGs inventory
- Regional emission factors
- IPCC default emission factors, provided that a careful review of the consistency of these factors with the country conditions has been made. IPCC default factors may be used when no other information is available.

Project participants shall make conservative and credible assumptions of yearly fuel consumption taking into account travel distances, vehicle/machine fuel efficiency, machine hours, and timing of planting and harvesting. Whenever possible, the assumptions shall be supported by verifiable evidence.

6.2.2. Calculation of non-CO_2 emissions from biomass burning

If slash and burn occurs during site preparation before planting and/or replanting, this results in non-CO_2 emissions (CO_2 emission has been covered above as decreases in the stocks of the carbon pools). Based on GPG for LULUCF[20], this type of emission can be estimated as follows:

$$E_{Non-CO_2,BiomassBurn} = E_{BiomassBurn,N_2O} + E_{BiomassBurn,CH_4} \quad (43)$$

$$E_{BiomassBurn,\ N2O} = E_{BiomassBurn,\ C} \cdot (N/C\ ratio) \cdot ERat_{N2O} \cdot MW_{N2O\text{-}N} \cdot GWP_{N2O} \quad (44)$$

$$E_{BiomassBurn,\ CH4} = E_{BiomassBurn,\ C} \cdot ERat_{CH4} \cdot MW_{CH4\text{-}C} \cdot GWP_{CH4} \quad (45)$$

Where[21]:

$E_{Non\text{-}CO2,\ BiomassBurn}$	the increase in Non-CO_2 emission as a result of biomass burning in slash and burn; t CO_2-e. yr^{-1}
$E_{BiomassBurn,\ N2O}$	N_2O emission from biomass burning in slash and burn; t CO_2-e. yr^{-1}
$E_{BiomassBurn,\ CH4}$	CH_4 emission from biomass burning in slash and burn; t CO_2-e. yr^{-1}
$E_{BiomassBurn,C}$	loss of carbon stock in aboveground biomass due to slash and burn; t C yr^{-1}
N/C ratio	nitrogen-carbon ratio, t N $(t\ C)^{-1}$
$MW_{N2O\text{-}N}$	ratio of molecular weights of N_2O and N (44/28); t N_2O $(t\ N)^{-1}$
$MW_{CH4\text{-}C}$	ratio of molecular weights of CH_4 and C (16/12); t CH_4 $(t\ C)^{-1}$
$ERat_{N2O}$	IPCC default emission ratio for N_2O (0.007); dimensionless
$ERat_{CH4}$	IPCC default emission ratio for CH_4 (0.012); dimensionless
GWP_{N2O}	Global Warming Potential for N_2O (310 for the first commitment period); t CO_2-e. $(t\ N_2O)^{-1}$
GWP_{CH4}	Global Warming Potential for CH_4 (21 for the first commitment period); t CO_2-e. $(t\ CH_4)^{-1}$

$$E_{BiomassBurn,C} = \sum_{i=1}^{m_{PS}} A_{burn,i} \cdot B_i \cdot CE \cdot CF \quad (46)$$

[20] Refers to equation 3.2.20 in GPG -LULUCF
[21] Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF and Equation 3.2.19 in GPG LULUCF

Where:

$E_{BiomassBurn,C}$	loss of carbon stock in aboveground biomass due to slash and burn; t C yr^{-1}
$A_{burn,i}$	area of slash and burn for stratum *i*; ha yr^{-1}
B_i	average stock in aboveground living biomass before burning for stratum *i*; t d.m. ha^{-1}
CE	combustion efficiency (IPCC default =0.5); dimensionless
CF	carbon fraction of dry biomass; t C $(t\ d.m)^{-1}$
i	stratum (m_{PS} = total number of strata)

The combustion efficiencies may be chosen from Table 3.A.14 of GPG-LULUCF. If no appropriate combustion efficiency can be used, the IPCC default of 0.5 should be used, see section 3.2.1.4.2.2 in GPG LULUCF. The nitrogen-carbon ratio (N/C ratio) is approximated to be about 0.01. This is a general default value that applies to leaf litter, but lower values would be appropriate for fuels with greater woody content, if data are available.

6.2.3. Calculation of nitrous oxide emissions from nitrogen fertilization

Emissions of nitrous oxide from nitrogen fertilization is given by[22]:

$$N_2O_{direct\text{-}Nfertilizer} = (F_{SN} + F_{ON}) \cdot EF_1 \cdot MW_{N2O\text{-}N} \cdot GWP_{N2O} \qquad (47)$$

$$F_{SN\,t} = N_{SN\text{-}Fert,t} \cdot (1\text{-}Frac_{GASF}) \qquad (48)$$

$$F_{ON\,t} = N_{ON\text{-}Fert\,t} \cdot (1\text{-}Frac_{GASM}) \qquad (49)$$

Where:

$N_2O_{direct\text{-}Nfertilizer}$	direct N_2O emission as a result of nitrogen application within the project boundary up to time *t**; t CO_2-e.
$F_{SN\,t}$	amount of synthetic fertilizer nitrogen applied at time *t* adjusted for volatilization as NH_3 and NO_x; t N
$F_{ON\,t}$	annual amount of organic fertilizer nitrogen applied at time *t* adjusted for volatilization as NH_3 and NO_x; t N
$N_{SN\text{-}Fert\,t}$	amount of synthetic fertilizer nitrogen applied at time *t*; t N
$N_{ON\text{-}Fert\,t}$	amount of organic fertilizer nitrogen applied at time *t*; t N
EF_1	emission factor for emissions from N inputs; t N_2O-N $(t\ N\ input)^{-1}$
$Frac_{GASF}$	fraction that volatilizes as NH_3 and NO_x for synthetic fertilizers; t NH_3-N and NO_x-N $(t\ N)^{-1}$
$Frac_{GASM}$	fraction that volatilizes as NH_3 and NO_x for organic fertilizers; t NH_3-N and NO_x-N $(t\ N)^{-1}$
$MW_{N2O\text{-}N}$	ratio of molecular weights of N_2O and N (44/28); t N_2O $(t\ N)^{-1}$
GWP_{N2O}	Global Warming Potential for N_2O (310 for the first commitment period); t CO_2-e. $(t\ N_2O)^{-1}$

As noted in GPG 2000, the default emission factor (EF_1) is 1.25 % of applied N, and this value should be used when country-specific factors are unavailable. The default values for the fractions of synthetic and organic fertilizer nitrogen that are emitted as NO_x and NH_3 are 0.1 and 0.2 respectively in 2006 IPCC Guideline. Project participants may use scientifically established specific emission factors that are more

[22] Refers to Equation 3.2.18 in IPCC GPG-LULUCF

appropriate for their project. Specific good practice guidance on how to derive specific emission factors is given in Box 4.1 of GPG 2000.

7. Leakage

Leakage (LK) represents the increase in GHGs emissions by sources which occurs outside the boundary of an A/R CDM project activity which is measurable and attributable to the A/R CDM project activity. According to the guidance provided by the Executive Board, leakage also includes the decrease in carbon stocks which occurs outside the boundary of an A/R CDM project activity which is measurable and attributable to the A/R CDM project activity (see EB 22, Annex 15).

There are four sources of the leakage covered by this methodology (Table 9):

- GHG emissions caused by vehicle fossil fuel combustion due to transportation of seedling, labour, staff and harvest products to and/or from project sites;
- GHG emissions caused by displacement of people. These people have no influence over pre-project land use, and therefore do not fall under the activity displacement leakage [e.g., these people could be employees];
- Displacement of fuelwood collection and charcoal production from inside to outside the project boundary;
- Increased use of wood posts for fencing.

Table 9 : Emissions sources included in or excluded from leakage

Sources	Gas	Included/ excluded	Justification / Explanation of choice
Combustion of fossil fuels by vehicles	CO_2	Included	Significant source of leakage
	CH_4	Excluded	Insignificant source of leakage
	N_2O	Excluded	Insignificant source of leakage
Displacement of people	CO_2	Included	Significant source of leakage
	CH_4	Excluded	Not significant
	N_2O	Excluded	Not significant
Displacement of pre-project grazing and agricultural activities	CO_2	Excluded	Will not occur according to applicability conditions
	CH_4	Excluded	Not significant
	N_2O	Excluded	Not significant
Activity displace-ment: fuelwood collection	CO_2	Included	Decrease in carbon stocks outside the project boundary
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable
Increased use of wood posts for fencing	CO_2	Included	Decrease in carbon stocks outside the project boundary
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable

Total leakage is quantified as follows:

$$LK = LK_{Vehicle} + LK_{PeopleDiscplacement} + LK_{fuel\text{-}wood} + LK_{fencing} \quad (50)$$

Where:

LK total leakage; t CO_2-e.

$LK_{PeopleDisplacement}$	total leakage due to deforestation due to people displacement; t CO_2-e.
$LK_{Vehicle}$	total GHG emissions due to fossil fuel combustion from vehicles; t CO_2-e.
$LK_{fuel\text{-}wood}$	leakage due to displacement of fuel-wood collection up to year *t**; t CO_2-e.
$LK_{fencing}$	leakage due to increased use of wood posts for fencing up to year *t**; t CO_2-e.

Note: In this methodology Equation 50 is used to estimate leakage for the period of time elapsed between project start (*t=1*) and the year *t=t*, t** being the year for which actual net greenhouse gas removals by sinks are estimated.

7.1. Estimation of $LK_{Vehicle}$ (leakage due to fossil fuel consumption)

$$LK_{Vehicle} = LK_{Vehicle,CO_2} \quad (51)$$

$$LK_{Vehicle,CO_2} = \sum_{t=1}^{t*} \sum_{x} \sum_{y} (EF_{xy} \cdot FuelConsumption_{xyt}) \quad (52)$$

$$FuelConsumption_{xyt} = n_{xyt} \cdot k_{xyt} \cdot e_{xyt} \quad (53)$$

Where:

$LK_{Vehicle}$	total GHG emissions due to fossil fuel combustion from vehicles; t CO_2-e. yr^{-1}
$LK_{Vehicle,CO2}$	CO_2 emissions due to fossil fuel combustion from vehicles; t CO_2-e. yr^{-1}
x	vehicle type
y	fuel type
EF_{xy}	CO_2 emission factor for vehicle type *x* with fuel type *y;* dimensionless
$FuelConsumption_{xyt}$	recorded consumption of fuel type *y* of vehicle type *x* at time *t*; liters
n_{xyt}	number of vehicles
k_{xyt}	kilometers traveled by each of vehicle type *x* with fuel type *y* at time *t*; km
e_{xyt}	fuel efficiency of vehicle type *x* with fuel type *y* at time *t*; liters km^{-1}
t	1, 2, 3, … *t** years elapsed since the start of the A/R CDM project activity

Country-specific emission factors shall be used. There are three possible sources of emission factors:

- National emission factors: These emission factors may be developed by national programmes such as national GHGs inventory
- Regional emission factors
- IPCC default emission factors, provided that a careful review of the consistency of these factors with the country conditions has been made. IPCC default factors may be used when no other information is available.

Project participants shall make conservative and credible assumptions of yearly fuel consumption taking into account travel distances, vehicle/machine fuel efficiency, machine hours, and timing of planting and harvesting. Whenever possible, the assumptions shall be supported by verifiable evidence.

7.2. Estimation of $LK_{PeopleDisplacement}$ (leakage caused by displacement of people that have no influence over pre-project land use, and therefore do not fall under the activity displacement leakage)

By terminating a current land use, the A/R CDM activity may cause the loss of employment, and therefore cause the displacement of former employees. People displacement leakage may occur in the years immediately after employees are made redundant, when these individuals displaced by the project re-establish their livelihoods. This leakage does not necessarily occur immediately after the start of the project activity, since the project's planting activities may provide initial employment.

If employment is lost, some of the displaced employees and their households may decide to establish a farm as their new livelihood. Establishment of new farms may potentially lead to deforestation. Where forest loss occurs through the actions of the displaced households a leakage debit will be taken by the project.

People displacement leakage is fundamentally different from activity shifting leakage, since the displaced people do not have a direct link with the pre-project land use. Conversely, activity shifting leakage is a situation where land use activities that are taking place on the project lands are continued elsewhere after project initiation, either because those responsible for the land use activities are displaced (i.e. farmers, cattle ranchers) or because third persons take up the land use activity elsewhere to fill a market gap left by the activities ceased by the project.

Step 1: Record the number of employees that the pre-project land uses sustain.

Step 2: Assume for the ex-ante estimation that all of these jobs will be lost and that all the households move away.

Step 3: Project proponents shall estimate the likelihood that a household that moves establishes a new farm based on an analysis of trends for rural-rural and rural-urban migration in the region or the country. Sources for estimating migration trends include official data (e.g., regional or national demographic censuses) and expert opinions. In order to be conservative, all displacement of workers is assumed to lead to a move and all rural-rural migration is assumed to lead to colonization (i.e. new farm establishment and not new wage employment elsewhere). (For instance, the project proponents shall assume that 3 households establish a new farm, if 5 jobs will be lost and if national census reports indicate that 60% of internal migration originating from rural areas involves moves to other rural areas, rather than moves to cities.)

Step 4: Project proponents shall present transparent and verifiable information regarding the average area of smallholder farms in the region.

Step 5: Calculate the total leakage of all households according to the following formula:

$$LK_{PeopleDisplacement} = NDH \cdot AD \cdot FS \tag{54}$$

$$AD = ASF \tag{55}$$

Where:

$LK_{PeopleDisplacement}$ total leakage due to deforestation due to people displacement; t CO_2-e.
NDH number of employees that are deemed likely to establish a new farm; dimensionless
AD area deforested by each displaced household; ha

ASF	average size of small-holder farms in the larger project area; ha
FS	mean carbon stock of primary forests according to the GPG-LULUCF, Table 3A 1.4, pages 3.159-3.162; t CO_2-e. ha^{-1}

7.3. Demonstrate that leakage from activity displacement due to displacement of pre-project grazing activities does not occur

Following applicability condition 13, this methodology only applies for a specific project if the project proponents can demonstrate that the livestock are not displaced somewhere else, but slaughtered or sold to be slaughtered. The project proponents shall provide evidence of what happened to the livestock at the initial verification.

It needs to be demonstrated that there are sufficient areas where the land is used below its sustainable capacity in the vicinity to the project area, within the same market area ("project region"). Therefore, it is not expected that any stocked areas will need to be converted to grazing land or to cropland.

For the purpose of demonstrating that market effects would not trigger conversion of stocked areas to grazing land or crop land, the project region is understood as the region that delivers to the same regional markets for products from the grazing and agricultural land uses on the project sites identified below in Step 1. The project proponents shall define the project region based on past practices of selling products from the project lands, and/or based on interviews with the local population.

Sustainable land-use capacity of agricultural land and sustainable carrying capacity of lands shall be determined based on the following possible data sources[23]: interviews with animal owners, a Participatory Rural Appraisal (PRA), local or regional animal census data, land-use census data, interviews with local experts, scientific sources, IPCC default values.

In order to compare the un-used land-use capacity to the required capacity, follow the procedure in Steps 3-6 for pasture land use and in Steps 7-8 for agricultural land use:

Step 1: Before planting, collect data on the pre-project land uses on the project sites:

a) Record the total number of pre-project animal units in the project boundary. This is the total need for displacement of pre-project grazing activities to outside the project boundary within the project region.
b) Record the total area of pre-project agricultural activities in the project boundary. This is the total need for area for displacement of pre-project agricultural activities to outside the project boundary within the project region.

Step 2: Collect data on the land-use situation in the project region outside the project boundary. Record the total area of pre-project existing pastures in the project region outside the project boundary:

a) Record the average cattle stocking rates on pre-project existing pastures in the project region outside the project boundary.
b) Record the average carrying capacity of the total area under pre-project existing pasture in the project region outside the project boundary.
c) Record the area of pre-project abandoned lands available in the project region outside the project boundary that are not regenerating.

[23] This methodology does not consider increasing land-use capacity by using fertilizers. If a project wants to consider increased use of fertilizers, an amendment shall be proposed.

d) Determine the average carrying capacity of the abandoned lands identified in step 2d. Determine the area of these abandoned lands that are suitable for sustaining the pre-project agricultural land uses.

Step 3: Derive the unused carrying capacity on existing pastures, available for absorbing the displacement of pre-project grazing activities from inside the project boundary to outside the project boundary within the project region. In doing so, the unused carrying capacity corresponds to the difference between the average cattle stocking rates (from Step 2b) and the average carrying capacity (from Step 2c), multiplied by the area being used for pasture land-use activities outside the project boundary (from Step 2a).

Step 4: Check whether there is sufficient un-used carrying capacity available on existing pastures for displacement of pre-project grazing activities (comparing the un-used carrying capacities in Step 3 to the need for carrying capacity from Step 1a). If not, consider Step 5.

Step 5: Derive the total carrying capacity on abandoned lands that are not regenerating, available for absorbing the displacement of pre-project grazing activities from inside the project boundary to outside the project boundary within the project region. In doing so, the total carrying capacity available on abandoned lands that are not regenerating corresponds to the product of those areas (as determined in Step 2d) and the average carrying capacity on those areas (from Step 2e).

Step 6: Check whether there is sufficient carrying capacity on abandoned lands that are not regenerating, available for absorbing the displacement of pre-project grazing activities (comparing the un-used carrying capacities in Step 5 to the remaining need for carrying capacity after Step 4). If not, this methodology is not applicable.

Step 7: Derive the total area of abandoned lands that are not regenerating and that will not be occupied by the displacement of the pre-project grazing activities, available for absorbing the displacement of pre-project agricultural activities. In doing so, the areas available are the remainder after Step 6, if they are suitable to support the agricultural activities that occur inside the project boundary in a sustainable way (as determined in step 2e).

Step 8: Check whether there are sufficient areas on abandoned lands that are not regenerating available for absorbing the displacement of pre-project agricultural activities (comparing the un-used areas in Step 7 to the need for areas from Step 1b). If not, this methodology is not applicable.

7.4. Estimation of $LK_{fuel\text{-}wood}$ (Leakage due to displacement of fuel-wood collection)

Depending on the specific project circumstance, all pre-project fuel-wood collection activities (including in-site charcoal production), or a fraction of them, may have to be displaced permanently, or temporarily, outside the project boundary. Where pre-project fuel-wood collection and/or charcoal production activities exist, it is necessary to estimate the pre-project consumption of fuel-wood in randomly selected different discrete parcels or sub-areas within the project area. This can be done by interviewing households or implementing a Participatory Rural Appraisal (PRA). Where several discrete parcels are present in the project area, sampling techniques can be used. Others sources of information, such as local studies on fuel-wood consumption and/or charcoal production may also be used. Average data from the 5 to 10 years time period preceding the starting date of the A/R-CDM project activity should be used whenever possible.

$$FG_{BL} = \frac{sFG_{BL}}{SFR_{PAfw}} \qquad (56)$$

Where:

FG_{BL}	average pre-project annual volume of fuel-wood gathering in the project area; $m^3\ yr^{-1}$
sFG_{BL}	sampled average pre-project annual volume of fuel-wood gathering in the project area; $m^3\ yr^{-1}$
SFR_{PAfw}	fraction of total area or households in the project area sampled; dimensionless

The methodology assumes that the estimated historical or current fuel-wood consumption and/or charcoal production (FG_{BL}) will remain constant over the entire crediting period. Based on the planned afforestation or reforestation establishment schedule and the prescribed management, the periods of time from which fuel-wood collection and/or charcoal production should be excluded from the considered sample discrete areas as well as the amounts of fuel-wood produced in the different stands through thinning, coppicing and harvesting can be specified. This planning should be used to estimate the amount of fuel-wood and/or charcoal that may have to be obtained each year from sources outside the project boundary.

$$FG_{outside,t} = FG_{BL} - FG_{AR,t} \qquad (57)$$

Where:

$FG_{outside,t}$	volume of fuel-wood gathering displaced outside the project area at year *t*; $m^3\ yr^{-1}$
FG_{BL}	average pre-project annual volume of fuel-wood gathering in the project area; $m^3\ yr^{-1}$
$FG_{AR,t}$	volume of fuel-wood gathering allowed/planned in the project area under the proposed A/R CDM project activity; $m^3\ yr^{-1}$

Leakage due to displacement of fuel-wood collection can be set as zero ($LK_{fuel\text{-}wood} = 0$) under the following circumstances:

- $FG_{BL} < FG_{AR,t}$
- $LK_{fuel\text{-}wood} <$ 2% of actual net GHG removals by sinks (See EB22, Annex 15).

In all other cases, leakage due to displacement of fuel-wood collection shall be estimated as follow (IPCC GPG-LULUCF - Eq. 3.2.8):

$$LK_{fuel\text{-}wood} = \sum_{t=1}^{t^*} FG_t \cdot D \cdot R \cdot CF \cdot MW_{CO2\text{-}C} \qquad (58)$$

$$FG_t = FG_{outside,t} \qquad (59)$$

Where:

$LK_{fuel\text{-}wood}$	leakage due to displacement of fuel-wood collection up to year *t**; t CO_2-e.
FG_t	volume of fuel-wood gathering displaced in unidentified areas; $m^3\ yr^{-1}$
$FG_{outside,t}$	volume of fuel-wood gathering displaced outside the project area at year *t*; $m^3\ yr^{-1}$
D	average basic wood density (see IPCC GPG-LULUCF, Table 3A.1.9); t d.m. m^{-3}
CF	carbon fraction of dry matter (default = 0.5); t C (t d.m.)$^{-1}$

R	root-shoot ratio; dimensionless
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); t CO_2 (t C)$^{-1}$
t	1, 2, 3, … *t** years elapsed since the start of the A/R CDM project activity

7.5. Estimation of $LK_{fencing}$ (Leakage due to increased use of wood posts for fencing)

The protection of natural regeneration and planted trees from animal grazing and fuel-wood collection may require fencing using wood posts. Where the wood posts are not obtained from sources inside the project area, they may have to be supplied from outside sources. If these outside sources are not renewable (e.g. the production of posts leads to forest degradation, deforestation or devegetation), leakage may occur. The supply source of the posts used for fencing should be specified in the PDD. If the outside source used is not renewable, leakage due to increased use of wood posts for fencing shall be estimated as follow:

$$LK_{fencing} = \sum_{t=1}^{t^*} \frac{PAR_t}{DBP} \cdot FNRP \cdot APV \cdot D \cdot BEF_2 \cdot CF \cdot MW_{CO2\text{-}C} \qquad (60)$$

where:

$LK_{fencing}$	leakage due to increased use of wood posts for fencing up to year *t**; t CO_2-e.
PAR_t	perimeter of the areas to be fenced at year *t*; m
DBP	average distance between wood posts; m
FNRP	fraction of posts from off-site non-renewable sources; dimensionless
APV	average volume of o wood posts (estimated from sampling); m^3
D	average basic wood density; t d.m. m^{-3} (See IPCC GPG-LULUCF, 2003 Table 3A.1.9)
BEF_2	biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark); dimensionless Table 3A.1.10
CF	carbon fraction of dry matter (default = 0.5); t C (t d.m.)$^{-1}$
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); t CO_2 (t C)$^{-1}$
t	1, 2, 3, … *t** years elapsed since the start of the A/R CDM project activity

Note: As per the guidance provided by the Executive Board (See EB22, Annex 15) leakage due to increased use of wood posts for fencing can be excluded from the calculation of leakages under the following circumstance:

- $LK_{fencing}$ < 2% of actual net GHG removals by sinks (See EB22, Annex 15).

8. Ex ante net anthropogenic GHG removal by sinks

The net anthropogenic GHG removals by sinks is the actual net GHG removals by sinks minus the baseline net GHG removals by sinks minus leakage, therefore, the following general formula can be used to calculate the net anthropogenic GHG removals by sinks of an A/R CDM project activity ($C_{AR\text{-}CDM}$), in t CO_2-e. :

$$C_{AR-CDM} = C_{ACTUAL} - C_{BSL} - LK \qquad (61)$$

Where:

$C_{AR\text{-}CDM}$	net anthropogenic greenhouse gas removals by sinks; t CO_2-e.
C_{ACTUAL}	actual net greenhouse gas removals by sinks; t CO_2-e.

C_{BSL}	baseline net greenhouse gas removals by sinks; t CO_2-e.
LK	leakage; t CO_2-e.

Note: In this methodology Equation 61 is used to estimate net anthropogenic GHG removals by sinks for the period of time elapsed between project start ($t=1$) and the year $t=t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are estimated. This is done because project emissions and leakage are permanent, which requires to calculate their cumulative values since the starting date of the A/R CDM project activity.

Calculation of tCERs and lCERs

To estimate the amount of CERs that can be issued at time $t^* = t_2$ (the date of verification) for the monitoring period $T = t_2 - t_1$, this methodology uses the EB approved equations[24] , which produce the same estimates as the following:

$$tCERs = C_{AR\text{-}CDM,t2} \tag{62}$$

$$lCERs = C_{AR\text{-}CDM,t2} - C_{AR\text{-}CDM,t1} \tag{63}$$

Where:

$tCERs$	number of units of temporary Certified Emission Reductions
$lCERs$	number of units of long-term Certified Emission Reductions
$C_{AR\text{-}CDM,t2}$	net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$; t CO_2-e.
$C_{AR\text{-}CDM,t1}$	net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$; t CO_2-e.

9. Uncertainties

The approach provided in Section III.11 should be applied.

[24] See EB 22, Annex 15 (http://cdm.unfccc.int/EB/Meetings/022/eb22_repan15.pdf)

10. Data needed for *ex ante* estimations

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
Historical land use/cover data	dimension-less	Determining baseline approach		
Demonstrating eligibility of land	dimension-less	Earliest possible up to now	Publications, national or regional forestry inventory, local government, interview	
Land use/cover map	dimension-less	Demonstrating eligibility of land, stratifying land area	Reforestation: ~1990. Afforestation: 50 years prior to project start and the most recent date.	Forestry inventory
Satellite image	dimension-less	Demonstrating eligibility of land, stratifying land area	Reforestation: ~1990. Afforestation: 50 years prior to project start and themost recent date	e.g. Landsat
Landform map	dimension-less	Stratifying land area	most recent date	Local government
Soil map	dimension-less	Stratifying land area	most recent date	Local government and institutional agencies
National and sectoral policies	dimension-less	Additionality consideration	Before 1998	
UNFCCC decisions	dimension-less		1997 up to now	UNFCCC website
IRR, NPV, unit cost of service	dimension-less	Indicators of investment analysis	Most recent data	Calculation (if any, depends on the way of additionality analysis)

Data / Parameter	**Unit**	**Description**	**Vintage**	**Data sources and geographical scale**
Investment costs	dimension-less	Including land purchase or rental, machinery, equipments, buildings, fences, site and soil preparation, seedling, planting, weeding, pesticides, fertilization, supervision, training, technical consultation, etc. that occur in the establishment period	Most recent date, taking into account market risk	Local statistics, published data and/or survey (if any, depends on the way of additionality analysis)
Operations and maintenance costs	dimension-less	Including costs of thinning, pruning, harvesting, replanting, fuel, transportation, repairs, fire and disease control, patrolling, administration, etc.	Most recent date, taking into account market risk	Local statistics, published data and/or survey (if any, depends on the way of additionality analysis)
Transaction costs	dimension-less	Including costs of project preparation, validation, registration, monitoring, etc.	Most recent date	DOE
Revenues	dimension-less	Revenues from timber, fuel-wood, non-wood products, with and without CER revenues, etc.	Most recent date, taking into account market risk	Local statistics, published data and/or survey (if any, depends on the way of additionality analysis.
0.001	$kg\ t^{-1}$	Conversion from kg to tones of CO_2		IPCC. Global default
$ERat_{N2O}$	dimension-less	IPCC default emission ratio for N_2O (0.007);		IPCC. Global default
$ERat_{CH4}$	dimension-less	IPCC default emission ratio for CH_4 (0.012)		IPCC. Global default
$MW_{CH4\text{-}C}$	$t\ CH_4\ (t\ C)^{-1}$	Ratio of molecular weights of CH_4 and C (16/12);		IPCC. Global default
$MW_{N2O\text{-}N}$	$t\ N_2O\ (t\ N)^{-1}$	Ratio of molecular weights of N_2O and N (44/28);		IPCC. Global default
$MW_{CO2\text{-}C}$	$t\ CO_2\ (t\ C)^{-1}$	Ratio of molecular weights of CO_2 and C (44/12);		IPCC. Global default

Data / Parameter	**Unit**	**Description**	**Vintage**	**Data sources and geographical scale**
GWP_{CH4}	t CO_2-e. (t CH_4)$^{-1}$	Global Warming Potential for CH_4 (21 for the first commitment period);		IPCC. Global default
GWP_{N2O}	t CO_2-e. (t N_2O)$^{-1}$	Global Warming Potential for N_2O (310 for the first commitment period);		IPCC. Global default
$A_{burn,i}$	ha yr^{-1}	Area of slash and burn for stratum *i*		Estimated ex ante, monitored ex post
AD	ha	Area deforested by each displaced household		Monitored ex post or assumed
$Adist_{ijt}$	ha yr^{-1}	Forest areas affected by disturbances in stratum *i,* species *j*, time *t*	Most updated	Estimated ex ante, monitored ex post. Stratum and species
$Adist_{ijT}$	ha^{-1} yr^{-1}	Average annual area affected by disturbances for stratum *i*, species *j*, during the period *T*	Most updated	Estimated ex ante
A_i	ha	Area of stratum *i*	Most updated	Estimated ex ante
A_{ijt}	ha	Area of stratum *i*, species *j*, at time *t*	Most updated	Estimated ex ante
$A_{Remain\ ijt}$	ha	Area of the land-use type *j* that is expected to remain, in stratum *i,* between the year *t=tx* and *t=tx*+1		Estimated ex-ante
$A_{Change\ ijt}$	ha	Area of the land-use type *j* that is expected to change, in stratum *i,* between the year *t=tx* and *t=tx*+1		Estimated ex-ante
A_{ijT}	ha yr^{-1}	Average annual area for stratum *i*, species *j*, during the period *T*	Most updated	Estimated ex ante
ASF	ha	Average size of small-holder farms in the larger project area		Estimated ex ante
$BEF_{1,j}$	dimension-less	Biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total above-ground biomass increment for species *j*		GPG-LULUCF, national GHG inventory, local survey.

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
$BEF_{2,,j}$	dimension-less	Biomass expansion factor for converting merchantable volumes of extracted roundwood to total aboveground biomass (including bark) for species *j*		GPG-LULUCF, national GHG inventory, local survey
B_i	t d.m. ha^{-1}	Average stock in above-ground living biomass before burning for stratum *i*		GPG-LULUCF, national GHG inventory, local survey
$B_{non\text{-}tree,\ it}$	t d.m. ha^{-1}	Average non-tree biomass stock on land to be planted before the start of a proposed A/R CDM project activity for stratum *i*, time *t*		Estimated ex-ante
$B_{w,\ ijt}$	t d.m. ha^{-1}	Average above-ground biomass stock for stratum *i*, species *j*, time *t*		GPG-LULUCF, national GHG inventory, local survey
$C_{AB,ijt}$	t C	Carbon stock in above-ground biomass for stratum *i*, species *j*, at time *t*		Calculated. Local and species specific.
C_{ACTUAL}	t CO_2-e.	Actual net greenhouse gas removals by sinks		Calculated. Project specific.
$C_{BB,ijt}$	t C	Carbon stock in below-ground biomass for stratum *i*, species *j*, at time *t*		Calculated. Local and species specific
$C_{DW\ ijt1}$	t C	Total carbon stock in deadwood for stratum *i*, species *j*, calculated at time $t=t_1$		Calculated
$C_{DW\ ijt2}$	t C	Total carbon stock in deadwood for stratum *i*, species *j*, calculated at time $t=t_2$		Calculated
$C_{DWij,t-1}$	t CO_2-e.	Carbon stock in the deadwood carbon pool in stratum *i*, species *j*, time *t* $= t^{-1}$ *year*		Calculated

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
CE	dimension-less	Combustion efficiency (IPCC default =0.5)		IPCC GPG-2000, national GHG inventory. Global and national default
CF_j	t C (t d.m)$^{-1}$	Carbon fraction of dry matter for species *j*		IPCC GPG-2000, national GHG inventory. Global and national default
$CF_{non\text{-}tree}$	t C (t d.m.)$^{-1}$	Carbon fraction of dry biomass in non-tree vegetation		IPCC GPG-2000, national GHG inventory. Global and national default
$C_{LB\ ijt1}$	t C	Average annual carbon stock change in living biomass of trees		Calculated
$C_{LB\ ijt2}$	t C	Total carbon stock in living biomass of trees for stratum *i*, species *j*, calculated at time $t=t_2$		Calculated
$C_{LI\ ijt1}$	t C	Total carbon stock in litter for stratum *i*, species *j*, calculated at time $t=t_1$		Calculated
$C_{LI\ ijt2}$	t C	Total carbon stock in litter for stratum *i*, species *j*, calculated at time $t=t_2$		Calculated
DBH_t	cm	Mean diameter at breast height at time *t*		Estimated
DC	dimension-less	Decomposition rate (% carbon stock in total deadwood stock decomposed annually)		GPG-LULUCF, national and local forestry inventory, preferably investigated ex post
D_j	t d.m. m^{-3}	Basic wood density for species *j*		GPG-LULUCF, national and local forestry inventory, preferably investigated ex post

Data / Parameter	**Unit**	**Description**	**Vintage**	**Data sources and geographical scale**
Dw_j	t d.m. m^{-3} merchantable volume	Intermediate deadwood density for species *j*		GPG-LULUCF, national and local forestry inventory, preferably investigated ex post
$E_{BiomassBurn,\ CH4}$	t CO_2-e. yr^{-1}	CH_4 emission from biomass burning in slash and burn		Calculated.
$E_{BiomassBurn,\ N2O}$	t CO_2-e. yr^{-1}	N_2O emission from biomass burning in slash and burn		Calculated.
$E_{BiomassBurn,C}$	t C yr^{-1}	Loss of carbon stock in aboveground biomass due to slash and burn		Calculated
$E_{biomassloss}$	t CO_2-e.	Decrease in the carbon stock in the tree and non-tree living biomass, deadwood and litter carbon pools of pre-existing vegetation in the year of site preparation up to time *t**		Calculated
EF_1	t N_2O-N (t N input)$^{-1}$	Emission Factor for emissions from N inputs		GPG 2001. Global default
$E_{FuelBurn}$	t CO_2-e. yr^{-1}	Total GHG emissions due to fossil fuel combustion from vehicles		Calculated
EF_{xy}	dimension-less	CO_2 emission factor for vehicle type *x* with fuel type *y*		GPG-2000, 2006 IPCC Guideline, national GHG inventory
$E_{Non\text{-}CO2,\ BiomassBurn}$	t CO_2-e. yr^{-1}	Non-CO_2 emission as a result of biomass burning within the project boundary		Estimated ex ante, monitored ex post
e_{xyt}	liters km^{-1}	Fuel efficiency of vehicle type *x* with fuel type *y* at time *t*		GPG-2000, 2006 IPCC Guideline, national GHG inventory
$E_{Vehicle,CO2}$	t CO_2-e. yr^{-1}	Total CO_2 emissions due to fossil fuel combustion from vehicles		Calculated

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
$FG_{AR,t}$	m^3 yr^{-1}	Volume of fuel-wood gathering allowed/planned in the project area under the proposed A/R-CDM project activity		Calculated
FG_{BL}	m^3 yr^{-1}	Average pre-project annual volume of fuel-wood gathering in the project area		Calculated
FG_{ijt}	m^3 yr^{-1}	Annual volume of fuel wood harvesting of living trees for stratum *i*, species *j*, time *t*		Estimated ex ante, monitored ex post
FG_{ijT}	m^3 ha^{-1} yr^{-1}	Average annual volume of fuel wood harvested for stratum *i*, species *j*, during the period *T*		Estimated ex ante, monitored ex post
$FG_{outside,t}$	m^3 yr^{-1}	Volume of fuel-wood gathering displaced outside the project area at year *t*		Calculated
FG_t	m^3 yr^{-1}	Volume of fuel-wood gathering displaced in unidentified areas		Calculated
FNRP	dimension-less	Fraction of posts from off-site non-renewable sources		Estimated
$f_j(DBH_t,H_t)$	dimension-less	Allometric equation linking above-ground biomass (d.m ha^{-1}) to mean diameter at breast height (DBH) and possibly mean tree height (H) for species *j*		Forestry inventory, published data, local survey
$F_{ON\,t}$	t N	Amount of organic fertilizer nitrogen applied at time *t* adjusted for volatilization as NH_3 and NO_x		Estimated
$Frac_{GASF}$	t NH_3-N and NO_x-N $(t\ N)^{-1}$	Fraction that volatilises as NH_3 and NO_x for synthetic fertilizers;		IPCC Guideline. Global default
$Frac_{GASM}$	t NH_3-N and NO_x-N $(t\ N)^{-1}$	Fraction that volatilises as NH_3 and NO_x for organic fertilizers;		IPCC Guideline. Global default

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
FS	CO_2-e. ha^{-1}	Mean carbon stock of forest vegetation in the larger project		GPG-LULUCF, national and local forestry inventory.
$F_{SN\,t}$	t N	Amount of synthetic fertilizer nitrogen applied at time t adjusted for volatilization as NH_3 and NO_x		Estimated to measured ex ante, measured ex post
$FuelConsumption_{xyt}$	liters	Recorded consumption of fuel type y of vehicle type x at time t		Estimated to measured ex ante, measured ex post
Fwf_{ijt}	dimension-less	Fraction of annually harvested deadwood carbon stock harvested as fuel wood for stratum i, species j, time t		Estimated to measured ex ante, measured ex post
GHG_E	t CO_2-e. yr^{-1}	GHG emissions as a result of the implementation of the A/R CDM project activity within the project boundary		Calculated
$G_{TOTAL,ij}$	t d.m ha^{-1} yr^{-1}	Annual average increment rate in total biomass in units of dry matter for stratum i, species j	Most recent	GPG-LULUCF, national and local forestry inventory
$G_{w,ij}$	t d.m ha^{-1} yr^{-1}	Average annual above-ground dry biomass increment of living trees for stratum i, species j		GPG-LULUCF, national and local forestry inventory
Hf_{ijt}	dimension-less	Fraction of annually harvested merchantable volume not extracted and left on the ground as harvesting residue for stratum i, species j, time t		Estimated ex ante, monitored ex post
H_{ijt}	m^3 ha^{-1} yr^{-1}	Annually extracted merchantable volume for stratum i, species j, time t		Estimated ex ante, monitored ex post
H_{ijT}	m^3 ha^{-1} yr^{-1}	Average annual net increment in merchantable volume for stratum i, species j during the period T		Estimated ex ante, monitored ex post
H_t	m	Mean tree height at time t		Estimated ex-ante, monitored ex-post

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
i	dimension-less	1, 2, 3, … m_{BL} baseline strata		Estimated ex ante, monitored ex post
$I_{v,ij}$	m^3 ha^{-1} yr^{-1}	Average annual increment in merchantable volume for stratum i species j		Estimated ex ante
$I_{v,ijT}$	m^3 ha^{-1} yr^{-1}	Average annual net increment in merchantable volume for stratum i, species j during the period T		Estimated ex ante
j	dimension-less	1, 2, 3, … s_{BL} baseline tree species		Estimated ex ante, monitored ex post
k_{xyt}	km	Kilometers traveled by each of vehicle type y with fuel type x at time t		Estimated ex ante, monitored ex post
$L_{fw,\ ijt}$	CO_2-e. yr^{-1}	Annual carbon loss due to fuel wood gathering for stratum stratum i, species j, time t		Estimated ex ante, monitored ex post
$L_{hr,\ ijt}$	t CO_2-e. yr^{-1}	Annual carbon loss due to commercial harvesting for stratum i, species j, time t		Estimated ex ante, monitored ex post
LK	t CO_2-e.	Leakage		Calculated
$LK_{fencing}$	t CO_2-e.	Leakage due to increased use of wood posts for fencing up to year t*		Calculated
$LK_{fuel\text{-}wood}$	t CO_2-e.	Leakage due to displacement of fuel-wood collection up to year t*		Calculated
$LK_{People\ Displacement}$	t CO_2-e.	Total carbon stock decreases outside the project boundary due to forest loss attributable to displacement of people		Calculated
$LK_{Vehicle}$	t CO_2-e. yr^{-1}	Total GHG emissions due to fossil fuel combustion from vehicles		Calculated
$LK_{Vehicle,CO2}$	t CO_2-e. yr^{-1}	Total CO_2 emissions due to fossil fuel combustion from vehicles		Calculated
$L_{ot,\ ijt}$	CO_2-e. yr^{-1}	Annual natural losses (mortality) of carbon for stratum stratum i, species j, time t		Calculated

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
Mf_{ijT}	dimension-less	Mortality factor = fraction of V_{ijt1} died during the period T		Estimated
Mf_{ijt}	dimension-less	Mortality factor = fraction of V_{ijt} dying at time t		Estimated
$N_2O_{direct\text{-}Nfertilizer}$	t CO_2-e. yr^{-1}	the direct N_2O emission as a result of nitrogen application within the project boundary		Estimated.
N/C ratio	t N $(t\ C)^{-1}$	Nitrogen-Carbon ratio;		IPCC. Global default
NDH	dimension-less	Number of employees that are deemed likely to establish a new farm		Estimated ex ante, monitored ex post
$N_{ON\text{-}Fert\ t}$	t N	Amount of organic fertilizer nitrogen applied at time t		Estimated ex ante, monitored ex post
$N_{SN\text{-}Fert\ t}$	t N	Amount of synthetic fertilizer nitrogen applied at time t		Estimated ex ante
nTR_{ijt}	ha^{-1}	Number of trees in stratum i, species j, at time t		Estimated ex ante, monitored ex post
n_{xyt}		Number of vehicles		Estimated ex ante
PAR_t	m	Perimeter of the areas to be fenced at year t		Estimated ex ante
tCERs	dimension-less	Number of units of temporary Certified Emission Reductions		Estimated ex ante
lCERs	dimension-less	Number of units of long-term Certified Emission Reductions		Estimated ex ante
$C_{AR\text{-}CDM,t2}$	t CO_2-e.	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$		Estimated ex ante
$C_{AR\text{-}CDM,t1}$	t CO_2-e.	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$		Estimated ex ante

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
R_j	dimension-less	Root-shoot ratio appropriate to increments for species *j*		IPCC GPG-2000, national GHG inventory. Global and national default
SFG_{BL}	$m^3\ yr^{-1}$	Sampled average pre-project annual volume of fuel-wood gathering in the project area		
SFR_{PAfw}	dimension-less	Fraction of total area or households in the project area sampled		
t	years	1, 2, 3, ...*t** years elapsed since the start of the A/R CDM project activity		
T	years	Number of years between times t_2 and t_1 $(T = t_2\text{-}t_1)$		Estimated ex ante, monitored ex post
V_{ijt}	$m^3\ ha^{-1}$	Average merchantable volume of stratum *i*, species *j*, at time *t*		Forestry inventory, yield table, local survey. Local and species specific.
V_{ijt1}	$m^3\ ha^{-1}$	Average merchantable volume of stratum *i*, species *j*, at time $t = t_1$		Forestry inventory
V_{ijt2}	$m^3\ ha^{-1}$	Average merchantable volume of stratum *i*, species *j*, at time $t = t_2$		Forestry inventory
x	dimension-less	Vehicle type		Estimated ex ante, monitored ex post
y	dimension-less	Fuel type		Estimated ex ante, monitored ex post
ΔC_{Change}	t CO_2-e.	Sum of the carbon-stock changes in all biomass pools from land uses that change		Calculated
$C_{increase\ ijt}$	t C	Decreases in carbon stock in all biomass pools due to decreasing areas for stratum *i*, species *j*, calculated at time *t*		Calculated
$C_{decrease\ ijt}$	t C	Increases in carbon stock in all biomass pools due to increasing areas for stratum *i*, species *j*, at time *t*		Calculated

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
$A_{Change\ ijt}$	ha	Area of a land-use type *j* expected to change between a given year *t* and the subsequent year *t*+1 in stratum *i*		Estimated
B_{ijt}	t d.m. ha^{-1}	Average biomass stock on land before or after the land-use change for stratum *i*, species *j*, time *t*		Estimated
$\Delta Cdesc_{DW\ ijt}$	t CO_2-e. yr^{-1}	Annual decrease of carbon stock in the deadwood carbon pool due to deadwood decomposition for stratum *i*, species *j*, time *t*		Calculated
$\Delta Cdesc_{LI\ ijt}$	t CO_2-e. yr^{-1}	Annual decrease of carbon stock in the litter carbon pool due to litter decomposition for stratum *i*, species *j*, time *t*		Calculated
ΔC_{DW}	t CO_2-e.	Sum of the changes in deadwood carbon stocks		Calculated
$\Delta C_{DW\ ijt}$	t CO_2-e. yr^{-1}	Annual carbon stock change in deadwood for stratum *i*, species *j*, time *t*		Calculated
$\Delta Cfw_{DW\ ijt}$	t CO_2-e. yr^{-1}	Annual decrease of carbon stock in the deadwood carbon pool due to harvesting of deadwood for stratum *i*, species *j*, time *t*		Estimated ex ante, monitored ex post
$\Delta Cfw_{LI\ ijt}$	t CO_2-e. yr^{-1}	Annual decrease of carbon stock in the litter carbon pool due to harvesting of litter for stratum *i*, species *j*, time *t*		Estimated ex ante, monitored ex post
$\Delta C_{G,\ ijt}$	t CO_2-e. yr^{-1}	Annual increase in carbon stock due to biomass growth for stratum *i*, species *j*, time *t*		Estimated ex ante, monitored ex post
$\Delta Chr_{DW\ ijt}$	t CO_2-e. yr^{-1}	Annual increase of carbon stock in the deadwood carbon pool due to harvesting residues not collected for stratum *i*, species *j*, time *t*		Estimated ex ante, monitored ex post

Data / Parameter	Unit	Description	Vintage	Data sources and geographical scale
$\Delta Chr_{LI\ ijt}$	t CO_2-e. yr^{-1}	Annual increase of carbon stock in the litter carbon pool due to harvesting residues not collected for stratum *i*, species *j*, time *t*		Estimated ex ante, monitored ex post
$\Delta C_{L,\ ijt}$	t CO_2-e. yr^{-1}	Annual decrease in carbon *stock* due to biomass loss for stratum *i*, species *j*, time *t*		Estimated ex ante, monitored ex post
ΔC_{LB}	t CO_2-e.	Sum of the changes in living biomass carbon stocks (above- and below-ground)		Calculated
$\Delta C_{LB\ ijt}$	t CO_2-e. yr^{-1}	Annual carbon stock change in living biomass for stratum *i*, species *j*, time *t*		Calculated
ΔC_{LI}	t CO_2-e.	Sum of the changes in litter carbon stocks		Calculated
$\Delta C_{LI\ ijt}$	t CO_2-e. yr^{-1}	Annual carbon stock change in litter for stratum *i*, species *j*, time *t*;		Calculated
$\Delta Cmlb_{DW\ ijt}$	t CO_2-e. yr^{-1}	Annual increase of carbon stock in the deadwood carbon pool due to mortality of the living biomass for stratum *i*, species *j*, time *t*		Estimated ex ante, monitored ex post
$\Delta Cmlb_{LI\ ijt}$	t CO_2-e. yr^{-1}	Annual increase of carbon stock in the litter carbon pool due to mortality of the living biomass for stratum *i*, species *j*, time *t*		Calculated

11. Other information

The baseline net GHG removal by sinks, actual net GHG removal by sinks and net anthropogenic GHG removal by sinks are expressed annually since not all emission/removals occur every year. Some sources such as fertilizer application, machinery usage and slash and burn occur only in selected years. The annual carbon stock change is calculated in the timeframe of a monitoring interval followed by dividing by the year of the interval. Hence at the end, all source/sinks are expressed in annual numbers. Since CERs will not be issued annually, the issued tCERs or lCERs will be calculated according to equations made available in the chapter: Ways of calculating tCERs and lCERs.

Section III: Monitoring methodology description

1. Monitoring project boundary and project implementation

Monitoring of project implementation includes:

- Monitoring of the project boundary
- Monitoring of forest establishment
- Monitoring of forest management

The corresponding methodology procedures are outlined below.

a. Monitoring of the boundary of the proposed A/R CDM project activity

This is meant to demonstrate that the actual area afforested or reforested conforms with the afforestation or reforestation area outlined in the project plan. The following activities are foreseen:

- Field surveys concerning the actual project boundary within which A/R activity has occurred, site by site.
- Measuring geographical positions (latitude and longitude of each corner polygon sites) using GPS, analysis of geo-referenced spatial data, or other appropriate techniques.
- Checking whether the actual boundary is consistent with the description in the CDM-AR-PDD.
- Input the measured geographical positions into the GIS system and calculate the eligible area of each stratum and stand.
- The project boundary shall be monitored periodically all through the crediting period, including through remote sensing as applicable. If the forest area changes during the crediting period, for instance, because deforestation occurs on the project area, the specific location and area of the deforested land shall be identified. Similarly, if the planting on certain lands within the project boundary fails; these lands will be documented.

b. Monitoring of forest establishment

To ensure that the planting quality conforms to the practice described in CDM-AR-PDD and is well-implemented, the following monitoring activities shall be conducted in the first three years after planting:

- Confirm that site and soil preparations are implemented based on practice documented in PDD. If pre-vegetation is removed, e.g., slash and burn of pre-existing vegetation, emissions associated shall be accounted for (described in section below).
- Survival checking:
  - ✓ The initial survival rate of planted trees shall be counted three months after the planting, and re-planting shall be conducted if the survival rate is lower than 90 percent of the final planting density.
  - ✓ Final checking three years after the planting.
  - ✓ The checking of the survival rate may be conducted using permanent sample plots.
- Weeding checking: check and confirm that the weeding practice is implemented as described in the PDD.
- Survey and check that species and planting for each stratum are in line with the PDD.
- Document and justify any deviation from the planned forest establishment.

c. Monitoring of forest management

Forest management practices are important drivers of the GHG balance of the project, and thus must be monitored. Practices to be monitored include:

- Cleaning and site preparation measures: date, location, area, biomass removed and other measures undertaken.
- Planting: date, location, area, tree species.
- Fertilization: date, location, area, tree species, amount and type of fertilizer applied, etc.
- Thinning: date, location, area, tree species, thinning intensity, volumes or biomass of trees removed.
- Harvesting: date, location, area, tree species, volumes or biomass of trees removed.
- Coppicing: date, location, area, tree species, volumes or biomass of trees removed.
- Fuel wood collection: date, location, area, tree species, volumes or biomass of trees removed
- Checking and confirming that harvested lands are re-planted, re-sowed or coppiced as planned and/or as required by forest law:
- Checking and ensuring that good conditions exist for natural regeneration if harvested lands are allowed to regenerate naturally.
- Monitoring of disturbances: date, location, area (GPS, analysis of geo-referenced spatial data, or other appropriate techniques, tree species, type of disturbance, biomass lost, implemented corrective measures, change in the boundary of strata and stands.

2. Sampling design and stratification

The number and boundaries of the strata defined *ex ante* using the methodology procedure outlined in Section II.3 may change during the crediting period (*ex post*). For this reason, strata should be monitored periodically. If a change in the number and area of the project strata occurs, the sampling framework should be adjusted accordingly. The methodology procedures for monitoring strata and defining the sampling framework are outlined below.

2.1. Monitoring of strata

Stratification of the project area into relatively homogeneous units can either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit. Project participants should present in the CDM-AR-PDD an *ex ante* stratification of the project area using the methods outlined in section II.2 and build a geo-referenced spatial data base in a GIS platform for each parameter used for stratification of the project area under the baseline and the project scenario. This geo-referenced spatial data base should be completed at the earliest stages of the implementation of the A/R CDM project activity. The DOE shall verify the achievement of this stratification and geo-referenced spatial data base at the first verification. The consistency of the actual boundary of the strata and stands as monitored in the field with the description in the CDM-AR-PDD shall be periodically monitored as the boundaries may change due to the following:

- Unexpected disturbances occurring during the crediting period (e.g. due to fire, pests or disease outbreaks), affecting differently different parts of an originally homogeneous stratum or stand.
- Forest management (cleaning, planting, thinning, harvesting, coppicing, re-replanting) may be implemented at different intensities, dates and spatial locations than originally planned in the PDD.
- Land not yet under the control of the project participant at the start of the project activity may be selected among pre-identified candidate areas and included in the project boundary.
- Two different strata may be similar enough to allow their merging into one stratum.

If one of the above occurs, *ex post* stratification is required. The possible need for *ex post* stratification shall be evaluated at each monitoring event and changes in the strata should be reported to the DOE for verification. Monitoring of strata and stand boundaries shall be done using a Geographical Information System (GIS) which allows for integrating data from different sources (including GPS coordinates and Remote Sensing data). The monitoring of strata and stand boundaries is critical for a transparent and verifiable monitoring of the variable A_{ijt} (area of stratum *i,* species *j*, at time *t*), which is of outmost importance for an accurate and precise calculation of net anthropogenic GHG removals by sinks.

2.2. Sampling framework

The sampling framework, including sample size, plot size, plot shape and plot location should be specified in the CDM-AR-PDD.

2.2.1. Definition of the sample size and allocation among strata

Permanent sampling plots will be used for sampling over time to measure and monitor changes in carbon stocks. Permanent sample plots are generally regarded as statistically efficient in estimating changes in forest carbon stocks because typically there is high covariance between observations at successive sampling events. However, it should be ensured that the plots are treated in the same way as other lands within the project boundary, e.g., during site and soil preparation, weeding, fertilization, irrigation, thinning, etc., and should not be destroyed over the monitoring interval. Ideally, staff involved in management activities should not be aware of the location of monitoring plots. Where local markers are used, these should not be visible.

The number of sample plots is estimated as dependent on accuracy and costs.

It is assumed that the following parameters are from pre-project estimates (e.g. results from a pilot study) or literature data:

A	total size of all strata, e.g. the total project area; ha
A_i	size of each stratum (= $\sum_{t=1}^{tcr}\sum_{j}^{S_{PS}} A_{ijt}$ where *tcr* is the end of the crediting period); ha
AP	sample plot size; ha
st_i	standard deviation for each stratum *i*; dimensionless
C_i	cost of establishment of a sample plot for each stratum *i;* e.g. US$
Q	approximate average value of the estimated quantity *Q,* (e.g. wood volume); e.g. m^3 ha^{-1}
p	desired level of precision (e.g. 10%); dimensionless

Then:

$$N = A / AP \tag{64}$$

$$N_i = A_i / AP \tag{65}$$

$$E = Q * p \tag{66}$$

Where:

N	maximum possible number of sample plots in the project area; dimensionless
N_i	maximum possible number of sample plots in stratum *i*; dimensionless

A	total size of all strata, e.g. the total project area; ha
A_i	size of each stratum (= $\sum_{t=1}^{tcr}\sum_{j}^{S_{PS}} A_{ijt}$ where *tcr* is the end of the crediting period); ha
AP	sample plot size; ha
E	allowable error; dimensionless
Q	approximate average value of the estimated quantity Q, (e.g. wood volume); e.g. m^3 ha^{-1}
p	desired level of precision (e.g. 10%); dimensionless

With the above information, the sample size (number of sample plots to be established and measured) can be estimated as follows:

$$n = \frac{\left[\sum_{i=1}^{m_{PS}} N_i * st_i * \sqrt{Ci}\right] * \left[\sum_{i=1}^{m_{PS}} N_i * st_i \Big/ \sqrt{C_i}\right]}{\left(N * \frac{E}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{m_{PS}} N_i * (st_i)^2} \quad (67)$$

$$n_i = \frac{\sum_{i=1}^{m_{PS}} N_i * st_i * \sqrt{C_i}}{\left(N * \frac{E}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{m_{SP}} N_i * (st_i)^2} * \frac{N_i * st_i}{\sqrt{C_i}} \quad (68)$$

Where:

n	sample size (total number of sample plots required) in the project area; dimensionless
n_i	sample size for stratum *i*; dimensionless
N	maximum possible number of sample plots in the project area; dimensionless
N_i	maximum possible number of sample plots in stratum *i*; dimensionless
i	1, 2, 3, ... m_{SP} project scenario (ex-post) strata; dimensionless
$z_{\alpha/2}$	value of the statistic z (normal probability density function), for α = 0.05 (implying a 95% confidence level); dimensionless
st_i	standard deviation for each stratum *i*; dimensionless
C_i	cost of establishment of a sample plot for each stratum *i;* e.g. US$
Q	approximate average value of the estimated quantity *Q,* (e.g. wood volume); e.g. m^3 ha^{-1}

When no information on costs is available or the costs may be assumed as constant for all strata, then:

$$n = \frac{\left[\sum_{i=1}^{m_{PS}} N_i \cdot st_i \right]^2}{\left(N \cdot \frac{E}{z_{\alpha/2}} \right)^2 + \sum_{i=1}^{m_{PS}} N_i \cdot (st_i)^2} \tag{69}$$

$$n_i = \frac{\sum_{h=1}^{m_{PS}} N_i \cdot st_i}{\left(N \cdot \frac{E}{z_{\alpha/2}} \right)^2 + \sum_{i=1}^{m_{PS}} N_i \cdot (st_i)^2} \cdot N_i \cdot st_i \tag{70}$$

Where: see above

It is possible to reasonably modify the sample size after the first monitoring event based on the actual variation of the carbon stocks determined from taking the *n* samples.

2.2.2. Sample plot size

The plot area *a* has major influence on the sampling intensity and time and resources spent in the field measurements. The area of a plot depends on the stand density. Therefore, increasing the plot area decreases the variability between two samples. According to Freese (1962)[25], the relationship between coefficient of variation and plot area can be denoted as follows:

$$CV_2^{\ 2} = \ CV_1^{\ 2} \sqrt{(a_1 / a_2)} \tag{71}$$

where a_1 and a_2 represent different sample plot areas and their corresponding coefficient of variation (*CV*). Thus, by increasing the sample plot area, variation among plots can be reduced permitting the use of small sample size at the same precision level. Usually, the size of plots is between 100 m^2 for dense stands and 1000 m^2 for open stands.

2.2.3. Plot location

To avoid subjective choice of plot locations (plot centers, plot reference points, movement of plot centers to more “convenient” positions), the permanent sample plots shall be located systematically with a random start, which is considered good practice in IPCC GPG-LULUCF. This can be accomplished with the help of a GPS in the field. The geographical position, administrative location, stratum and stand, series number of each plots shall be recorded and archived.

Also, it is to be ensured that the sampling plots are as evenly distributed as possible. For example, if one stratum consists of three geographically separated sites, then it is proposed to

[25] Freese, F. 1962. Elementary Forest Sampling. USDA Handbook 232. GPO Washington, DC. 91 pp

- divide the total stratum area by the number of plots, resulting in the average area represented by each plot
- divide the area of each site by this average area per plot, and assign the integer part of the result to this site. e.g., if the division results in 6.3 plots, then 6 plots are assigned to this site, and 0.3 plots are carried over to the next site, and so on.

2.2.4. Monitoring frequency

Monitoring interval depends on the variability in carbon stocks and the rate of carbon accumulation, i.e., the growth rate of trees as of living biomass. Although the verification and certification shall be carried out every five years after the first verification until the end of the crediting period (paragraph 32 of decision 19/CP.9), monitoring interval may be less than five years. However, to reduce the monitoring cost, the monitoring intervals shall coincide with verification time, i.e., five years of interval. Logically, one monitoring and verification event will take place close to the end of the first commitment period, e.g. in the second half of the year 2012.

Project participants shall determine the first monitoring time, taking into account:

- The growth rate of trees and the financial needs of the project activity: the later the date of the first verification, the higher will be the amount of net anthropogenic GHG removals by sinks but the lower the financial net present value of a CER.
- Harvesting events and rotation length: The time of monitoring and subsequent verification and certification shall not coincide with peaks in carbon stocks based on paragraph 12 of appendix B in decision 19/CP.9.

2.2.5. Measuring and estimating carbon stock changes over time

The growth of individual trees on plots shall be measured at each monitoring event. Pre-existing (baseline) trees should conservatively and consistently with the baseline methodology not be measured and accounted for. Although non-tree vegetation such as herbaceous plants, grasses, and shrubs can occur, usually with biomass less than 10 percent, there is also non-tree vegetation on degraded lands and the baseline scenario has assumed the zero stock change for this non-tree biomass. Therefore, non-tree vegetation will not be measured and accounted. The omission of non-tree biomass removals in project scenario makes the monitoring conservative. Even if the initial site preparation results in a removal of non-tree biomass, there is no risk to over-estimate the removals because all pre-existing biomass have been treated as carbon loss during site preparation (see Section III.5.1.1 below). The carbon stock changes in living biomass of trees on each plot are then estimated through Biomass Expansion Factors (BEF) method or allometric equations method.

2.2.6. Monitoring GHG emissions by sources increased as results of the A/R CDM project activity

An A/R CDM project activity may increase GHGs emissions, in particular CO_2, CH_4 and N_2O. The list below contains factors that may result in an increase of GHGs emissions[26]:

- Emissions of greenhouse gases from burning of fossil fuels for site preparation, logging and other forestry operation;
- Emissions of greenhouse gases from biomass burning for site preparation (slash and burn activity);
- N_2O emissions caused by nitrogen fertilization practices;

Changes in GHG emissions caused by these practices can be estimated by monitoring activity data and selecting appropriate emission factors.

[26] Refer to Box 4.3.1 and Box 4.3.4 in IPCC GPG-LULUCF

3. Calculation of *ex-post* baseline net GHG removals by sinks, if required

Under this methodology there is no need for monitoring the baseline because the per hectare baseline estimates were frozen in the ex-ante estimation. If the area changes because new areas come under the control of the project proponents this will be reflected in the monitoring of the project boundary (section III.1).

4. Data to be collected and archived for of baseline net GHG removals by sinks

Under this methodology there is no need for monitoring the baseline.

5. Calculation of ex post actual net GHG removal by sinks

The actual net greenhouse gas removals by sinks represent the sum of the verifiable changes in carbon stocks in the carbon pools within the project boundary, minus the increase in GHG emissions measured in CO_2 equivalents by the sources that are increased as a result of the implementation of an A/R CDM project activity, while avoiding double counting, within the project boundary, attributable to the A/R CDM project activity. Therefore[27],

$$C_{ACTUAL} = \Delta C_{LB} + \Delta C_{DW} + \Delta C_{LI} - E_{biomassloss} - GHG_E \qquad (72)$$

Where:

C_{ACTUAL}	actual net greenhouse gas removals by sinks; t CO_2-e.
ΔC_{LB}	sum of the changes in living biomass carbon stocks of trees (above- and below-ground); t CO_2-e.
ΔC_{DW}	sum of the changes in deadwood carbon stocks; t CO_2-e.
ΔC_{LI}	sum of the changes in litter carbon stocks; t CO_2-e.
$E_{biomassloss}$	decrease in the carbon stock in the tree and non-tree living biomass, deadwood and litter carbon pools of pre-existing vegetation in the year of site preparation up to time t^*; t CO_2-e.
GHG_E	sum of the increases in GHG emissions by sources within the project boundary as a result of the implementation of an A/R CDM project activity; t CO_2-e.

Note: In this methodology Equation 72 is used to estimate actual net greenhouse gas removal by sinks for the period of time elapsed between project start ($t=1$) and the year $t=t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are estimated. The "stock change" method should be used to determine annual or periodical values. The decrease in the carbon stocks of the pre-existing vegetation are initial losses, and therefore accounted once upfront as part of the first monitoring interval, not per year.

5.1 Verifiable changes in carbon stocks in the carbon pools

5.1.1. Treatment of pre-existing vegetation and trees

This methodology allows for the simplifying and conservative assumption that all the biomass in tree and non-tree living biomass, deadwood and litter of the pre-project vegetation is removed upon site preparation. Therefore, this methodology includes a carbon-stock decrease on project start, even though in some

[27] GPG-LULUCF Equation 3.2.1

projects after site preparation pre-project vegetation may remain. At project start, the project can take a discount corresponding to the entire pre-project carbon stocks. Therefore, during the monitoring events, the carbon stocks of remaining pre-project vegetation (e.g., trees left standing) shall be measured and accounted for in the same way as the vegetation that the project establishes.

Ex post, the decrease in the carbon stock in the tree and non-tree living biomass, deadwood and litter carbon pools of pre-existing vegetation due to site preparation shall be estimated in the same way as ex-ante. The procedures for the estimation of $E_{biomassloss}$ described in section II.7.1.1 shall be applied here as well.

5.1.2. Estimation of actual ΔC_{LB} (changes in biomass carbon stocks of living trees)

The verifiable carbon stock changes in aboveground biomass and belowground biomass ***of living trees*** within the project boundary are estimated using equation[28]

$$\Delta C_{LB} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{PS}}\sum_{j=1}^{s_{PS}} \Delta C_{LBijt} \text{ [29]} \qquad \textbf{(73)}$$

Where:

ΔC_{LB}	sum of the changes in biomass carbon stocks (above- and below-ground) *of living trees*; t CO_2-e.
$\Delta C_{LB\,ijt}$	annual carbon stock change in biomass *of living trees* for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
i	1, 2, 3, … m_{PS} ex-post strata
j	1, 2, 3, … s_{PS} planted tree species
t	1, 2, 3, … t^* years elapsed since the start of the A/R CDM project activity

$$\Delta C_{LBijt} = (\Delta C_{AB,ijt} + \Delta C_{BB,ijt}) \cdot MW_{CO2\text{-}C} \qquad \textbf{(74)}$$

$$\Delta C_{AB,ijt} = (C_{AB,ijt2} - C_{AB,ijt1})/T \qquad \textbf{(75)}$$

$$\Delta C_{BB,ijt} = (C_{BB,ijt2} - C_{BB,ijt1})/T \qquad (76)$$

Where:

$\Delta C_{LB\,ijt}$	verifiable changes in carbon stock in living biomass of trees for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$\Delta C_{AB,ijt}$	changes in carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, time *t*; t C yr^{-1}
$\Delta C_{BB,ijt}$	changes in carbon stock in belowground biomass of living trees for stratum *i*, species *j*, time *t*; t C yr^{-1}
T	number of years between times t_2 and t_1 $(T = t_2 - t_1)$; years

---

[28] Refers to GPG-LULUCF Equation 3.2.3

[29] In this methodology, time notations and sums over time since project start have been added, while those referring to "sub-strata" have been deleted. This has been made because "strata" + "sub-strata" are considered "strata" in this methodology (and strata are adjusted ex-post - if needed). The sum over time since the start of the project activity is considered necessary as carbon stocks can decrease, and the "sum of changes" over time can better reproduce these ups and downs in carbon stocks (thus showing "net changes"). In addition, the project emissions can only increase and are permanent, which requires to account for their cumulative value at each point in time.

$C_{AB,ijt2}$	carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, calculated at time $t=t_2$; t C
$C_{AB, ijt1}$	carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, calculated at time $t=t_1$; t C
$C_{BB,ijt2}$	carbon stock in belowground biomass of living trees for stratum *i*, species *j*, calculated at time $t=t_2$; t C
$C_{BB,ijt1}$	carbon stock in belowground biomass of living trees for stratum *i*, species *j*, calculated at time $t=t_1$; t C
MW_{CO2-C}	ratio of molecular weights of CO_2 and C (44/12); t CO_2 $(t\ C)^{-1}$

The mean carbon stocks in above-ground biomass and below-ground biomass of living trees per unit area are estimated based on field measurements on permanent plots. There are two methods, namely the Biomass Expansion Factors (BEF) method and the Allometric Equations method.

Method 1: BEF Method

Step 1: Measuring the diameter at breast height (DBH, at 1.3 m above ground) and preferably height of all the trees in the permanent sample plots above a minimum DBH. The minimum DBH varies depending on tree species and climate, for instance, the minimum DBH may be as small as 2.5 cm in arid environments where trees grow slowly, whereas it could be up to 10 cm for humid environments where trees grow rapidly (GPG-LULUCF).

Step 2: Estimating the volume of the commercial component of trees based on locally derived equations, then sum for all trees within a plot and express as volume per unit area (e.g., m^3/ha). It is also possible to combine step 1 and step 2 if there are field instruments (e.g. relascope) that measure volume of each tree directly.

Step 3: Choosing BEF and root-shoot ratio: The BEF and root-shoot ratio vary with local environmental conditions, species and age of trees, and the volume of the commercial component of trees. These parameters can be determined by either developing a local regression equation or selecting from national inventory, Annex 3A.1 Table 3A.1.10 of GPG LULUCF, or from published sources. If a significant amount of effort is required to develop local BEFs and root-shoot ratio, involving, for instance, harvest of trees, then it is recommended not to use this method but rather to use the resources to develop local allometric equations as described in the allometric method below (refers to Chapter 4.3 in GPG LULUCF). If that is not possible either, national species specific defaults for BEF and R can be used. Since both BEF and the root-shoot ratio are age dependent, it is desirable to use age-dependent equations. Stemwood volume can be very small in young stands and BEF can be very large, while for old stands BEF is usually significantly smaller. Therefore using average BEF value may result in significant errors for both young stands and old stands. It is preferable to use allometric equations, if the equations are available, and as a second best solution, to use age-dependent BEFs (but for very young trees, multiplying a small number for stemwood with a large number for the BEF can result in significant error).

Step 4: Converting the volume of the commercial component of trees into carbon stock in aboveground biomass and belowground biomass via basic wood density, BEF, root-shoot ratio and carbon fraction, given by[30]:

$$MC_{AB,ijt} = MV_{ijt} \cdot D_j \cdot BEF_j \cdot CF_j \qquad (77)$$

[30] Refers to GPG LULUCF Equation 4.3.1

$$MC_{BB,ijt} = MC_{AB,ijt} \cdot R_j \tag{78}$$

Where:

$MC_{AB,\ ijt}$	mean carbon stock in above-ground biomass of living trees per unit area for stratum *i*, species *j*, time *t*; t C ha^{-1}
$MC_{BB,\ ijt}$	mean carbon stock in below-ground biomass of living trees per unit area for stratum *i*, species *j*, time *t*; t C ha^{-1}
MV_{ijt}	mean merchantable volume per unit area for stratum *i*, species *j*, time *t*; m^3 ha^{-1}
D_j	volume-weighted average wood density for species *j*; t d.m. m^{-3} merchantable volume
BEF_j	biomass expansion factor for conversion of biomass of merchantable volume to above-ground biomass; dimensionless
CF_j	carbon fraction for species j; t C (t d.m)$^{-1}$ (IPCC default value = 0.5); dimensionless
R_j	Root-shoot ratio; dimensionless

Step 5: The total carbon stock in living biomass of trees for each stratum *i*, species *j*, time *t* is calculated from the area of stratum *i*, species *j*, time *t* and the mean carbon stock in aboveground biomass and belowground biomass of living trees per unit area, as follows:

$$C_{AB,\ ijt} = A_{ijt} \cdot MC_{AB,\ ijt} \tag{79}$$

$$C_{BB,\ ijt} = A_{ijt} \cdot MC_{BB,\ ijt} \tag{80}$$

Where:

$C_{AB,\ ijt}$	carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, calculated at time *t*; t C
$C_{BB,\ ijt}$	carbon stock in belowground biomass of living trees for stratum *i*, species *j*, calculated at time *t*; t C
A_{ijt}	area of stratum *i*, species *j*, time *t*; ha Note: The area of a stratum i planted with species *j* has a time notation because stands with species *j* will be established (planted) at different dates.
$MC_{AB,\ ijt}$	mean carbon stock in aboveground biomass of living trees per unit area for stratum *i*, species *j*, time *t*; t C ha^{-1}
$MC_{BB,\ ijt}$	mean carbon stock in belowground biomass of living trees per unit area for stratum *i*, species *j*, time *t*; t C ha^{-1}

Step 6: The change in carbon stock in living biomass of trees over time is given by:

$$\Delta C_{AB,\ ijt} = (C_{AB,\ ijt2} - C_{AB,\ ijt1})/T \tag{81}$$

$$\Delta C_{BB,\ ijt} = (C_{BB,\ ijt2} - C_{BB,\ ijt1})/T \tag{82}$$

Where:

$\Delta C_{AB,\ ijt}$	changes in carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, time *t*; t C yr^{-1}
$\Delta C_{BB,\ ijt}$	changes in carbon stock in belowground biomass of living trees for stratum *i*, species *j*, time *t*; t C yr^{-1}
$C_{AB,\ ijt2}$	carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, calculated at time $t=t_2$; t C

$C_{AB,\ ijt1}$	carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, calculated at time $t=t_1$; t C
$C_{BB,\ ijt2}$	carbon stock in belowground biomass of living trees for stratum *i*, species *j*, calculated at time $t=t_2$; t C
$C_{BB,\ ijt1}$	carbon stock in belowground biomass of living trees for stratum *i*, species *j*, calculated at time $t=t_1$; t C
T	number of years between monitoring time t_1 and t_2 $(T=t_2-t_1)$; years.

Method 2: Allometric method

Step 1: Measure the diameter at breast height (DBH, at 1.3 m above ground) and preferably height of all the trees in the permanent sample plots above a minimum DBH. The minimum DBH varies depending on tree species and climate, for instance, the minimum DBH may be as small as 2.5 cm in arid environments where trees grow slowly, whereas it could be up to 10 cm for humid environments where trees grow rapidly (IPCC's GPG-LULUCF). When first measured all trees should be tagged to permit the tracking of individual trees in plots through time. Where a tree has died, been harvested or can not be found then the biomass at time 2 should be made equal to zero to give the requisite deduction.

Step 2: Choose or establish appropriate allometric equations.

$$TB_{ABj} = f_j(DBH, H) \tag{83}$$

Where:

TB_{ABj}	above-ground biomass of a tree of species *j*; kg tree^{-1}
$f_j(DBH,H)$	allometric equation for species *j* linking above-ground tree biomass (kg tree^{-1}) to diameter at breast height (DBH) and possibly tree height (H) measured in plots for stratum *i*, species *j*, time *t*; t d.m. ha^{-1}

The allometric equations are preferably local-derived and species-specific. When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of GPG LULUCF, are used, it is necessary to verify by destructively harvesting, within the project area but outside the sample plots, a few trees of different sizes and estimate their biomass and then compare against a selected equation. If the biomass estimated from the harvested trees is within about ±10% of that predicted by the equation, then it can be assumed that the selected equation is suitable for the project.

Step 3: Estimating carbon stock in aboveground biomass per tree using selected allometric equations applied to the tree measurements in Step 1.

$$TC_{AB} = TB_{AB} \cdot CF \tag{84}$$

Where:

TC_{AB}	carbon stock in above-ground biomass per tree; kg C tree^{-1}
TB_{AB}	above-ground biomass of a tree; kg tree^{-1}
CF	carbon fraction, t C (t d.m)$^{-1}$, IPCC default value = 0.5.

Step 4: Calculate the increment of above-ground biomass carbon accumulation at the tree level. Calculate by subtracting the biomass carbon at time 2 from the biomass carbon at time 1 for each tree.

$$\Delta TC_{ABT} = TC_{AB,\,t2} - TC_{AB,\,t1} \quad (85)$$

Where:

ΔTC_{ABT}	change in above-ground biomass carbon per tree between two monitoring events; kg C tree^{-1}
$TC_{AB,\,t2}$	carbon stock in above-ground biomass per tree, calculated at time $t=t_2$; kg C tree^{-1}
$TC_{AB,\,t1}$	carbon stock in above-ground biomass per tree, calculated at time $t=t_1$; kg C tree^{-1}

Step 5: Calculate the increment in above-ground biomass carbon per plot on a per area basis. Calculate by summing the change in biomass carbon per tree within each plot and multiplying by a plot expansion factor which is proportional to the area of the measurement plot. This is divided by 1,000 to convert from kg to tonnes.

$$\Delta PC_{ABT} = 1/1000 \sum_{tr=1}^{TR} \Delta TC_{ABT,\,tr} \cdot XF \quad (86)$$

$$XF = 1 / AP \quad (89)$$

Where:

ΔPC_{ABT}	plot level change in above ground mean carbon stock between two monitoring events; t C ha^{-1}
$\Delta TC_{ABT,\,tr}$	change in above-ground biomass carbon per tree *tr* between two monitoring events; kg C tree^{-1}
XF	plot expansion factor from per plot values to per hectare values
AP	sample plot size; ha
tr	tree (*TR* = total number of trees in the plot)

Step 6: Calculate mean carbon stock change within each stratum. Calculate by averaging across plots in a stratum or stand:

$$\Delta MC_{ABijT} = 1 / PL_{ij} \cdot \sum_{pl=1}^{PL_{ij}} \Delta PC_{ABijT,pl} \quad (87)$$

Where:

ΔMC_{ABijT}	mean change in above-ground carbon stock in stratum *i*, species *j*, between two monitoring events; t C ha^{-1}.
$\Delta PC_{ABijT,pl}$	plot-level change in above-ground mean carbon stock in stratum *i*, species *j*, between two monitoring events; t C ha^{-1}.
pl	plot number in stratum *i*, species *j* (*PL* = total number of plots); dimensionless

Step 7: Estimate carbon stock in below-ground biomass using root-shoot ratios and above-ground carbon stock.

$$TC_{BB} = TC_{AB} \cdot R_j \quad (88)$$

$$\Delta TC_{BB} = TC_{BB,t2} - TC_{BB,t1} \quad (89)$$

$$\Delta PC_{BBT} = 1/1000 \cdot \sum_{tr=1}^{TR} \Delta TC_{BBT,\,tr} \cdot XF \qquad (90)$$

$$\Delta MC_{BBijT} = 1 / PL_{ij} \cdot \sum_{pl=1}^{PL_{ij}} \Delta PC_{BBijT,pl} \qquad (91)$$

Where:

TC_{BB}	carbon stock in below-ground biomass per tree; kg C tree^{-1}
TC_{AB}	carbon stock in above-ground biomass per tree; kg C tree^{-1}
R_j	root-shoot ratio appropriate to increments for species *j*; dimensionless
ΔPC_{BBT}	plot level change in below-ground mean carbon stock between two monitoring events; t C ha^{-1}
$\Delta TC_{BBT,\,tr}$	change in below-ground biomass carbon per tree *tr* between two monitoring events; kg C tree^{-1}
tr	tree (*TR* = total number of trees in the plot)
ΔMC_{BBijT}	mean change in below-ground carbon stock in stratum *i*, species *j*, between two monitoring events; t C ha^{-1}.
$\Delta PC_{BBijT,pl}$	plot level change in below-ground mean carbon stock in stratum *i*, species *j*, between two monitoring events; t C ha^{-1}.
pl	plot number in stratum *i*, species *j* (*PL* = total number of plots); dimensionless

Step 8: Calculate the change in stock per unit time by dividing by the number of years between monitoring events.

$$\Delta MC_{AB,ijt} = \Delta MC_{ABijT} / \mathrm{T} \qquad (92)$$

$$\Delta MC_{BB,ijt} = \Delta MC_{BBijT} / \mathrm{T} \qquad (93)$$

Where:

$\Delta MC_{AB,ijt}$	annual mean changes in carbon stock in above-ground biomass for stratum *i*, species *j*, at year *t*; t C ha^{-1} yr^{-1}
$\Delta MC_{BB,ijt}$	annual mean changes in carbon stock in below-ground biomass for stratum *i*, species *j*, at year *t*; t C ha^{-1} yr^{-1}
ΔMC_{ABijT}	mean change in above-ground carbon stock in for stratum *i*, species *j*, between two monitoring events; t C ha^{-1} yr^{-1}
ΔMC_{BBijT}	mean change in below-ground carbon stock in for stratum *i*, species *j*, between two monitoring events; t C ha^{-1} yr^{-1}
T	number of years between two monitoring events which in this methodology is 5 years; years

Step 9: The annual carbon stock change in living biomass of trees for each stratum *i*, species *j* at time *t* is calculated from the area of each stratum *i*, species *j* at time *t* and the annual mean carbon stock in above-ground biomass and below-ground biomass per unit area, given by:

$$\Delta C_{AB,ijt} = A_{ijt} \cdot \Delta MC_{AB,ijt} \qquad (94)$$

$$\Delta C_{BB,ijt} = A_{ijt} \cdot \Delta MC_{BB,ijt} \qquad (95)$$

Where:

A_{ijt}	area of stratum *i*, species *j*, at time *t*; ha
$\Delta C_{AB,ijt}$	changes in carbon stock in above-ground biomass of living trees for stratum *i*, species *j*, at time *t*; t C yr^{-1}
$\Delta C_{BB,ijt}$	changes in carbon stock in below-ground biomass of living trees for stratum *i*, species *j*, at time *t*; t C yr^{-1}
$\Delta MC_{AB,ijt}$	annual mean change in above-ground carbon stock of living trees in stratum *i*, species *j*, at time *t*; t C ha^{-1} yr^{-1}
$\Delta MC_{BB,ijt}$	annual mean change in below-ground carbon stock of living trees in stratum *i*, species *j*, at time *t*; t C ha^{-1} yr^{-1}

5.1.3. Estimation of actual ΔC_{DW} (changes in deadwood carbon stocks):

There are two categories of deadwood that may be relevant in the context of the A/R CDM project activity: standing deadwood (DWs) and lying deadwood (DWl). Depending on the specific local circumstances (frequency of thinning and harvesting, extraction or not extraction of thinning and fuel wood volumes) deadwood carbon stocks may accumulate standing and/or laying. Project participants shall decide if they want to account for all sub-pools or for only two or one of them taking into account their project specific circumstances. Monitoring frequency of the deadwood sub-pools may also differ. Since the occurrence of lying deadwood in the early stages of a stand is generally insignificant, lying deadwood may be monitored with a different frequency as that of the tree biomass, while standing deadwood may be monitored with the same frequency.

When monitoring deadwood, care should be taken not to measure deadwood stocks from pre-existing (baseline) trees to be consistent with the baseline methodology. Deadwood density measurements shall be done in accordance with IPCC Good Practice Guidance, section 4.3.3.5.3.

Changes in deadwood carbon stocks are calculated using the following equation:

$$\Delta C_{DW} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{PS}} \sum_{j=1}^{s_{PS}} \Delta C_{DW\,ijt} \tag{96}$$

Where:

ΔC_{DW}	sum of the changes in deadwood carbon stocks; t CO_2-e. (as per Equation 72)
ΔC_{DWijt}	annual carbon stock change in the deadwood carbon pool for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
i	1, 2, 3, … m_{PS} ex-post strata
j	1, 2, 3, … s_{PS} planted tree species
t	1, 2, 3, … *t** years elapsed since the start of the A/R CDM project activity

$$\Delta C_{DW\,ijt} = (\Delta C_{DWs\,ijt} + \Delta C_{DWl\,ijt}) \cdot MW_{CO2\text{-}C} \tag{97}$$

$$\Delta C_{DWs\,ijt} = (C_{DWs\,ijt_2} - C_{DWs\,ijt_1}) / T \tag{98}$$

$$\Delta C_{DWl_{ijt}} = (C_{DWl\,ijt_2} - C_{DWl\,ijt_1}) / T \tag{99}$$

Where:

ΔC_{DWijt}	annual carbon stock change in deadwood for stratum *i*, species *j*, time *t*; t CO_2-e. yr^{-1}
$\Delta C_{DWs,ijt}$	annual carbon stock change in standing deadwood for stratum *i*, species *j*, time *t*; t C yr^{-1}
$\Delta C_{DWl,ijt}$	annual carbon stock change in lying deadwood for stratum *i*, species *j*, time *t*; t C yr^{-1}
$C_{DWs,ijt2}$	carbon stock in standing deadwood for stratum *i*, species *j*, calculated at time $t=t_2$; t C
$C_{DWs,ijt1}$	carbon stock in standing deadwood for stratum *i*, species *j*, calculated at time $t=t_1$; t C
$C_{DWl,ijt2}$	carbon stock in laying deadwood for stratum *i*, species *j*, calculated at time $t=t_2$; t C
$C_{DWl,ijt1}$	carbon stock in laying deadwood for stratum *i*, species *j*, calculated at time $t=t_1$; t C
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); t CO_2 $(t\ C)^{-1}$
T	number of years between monitoring time t_2 and t_1 ($T = t_2 - t_1$); years

The total carbon stocks of deadwood for stratum *i*, species *j*, time *t* are calculated from the area for stratum *i*, species *j*, time *t* and the mean carbon stocks in the deadwood sub-pools per unit area, as follows:

$$C_{DWs,ijt} = A_{ijt} \cdot MC_{DWs,\ ijt} \quad (100)$$

$$C_{DWl,ijt} = A_{ijt} \cdot MC_{DWl,\ ijt} \quad (101)$$

Where:

$C_{DWs,ijt}$	carbon stock in standing deadwood for stratum *i*, species *j*, at time *t*; t C
$C_{DWl,ijt}$	carbon stock in lying deadwood for stratum *i*, species *j*, at time *t*; t C
A_{ijt}	area of stratum *i,* species *j*, at time *t*; ha
$MC_{DWs,\ ijt}$	mean carbon stock in standing deadwood per unit area for stratum *i*, species *j*, time *t*; t C ha^{-1}
$MC_{DWl,\ ijt}$	mean carbon stock in laying deadwood per unit area for stratum *i*, species *j*, time *t*; t C ha^{-1}

The mean carbon stocks in standing and lying deadwood per unit area are estimated based on field measurements on permanent plots and transect lines, respectively.

Standing deadwood

Standing dead trees shall be measured using the same criteria and monitoring frequency used for measuring live trees. In addition, the decomposed portion that corresponds to the original living biomass is discounted. The decomposition state of the dead tree and the diameter at breast height shall be recorded and the standing deadwood is categorized under the following four decomposition classes.

(1) Tree with branches and twigs that resembles a live tree (except for leaves)
(2) Tree with no twigs but with persistent small and large branches
(3) Tree with large branches only
(4) Bole only, no branches

The biomass may be estimated as for living trees in decomposition class 1. When only bole is remaining in decomposition classes 2, 3 and 4, it is recommend to estimate the biomass of the main trunk of the tree. If the top of the standing dead tree is missing, the height of the remaining stem is measured and the top diameter is estimated as the ratio of the top diameter to the basal diameter. The volume is converted to carbon as follows:

$$MC_{DWs,ijt} = \sum_{dc} A_{ijt} \cdot MV_{DWs\,ijt,dc} \cdot D_{DWs\,dc} \cdot CF_j \quad (102)$$

Where:

$MC_{DWs,\,ijt}$	mean carbon stock in standing deadwood per unit area for stratum *i*, species *j*, time *t*; t C ha^{-1}
A_{ijt}	area of stratum *i*, species *j*, at time *t*; ha
$MV_{DWsijj,dc}$	mean carbon stock in standing deadwood per unit area for stratum *i*, species *j*, time *t*; t C ha^{-1}
D_{DWsdc}	volume-weighted average deadwood density for decomposition class *dc*; t d.m. m^{-3} standing deadwood volume
CF_j	carbon fraction for species j; t C (t d.m)$^{-1}$; IPCC default value = 0.5
dc	decomposition class 2, 3, or 4.

Lying deadwood

The lying deadwood can increase as the stand ages. It may be sampled using the line-intersect method as per IPCC GPG (2003). Two 50-meter length lines can be placed at right angles across the each plot centre and the diameters of lying deadwood (≥ 5 cm diameter) intersecting the lines are measured at the intersection. Each deadwood is assigned to one of the three density states *ds* (sound, intermediate, and rotten), and the volume of lying deadwood in each density state per hectare is calculated using the following equation[31]:

$$MV_{DWlijt,ds} = \sum_{ds} \left[\pi^2 \cdot \frac{(D_1^2 + D_2^2 ... + D_n^2)_{ijt}}{8 \cdot LT} \right] \tag{103}$$

Where:

$MV_{DWlijt,ds}$	mean volume of lying deadwood per area unit in density state *ds* for stratum *i*, species *j*, time *t*;m^3 ha^{-1}
$D_1, D_2, \ldots, D_n$	diameter of pieces of deadwood in density state *ds* measured in plots for stratum *i*, species *j*, time *t*; cm
LT	transect length; (100 m)
Ds	deadwood density state (sound, intermediate, and rotten); dimensionless

The mean volumes are converted to carbon using Equation 102.

5.1.4. Estimation of actual ΔC_{LI} (changes in litter carbon stocks):

Changes in litter carbon stocks are calculated using the following equation:

$$\Delta C_{LI} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{PS}} \sum_{j=1}^{s_{PS}} \Delta C_{LI\,it} \tag{104}$$

Where:

ΔC_{LI}	sum of the changes in litter carbon stocks; t CO_2-e. (as per Equation 72)
$\Delta C_{LI\,it}$	annual carbon stock change in litter for stratum *i*, time *t*; t CO_2-e. yr^{-1}
i	1, 2, 3, … m_{PS} ex-post strata
j	1, 2, 3, … s_{PS} planted tree species

[31] IPCC GPG-LULUCF Equation 4.3.2

t	1, 2, 3, … t^* years elapsed since the start of the A/R CDM project activity

$$\Delta C_{LI\,it} = (C_{LI\,it\,2} - C_{LI\,it\,1})/T \cdot MW_{CO2\text{-}C} \quad (105)$$

$C_{LI\,it2}$	carbon stock in litter for stratum i, calculated at time $t{=}t_2$; t C
$C_{LI\,it1}$	carbon stock in litter for stratum i, calculated at time $t{=}t_1$, t C
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); t CO_2 (t C)$^{-1}$
T	number of years between times t_2 and t_1 ($T = t_2\text{-}t_1$); years

The total carbon stocks of litter for stratum i, species j, time t are calculated from the area for stratum i, species j, time t and the mean carbon stocks in the litter sub-pools per unit area, as follows:

$$C_{LI\,it} = A_{it} \cdot MC_{LI\,it} \quad (106)$$

Where:

$C_{LI\,it}$	carbon stock in litter for stratum i, at time t; t C
A_{it}	area of stratum i, at time t; ha
MC_{LIit}	mean carbon stock in litter per unit area for stratum i, time t; t C ha^{-1}

The mean carbon stocks in litter per unit area are estimated based on field measurements.

Litter includes all dead biomass of less than 10 cm diameter and dead leaves, twigs, dry grass, and small branches. During early stages of stand development, litter increases rapidly and stabilizes during the later part of the stand. Therefore, if seasonal effects apply to the project region, litter samples shall be collected at the same time of the year in order to account for natural and anthropogenic influences on the litter accumulation and to eliminate seasonal effects

Step 1: Litter shall be sampled using a 30 cm radius circular frame. The frame is placed four times at random locations or plot corners within the small nested plot (10 m x 5 m).

Step 2: At each location, all litter (leaves, fruits, small wood, etc.) within the frame shall be collected.
Step 3: The collected litter is oven dried and weighed to determine the dry weight and analysed in the laboratory to estimate the carbon content. If laboratory method is not feasible, the dry mass of litter shall be converted into carbon using the default carbon fraction (0.370) used for litter as recommended by the GPG/LULUCF (Chapter 3.2, p.3.36).

$$MC_{LI\,it} = MW_{LI\,it} \cdot CF_{LI\,it} \quad (107)$$

Where:

$MC_{LI\,it}$	mean carbon stock in litter per unit area for stratum i, time t; t C ha^{-1}
$MW_{LI\,it}$	mean weight of litter per unit area for stratum i, time t; t d.m. ha^{-1}
$CF_{LI\,it}$	carbon fraction of litter from stratum i, time t as determined in laboratory analysis if feasible (default value = 0.370); t C (t d.m)$^{-1}$

5.2. GHG emissions by sources

The increase in GHG emission as a result of the implementation of the proposed A/R CDM project activity within the project boundary can be estimated by:

$$GHG_{E,t} = E_{FuelBurn,t} + E_{Non-CO_2,BiomassBurn,t} + N_2O_{direct-N_{fertilizer},t} \quad (108)$$

Where:

$GHG_{E,t}$	increase in GHG emission as a result of the implementation of the proposed A/R CDM project activity within the project boundary in year t; t CO_2-e. yr^{-1}
$E_{FuelBurn,t}$	increase in GHG emission as a result of burning of fossil fuels within the project boundary in year t; t CO_2-e. yr^{-1}
$E_{Non-CO2,BiomassBurn,t}$	increase in Non-CO_2 emission as a result of biomass burning within the project boundary in year t; t CO_2-e. yr^{-1}
$N_2O_{direct-Nfertilizer,\ t}$	increase in N_2O emission as a result of direct nitrogen application within the project boundary in year t; t CO_2-e. yr^{-1}

Note: In this methodology Equation 108 is used to estimate the increase in GHG emission for the period of time elapsed between project start ($t = 1$) and the year $t = t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are estimated.

5.2.1. GHG emissions from burning of fossil fuel

In the context of the afforestation or reforestation, the increase in GHG emission by burning of fossil fuels is most likely resulted from machinery use during site preparation, thinning and logging.

Step 1: Monitoring the type and amount of fossil fuels consumed in site preparation and/or logging. This can be done using indirect methods (e.g. Hours of machine use x average fuel consumption per hour; traveled kilometers x average fuel consumption per traveled kilometer; cubic meters harvested x average fuel consumption per cubic meter, etc).

Step 2: Choosing emission factors. There are three possible sources of emission factors:

- National emission factors: These emission factors may be developed by national programs such as national GHG inventory;
- Regional emission factors;
- IPCC default emission factors, provided that a careful review of the consistency of these factors with the country conditions has been made. IPCC default factors may be used when no other information is available.

Step 3: Estimating of GHG emissions resulted from the burning of fossil fuel during site preparation and logging. Although some non-CO_2 GHG (CO, CH_4, NMVOCs) may be released during combustion process, all the released carbon are accounted as CO_2 emissions based on the 2006 IPCC Guidelines for energy:

$$E_{FuelBurn,t} = (CSP_{diesel,t} \cdot EF_{diesel} + CSP_{gasoline,t} \cdot EF_{gasoline}) \cdot 0.001 \quad \textbf{(109)}$$

Where:

$E_{FuelBurn,t}$	increase in GHG emission as a result of burning of fossil fuels within the project boundary in year t; t CO_2-e. yr^{-1}
$CSP_{diesel,t}$	amount of diesel consumption in year t; liter (l) yr^{-1}
$CSP_{gasoline,t}$	amount of gasoline consumption in year t; l yr^{-1}
EF_{diesel}	emission factor for diesel; kg CO_2 l^{-1}
$EF_{gasoline}$	emission factor for gasoline; kg CO_2 l^{-1}

5.2.2. GHG emissions from biomass burning

Slash and burn or removal of pre-existing vegetation occurs traditionally in some regions during site preparation before planting and/or replanting. Since this methodology covers CO_2 emission as a verifiable change in the carbon stocks of the carbon pools, only non-CO_2 emissions are accounted here.

Step 1: Estimating the mean aboveground biomass stock per unit area before slash and burn.
The pasture or agricultural land, degraded land or logged land is usually dominated by herbaceous plants and shrubs. Therefore, this value can be obtained by following simple harvesting techniques:
The herbaceous plants can be measured by simple harvesting techniques. A small frame (either circular or square), usually encompassing about 0.5-1.0 m^2 or less, is used to aid this task. The material inside the frame is cut to ground level and weighed, and the underground part is also dug and weighed. Well-mixed samples are then collected and oven dried to determine dry-to-wet matter ratios. These ratios are then used to convert the entire sample to oven-dry matter. For shrubs, destructive harvesting techniques can also be used to measure the living biomass. An alternative approach, if the shrubs are large, is to develop local shrub allometric equations based on variables such as crown area and height or diameter at base of plant or some other relevant variable (e.g., number of stems in multi-stemmed shrubs). The equations would then be based on regressions of biomass of the shrub versus some logical combination of the independent variables. The independent variable or variables would then be measured in the sampling plots (Refers to Chapter 4.3 in GPG LULUCF).
If average carbon stocks for agricultural land uses are to be determined, peak carbon stocks in the management cycle shall be used.

Step 2: Estimating combustion efficiencies and emission factors. The combustion efficiencies may be chosen from Table 3.A.14 of GPG-LULUCF. If no appropriate combustion efficiency can be used, the IPCC default of 0.5 should be used. The nitrogen-carbon ratio (N/C ratio) is approximated to be about 0.01. This is a general default value that applies to leaf litter, but lower values would be appropriate for fuels with greater woody content, if data are available. Emission factors for use with above equations are provided in Tables 3.A 15 and 3.A.16 of GPG-LULUCF.

Step 3: Estimating of GHG emissions resulted from the slash and burn based on 2006 IPCC Guidelines for LULUCF and GPG LULUCF:

$$E_{Non-CO_2,BiomassBurn,t} = E_{BiomassBurn,N_2O} + E_{BiomassBurn,CH_4} \quad \forall t = 1 \tag{110}$$

$$E_{Non-CO2,BiomassBurn,\ t} = 0 \ \forall t > 1 \tag{111}$$

Where:

$E_{Non-CO2,BiomassBurn,t}$ the increase in Non-CO_2 emission as a result of biomass burning in slash and burn at start of the project; t CO_2-e. yr^{-1}
$E_{BiomassBurn,\ N2O}$ N_2O emission from biomass burning in slash and burn; t CO_2-e. yr^{-1}
$E_{BiomassBurn,\ CH4}$ CH_4 emission from biomass burning in slash and burn; t CO_2-e. yr^{-1}

$$E_{BiomassBurn,\ N2O} = E_{BiomassBurn,C} \cdot (N/C\ ratio) \cdot ERat_{N2O} \cdot MW_{N2O-N} \cdot GWP_{N2O} \tag{112}$$

$$E_{BiomassBurn,\ CH4} = E_{BiomassBurn,C} \cdot ERat_{CH4} \cdot MW_{CH4-C} \cdot GWP_{CH4} \tag{113}$$

Where[32]:

$E_{BiomassBurn,\ N2O}$	N_2O emission from biomass burning in slash and burn; t CO_2-e. yr^{-1}
$E_{BiomassBurn,\ CH4}$	CH_4 emission from biomass burning in slash and burn; t CO_2-e. yr^{-1}
$E_{BiomassBurn,C}$	loss of aboveground biomass carbon due to slash and burn; t C yr^{-1}
$N/C\ ratio$	nitrogen-carbon ratio; t N $(t\ C)^{-1}$
$MW_{N2O\text{-}N}$	ratio of molecular weights of N_2O and N (44/28); t N_2O $(t\ N)^{-1}$
$MW_{CH4\text{-}C}$	ratio of molecular weights of CH_4 and C (16/12); t CH_4 $(t\ C)^{-1}$
$ERat_{N2O}$	IPCC default emission ratio for N_2O (0.007); dimensionless
$ERat_{CH4}$	IPCC default emission ratio for CH_4 (0.012); dimensionless
GWP_{N2O}	Global Warming Potential for N_2O (310 for the first commitment period); t CO_2-e. $(t\ N_2O)^{-1}$
GWP_{CH4}	Global Warming Potential for CH_4 (21 for the first commitment period); t CO_2-e. $(t\ CH_4)^{-1}$

$$E_{BiomassBurn,C} = \sum_{i}^{m_{PS}} A_{burn,i} \cdot B_i \cdot CE \cdot CF \qquad (114)$$

Where:

$E_{BiomassBurn,C}$	loss of aboveground biomass carbon due to slash and burn; t C yr^{-1}
$A_{burn,i}$	area of slash and burn for stratum i; ha yr^{-1}
B_i	average aboveground stock in living biomass before burning for stratum i; t d.m. ha^{-1}
CE	combustion efficiency (IPCC default =0.5); dimensionless
CF	carbon fraction of dry biomass; t C $(t\ d.m)^{-1}$
I	stratum (m_{PS}= total number of strata)

5.2.3. Nitrous oxide emissions from nitrogen fertilization practices

Only direct N_2O emissions from nitrogen fertilization are monitored and estimated in this methodology, because indirect N_2O emissions (e.g., leaching and runoff) are smaller in forest than in agricultural land and the emission factor used in the 2006 IPCC Guidelines appears to be high (GPG LULUCF). The method of 2006 IPCC Guideline, GPG-2000 and GPG LULUCF can be used to estimate the direct N_2O emissions.

Step 1: Monitoring and estimating the amount of nitrogen in synthetic and organic fertilizer used within the project boundary[33]:

$$N_{SN\text{-}Fert} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{PS}} \sum_{j=1}^{s_{PS}} A_{ijt} \cdot N_{SN\text{-}Fert\ ijt} \cdot 0.001 \qquad (115)$$

$$N_{ON\text{-}Fert} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{PS}} \sum_{j=1}^{s_{PS}} A_{ijt} \cdot N_{ON\text{-}Fert\ ijt} \cdot 0.001 \qquad (116)$$

---

[32] Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF and Equation 3.2.19 in GPG LULUCF
[33] Refers to Equation 3.2.18 in IPCC GPG-LULUCF

Where:

$N_{SN\text{-}Fert}$	total amount of synthetic fertilizer within the project boundary ; t N Note: This quantity could also be estimated by monitoring and recording annual purchases and use of synthetic fertilizers at the project level (instead of the actual consumption at the stand level, A_{ijt})
$N_{ON\text{-}Fert}$	total amount of organic fertilizer within the project boundary; t N Note: This quantity could also be estimated by monitoring and recording annual purchases and use of synthetic fertilizers at the project level (instead of the actual consumption at the stand level, A_{ijt})
$N_{SN\text{-}Fert\ ijt}$	use of synthetic fertilizer per unit area for stratum *i*, tree species *i* in year *t*; kg N ha^{-1} yr^{-1}
$N_{ON\text{-}Fert,ijt}$	use of organic fertilizer per unit area for stratum *i*, tree species *i* in year *t*; kg N ha^{-1} yr^{-1}
i	1, 2, 3, … m_{PS} ex-post strata
j	1, 2, 3, … s_{PS} planted tree species
t	1, 2, 3, … *t** years elapsed since the start of the A/R CDM project activity

Step 2: Choosing the fractions of synthetic and organic fertilizer nitrogen that is emitted as NO_x and NH_3, and emission factors. As noted in GPG 2000 and 2006 IPCC Guideline, the default emission factor is 1.25 % of applied N, and this value should be used when country-specific factors are unavailable. Project developer may develop specific emission factors that are more appropriate for their project. Specific good practice guidance on how to derive specific emission factors is given in Box 4.1 of GPG 2000. The default values for the fractions of synthetic and organic fertilizer nitrogen that are emitted as NO_x and NH_3 are 0.1 and 0.2 respectively in 2006 IPCC Guideline[34].

Step 3: Calculating direct N_2O emissions from nitrogen fertilization[35]

$$N_2O_{direct-N_{fertilizer},t} = (F_{SN} + F_{ON}) \cdot EF_1 \cdot MW_{N2O\text{-}N} \cdot GWP_{N2O} \tag{117}$$

$$F_{SN} = N_{SN-Fert,t} \cdot (1 - Frac_{GASF}) \tag{118}$$

$$F_{ON} = N_{ON-Fert,t} \cdot (1 - Frac_{GASM}) \tag{119}$$

Where:

$N_2O_{direct\text{-}Nfertilizer}$	total direct N_2O emission as a result of nitrogen application within the project boundary at time t*; t CO_2-e.
F_{SN}	total amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_x; t N
F_{ON}	total amount of organic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_x; t N
$N_{SN\text{-}Fert}$	amount of synthetic fertilizer nitrogen applied; t N yr^{-1}
$N_{SN\text{-}Fert}$	amount of organic fertilizer nitrogen applied; t N yr^{-1}
EF_1	emission factor for emissions from N inputs; t N_2O-N $(t\ N\ input)^{-1}$
$Frac_{GASF}$	fraction that volatilises as NH_3 and NO_x for synthetic fertilizers; t NH_3-N and NO_x-N $(t\ N)^{-1}$
$Frac_{GASF}$	fraction that volatilises as NH_3 and NO_x for organic fertilizers; t NH_3-N and NO_x-N $(t\ N)^{-1}$

[34] Refers to table 4-17 and table 4-18 in 1996 IPCC Guideline

[35] Refers to Equation 3.2.18 in IPCC GPG-LULUCF, Equation 4.22 and Equation 4.23 in GPG 2000

MW_{N2O-N}	ratio of molecular weights of N_2O and N (44/28); t N_2O (t N)$^{-1}$
GWP_{N2O}	Global Warming Potential for N_2O (310 for the first commitment period); t CO_2-e. (t N_2O)$^{-1}$

6. Data to be collected and archived for actual net GHG removals by sinks

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.01	Stratum ID	Alpha numeric	Stratification map, GIS		Before and after the start of the project	100%	Each stratum has a particular combination of soil type, climate, and possibly tree species
2.1.1.02	Stand ID	Alpha numeric	Stand map, GIS		At stand establishment	100%	Each stand has a particular year to be planted under each stratum
2.1.1.03	Confidence level	%			Before the start of the project	100%	For the purpose of QA/QC and measuring and monitoring precision control
2.1.1.04	Precision level	%			Before the start of the project	100%	For the purpose of QA/QC and measuring and monitoring precision control
2.1.1.05	Standard deviation of each stratum			e	At each monitoring event	100%	Used for estimating numbers of sample plots of each stratum and stand, as necessary
2.1.1.06	Number of sample plots			c	Before the start of the project and adjusted thereafter	100%	For each stratum calculated from 2.1.1.03-2.1.1.05
2.1.1.07	Sample plot ID	Alpha numeric	Project and plot map, GIS		Before the start of the project	100%	Numeric series ID will be assigned to each permanent sample plot

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.08	Plot location		Project and plot map and GPS locating, GIS	m	5 years	100%	Using GPS to locate before start of the project and at time of each field measurement
2.1.1.09	Tree species		Project design map		5 years	100%	Arranged in PDD
2.1.1.10	Age of plantation	year	GIS	m	At stand establishment	100%	Counted since the planted year
2.1.1.11	Number of trees	number	Plot measurement	m	5 years	100% trees in plots	Counted in plot measurement
2.1.1.12	Diameter at breast height of living and standing dead trees (DBH)	cm (living/dead)	Plot measurement	m	5 year	100% trees in plots	Measuring at each monitoring time per sampling method
2.1.1.13	Mean DBH	cm	Calculated	c	5 year	100% of sampling plots	Calculated from 2.1.1.11 and 2.1.1.12
2.1.1.14	Height of living and dead trees	m	Plot measurement	m	5 year	100% trees in plots	Measuring at each monitoring time per sampling method
2.1.1.15	Mean tree height	m	Calculated	c	5 year	100% of sampling plots	Calculated from 2.1.1.11 and 2.1.1.14
2.1.1.16	Merchantable volume	$m^3 \cdot ha^{-1}$	Calculated or plot measurement	c/m	5 year	100% of sampling plots	Calculated from 2.1.1.13 and possibly 2.1.1.15 using local-derived equations, or directly measured by field instrument
2.1.1.17	Wood density	t d.m. m^{-3}	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species-specific value have the priority

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.18	Biomass expansion factor (BEF)	dimensionless	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species-specific value have the priority
2.1.1.19	Carbon fraction	$t\ C.(t\ d.m)^{-1}$	Local, national, IPCC	e	5 year	100% of sampling plots	Local-derived and species-specific value have the priority
2.1.1.20	Root-shoot ratio	Dimensionless	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species-specific value have the priority
2.1.1.21	Carbon stock in above-ground biomass of stands	t C	Calculated from equation	c	5 year	100% of strata	Calculated from 2.1.1.23 and 2.1.1.25
2.1.1.22	Carbon stock in below-ground biomass of stands	t C	Calculated from equation	c	5 year	100% of strata	Calculated from 2.1.1.24 and 2.1.1.25
2.1.1.23	Mean Carbon stock in above-ground biomass per unit area per stratum per species	$t\ C\ ha^{-1}$	Calculated from plot data	c	5 year	100% of stands	Calculated from 2.1.1.6 - 2.1.1.19 or 2.1.1.24 and 2.1.1.25
2.1.1.24	Mean carbon stock in below-ground biomass per unit area per stratum per species	$t\ C\ ha^{-1}$	Calculated from plot data	c	5 year	100% of stands	Calculated from 2.1.1.23 2.1.1.06 and 2.1.1.20
2.1.1.25	Area of stand	ha	Stratification map and stand data, GIS	m	At stand establishment	100% of stands	Actual area of each stand

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.26	Deadwood category of standing tree	Dimensionless	Plot measurement	m	5 year	100% of sampling plots	Measuring at each monitoring time per sampling method
2.1.1.27	Diameter of lying dead tree in each density class	cm/density class	Plot measurement	m	5 year or more	100% of strata and stands	Measuring at each monitoring time per sampling method
2.1.1.28	Carbon stock change in above-ground biomass	$t\ C\ yr^{-1}$	Calculated from equation	c	5 year	100% of strata	Calculated from 2.1.1.21
2.1.1.29	Carbon stock change in below-ground biomass	$t\ C\ yr^{-1}$	Calculated from equation	c	5 year	100% of strata	Calculated from 2.1.1.22
2.1.1.30	Deadwood stock	t C	Calculated from equations	c	5 year	100% of strata	Calculated from 2.1.1.25-2.1.127and 2.1.1.17-2.1.1.20
2.1.1.31	Decomposition rate	$\%\ yr^{-1}$	Plot measurement	m	5 year	Experimental plots	Field measurements
2.1.1.32	Carbon stock change in deadwood	t C	Calculated from equations	c	5 year	100% of strata	Calculated
2.1.1.33	Annually harvested volume and fuel wood	m^3	Harvesting statistics	c	annually	100% stands	Annually recorded
2.1.1.34	Annual carbon stock change in litter	$t\ C\ yr^{-1}$	Calculated from formula	c	5 year	100% of strata and stands	Calculated from 2.1.1.35
2.1.1.35	Mean carbon stock in litter	t C	Calculated from formula	c	5 year	100% of strata and stands	Calculated from 2.1.1.35
2.1.1.36	Mean weight of litter	$t\ ha^{-1}$	Laboratory measurement	m	5 year	100% of strata and stands	Measuring at each monitoring time
2.1.1.37	Carbon fraction of litter	$t\ C\ (t\ d.m.)^{-1}$	Laboratory measurement	m	5 year	100% of strata and stands	Measuring at each monitoring time

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.2.01	Amount of diesel consumed in machinery use for site prep, thinning or logging	On-site monitoring	Liter	m	annually	100%	Measuring either diesel consumption per unit area for site preparation, or per unit volume logged or thinned
2.1.2.02	Amount of gasoline consumed in machinery use for site prep, thinning or logging	On-site monitoring	Liter	m	annually	100%	Measuring either diesel consumption per unit area for site preparation, or per unit volume logged or thinned
2.1.2.03	Emission factor for diesel	GPG 2000, IPCC Guidelines, national inventory	kg/ liter	e	At beginning of the project	100%	National inventory value should has priority
2.1.2.04	Emission factor for gasoline	GPG 2000, IPPCC Guidelines, national inventory	kg/ liter	e	At beginning of the project	100%	National inventory value should has priority
2.1.2.05	Emission from fossil fuel use within project boundary	Calculated from Equation (23)	t CO_2-e. yr^{-1}	e	annually	100%	Calculating using Equation (23) via 2.1.2.01-2.1.2.04
2.1.2.06	Area of slash and burn	Measured during implementation	ha	m	During thr first year of the project duration	100%	Measured for different strata and sub-strata
2.1.2.07	Mean biomass stock per unit area before slash and burn	Measured before slash and burn	t d.m. ha^{-1}	m	During thr first year of the project duration	100%	Sampling survey for different strata and sub-strata before slash and burn
2.1.2.08	Proportion of biomass burnt	Measured after slash and burn	dimensionless	m	During the first year of the project duration	100%	Sampling survey after slash and burn

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.2.09	Biomass combustion efficiency	GPG LU-LUCF National inventory	dimensionless	e	Before the start of the project	100%	IPCC default value (0.5) is used
2.1.2.10	Carbon fraction	Local, national, IPCC	t C.(t d.m)$^{-1}$	e	Before the start of the project	100%	2.1.1.19 can be used if no appropriate value
2.1.2.11	Loss of above-ground biomass carbon due to slash and burn	Calculated using Equation	t C yr^{-1}	c	During the first year of the project duration	100%	Calculated using Equation
2.1.2.12	N/C ratio	GPG LU-LUCF National inventory, publications	t N (t C)$^{-1}$	e	Before the start of the project	100%	IPCC default value (0.01) is used if no appropriate value
2.1.2.13	N_2O emission from biomass burn	Calculated using Equation	t CO_2-e. yr^{-1}	c	During the first year of the project duration	100%	Calculated using Equation via 2.1.2.11-2.1.2.12
2.1.2.14	CH_4 emission from biomass burn	Calculated using Equation	t CO_2-e. yr^{-1}	c	During the first year of the project duration	100%	Calculated using Equation via 2.1.2.11
2.1.2.16	Amount of synthetic fertilizer N applied per unit area	Monitoring activity	kg N ha^{-1} yr^{-1}	m	annually	100%	For different tree species and/or management intensity
2.1.2.17	Amount of organic fertilizer N applied per unit area	Monitoring activity	kg N ha^{-1} yr^{-1}	m	annually	100%	For different tree species and/or management intensity
2.1.2.18	Area of land with N applied	Monitoring activity	ha yr^{-1}	m	annually	100%	For different tree species and/or management intensity
2.1.2.19	Amount of synthetic fertilizer N applied	Calculated using Equation	t N yr^{-1}	c	annually	100%	Calculated using Equation via 2.1.2.16 and 2.1.2.18
2.1.2.20	Amount of organic fertilizer N applied	Calculated using Equation	t N yr^{-1}	c	annually	100%	Calculated using Equation via 2.1.2.17 and 2.1.2.18

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.2.21	Fraction that volatilises as NH_3 and NO_x for synthetic fertilizers	GPG 2000, GPG LU-LUCF, IPCC Guideline National inventory	t NH_3-N and NO_x-N $(t\ N)^{-1}$	e	Before start of monitoring	100%	IPCC default value (0.1) is used if no more appropriate data
2.1.2.22	Fraction that volatilises as NH_3 and NO_x for organic fertilizers	GPG 2000, GPG LU-LUCF, IPCC Guidelines National inventory	t NH_3-N and NO_x-N $(t\ N)^{-1}$	e	Before start of monitoring	100%	IPCC default value (0.2) is used if no more appropriate data
2.1.2.23	Emission factor for emission from N input	GPG 2000, GPG LU-LUCF, IPCC Guidelines National inventory	N_2O N-input^{-1}	e	Before start of monitoring	100%	IPCC default value (1.25%) is used if no more appropriate data
2.1.2.24	Direct N_2O emission of N input	Calculated using Equation	t CO_2-e. yr^{-1}	c	annually	100%	Calculated using Equation via 2.1.2.19-2.1.2.23

7. Leakage

Leakage represents the increase in GHG emissions by sources, which occurs outside the boundary of an A/R CDM project activity that is measurable and attributable to the A/R CDM project activity.

This methodology applies to A/R CDM project activities that have four likely sources of leakage:

- GHG emissions caused by vehicle fossil fuel combustion due to transportation of seedling, labour, staff and harvest products to and/or from project sites;
- GHG emissions caused by displacement of people. These people have no influence over pre-project land use, and therefore do not fall under the activity displacement leakage (e.g., these people could be employees).
- Carbon-stock decreases caused by the displacement of fuel-wood collection
- Carbon-stock decreases due to the increased use of wood posts for fencing.

$$LK = LK_{Vehicle} + LK_{PeopleDiscplacement} + LK_{fuel\text{-}wood} + LK_{fencing} \tag{120}$$

Where:

LK	total leakage; t CO_2-e.
$LK_{PeopleDisplacement}$	total leakage due to deforestation due to people displacement; t CO_2-e.
$LK_{Vehicle}$	total GHG emissions due to fossil fuel combustion from vehicles; t CO_2-e.
$LK_{fuel\text{-}wood}$	leakage due to the displacement of fuel-wood collection; t CO_2-e.
$LK_{fencing}$	leakage due to increased use of wood posts for fencing up to year t^*; t CO_2-e

Note: In this methodology Equation 120 is used to estimate leakage for the period of time elapsed between project start ($t=1$) and the year $t=t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are estimated.

In line with the applicability conditions 13, this methodology excludes the following source of leakage:

- GHG emissions and carbon-stock decreases outside the project boundary caused by displacement of pre-project grazing activities.

7.1. Estimation of $LK_{Vehicle}$ (leakage due to fossil fuel consumption)

Leakage due to fossil fuel combustion from vehicles shall be estimated using the following steps and formulae.

Step 1: Collecting the traveled distance of different types of vehicles using different fuel types.

Step 2: Determining emission factors for different types of vehicles using different fuel types. Country-specific emission factors shall be developed and used if possible. Default emission factors provided in the IPCC Guidelines and updated in the GPG 2000 may be used if there are no locally available data.

Step 3: Estimating the GHG emissions using bottom-up approach described in GPG 2000 for energy sector[1].

[1] Refer to Equation 2.5 and Equation 2.6 in IPCC GPG 2000 for energy sector

$$LK_{Vehicle} = LK_{Vehicle,CO_2} \tag{121}$$

$$LK_{Vehicle,CO_2} = \sum_{t=1}^{t*}\sum_{x}\sum_{y}(EF_{xy} \cdot FuelConsumption_{xyt}) \tag{122}$$

$$FuelConsumption_{xyt} = n_{xyt} \cdot k_{xyt} \cdot e_{xyt} \tag{123}$$

Where:

$LK_{Vehicle}$	total GHG emissions due to fossil fuel combustion from vehicles; t CO_2-e. yr^{-1}
$LK_{Vehicle,CO2}$	total CO_2 emissions due to fossil fuel combustion from vehicles; t CO_2-e. yr^{-1}
x	vehicle type
y	fuel type
EF_{xy}	CO_2 emission factor for vehicle type x with fuel type y; dimensionless
$FuelConsumption_{xyt}$	consumption of fuel type y of vehicle type x at time t; liters
n_{xyt}	number of vehicles
k_{xyt}	kilometers traveled by each of vehicle type x with fuel type y at time t; km
e_{xyt}	fuel efficiency of vehicle type x with fuel type y at time t; liters km^{-1}
t	1, 2, 3, … $t*$ years elapsed since the start of the A/R CDM project activity

Country-specific emission factors shall be used if available. Default emission factors provided in the IPCC Guidelines and updated in the GPG 2000 may be used if there are no locally available data.

7.2. Estimation of $LK_{PeopleDisplacement}$ (leakage caused by displacement of people that have no influence over pre-project land use, and therefore do not fall under the activity displacement leakage)

By terminating a current land use, the A/R CDM activity may cause the loss of employment, and therefore cause the displacement of former employees. These people do not have influence over pre-project land use, and therefore do not fall under the activity displacement leakage. People displacement leakage may occur in the years immediately after employees are made redundant, when these individuals displaced by the project establish their new livelihoods. This leakage does not necessarily occur immediately after the start of the project activity, since the project's planting activities may provide initial employment.

If employment is lost, some of the displaced employees and their households may decide to establish a farm as their new livelihood. Establishment of new farms may lead to deforestation. Where forest loss occurs through the actions of the displaced households a leakage debit will be taken by the project, which will be determined as follows:

Step 1: Prior to the start of project activities, record the number of employees that the pre-project land uses sustain. Randomly select at least 10% of the employees that may be displaced by the project.

Step 2: Return at least 1 year but at most 5 years after the project start to determine how many permanent jobs were lost. Among the employees randomly selected in Step 1, record the households that have moved and cannot be monitored further. For households that cannot be monitored, follow Steps 4 and 5 below. For households that can be monitored record the area deforested by them.

Step 3: Return at least 1 year but at most 5 years after the conclusion of the project's initial planting activities to determine how many permanent jobs were lost. Record the households that have moved and cannot be monitored further. For households that cannot be monitored, follow Step 4 below. For households that can be monitored record the area deforested by them.

Step 4: Where a sampled household has moved away and can not be monitored further, there is some possibility that the household has established a new farm for its livelihood and caused deforestation. Project proponents shall present transparent and verifiable information regarding the average area of smallholder farms in the region.
Project proponents shall estimate the likelihood that a household that has moved has established a new farm based on an analysis of trends for rural-rural and rural-urban migration in the region or the country. Sources for estimating migration trends include official data (e.g., regional or national demographic censuses) and expert opinions. In order to be conservative, all displacement of workers is assumed to lead to a move and all rural-rural migration is assumed to lead to colonization (i.e. new farm establishment and not new wage employment elsewhere). (For instance, the project proponents shall assume that 3 households established a new farm, if 5 households cannot be found and if national census reports indicate that 60% of internal migration originating from rural areas involves moves to other rural areas, rather than moves to cities.)

Step 5: Sum the leakage for all sampled households. As at least 10% of households were sampled, calculate the total leakage of all households from the summed leakage of all sampled households.

$$LK_{PeopleDisplacement} = \sum_{h=1}^{H} AD_h \cdot FS \cdot 100 / 10 \qquad (124)$$

Where:

$LK_{PeopleDiscplacement}$	total leakage due to deforestation due to people displacement; t CO_2-e.
AD_h	area deforested by displaced household *h*; ha Note: the area can be either recorded or estimated
FS	mean carbon stock of primary forests according to the GPG-LULUCF, Table 3A 1.4, pages 3.159-3.162; t CO_2-e. ha^{-1}
h	1, 2, 3, ..., *H*, individual employments lost

Note: The factor of 10 may have to be adjusted, if a larger fraction than 10% of the households were sampled.

Any later displacement of former employees of the pre-project land-uses on the project sites will not be attributed to the project.

7.3. Demonstrate that leakage from activity displacement due to displacement of pre-project grazing activities does not occur

Following applicability condition 13, this methodology is only applicable if the project proponents can demonstrate that the cattle are not displaced somewhere else, but slaughtered or sold to be slaughtered. The project proponents shall provide evidence of what happened to the cattle at the initial verification.

7.4. Estimation of $LK_{fuel\text{-}wood}$ (Leakage due to displacement of fuel-wood collection)

Step 1*:* For each verification period, estimate the average fuel-wood collection in the project area to estimate the volume of fuel-wood gathering displaced outside the project boundary. Monitoring can be done by periodically interviewing households, through a Participatory Rural Appraisal (PRA) or field-sampling.

$$FG_{outside,t} = FG_{BL} - FG_{AR,t} \quad (125)$$

Where:

$FG_{outside,t}$	volume of fuel-wood gathering displaced outside the project area at year t; m^3 yr^{-1}
FG_{BL}	average pre-project annual volume of fuel-wood gathering in the project area – estimated *ex ante* and specified in the CDM-AR-PDD; m^3 yr^{-1}
$FG_{AR,t}$	volume of fuel-wood gathered in the project area according to monitoring results; m^3 yr^{-1}

Step 2*:* Leakage due to displacement of fuel-wood collection can be set as zero ($LK_{fuel\text{-}wood} = 0$) under the following circumstances:

- $FG_{BL} < FG_{AR,t}$
- $LK_{fuel\text{-}wood} < 2\%$ of actual net GHG removals by sinks (See EB22, Annex 15).

If one of the above assumptions was made in the CDM-AR-PDD, it is necessary to monitor FG_{ARt} and/or FG_{NGLt} to prove that the assumption is still valid.

In all other cases, leakage due to displacement of fuel-wood collection shall be estimated as follow (IPCC GPG-LULUCF - Eq. 3.2.8):

$$LK_{fuel\text{-}wood} = \sum_{t=1}^{t^*} FG_t \cdot D \cdot R \cdot CF \cdot MW_{CO2\text{-}C} \quad (126)$$

$$FG_t = FG_{outside,t} \quad (127)$$

Where:

$LK_{fuel\text{-}wood}$	leakage due to displacement of fuel-wood collection up to year t^*; t CO_2-e.
FG_t	volume of fuel-wood gathering displaced in unidentified areas; m^3 yr^{-1}
$FG_{outside,t}$	volume of fuel-wood gathering displaced outside the project area at year t – as per step 1; m^3 yr^{-1}
D	average basic wood density; t d.m. m^{-3} (See IPCC GPG-LULUCF - Table 3A.1.9)
CF	carbon fraction of dry matter (default = 0.5); t C (t d.m.)$^{-1}$
R	root-shoot ratio; dimensionless
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); t CO_2 (t C)$^{-1}$
t	1, 2, 3, … t^* years elapsed since the start of the A/R CDM project activity

7.5. Estimation of $LK_{fencing}$ (Leakage due to increased use of wood posts for fencing)

Step 1: Monitor the lengths of the perimeters that are fenced (PAR_t), average distance between wood posts (DBP) and the fraction of posts that is produced off-site from non renewable sources ($FNRP$).

Step 2: Estimate leakage due to increased use of wood posts for fencing as follow:

$$LK_{fencing} = \sum_{t=1}^{t*} \frac{PAR_t}{DBP} \cdot FNRP \cdot APV \cdot D \cdot BEF_2 \cdot CF \cdot \mathrm{MW_{CO2\text{-}C}} \qquad (128)$$

Where:

$LK_{fencing}$	leakage due to increased use of wood posts for fencing up to year t*; t CO_2
PAR_t	perimeter of the areas to be fenced at year t; m
DBP	average distance between wood posts; m
$FNRP$	fraction of posts from off-site non-renewable sources; dimensionless
APV	average volume of wood posts (estimated from sampling); m^3
D	average basic wood density of the posts; t d.m. m^{-3} (See IPCC GPG-LULUCF - Table 3A.1.9)
BEF_2	biomass expansion factor for converting volumes of extracted round-wood to total above-ground biomass (including bark); dimensionless Table 3A.1.10
CF	carbon fraction of dry matter (default = 0.5); t C (t d.m.)$^{-1}$
$MW_{CO2\text{-}C}$	ratio of molecular weights of CO_2 and C (44/12); CO_2 (t C)$^{-1}$
t	1, 2, 3, … t* years elapsed since the start of the A/R CDM project activity

Note: As per the guidance provided by the Executive Board (See EB22, Annex 15) leakage due to increased use of wood posts for fencing can be excluded from the calculation of leakages if $LK_{fencing} < 2\%$ of actual net GHG removals by sinks (See EB22, Annex 15).

8. Data to be collected and archived for leakage

ID number	Data Variable	Data unit	Data source	Measured (m) Calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.1.01	Number of each vehicle type used	number	Monitoring of project activity	m	Annually	100%	Monitoring number of each vehicle type used
3.1.02	Emission factors for road transportation	kg CO_2-e. l^{-1}	GPG 2000, IPCC Guidelines, national inventory	e	Annually	100%	National or local value has the priority
3.1.03	Kilometers travelled by vehicles	km	Monitoring of project activity	m	Annually	100%	Monitoring km for each vehicle and fuel type
3.1.04	Fuel consumption per km	l km^{-1}	Local data, national data, IPCC	e	5 years	100%	Estimated for each vehicle and fuel type
3.1.05	Fuel consumption for road transportation	l	Calculated via 3.1.01, 3.1.03, 3.1.04	c	Annually	100%	Calculated via 3.1.01, 3.1.03, 3.1.04
3.1.06	Leakage due to vehicle use for transportation	t CO_2-e. yr^{-1}	Calculated via 3.1.02, 3.1.05	c	Annually	100%	Calculated via 3.1.02, 3.1.05
3.1.07	Number of employees that the pre-project land uses sustain	number	Monitoring of project leakage	m	Prior to the start of project activities	100%	Monitoring of leakage
3.1.08	Number of employments lost	number	Monitoring of project leakage	m	At least 1 year but at most 5 years after the project start	100%	Monitoring of leakage
3.1.09	Number of households that have moved and cannot be monitored further	number	Monitoring of project leakage	m	At least 1 year but at most 5 years after the project start	at least 10%	Monitoring of leakage

ID number	Data Variable	Data unit	Data source	Measured (m) Calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.1.10	Number of households that have moved and cannot be monitored further	number	Monitoring of project leakage	m	At least 1 year but at most 5 years after the conclusion of the project's planting activities	at least 10%	Monitoring of leakage
3.1.11	Area deforested by households of former employees that lost their jobs and that could be found in the monitoring	ha	Interview	e	At least 1 year but at most 5 years after the project start	at least 10%	Monitoring of leakage
3.1.12	Area deforested by households of former employees that lost their jobs and that could be found in the monitoring	ha	Interview	m	At least 1 year but at most 5 years after the conclusion of the project's planting activities	at least 10%	Monitoring of leakage
3.1.13	Area deforested by households of former employees that lost their jobs and that could not be found in the monitoring	ha	Assumed to correspond to 3.1.15	c	At least 1 year but at most 5 years after the project start	at least 10%	Monitoring of leakage
3.1.14	Area deforested by households of former employees that lost their jobs and that could not be found in the monitoring	ha	Assumed to correspond to area from 3.1.15	c	At least 1 year but at most 5 years after the conclusion of the project's planting activities	at least 10%	Monitoring of leakage
3.1.15	Average area of smallholder farms in the region	ha	Expert consultations or published sources	e	During monitoring	100%	Monitoring of leakage

ID number	Data Variable	Data unit	Data source	Measured (m) Calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.1.16	Mean carbon stock of primary forests in the region	t CO_2-e./ha	GPG-LU-LUCF, Table 3A 1.4, pages 3.159-3.162	e	During monitoring	100%	Monitoring of leakage
3.1.17	Average pre-project annual volume of fuel-wood gathering in the project area	m^3 yr^{-1}	Interview	e	Prior to the start of project activities		
3.1.18	Volume of fuel-wood gathered in the project area	m^3 yr^{-1}	Interview	e	During monitoring		
3.1.19	Leakage due to displacement of fuel-wood collection up to year *t**	t CO_2-e.	Calculated	c	During monitoring		
3.1.20	Volume of fuel-wood gathering displaced in unidentified areas	m^3 yr^{-1}	Interviews	c	During monitoring		
3.1.21	Volume of fuel-wood gathering displaced outside the project area at year *t*	m^3 yr^{-1}	Calculated	c	During monitoring		
3.1.23	Leakage due to increased use of wood posts for fencing up to year *t**	t CO_2	Calculated	c	During monitoring		
3.1.24	Perimeter of the areas to be fenced at year *t*	m	Measurement	m	During monitoring		
3.1.25	Average distance between wood posts	m	Measurement	m	During monitoring		
3.1.26	Fraction of posts from off-site non-renewable sources	dimensionless	Interview	e	During monitoring		
3.1.27	Average volume of wood posts	m^3	Sampling	e	During monitoring		

9. Ex post net anthropogenic GHG removal by sinks

The net anthropogenic GHG removals by sinks is the actual net GHG removals by sinks minus the baseline net GHG removals by sinks minus leakage, therefore, following general formula can be used to calculate the net anthropogenic GHG removals by sinks of an A/R CDM project activity (C_{AR-CDM}), in t CO_2-e. :

$$C_{AR-CDM} = C_{ACTUAL} - C_{BSL} - LK \tag{129}$$

Where:

C_{AR-CDM}	net anthropogenic greenhouse gas removals by sinks; t CO_2-e.
C_{ACTUAL}	actual net GHG removals by sinks; t CO_2-e.
C_{BSL}	baseline net GHG removals by sinks; t CO_2-e.
LK	leakage, t CO_2-e.

Note: In this methodology Equation 129 is used to estimate net anthropogenic GHG removals by sinks for the period of time elapsed between project start ($t=1$) and the year $t=t^*$, t^* being the year for which actual net greenhouse gas removals by sinks are estimated. This is done because project emissions and leakage are permanent, which requires to calculate their cumulative values since the starting date of the A/R CDM project activity.

Calculation of tCERs and lCERs

To estimate the amount of CERs that can be issued at time $t^* = t_2$ (the date of verification) for the monitoring period $T = t_2 - t_1$, this methodology uses the EB approved equations[1] , which produce the same estimates as the following:

$$tCERs = C_{AR-CDM,t2} \tag{130}$$

$$lCERs = C_{AR-CDM,t2} - C_{AR-CDM,t1} \tag{131}$$

Where:

$tCERs$	number of units of temporary Certified Emission Reductions
$lCERs$	number of units of long-term Certified Emission Reductions
$C_{AR-CDM,t2}$	net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$; t CO_2-e.
$C_{AR-CDM,t1}$	net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$; t CO_2-e.

10. Uncertainties

(a) Uncertainties to be considered

The percentage uncertainty on the estimate of certain parameters and data (yield table values, biomass expansion factors, wood density, carbon fraction and other biophysical parameters) can be assessed from the sample standard deviation of measured sample values, using half the 95% confidence interval width divided by the estimated value, i.e.[2],

[1] See EB 22, Annex 15 (http://cdm.unfccc.int/EB/Meetings/022/eb22_repan15.pdf)
[2] Box 5.2.1 in GPG LULUCF

$$U_s(\%) = \frac{\frac{1}{2}(95\%ConfidenceIntervalWidth)}{\mu} \cdot 100 \qquad (132)$$

$$= \frac{\frac{1}{2}(4\sigma)}{\mu} \cdot 100$$

Where:

U_s	percentage uncertainty on the estimate of the mean parameter value; %
μ	sample mean value of the parameter
σ	sample standard deviation of the parameter

If the default parameters are used, uncertainty will be higher than if locally measured parameters are used, and can be only roughly estimated with expert judgment[3].

The percentage uncertainties on quantities that are the product of several terms are then estimated using the following equation[4]:

$$U_S = \sqrt{U_1^2 + U_2^2 + \cdots U_n^2} \qquad (133)$$

Where:

U_S	percentage uncertainty of product (emission by sources or removal by sinks)
U_i	percentage uncertainties associated with each term of the product (parameters and activity data), i=1,2,…,n

The percentage uncertainty on quantities that are the sum or difference of several terms can be estimated using following simple error propagation equation[5]:

$$U_c = \frac{\sqrt{(U_{s1} \cdot C_{s1})^2 + (U_{s2} \cdot C_{s2})^2 + \cdots + (U_{sn} \cdot C_{sn})^2}}{\left| C_{s1} + C_{s2} + \cdots + C_{sn} \right|} \qquad (134)$$

Where:

U_c	combined percentage uncertainty; %
U_{si}	percentage uncertainty on each term of the sum or difference; %
C_{si}	mean value of each term of the sum or difference

This methodology can basically reduce uncertainties through:

(i) Proper stratification of the project area into relatively homogenous strata;

(ii) Setting values for BEFs and root-shoot ratios.

11. Other information

This methodology is based on the approved methodology AR-AM0001. This methodology considers one additional source of leakage due to people displacement, and provides a procedure for making sure that other sources of leakage would not occur. This methodology not only accounts for living biomass, but also accounts for deadwood and litter. The baseline allows for land-use change.

---

[3] GPG LULUCF Chapter 5.2 and Chapter 3.2

[4] Equation 5.2.1 in GPG LULUCF

[5] Refers to equation 5.2.2 in GPG LULUCF

Section IV: Lists of variables, acronyms and references

1. List of variables used in equations

Variable	SI Unit	Description
$N_2O_{direct\text{-}Nfertilizer,\ t}$	t CO_2-e. yr^{-1}	increase in N_2O emission in year *t* as a result of direct nitrogen application within the project boundary
μ	dimensionless	sample mean value of the parameter
σ	dimensionless	sample standard deviation of the parameter
$\Delta C_{AB,\ ijt}$	t C yr^{-1}	changes in carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, time *t*
$\Delta C_{AB,ijt}$	t C yr^{-1}	changes in carbon stock in aboveground biomass of living trees for stratum *i*, species *j*, time *t*
$\Delta C_{BB,\ ijt}$	t C yr^{-1}	changes in carbon stock in belowground biomass of living trees for stratum *i*, species *j*, time *t*
$\Delta Cdesc_{DW\ ijt}$	t CO_2-e. yr^{-1}	annual decrease of carbon stock in the deadwood carbon pool due to deadwood decomposition for stratum *i*, species *j*, time *t*
$\Delta Cdesc_{LI\ ijt}$	t CO_2-e. yr^{-1}	annual decrease of carbon stock in the litter carbon pool due to litter decomposition for stratum *i*, species *j*, time *t*
ΔC_{DW}	t CO_2-e.	sum of the changes in deadwood carbon stocks
$\Delta C_{DW\ ijt}$	t CO_2-e. yr^{-1}	annual carbon stock change in deadwood for stratum *i*, species *j*, time *t*
$\Delta C_{DWl,ijt}$	t C yr^{-1}	annual carbon stock change in lying deadwood for stratum *i*, species *j*, time *t*
$\Delta C_{DWs,ijt}$	t C yr^{-1}	annual carbon stock change in standing deadwood for stratum *i*, species *j*, time *t*
$\Delta Cfw_{DW\ ijt}$	t CO_2-e. yr^{-1}	annual decrease of carbon stock in the deadwood carbon pool due to harvesting of deadwood for stratum *i*, species *j*, time *t*
$\Delta Cfw_{LI\ ijt}$	t CO_2-e. yr^{-1}	annual decrease of carbon stock in the litter carbon pool due to harvesting of litter for stratum *i*, species *j*, time *t*
$\Delta C_{G,\ ijt}$	t CO_2-e. yr^{-1}	annual increase in carbon stock due to biomass growth of trees for stratum *i*, species *j*, time *t*
$\Delta Chr_{DW\ ijt}$	t CO_2-e. yr^{-1}	annual increase of carbon stock in the deadwood carbon pool due to harvesting residues not collected for stratum *i*, species *j*, time *t*
$\Delta Chr_{LI\ ijt}$	t CO_2-e. yr^{-1}	annual increase of carbon stock in the litter carbon pool due to harvesting residues not collected for stratum *i*, species *j*, time *t*
$\Delta C_{L,\ ijt}$	t CO_2-e. yr^{-1}	annual decrease in carbon *stock* due to biomass loss of trees for stratum *i*, species *j*, time *t*
ΔC_{LB}	t CO_2-e.	sum of the changes in living biomass carbon stocks of trees (above- and below-ground)
$\Delta C_{LB\ ijt}$	t CO_2-e. yr^{-1}	verifiable changes in carbon stock in living biomass of trees for stratum *i*, species *j*, time *t*
ΔC_{LI}	t CO_2-e.	sum of the changes in litter carbon stocks
$\Delta C_{LI\ ijt}$	t CO_2-e. yr^{-1}	annual carbon stock change in litter for stratum *i*, species *j*, time *t*
$\Delta Cmlb_{DW\ ijt}$	t CO_2-e. yr^{-1}	annual increase of carbon stock in the deadwood carbon pool due to mortality of the living biomass for stratum *i*, species *j*, time *t*

Variable	SI Unit	Description
$\Delta Cmlb_{LI\ ijt}$	$t\ CO_2$-e. yr^{-1}	annual increase of carbon stock in the litter carbon pool due to mortality of the living biomass for stratum *i*, species *j*, time *t*
0.001	dimensionless	conversion kg to tonnes
$ERat_{N2O}$	dimensionless	IPCC default emission ratio for N_2O (0.007)
$ERat_{CH4}$	dimensionless	IPCC default emission ratio for CH_4 (0.012)
$MW_{CH4\text{-}C}$	$t\ CH_4\ (t\ C)^{-1}$	ratio of molecular weights of CH_4 and C (16/12)
GWP_{CH4}	$t\ CO_2$-e. $(t\ CH_4)^{-1}$	Global Warming Potential for CH_4 (21 for the first commitment period)
GWP_{N2O}	$t\ CO_2$-e. $(t\ N_2O)^{-1}$	Global Warming Potential for N_2O (310 for the first commitment period)
$MW_{CO2\text{-}C}$	$t\ CO_2\ (t\ C)^{-1}$	ratio of molecular weights of CO_2 and C (44/12)
$MW_{N2O\text{-}N}$	$t\ N_2O\ (t\ N)^{-1}$	ratio of molecular weights of N_2O and N (44/28)
A	ha	total size of all strata, e.g. the total project area
$A_{burn,i}$	ha yr^{-1}	area of slash and burn for stratum *i*
AD	ha	area deforested by each displaced household
AD_h	ha	area deforested by displaced household *h*
$Adist_{ijt}$	ha yr^{-1}	forest areas affected by disturbances in stratum *i*, species *j*, time *t*
$Adit_{ijT}$	$ha^{-1}\ yr^{-1}$	average annual area affected by disturbances for stratum *i*, species *j*, during the period *T*
A_i	ha	area of stratum *i*
A_i	ha	size of each stratum (= $\sum_{t=1}^{tcr}\sum_{j}^{S_{PS}} A_{ijt}$ where *tcr* is the end of the crediting period)
A_{ijt}	ha	area of stratum *i*, species *j*, at time *t*
A_{ijT}	ha yr^{-1}	average annual area for stratum *i*, species *j*, during the period *T*
A_{it}	ha	area of stratum *i*, at time *t*
A_i	ha yr^{-1}	area of tree species *i* with fertilization
AP	ha	sample plot size
APV	m^3	average volume of wood posts (estimated from sampling)
ASF	ha	average size of small-holder farms in the larger project area
$BEF_{1,j}$	dimensionless	biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total above-ground biomass increment for species *j*
$BEF_{2,,j}$	dimensionless	biomass expansion factor for converting merchantable volumes of extracted roundwood to total aboveground biomass (including bark) for species *j*
BEF_j	dimensionless	biomass expansion factor for conversion of biomass of merchantable volume to above-ground biomass
B_i	t d.m. ha^{-1}	average aboveground stock in living biomass before burning for stratum *i*
$B_{non\text{-}tree\ i}$	t d.m. ha^{-1}	average non-tree biomass stock on land to be planted before the start of a proposed A/R CDM project activity for stratum *i*
$B_{w,\ ijt}$	t d.m. ha^{-1}	average above-ground biomass stock for stratum *i*, species *j*, time *t*
$C_{AB,\ ijt1}$	t C	carbon stock in aboveground biomass for stratum *i*, species *j*, calculated at time $t=t_1$

Variable	SI Unit	Description
$C_{AB,\ ijt2}$	t C	carbon stock in aboveground biomass for stratum *i*, species *j*, calculated at time $t=t_2$
$C_{AB,ijt}$	t C	carbon stock in aboveground biomass for stratum *i*, species *j*, at time *t*
C_{ACTUAL}	t CO_2-e.	actual net greenhouse gas removals by sinks
$C_{AR\text{-}CDM}$	t CO_2-e.	net anthropogenic greenhouse gas removals by sinks
$C_B(t_v)$	t CO_2	estimated carbon stocks of the baseline scenario at time of verification t_v
$C_{BB,\ ijt1}$	t C	carbon stock in belowground biomass for stratum *i*, species *j*, calculated at time $t=t_1$
$C_{BB,\ ijt2}$	t C	carbon stock in belowground biomass for stratum *i*, species *j*, calculated at time $t=t_2$
$C_{BB,ijt}$	t C	carbon stock in belowground biomass for stratum *i*, species *j*, at time *t*
C_{BSL}	t CO_2-e. yr^{-1}	baseline net GHG removals by sinks
$C_{DW\ ijt1}$	t C	total carbon stock in deadwood for stratum *i*, species *j*, calculated at time $t=t_1$
$C_{DW\ ijt2}$	t C	total carbon stock in deadwood for stratum *i*, species *j*, calculated at time $t=t_2$
$C_{DWij,t\text{-}1}$	t CO_2-e.	Carbon stock in the deadwood carbon pool in stratum *i*, species *j*, time $t = t\text{-}1\ year$
$C_{DWl,ijt1}$	t C	carbon stock in lying deadwood for stratum *i*, species *j*, calculated at time $t=t_1$
$C_{DWl,ijt2}$	t C	carbon stock in lying deadwood for stratum *i*, species *j*, calculated at time $t=t_2$
$C_{DWs,ijt1}$	t C	carbon stock in standing deadwood for stratum *i*, species *j*, calculated at time $t=t_1$
$C_{DWs,ijt2}$	t C	carbon stock in standing deadwood for stratum *i*, species *j*, calculated at time $t=t_2$
CE	dimensionless	combustion efficiency (IPCC default =0.5)
CF	t C (t d.m)$^{-1}$	carbon fraction (IPCC default value = 0.5)
CF_j	t C (t d.m)$^{-1}$	carbon fraction of dry matter for species *j*
$CF_{LI\ it}$	t C (t d.m)$^{-1}$	carbon fraction of litter from stratum *i*, time *t* as determined in laboratory analysis if feasible (default value = 0.370)
$CF_{non\text{-}tree}$	t C (t d.m)$^{-1}$	the carbon fraction of dry biomass in non-tree vegetation
C_i	e.g. US$	cost of establishment of a sample plot for each stratum *i*
$C_{LB\ ijt1}$	t C	average annual carbon stock change in living biomass of trees
$C_{LI\ ijt1}$	t C	total carbon stock in litter for stratum *i*, species *j*, calculated at time $t=t_1$
$C_{LI\ ijt2}$	t C	total carbon stock in litter for stratum *i*, species *j*, calculated at time $t=t_2$
$C_{LI\ it2}$	t C	carbon stock in litter for stratum *i*, calculated at time $t=t_2$
$C_P(t_v)$	t CO_2-e.	existing carbon stocks at the time of verification t_v
C_{si}	dimensionless	mean value of each term of the sum or difference
CSP_{diesel}	liter (l) yr^{-1}	volume of diesel consumption
$CSP_{diesel,t}$	liter (l) yr^{-1}	amount of diesel consumption in year *t*
$CSP_{gasoline}$	liter (l) yr^{-1}	volume of gasoline consumption

Variable	SI Unit	Description
$CSP_{gasoline,t}$	$l\ yr^{-1}$	amount of gasoline consumption in year *t*
$D_1, D_2, ..., D_n$	cm	diameter of pieces of deadwood in density state *ds* measured in plots for stratum *i*, species *j*, time *t*
DBH_t	cm	mean diameter at breast height at time *t*
DBP	m	average distance between wood posts
dc	2, 3, or 4	decomposition class
DC	dimensionless	decomposition rate (% carbon stock in total deadwood stock decomposed annually)
D_{DWsdc}	t d.m. m^{-3} standing deadwood volume	volume-weighted average deadwood density for decomposition class *dc*
D_j	t d.m. m^{-3}	basic wood density for species *j*
ds	dimensionless	deadwood density state (sound, intermediate, and rotten)
Dw_j	t d.m. m^{-3} merchantable volume	intermediate deadwood density for species *j*
E	dimensionless	allowable error
E(t)	t CO_2-e.	project emissions in year *t*
$E_{BiomassBurn,\ CH4}$	t CO_2-e. yr^{-1}	CH_4 emission from biomass burning in slash and burn
$E_{BiomassBurn,\ N2O}$	t CO_2-e. yr^{-1}	N_2O emission from biomass burning in slash and burn
$E_{BiomassBurn,C}$	t C yr^{-1}	loss of carbon stock in aboveground biomass due to slash and burn
$E_{biomassloss}$	t CO_2-e.	decrease in the carbon stock in the tree and non-tree living biomass, deadwood and litter carbon pools of pre-existing vegetation in the year of site preparation up to time *t**
EF_1	t N_2O-N (t N input)$^{-1}$	emission factor for emissions from N inputs
EF_{diesel}	kg CO_2 l^{-1}	emission factor for diesel
$EF_{gasoline}$	kg CO_2 l^{-1}	emission factor for gasoline
$E_{FuelBurn}$	t CO_2-e. yr^{-1}	CO_2 emissions from combustion of fossil fuels within the project boundary
$E_{FuelBurn,t}$	t CO_2-e. yr^{-1}	increase in GHG emission as a result of burning of fossil fuels within the project boundary in year *t*
EF_{xy}	dimensionless	CO_2 emission factor for vehicle type *x* with fuel type *y*
$E_{Non\text{-}CO2,\ BiomassBurn}$	t CO_2-e. yr^{-1}	non-CO_2 emission as a result of biomass burning within the project boundary
$E_{Non\text{-}CO2,BiomassBurn,t}$	t CO_2-e. yr^{-1}	increase in Non-CO_2 emission as a result of biomass burning within the project boundary in year t
e_{xyt}	liters km^{-1}	fuel consumption of vehicle type *x* with fuel type *y* at time *t*
$FG_{AR,t}$	$m^3\ yr^{-1}$	volume of fuel-wood gathering allowed/planned in the project area under the proposed A/R-CDM project activity
FG_{BL}	$m^3\ yr^{-1}$	average pre-project annual volume of fuel-wood gathering in the project area
FG_{ijt}	$m^3\ yr^{-1}$	annual volume of fuel wood harvesting of living trees for stratum *i*, species *j*, time *t*
FG_{ijT}	$m^3\ ha^{-1}\ yr^{-1}$	average annual volume of fuel wood harvested for stratum *i*, species *j*, during the period *T*

Variable	SI Unit	Description
$FG_{outside,t}$	m^3 yr^{-1}	volume of fuel-wood gathering displaced outside the project area at year *t*
FG_t	m^3 yr^{-1}	volume of fuel-wood gathering displaced in unidentified areas
FNRP	dimensionless	fraction of posts from off-site non-renewable sources
$f_j(DBH,H)$	t d.m. ha^{-1}	allometric equation for species *j* linking above-ground tree biomass (kg $tree^{-1}$) to diameter at breast height (DBH) and possibly tree height (H) measured in plots for stratum *i*, species *j*, time *t*
F_{ON}	t N yr^{-1}	annual amount of organic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_x
$Frac_{GASF}$	t NH_3-N and NO_x-N $(t\ N)^{-1}$	fraction that volatilises as NH_3 and NO_x for synthetic fertilizers
$Frac_{GASM}$	t NH_3-N and NO_x-N $(t\ N)^{-1}$	fraction that volatilises as NH_3 and NO_x for organic fertilizers
FS	CO_2-e. ha^{-1}	mean carbon stock of forest vegetation in the larger project
F_{SN}	t N yr^{-1}	amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_x
$FuelConsumption_{xyt}$	liters	consumption of fuel type *x* of vehicle type *y* at time *t*
Fwf_{ijt}	dimensionless	fraction of annually harvested deadwood carbon stock harvested as fuel wood for stratum *i*, species *j*, time *t*
GHG_E	t CO_2-e. yr^{-1}	GHG emissions as a result of the implementation of the A/R CDM project activity within the project boundary
$GHG_{E,t}$	t CO_2-e. yr^{-1}	increase in GHG emission as a result of the implementation of the proposed A/R CDM project activity within the project boundary in year *t*
$G_{TOTAL,ij}$	t d.m ha^{-1} yr^{-1}	annual average increment rate in total biomass in units of dry matter for stratum *i,* species *j*
$G_{w,ij}$	t d.m ha^{-1} yr^{-1}	average annual aboveground dry biomass increment of living trees for stratum i species *j*
h	dimensionless	1, 2, 3, ..., *H*, individual employments deemed likely to get lost
Hf_{ijt}	dimensionless	fraction of annually harvested merchantable volume not extracted and left on the ground as harvesting residue for stratum *i*, species *j*, time *t*
H_{ijt}	m^3 ha^{-1} yr^{-1}	annually extracted merchantable volume for stratum *i*, species *j*, time *t*
H_{ijT}	m^3 ha^{-1} yr^{-1}	average annual net increment in merchantable volume for stratum *i*, species *j* during the period *T*
Historical land use/cover data	dimensionless	determining baseline approach
H_t	m	mean tree height at time *t*
i	dimensionless	1, 2, 3, ... m_{PS} ex-post strata
i	dimensionless	1, 2, 3, ... m_{BL} baseline strata
Investment costs	dimensionless	including land purchase or rental, machinery, equipments, buildings, fences, site and soil preparation, seedling, planting, weeding, pesticides, fertilization, supervision, training, technical consultation, etc. that occur in the establishment period
IRR, NPV, unit cost of service	dimensionless	indicators of investment analysis

Variable	SI Unit	Description
$I_{v,ij}$	m^3 ha^{-1} yr^{-1}	average annual increment in merchantable volume for stratum i species *j*
$I_{v,ijT}$	m^3 ha^{-1} yr^{-1}	average annual net increment in merchantable volume for stratum *i*, species *j* during the period *T*
j	dimensionless	1, 2, 3, … s_{PS} planted tree species
j	dimensionless	1, 2, 3, … s_{BL} baseline tree species
k_{xyt}	km	kilometers traveled by each of vehicle type *y* with fuel type *x* at time *t*
LT	100 m	transect length
Land use/cover map	dimensionless	demonstrating eligibility of land, stratifying land area
Landform map	dimensionless	stratifying land area
$l\text{-}CER(t_v)$	t CO_2-e.	l-CERs emitted at time of verification t_v
$L_E(t)$	t CO_2-e.	leakage: estimated emissions by sources outside the project boundary in year *t*
$L_{fw,\ ijt}$	CO_2-e. yr^{-1}	annual carbon loss due to fuel wood gathering for stratum stratum *i*, species *j*, time *t*
$L_{hr,\ ijt}$	t CO_2-e. yr^{-1}	annual carbon loss due to commercial harvesting for stratum *i*, species *j*, time *t*
LK	t CO_2-e.	leakage
$LK_{fencing}$	t CO_2-e.	leakage due to increased use of wood posts for fencing up to year *t**; t CO_2-e.
$LK_{fuel\text{-}wood}$	t CO_2-e.	leakage due to displacement of fuel-wood collection up to year *t**; t CO_2-e.
$LK_{PeopleDiscplacement}$	t CO_2-e.	total leakage due to deforestation due to people displacement
$LK_{Vehicle}$	t CO_2-e. yr^{-1}	total GHG emissions due to fossil fuel combustion from vehicles
$LK_{Vehicle,CO2}$	t CO_2-e. yr^{-1}	total CO_2 emissions due to fossil fuel combustion from vehicles
$L_{ot,\ ijt}$	CO_2-e. yr^{-1}	annual natural losses (mortality) of carbon for stratum *i*, species *j*, time *t*
$L_{P\_B}(t_v)$	t CO_2-e.	leakage: estimated carbon pools outside the project boundaries in the baseline scenario on areas that will be affected due to the implementation of a project activity at time of verification t_v
$L_{P\_P}(t)$	t CO_2-e.	leakage: existing carbon pools outside the project boundaries that have been affected by the implementation of a project activity at time of verification t_v
$MC_{AB,\ ijt}$	t C ha^{-1}	mean carbon stock in above-ground biomass per unit area for stratum *i*, species *j*, time *t*
$MC_{BB,\ ijt}$	t C ha^{-1}	mean carbon stock in below-ground biomass per unit area for stratum *i*, species *j*, time *t*
MC_{DWlijt}	t C ha^{-1}	mean carbon stock in lying deadwood per unit area for stratum *i*, species *j*, time *t*
$MC_{DWsij,dc}$	t C ha^{-1}	mean carbon stock in standing deadwood per unit area for stratum *i*, species *j*, time *t*
MC_{DWsijt}	t C ha^{-1}	mean carbon stock in standing deadwood per unit area for stratum *i*, species *j*, time *t*
$MC_{LI\ it}$	t C ha^{-1}	mean carbon stock in litter per unit area for stratum *i*, time *t*

Variable	SI Unit	Description
Mf_{ijT}	dimensionless	mortality factor = fraction of V_{ijt1} died during the period T
Mf_{ijt}	dimensionless	mortality factor = fraction of V_{ijt} dying at time t
$MV_{DWlijt,ds}$	$m^3\ ha^{-1}$	mean volume of lying deadwood per area unit in density state ds for stratum i, species j, time t
MV_{DWsijt}	$m^3\ ha^{-1}$	mean volume of dead standing deadwood per unit area for stratum i, species j, time t in decomposition class dc
MV_{ijt}	$m^3\ ha^{-1}$	mean merchantable volume per unit area for stratum i, species j, time t
$MW_{LI\ it}$	$t\ ha^{-1}$	mean weight of litter per unit area for stratum i, time t
n	dimensionless	sample size (total number of sample plots required) in the project area
n_i	dimensionless	sample size for stratum i
N	dimensionless	maximum possible number of sample plots in the project area
N_i	dimensionless	maximum possible number of sample plots in stratum i
N/C ratio	$t\ N\ (t\ C)^{-1}$	nitrogen-carbon ratio
National and sectoral policies	dimensionless	additionality consideration
NDH	dimensionless	number of employees that lose their employment due to the project activity
n_h.	dimensionless	number of samples per stratum that is allocated proportional to $W_h \cdot s_h / \sqrt{C_h}$
$N_{ON\text{-}Fert}$	$t\ N\ yr^{-1}$	mass of organic fertilizer nitrogen applied
$N_{ON\text{-}Fert,t}$	$t\ N\ yr^{-1}$	total use of organic fertiliser within the project boundary in year t
$N_{SN\text{-}Fert}$	$t\ N\ yr^{-1}$	amount of organic fertilizer nitrogen applied
$N_{SN\text{-}Fert}$	$t\ N\ yr^{-1}$	mass of synthetic fertilizer nitrogen applied
$N_{SN\text{-}Fert,t}$	$t\ N\ yr^{-1}$	total use of synthetic fertiliser within the project boundary in year t
nTR_{ijt}	ha^{-1}	number of trees in stratum i, species j, at time t
n_{xyt}	dimensionless	number of vehicles
n_{xyt}	dimensionless	number of vehicles
Operations and maintenance costs	dimensionless	including costs of thinning, pruning, harvesting, replanting, fuel, transportation, repairs, fire and disease control, patrolling, administration, etc.
p	dimensionless	desired level of precision (e.g. 10%)
pl	dimensionless	plot number in stratum i, species j
PL_{ij}	dimensionless	total number of plots in stratum i, species j
Q	e.g. $m^3\ ha^{-1}$	approximate average value of the estimated quantity Q, (e.g. wood volume)
Revenues	dimensionless	revenues from timber, fuel-wood, non-wood products, with and without CER revenues, etc.
R_j	dimensionless	root-shoot ratio
Satellite image	dimensionless	demonstrating eligibility of land, stratifying land area
st_i	dimensionless	standard deviation for each stratum i
Soil map	dimensionless	stratifying land area
SFG_{BL}	$m^3\ yr^{-1}$	sampled average pre-project annual volume of fuel-wood gathering in the project area

Variable	SI Unit	Description
SFR_{PAfw}	dimensionless	fraction of total area or households in the project area sampled
t	years	1, 2, 3, …t* years elapsed since the start of the A/R CDM project activity
T	years	number of years between monitoring time t_2 and t_1 ($T=t_2-t_1$)
T	years	number of years between two monitoring events which in this methodology is 5 years
T	years	number of years between times t_2 and t_1 ($T = t_2-t_1$)
TB_{ABj}	kg tree^{-1}	above-ground biomass of a tree
TC_{AB}	kg C tree^{-1}	carbon stock in above-ground biomass per tree
TC_{BB}	kg C tree^{-1}	carbon stock in below-ground biomass per tree
PAR_t	m	perimeter of the areas to be fenced at year t
$t\text{-}CER(t_v)$	t CO_2-e.	t-CERs emitted at time of verification t_v
tr	dimensionless	tree (TR = total number of trees in the plot)
Transaction costs	dimensionless	including costs of project preparation, validation, registration, monitoring, etc.
t_v	year	year of verification
U_c	%	combined percentage uncertainty
U_i	i=1,2,…,n	percentage uncertainties associated with each term of the product (parameters and activity data)
U_s	%	percentage uncertainty on the estimate of the mean parameter value
U_S	%	percentage uncertainty of product (emission by sources or removal by sinks)
U_{si}	%	percentage uncertainty on each term of the sum or difference
V_{ijt}	m^3 ha^{-1}	average merchantable volume of stratum i, species j, at time t
V_{ijt1}	m^3 ha^{-1}	average merchantable volume of stratum i, species j, at time $t = t_1$
V_{ijt2}	m^3 ha^{-1}	average merchantable volume of stratum i, species j, at time $t = t_2$
x	dimensionless	vehicle type
XF	dimensionless	plot expansion factor from per plot values to per hectare values
y	dimensionless	fuel type
$z_{\alpha/2}$	dimensionless	value of the statistic z (normal probability density function), for $\alpha = 0.05$ (implying a 95% confidence level)
$\Delta MC_{AB,ijt}$	t C ha^{-1} yr^{-1}	mean change in above-ground carbon stock in stratum i, species j, at time t
ΔMC_{ABij}	t C ha^{-1}	mean change in above-ground carbon stock in stratum i, species j, between two monitoring events
$\Delta MC_{BB,ijt}$	t C ha^{-1} yr^{-1}	mean change in below-ground carbon stock in stratum i, species j, at time t
ΔMC_{BBij}	t C ha^{-1}	mean change in below-ground carbon stock in stratum i, species j, between two monitoring events
ΔPC_{AB}	t C ha^{-1}	plot level change in above ground mean carbon stock between two monitoring events
$\Delta PC_{ABij,pl}$	t C ha^{-1}	plot level change in above-ground mean carbon stock in stratum i, species j, between two monitoring events

Variable	SI Unit	Description
ΔPC_{BB}	t C ha^{-1}	plot level change in below-ground mean carbon stock between two monitoring events
$\Delta PC_{BBij,pl}$	t C ha^{-1}	plot level change in below-ground mean carbon stock in stratum *i*, species *j*, between two monitoring events
ΔTC_{AB}	kg C tree^{-1}	change in above-ground biomass carbon per tree between two monitoring events
κ	year	time span between two verification occasions

2. List of acronyms used in the methodologies

Acronym	Description
A/R	Afforestation and Reforestation
EB	The Executive Board of the CDM
BEF	Biomass Expansion Factor (for converting from commercial volume to total tree biomass)
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CF	Carbon Fraction
CP	Conference of Parties to UNFCCC
DBH	Diameter at Breast Height
DNA	Designated National Authority
GIS	Geographic Information System
GHG	Greenhouse Gases
GPG	Good Practice Guidance
GWP	Global Warming Potential
H	Tree Height
IPCC	Intergovernmental Panel on Climate Change
lCER	long-term Certified Emission Reduction
LULUCF	Land Use Land-Use Change and Forestry
NFS	Nitrogen Fixing Species
PDD	Project Design Document
QA	Quality Assurance
QC	Quality Control
RS	Root to shoot ratio
tCER	temporary Certified Emission Reduction

3. References:

All references are quoted in footnotes.

- - - - -