Afforestation and reforestation baseline methodology AR-AM0005

"Afforestation and reforestation project activities implemented for industrial and/or commercial uses"

Source

This methodology is based on the draft CDM-AR-PDD "Reforestation as Renewable Source of Wood Supplies for Industrial Use in Brazil" whose baseline study, monitoring and verification plan and project design document were prepared by Plantar S/A - Belo Horizonte, Brazil; World Bank - Carbon Finance Business, Washington DC, US. For more information regarding the proposal and its consideration by the Executive Board please refer to case ARNM0015: "Reforestation as Renewable Source of Wood Supplies for Industrial Use in Brazil" at: http://cdm.unfccc.int/methodologies/ARmethodologies/publicview.html?OpenRound=7&OpenNM=ARNM0015&cases=B#ARNM0015.

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

"Changes in carbon stocks in the pools within the project boundary from the most likely land use at the time the project starts"

2. Applicability

This methodology is applicable to the following categories of project activities:

- Afforestation or reforestation activities undertaken to meet commercial or industrial needs on grasslands that are unmanaged or under extensive management, with low soil carbon content (compared to the expected soil carbon content under the project activity) because of soil degradation, or because climato-edaphic conditions naturally lead to thin, infertile soils with low carbon content.

This methodology anticipates two possible baseline scenarios:

1. Maintenance of the present land uses as unmanaged extensively managed grassland, and
2. Afforestation or reforestation activity undertaken intermittently in small amounts in the periods prior to the A/R CDM project activity;

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

- Land cover within the project boundary is in steady state either as unmanaged or extensively managed grassland;
- Lands will be afforested or reforested by direct planting and/or seeding;
- Natural regeneration is not expected to occur in the project area because of the absence of seed sources or because land use practices do not permit the establishment of tree vegetation;
- Carbon stocks in soil organic matter, litter and deadwood can be expected to decrease more or increase less in the absence of the project activity during the time frame that coincides with the crediting period of the project activity, relative to the baseline scenario. Lower soil carbon under grassland compared to plantations or secondary forests can be expected under

tropical conditions[1]; it cannot necessarily be expected under non-tropical conditions[2]; evidence has to be provided that the exclusion of soil organic carbon is conservative for the project case through, e.g. representative scientific literature;

- Grazing will not occur within the project boundary once the project commences; the total number of grazing animals is not increased compared to the pre-project conditions and thus non-CO_2 emissions from displaced livestock are not accounted as leakage in accordance with decision EB22, Annex 15, item 1.b[3]. To test this applicability condition, evidence shall be provided that the total number of animals is not increased as a consequence of the project activity (e.g. with records from slaughtering); potential effects on carbon pools outside the project boundary are accounted for as leakage from activity displacement;
- Flooding irrigation is not permitted;
- Soil drainage and disturbance are insignificant, so that non CO_2-greenhouse gas emissions from this these types of activities can be neglected;
- The amount of nitrogen-fixing species (NFS) used in the A/R CDM project activity is not significant, so that greenhouse gas emissions from denitrification can be neglected in the estimation of actual net greenhouse gas removals by sinks;
- A Geographical Information System (GIS) is required for the management of spatial data (e.g. for (ex-post) stratification).

This methodology is not applicable in project situations where:

- Pre-project activities such as grazing cannot be conceptually linked to households that are shifted from the project area; this excludes explicitly the use of this methodology where the animals that are grazing under pre-project conditions, are partly or entirely owned by the project entity (which possibly would not be considered to shift its 'household')[4].

3. Selected carbon pools:

Table I.1: Selection and justification of carbon pools

Carbon Pools	**Selected (answer with yes or no)**	**Justification / Explanation**
Above ground	Yes	Major carbon pool subjected to the project activity
Below ground	Yes	Major carbon pool subjected to the project activity
Dead wood	No	Conservative approach under applicability condition
Litter	No	Conservative approach under applicability condition

[1] Desjardins T, Andreux F, Vokoff B, Cerri CC (1994): Organic carbon and 13 C contents in soils and soil size-fractions, and their changes due to deforestation and pasture installation in eastern Amazonia. Geoderma 61, 103-118
Detwiler RP (1986): Land use change and the global carbon cycle: the role of tropical soils. Biogeochemistry 2, 67-93
Fearnside PM, Barbosa RI (1998): Soil carbon changes from conservation of forest to pasture in Brazilian Amazonia. Forest Ecology and Management 108, 147-166

[2] Guo LB, Gifford R, M, (2002): Soil carbon stocks and land use change: a meta analysis. Global Change Biology 8, 345-360

3 As per 1 (b) of Annex 15 EB22, (http://cdm.unfccc.int/EB/Meetings/022/eb22 repan15.pdf), the pre-project GHG emissions by sources which are displaced outside the project boundary in order to enable an A/R project activity under the CDM shall not be included under leakage if the displacement does not increase these emissions with respect to the pre-project conditions.

[4] This limitation is due to the fact that the unit for the assessment of leakage due to activity displacement is a household.

Soil organic carbon	No	Conservative approach under applicability condition

4. Summary of baseline and monitoring methodologies

This *baseline* methodology outlines transparent and conservative methods to estimate the net anthropogenic GHG removals by sinks resulting from A/R CDM project activities implemented to meet the demand for wood for industrial use (e.g., charcoal production for industrial uses etc.) and/or commercial use (e.g., furniture making, construction materials etc.). The methodology can be used as stand-alone or in conjunction with other methodologies that have provisions to account for the end-uses of the biomass from A/R CDM project activities that are proposed to reduce GHG emissions.

This methodology provides for the estimation of changes in carbon stock in selected carbon pools of A/R CDM project activities implemented on unmanaged or extensively managed grasslands. It accounts for carbon stock changes in the living biomass (above- and below-ground biomass) in the estimation of baseline net GHG removals by sinks and actual net GHG removals by sinks. The exclusion of deadwood, litter, and soil organic carbon is conservative considering the net increases in the carbon accumulated in these pools over the crediting period, relative to the baseline scenario.

It conservatively draws the baseline scenario(s) from amongst the plausible scenarios, and presents methods to transparently estimate the carbon stock changes expected from the most likely land use(s) prior to the start of the A/R CDM project activity.

The methodology adopts baseline approach 22(c) -"*changes in carbon stocks in the pools within the project boundary from the most likely land use at the time the project starts*", taking into account national, sector, and local policies influencing the land use prior to the start of the A/R CDM project activity, the scope of project alternatives relative to the baseline; and barriers to implement the A/R CDM project activity.

This methodology anticipates two possible baseline scenarios: (1) maintenance of the present land uses as unmanaged or extensively managed grassland, and (2) afforestation or reforestation activity undertaken intermittently in small amounts in the periods prior to the A/R CDM project activity.

It uses the latest version of the "*Tool for the Demonstration and Assessment of Additionality for Afforestation and Reforestation CDM Project Activities*[5]".

The *monitoring methodology* outlines methods to monitor carbon stock changes in the living biomass of A/R CDM project activities and increases in the GHG emissions that result from the implementation of the A/R CDM project activity. It outlines methods and procedures that complement the provisions of the baseline methodology. It assumes that the A/R CDM project activities are implemented on unmanaged or extensively managed grassland.

As per this methodology, the baseline scenario is identified and quantified *ex-ante* at the beginning of the A/R CDM project activity and will hold throughout the crediting period and does not require monitoring. The methodology outlines methods for assessing and accounting leakage from fossil fuels used in the project related travel undertaken outside the project boundary and displacement of economic activities attributable to the A/R CDM project activity.

The methodology recommends the use of field-based inventory methods and, depending on availability, remotely sensed data to monitor the implementation of the A/R CDM project activity. The methodology stratifies the project area based on climate, vegetation, and tree species and/or years of planting with the aid of land use/cover maps, remote sensing imagery, and/or field survey data. The methodology uses permanent sample plots to monitor the carbon stock changes in the living biomass in order to achieve the accuracy of ±10% of the mean at the 95% confidence level.

5 Available at http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html.

The plots shall be laid out in a way that facilitates easy location and ensures consistent monitoring over time, but are physically invisible to avoid preferential treatment.
The methodology specifies a monitoring frequency of 5–year intervals. In addition to monitoring the living biomass at successive monitoring intervals, it supports the recording of disturbances, if any. It recommends the adoption of standard operating procedures for monitoring, data collection, and archival, in order to maintain the integrity of the data collected in the monitoring process.

Baseline methodology steps:

The baseline methodology is structured into the following steps:

1. Delineation of project boundary: The land parcels included in the A/R project shall be delineated with a clearly traceable project boundary. Land eligibility is assessed applying stronger criteria than required by the CDM modalities and procedures.

2. Selection of carbon pools: The methodology provides for estimation of carbon stock changes in the living (above- and below-ground) biomass pools of A/R CDM project activities implemented on unmanaged or extensively managed grasslands. The exclusion of deadwood, litter, and soil organic carbon is conservative considering the net increase in carbon accumulated in these pools over the crediting period, in comparison to the baseline scenario.

3. Stratification: Stratification of the A/R CDM project area is undertaken based on data and information collected from the most recent land-use/land-cover maps, soil maps, vegetation maps and supplementary information on the baseline land-use/land-cover determined for each stratum. For the *ex ante* stratification of the project area, variables related to site quality, species and their silvicultural characteristics, year of planting and stand level management criteria are taken into account.

4. Assessment of baseline scenario: The methodology outlines procedures to select the baseline from amongst the plausible scenarios and evaluates land-use/land-cover of the baseline strata in order to estimate carbon stock changes expected under the most likely land-use at the time the project starts. The methodology anticipates two possible scenarios in the baseline: (1) land use as an unmanaged or extensively managed grassland; and (2) afforestation or reforestation activity undertaken as in small amounts in the period preceding the A/R CDM project.
The methodology adopts the baseline approach 22(c) -*"changes in carbon stocks in the pools within the project boundary from the most likely land-use at the time the project starts"* taking into account national, sector, and local policies influencing the land-use prior to the start of the A/R CDM project and plausible land-use alternatives and barriers to implementation of the project activity.

5. Estimation of the baseline net GHG removals by sinks: For grassland strata with herbaceous and non-woody vegetation, the methodology assumes the carbon stock in the baseline to remain constant in a low steady state, i.e., the baseline net GHG removals by sinks is zero. For strata with isolated trees and shrub vegetation, changes in carbon stocks of living biomass pools are estimated using the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (GPG/LULUCF) (IPCC 2003).

6. Demonstration of Additionality: The latest version of the *"Tool for the Demonstration and Assessment of Additionality for Afforestation and Reforestation CDM Project Activities*[6]" approved by the CDM Executive Board is used to test the additionality of the project.

6 http://cdm.unfccc.int/EB/021/eb21repan16.pdf

7. *Ex ante* estimation of the actual net GHG removals by sinks: The *ex ante* actual net GHG removals by sinks of stands established under the A/R CDM project activity are estimated using locally available allometric equations or yield models, taking into account the silvicultural management of the species included in the project. The increase in project emissions from fossil fuel consumption in the plantation activities, site preparation, natural or anthropogenic biomass burning, and fertilization are estimated following the guidance outlined in GPG/LULUCF (IPCC 2003).

8. Leakage: The increase in GHG emissions outside the project boundary is accounted, which is associated with emissions from fossil fuels used in the transport of staff, products and services, and displacement of pre-project land-use that leads to loss of vegetation and collection of fuelwood to areas outside the project's boundary.

9. *Ex ante* estimation of the net anthropogenic GHG removals by sinks:
The methodology estimates the net anthropogenic GHG removals by sinks according to the relevant provisions in the modalities and procedures for A/R CDM projects.
The methodology can be used stand alone or in conjunction with other methodologies that provide provisions for the end-use of the products from an A/R CDM project activity that result in greenhouse gas (GHG) emission reductions. To avoid double-counting of emission sources in a project activity, which has both A/R and non-A/R components, "emissions associated with A/R activities should be accounted for in the A/R project activity. In general all project activities using biomass for energy should account for emissions associated with production of biomass. However, in the case that it can be demonstrated that for a project activity using biomass for energy, which uses biomass originating from a registered A/R project activity (i.e. through contractual agreement for procurement of biomass) it need not account for emission related to biomass production" (EB 25 meeting report, para. 38);

Monitoring methodology steps:

The monitoring methodology is structured into the following steps:

1. Monitoring of the project boundary and forest establishment: This methodology outlines procedures to identify land parcels included in the project using field surveys and GPS methods and recording information on the project boundary. The methodology requests the use of field-based inventory methods and GPS data to verify consistency of the delineated project boundary of the parcels included in the project. The monitoring procedures cover information related to site preparation, species to be planted, and layout of planting adopted as per the management plan. The variables that influence the establishment of forest and the actual net GHG removals by sinks of the CDM-A/R project activity are taken into account as part of the procedures for monitoring of the forest establishment.

2. *Ex post* stratification of project area for monitoring: The *ex post* stratification considers monitoring of the project strata to verify the applicability of the *ex ante* stratification, and variables that influence the strata and establishment of the forest stands. The sample frame of the methodology specifies the number of permanent sample plots to be selected to monitor the carbon stock changes in living biomass in order to achieve an accuracy of ±10% in the mean at 95% confidence level. The *ex-post* stratification procedures facilitate cost-effective, consistent and accurate monitoring of carbon stock changes of the project during the crediting period.

3. Absence of baseline monitoring: The methodology prescribes validity of the baseline identified *ex ante* at the start of the A/R CDM project activity for the crediting period, thereby avoids the need for monitoring of the baseline over the crediting period, and achieves savings in the costs associated with baseline monitoring.

4. Calculation of the actual net GHG removals by sinks: The methodology provides for calculation of the actual net GHG removals by sinks from the project, using data on carbon stocks changes from the permanent sample plots, and the data on emissions from fossil fuel consumption, site preparation, burning of biomass and application of fertilizers in the project. The methods from Good Practice Guidance for Land use, Land Use Change and Forestry (GPG/LULUCF) (IPCC 2003) and the latest EB guidance are used in calculating the actual net GHG removals by sinks.

5. Monitoring leakage: Emissions related to staff travel outside the project boundary and displacement of economic activities from the project boundary to areas outside it, such as conversion of land to other uses and collection of fuelwood, are monitored and accounted in order to calculate the net anthropogenic GHG removals by sinks.

6. Quality Assurance (QA)/Quality Control (QC): The QA/QC guidelines proposed as part of the monitoring plan verify the accuracy and consistency of field measurements and ensure the integrity of data collection, management of project databases and the database archival during the crediting period.

Section II. Baseline methodology description

1. Project boundary

Project participants shall define the project boundary at the beginning of a proposed A/R CDM project activity and shall provide the geographical coordinates of lands to be afforested or reforested, so as to allow clear identification for the purpose of verification. The remotely sensed data[7] with adequate spatial resolution, officially certified topographic maps, land administration and tenure records, and/or other official documentation that facilitates the clear delineation of the project boundary can be used. The data shall be geo-referenced, and preferably provided in digital format. In the absence of requisite data and documentation, field surveys shall be undertaken to delineate the project boundary.

Table II.1: Gaseous emissions from sources other than those resulting from changes in carbon pools

Source	Gas	Included/ excluded	Justification / Explanation
Combustion of fossil fuels, e.g., on-site and/or off-site use of vehicles	CO_2	Included	
	CH_4	Excluded	Potential emission is negligibly small
	N_2O	Excluded	Potential emission is negligibly small
Biomass burning (Fires)	CO_2	Included	
	CH_4	Included	
	N_2O	Included	
Use of fertilizers	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable

7 Remotely sensed data includes data acquired from earth observation satellites or aerial photographs.

	N_2O	Included	
Removal of pre-existing non-tree vegetation	CO_2	Included	
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable

The definition of the project boundary is an iterative process and depends on the result of further elements of the baseline methodology, e.g. on the test of eligibility of lands in Section II.2.
The emission sources and gases likely to be emitted from the implementation of the proposed A/R CDM project activity are listed in the Table II.1.

2. Eligibility of land

Eligibility of the A/R CDM project activities under Article 12 of the Kyoto Protocol shall be 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 recommended by the EB.

3. Ex-ante stratification

This methodology recommends a hierarchical approach to stratification. The factors relevant at the regional scale, such as climate, topography or geographical conditions, should be considered on priority followed by the next level of variables in the hierarchy for the purpose of identifying the strata. The minimum contiguous area for stratum or a part of it that represents more than one discontinuous parcel should be equal to the minimum area defined for a forest by the DNA of the host country. The steps to be followed in the *ex ante* stratification are outlined below.

Step 1: Stratification taking into account pre-existing conditions and likely evolution of baseline.

The baseline strata should be identified using the following criteria that consider the pre-existing conditions and expected evolution of baseline scenario:

- The variables influencing carbon stock changes in above-ground and below-ground biomass pools shall be identified. Such variables could include climate, soil, topography, vegetation type, anthropogenic pressure etc. It is preferable to rank the variables so that stratification takes into account the variables that are specific to the baseline land use of the grasslands included in the project.
- The baseline information reflecting the status of grassland shall be collected from the most recent land use/cover maps, satellite images, soil and vegetation maps, and site information from published literature or local studies in order to identify most relevant stratification criteria.
- Data on pre-existing conditions of the grassland in terms of its vegetation and composition shall be collected in order to demonstrate the maintenance of grassland in its state in the absence of implementation of the A/R CDM project.
- Information on pre-project status of grassland shall be collected from the official data sources, land-use maps and field surveys. The project entity shall demonstrate the status of grassland such as whether the grassland was an unmanaged grassland or was managed as extensive grassland by providing relevant information on the land-use;

- Data on the pre-existing conditions of grassland and on the pre-project use of grassland shall be used to identify characteristic features that can be used in identifying the preliminary strata of the grassland.
- The specific features of the stratum levels should be identified in order to complement the information on the strata identified under preliminary stratification. Such characteristics could include;
    - The type of grassland vegetation, herbaceous vegetation, categories of shrub species and their growth characteristics such as diameter at the base (DBS) and height, and presence of isolated tree species, if any, and the characteristics of such vegetation;
    - Information on land tenure that reflects the nature of past management of grassland;
    - Nature and extent of past changes in the grassland vegetation in order to demonstrate the maintenance of grassland in its state or evidence demonstrating the steady state or the propensity to reach steady state in the near future;
    - Site characteristics that influence the evolution of the grassland, such as slope, gradient, soil type, soil depth, etc.;
- Differences in the strata demonstrating the occurrence of grassland areas in steady state and/or under extensive management and/or in a degraded state and/or with isolated vegetation that is expected to remain in such states in the future.
- If the analysis of preliminary strata reflects significant variation within the strata, taking into account specific characteristics of the stratum levels, further stratification should be undertaken based on more specific criteria in order to improve their distinctness. For highly variable landscapes, it is recommended to carry out systematic sampling in order to determine the percentage of project area with specific type of land use in each stratum.
- Based on the stratification criteria, strata are identified and their respective areas are estimated. Furthermore, dominant species of grassland vegetation should be considered as the basis to estimate the carbon stock changes under the baseline.

Step 2: Criteria of stratification to be considered in the proposed CDM A/R project activity:

i) The species and stand level characteristics of the project should be specified taking into account the following criteria:

- Species or species types that represent mix of species to be planted on a site within the same planting year shall be considered to represent a stand;
- The growth characteristics of species or species types representing mix of species with similar characteristics shall be specified;

ii) Silvicultural regime of species, such as planting, tending, thinning, harvesting, coppicing, and replanting cycle, shall be taken into account by specifying:

- The age class at which the management activities are proposed to be implemented;
- The type and quantity of fertilizer planned to be applied;
- The volume of wood that is proposed to be thinned or harvested;
- The rotation cycle or the coppicing cycle adopted

iii) The temporal and spatial information on the plantation establishment shall be specified by adopting:

- The planting date;
- The area to be planted (ha);
- The geographical location of the plantation site and stands proposed to be raised on the site should be identified and represented as the coordinates of polygons.

iv) The factors affecting actual net GHG removals by sinks should be reflected in the stratification. In order to maintain the optimal number of strata, the lands similar stocking levels and similar growth patterns could be included in a stratum and management factors such as thinning, harvesting and replanting, that may not warrant separate stratum levels could be kept out of the stratification criteria.

***Step 3: Ex ante stratification of A/R CDM project activity taking into account the stratification criteria and land use within the project boundary*.**

As part of the *ex ante* stratification, the boundary of each stratum should be delineated using land-use maps or geo-referenced data. As per the availability, data from remote sensing and global positioning systems should also be included. The project boundary shall be consistent with the parcels identified under the project.

***Step 4: Preparation of ex ante stratification map*.**

A stratification map showing different strata and their characteristic features should be prepared. The stratification should also include information pertaining to the sub-strata. If GIS systems are available it is good practice to present the overlays of GIS information on the ex-ante stratification map.

Step 5: The changes to the A/R project after the adoption of ex ante stratification shall be recorded

The relevant changes that occur to the project activity implementation after the *ex ante* stratification shall be recorded so that these could be taken into account during the *ex post* stratification at the monitoring stage of the project. The use of GIS overlays on the stratification maps facilitate the representation of changes to the ex ante stratification during the ex post stratification and spatial represented on the stratification map.

4. Procedure for selection of most plausible baseline scenario

The baseline scenario shall be determined through a sequence of steps, which reflect the changes in carbon stocks in above-ground biomass from the most likely land use at the time the project starts, in a transparent and conservative manner. The following steps shall be followed in selecting the baseline scenario:

Step 1: Demonstration of the most likely land use at the time the project starts

Demonstrate that as per the land eligibility established in Section II.2, the scenario anticipated for lands proposed under the project would remain under the existing grassland use that is expected to continue in the absence of the project activity. This can be done in at least one of the following ways:

- **Generally**: By demonstrating that similar lands, in the vicinity, are under similar use and are not expected to be used for alternative land uses. The financial and/or other barriers, which prevent alternative land uses can be identified;
- **Specifically for a forest as alternative land use:** Apply step 2 (investment analysis) or step 3 (barrier analysis) of the A/R "*Tool for the demonstration and assessment of additionality*", to demonstrate that this land use, in absence of the CDM, is unattractive, and that land pressures prevent the possibility of land being abandoned to natural forest regrowth;

- **Specifically, for other alternative land uses**: Use step 2 (investment analysis) or step 3 (barrier analysis) of the A/R "*Tool for the demonstration and assessment of additionality*" to demonstrate that alternative agricultural land uses would not occur in the absence of project activities

This analysis should use multiple sources of data including archives, maps and/or satellite images of land use/cover around 1990 and before the start of the proposed A/R CDM project activity, supplementary field investigation, landowner interviews, as well as collection of data from other sources.

Step 2: Assessment of national and sector policies and legislation

In order to adequately reflect the impacts of prevailing policies, project participants shall make an assessment of the relevant national or sector policies.

a) Policies related to the creation of wood sources

National or sector polices that have a direct influence on land use in the context of the A/R CDM project activity must be considered. Project participants must analyze the applicable policy incentives and constraints. "As a general principle, national and/or sectoral policies and circumstances are to be taken into account on the establishment of a baseline scenario, without creating perverse incentives that may impact host Parties' contributions to the ultimate objective of the Convention. National and/or sectoral land-use policies or regulations, which give comparative advantages to afforestation/reforestation activities and that have been implemented since the adoption by the COP of the CDM M&P (decision 17/CP.7, 11 November 2001), need not be taken into account in developing a baseline scenario (i.e. the baseline scenario could refer to a hypothetical situation without the national and/or sectoral policies or regulations being in place)" (EB 23, annex 19). Special attention shall be devoted to historical and/or prevailing land use and industrial policies, including incentives, subsidies, taxes and other fiscal and policy measures that influence the land use and the end use of the biomass from the afforestation /reforestation activities.
In case the A/R activity is affected by the policies in the competing industries or commercial end-uses, the policy analysis should evaluate the backward and forward linkages among the relevant sectors in order to demonstrate the additionality. The project participants shall identify and analyze specific policy contexts that had implications for A/R activities in the past or expected to have in the future.

b) Legislation related to the requirements of A/R activities and wood use

Project participants shall make an assessment of the impacts of prevailing legislation (federal, state, local) on the A/R activities, including the mandatory requirements on the land uses. The role of regulation and its enforcement is particularly relevant as the lack of effective regulation on the use of natural forests as biomass sources will effectively limit the incentives for implementing the A/R activities. In cases where widespread non-compliance is observed, evidence on the non-compliance shall be presented.
An analysis of the national policies and regulations related to natural forests and A/R activities, and their implications in terms of demand and supply of forest products and the impacts on the existing and future land uses shall be presented.

c) Other policy incentives and constraints

The macroeconomic and sector policies related to credit, marketing, and technology shall be evaluated in order to assess the influence of multi-sector policies on the land use for forestry.

Step 3: Assessment of demand and supply of wood resources for industrial and commercial purposes

The analysis of demand and supply balance of wood sources for industrial and commercial purposes shall be done, taking into account the factors influencing the A/R activities (e.g. end-uses of wood from the plantations). The impact of incentives and constraints in the land use for plantation activity shall be taken into account.
It is good practice to use long-term data to identify the land use and plantation establishment trends, in order to demonstrate the demand-supply balance / imbalance, i.e. supply shortages or constraints in the sustainability of wood production and supply.

Step 4 Assessment of land-use practices and prevailing land uses in the project region

Project participants shall make an assessment of the previous land uses in the region and the project area, and the management practices that are likely to impact the carbon stocks of the prevailing land uses now and in the future. The impact of policies and regulations shall be assessed to guide the choice of the most likely land uses. If applicable, project participants should explain how the incentives and constraints identified in Step 2, impact on land uses within the project area.
In case of the pre-project A/R activities that occurred in the absence of the proposed A/R CDM project activity, project participants must provide an estimate of the average regional and project entity-specific annual rates of A/R activities in the absence of the proposed A/R CDM project activity, so that it is considered within the listing of plausible land-use alternatives in Step 5. If the past policies resulted in an impact in terms of the implementation of the pre-project A/R in the region of the project area, the A/R activities attributable to these policies shall be considered as part of the baseline via the historical rate of afforestation/reforestation.
The determination of such an average regional and project-entity specific annual pre-project A/R rates must be established by means of historical data taking into account EB guidance on the consideration of national and sectoral policies (e.g. EB 23, annex 19) in accordance with the relevant incentives or constrains applicable to the pre-project A/R activities in the region of the project area and applicable to the project entity (e.g. impact of major policies identified in Step 2 such as the regulatory framework, suspension of previously applicable incentives, etc.). The region considered for the determination of the average regional annual pre-project A/R rate should contain the area with the same biophysical and socio-economic preconditions as the project area, including the project area. If regional data is not available or not reflecting sectoral conditions, average annual rate of pre-project A/R undertaken at the national level should be selected and adequate evidence be provided to justify this choice.
The analysis shall focus on the rate of A/R activities that is likely to occur in the absence of the A/R CDM project activity; the determination of such an average annual A/R rate must be established by means of verifiable data and supported by the reasons for the trends in the land uses. To provide conservative estimates, the average regional and project-entity specific annual pre-project A/R rates shall be compared and the higher one shall be selected as the baseline A/R rate.

Step 5: Identification of plausible and credible land-use alternatives

The identification of plausible and credible land-use alternatives shall be based on the scope of maintaining current land use, including the possibility of undertaking A/R as per the applicable trends shall be considered. If there are no specific geographic trends in the pre-project A/R activities, they are assumed to be applicable to all strata in proportion to the area of a stratum. Therefore, the proportion of project parcels of each stratum that are likely to be affected by the policies adopted prior to November 11, 2001 shall be assessed. In doing so, land records, field surveys, data and feedback from stakeholders, and other appropriate sources shall be used.

Step 6: Identification of the most likely land-use

Identification of the most likely land-use from among the alternatives listed in the project boundary at the start of the A/R CDM project shall be identified as the baseline scenario**.** Accordingly, the steps outlined for the determination of the baseline net GHG removals by sinks in Section II.5 could be adopted consistent with the baseline approach 22(c).
For each baseline stratum the most likely land-use alternative at the time the project starts from among the plausible land-use alternatives shall be identified. Furthermore, it should be demonstrated that in absence of the proposed CDM-A/R project activity, the most likely land-use would correspond to a plausible scenario that represents the grassland.

5. Estimation of baseline net GHG removals by sinks

This methodology outlines methods to estimate the changes in carbon stocks in the living biomass of unmanaged or extensively managed grassland, and the evolution of these changes in the absence of the A/R CDM project activity. The methods and algorithms used in assessing the baseline are outlined below.
If more than one category of land is anticipated in the baseline scenario (e.g., part of the land within the project scenario is expected to be under the existing land use, whereas other parts of the land uses are subjected to afforestation/reforestation at a pre-project rate that is significantly smaller than the area that can be afforested/reforested under the project scenario), the project participants shall stratify the lands under the baseline as per the likely land use or combinations of lands uses in the baseline, as per Step 6 of the Section II.4 above.
This methodology foresees two categories of land uses in the baseline scenario: maintenance of grassland in its present state; and the afforestation/reforestation implemented at a specified pre-project rate or a combination of both. Therefore, the baseline net GHG removals by sinks for the baseline scenario of the maintenance of grassland in its state, and the pre-project A/R activities that are likely to occur during the crediting period are represented as follows.

$$\Delta C_{BSL,t} = \Delta C_{GLB,t} + \Delta C_{ARB,t} \quad \textbf{(B.1)}$$

where:

$\Delta C_{BSL,t}$ = sum of carbon stock changes in living biomass of grassland (above and below-ground biomass) under the baseline scenario; tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{GLB,t}$ = sum of carbon stock changes in the living biomass of grassland (above and below-ground biomass) under the baseline scenario - *maintenance of grassland in its state*; tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{ARB,t}$ = the sum of carbon stock changes in living biomass of trees, under the baseline scenario with *A/R activities implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t* = ranges from 1 to length of the crediting period

(1) Maintenance of grassland in its state

The maintenance of unmanaged or extensively managed grassland occurs in the absence of seed sources within the project boundary or due to current land use practices preventing the regeneration of forests. Further on, the project land areas have low demand from competing land uses. Project participants shall stratify the grasslands by their condition and management regimes to allow a more precise estimation of expected net carbon stock change in the pools considered.
It must be noted that the stock changes in the living biomass occurs primarily in the early 15-20 years of grasslands. After this period, the biomass of grassland tends to achieve a steady state with limited expected changes in the foreseeable future, unless the grasslands are subjected to further changes in their management.
Under the baseline scenario, *maintenance of grassland in its state*, the carbon pools considered in this methodology are assumed to be in steady state. Hence, the sum of the carbon stock changes of the living biomass in the grassland, for any year *t,* is considered to be zero, as indicated in equation below.

$$\Delta C_{GLB,t} = 0 \quad \textbf{(B.2)}$$

where:

$\Delta C_{GLB,t}$ = sum of carbon stock changes in the living biomass of grassland (above and below-ground biomass) under the baseline scenario - *maintenance of grassland in its state*; tonnes CO_2 yr^{-1} in year *t*

For areas with isolated trees, the changes in carbon stocks of the living biomass for isolated trees shall be estimated and the baseline net GHG removals by sinks shall be represented as follows:

$$\Delta C_{GLB,t} = \Delta C_{ijk,t,\,ETB} \quad \textbf{(B.3)}$$

where:

$\Delta C_{GLB,t}$ = sum of carbon stock changes in the living biomass of grassland (above and below-ground biomass) under the baseline scenario - *maintenance of grassland in its state*; tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{ijk,t,\,ETB}$ = sum of annual changes in the carbon stocks of living biomass (above- and below-ground) of pre-existing trees in stratum *i*, substratum *j*, species *k;* t CO_2 yr^{-1}, using methods described in the step 5 of Section II.5.(2) below.

The sum of changes in the living biomass estimated as part of the baseline study prior to the project shall be frozen and adopted as the baseline to represent the scenario in the absence of the project.

(2) A/R implemented during the pre-project period

The changes in carbon stock in the living biomass expected from the annual rate of A/R activities undertaken during the pre-project, which is expected to occur in the future shall be included as part of the baseline before the *ex-ante* baseline is adopted under the baseline approach 22(c), and frozen for the crediting period. Accordingly, the following steps shall be adopted:

Step 1: Determine the applicable A/R rate as outlined in Section II.4, step 4.

Step 2: The project participants shall use the percentage of land area corresponding to the average annual pre-project A/R undertaken for the purpose of industrial/commercial sector at the regional level.

Step 3: To estimate the baseline carbon stock changes from the pre-project A/R activities, the species composition of the pre-project A/R activities shall be evaluated.

Step 4: Estimate the carbon stock changes of pre-project A/R activities undertaken as part of the baseline, as below:

$$\Delta C_{ARB,t} = \sum_{i=1}^{I}\sum_{j=1}^{J}\Delta C_{ARB,ij,t} \qquad \textbf{(B.4)}$$

where:

$\Delta C_{ARB,t}$	= sum of carbon stock changes in living biomass of trees, under the baseline scenario with *A/R activities implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t*
$\Delta C_{ARB,ij,t}$	= average annual change in carbon stock in the living biomass of trees for stratum *i,* species *j* under the baseline scenario with *A/R activities implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t*
i	= stratum *i* (*I* = total number of strata)
j	= species *j* (*J* = total number of species)

The following two generic methods are used to estimate the changes in carbon stock in living biomass of trees.

Method 1: Carbon gain-loss method[8]

$$\Delta C_{ARB,ij,t} = \Delta C_{ARB,G,ij,t} - \Delta C_{ARB,L,ij,t} \qquad \textbf{(B.5)}$$

where:

$\Delta C_{ARB,ij,t}$	= average annual change in carbon stock in the living biomass of trees for stratum *i*, species *j* under the baseline scenario with *A/R activities implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t*
$\Delta C_{ARB,G,ij,t}$	= average annual increase in carbon stock due to biomass growth of living trees for stratum *i,* species *j* under the baseline scenario with *A/R implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t*
$\Delta C_{ARB,L,ij,t}$	= average annual decrease in carbon stock due to biomass loss of living trees for stratum *i,* species *j* under the baseline scenario with *A/R implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t*

$$\Delta C_{ARB,G,ij,t} = A_{ARB,ij} \cdot G_{ARB,ij,t} \cdot CF_j \cdot \frac{44}{12} \qquad \textbf{(B.6)}$$

where:

8 GPG for LULUCF Equation 3.2.2, Equation 3.2.4 and Equation 3.2.5

$\Delta C_{ARB,G,ij,t}$ = average annual increase in carbon stock due to biomass growth of living trees for stratum *i,* species *j* under the baseline scenario with *A/R implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t*

$A_{ARB,ij}$ = area of stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*; hectare (ha)

$G_{ARB,ij,t}$ = average annual increment of total dry biomass of living trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period;* tonnes d.m. ha^{-1} yr^{-1} in year *t*

CF_j = carbon fraction of dry matter for species *j*; tonnes C (tonne d.m.)$^{-1}$

$\frac{44}{12}$ = ratio of molecular weights of CO_2 and carbon; dimensionless

Note: This methodology conservatively assumes that, for any time *t,* $C_{ARB,L,ij,t} = 0$ for the baseline scenario with A/R activities implemented during the pre-project period[9].

$$G_{ARB,ij,t} = G_{ARB,w,ij,t} \cdot (1 + R_j) \qquad \textbf{(B.7)}$$

$$G_{ARB,w,ij,t} = I_{ARB,v,ij,t} \cdot D_j \cdot BEF_{1,j} \qquad \textbf{(B.8)}$$

where:

$G_{ARB,ij,t}$ = average annual increment of total dry biomass of living trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period;* tonnes d.m. ha^{-1} yr^{-1} in year *t*

$G_{ARB,w,ij,t}$ = average annual above-ground biomass increment of trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*; tonnes d.m. ha^{-1} yr^{-1} in year *t*

R_j = root-shoot ratio relevant to the increments of 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).

$I_{ARB,v,ij,t}$ = average annual increment in merchantable volume for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*; m^3 ha^{-1} yr^{-1} in year *t*

Note*:* $I_{ARB,v,ij,t}$ for all subsequent rotation cycles, is smaller than that in the first cycle, for two reasons: it is assumed, conservatively, that there is no growth in the below-ground biomass; and the rate of growth is small at successive cycles.

D_j = basic wood density for species *j*; tonnes d.m. m^{-3}

BEF_{1j} = biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total above-ground biomass increment for species *j;* dimensionless

Method 2: stock change method [10]

9 This is conservative because the proportion of living biomass that dies or gets harvested is not deduced from the estimation of baseline net GHG removals by sinks and takes into account the loss of grass biomass under the pre-project A/R.

$$\Delta C_{ARB,ij,t} = \frac{C_{ARB,ij,t_2} - C_{ARB,ij,t_1}}{T} \cdot \frac{44}{12} \qquad \textbf{(B.9)}$$

$$C_{ARB,ij} = C_{ARB,AB,ij} + C_{ARB,BB,ij} \qquad \textbf{(B.10)}$$

$$C_{ARB,AB,ij} = A_{ARB,ij} \cdot V_{ARB,ij} \cdot D_j \cdot BEF_{2,j} \cdot CF_j \qquad \textbf{(B.11)}$$

$$C_{ARB,BB,ij} = C_{ARB,AB,ij} \cdot R_j \qquad \textbf{(B.12)}$$

where:

$G_{ARB,ij,t}$ = average annual increment of total dry biomass of living trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period;* tonnes d.m. ha^{-1} yr^{-1} in year *t*

C_{ARB,ij,t_2} = total carbon stock in living biomass of trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period* calculated at time t_2; tonnes C

C_{ARB,ij,t_1} = total carbon stock in living biomass of trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period* calculated at time t_1; tonnes C

T = number of years between times t_2 and t_1; years

$C_{ARB,AB,ij}$ = carbon stock in above-ground biomass for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period;* tonnes C

$C_{ARB,BB,ij}$ = carbon stock in below-ground biomass for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period;* tonnes C

$A_{ARB,ij}$ = area of stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*; hectare (ha)

$V_{ARB,ij}$ = merchantable volume of stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period;* m^3 ha^{-1}

D_j = wood density for species *j*; tonnes d.m. m^{-3} merchantable volume

$BEF_{2,j}$ = biomass expansion factor for conversion of merchantable volume to above-ground tree biomass for species *j*; dimensionless

CF_j = carbon fraction of dry matter for species *j;* tonnes C (tonne d.m.)$^{-1}$

R_j = root-shoot ratio for species *j;* dimensionless

An alternative way of estimating $C_{ARB,AB,ij}$ is to use allometric equations, which is considered good practice by the IPCC.

$$C_{ARB,AB,ij} = A_{ARB,ij} \cdot CF_j \cdot f_j(DBH, H) \qquad \textbf{(B.13)}$$

where:

10 GPG for LULUCF Equation 3.2.3

$C_{ARB,AB,ij}$	=	carbon stock in above-ground biomass for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period;* tonnes C
$A_{ARB,ij}$	=	area of stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*; hectare (ha)
CF_j	=	carbon fraction of dry matter for species *j;* tonnes C (tonne d.m.)$^{-1}$
$f_j(DBH,H)$	=	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* under the baseline scenario with *A/R implemented during the pre-project period* Note: allometric relationship between above-ground biomass and *DBH* and possibly *H* is a function of the species under consideration. Therefore, estimation of mean DBH and H values for stratum *i*, species *j* facilitates the estimation of carbon stock at time *t*.

Selection of parameters for estimation of carbon stocks in biomass

The following hierarchical order is recommended to select the respective parameters, tables and equations:

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

Conservative estimates shall be used for all parameters; the conservativeness of any parameter used to estimate tree biomass shall be substantiated in the PDD.

6. 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[11].

In addition, based on the paragraph 3 of Annex 19 in the EB 24 report, the assessment of additionality shall include the justification that the increased rate of A/R would not occur in the absence of the project activity and results from direct intervention by project participants[12].

7. Ex ante actual net GHG removal by sinks

The *ex-ante* estimation of actual removals involves (1) estimating the changes in carbon stocks in the living biomass pool; and (2) estimating the increase in emissions of greenhouse gases by the sources that are increased as a result of the implementation of the A/R CDM project activity, i.e.,

$$\Delta C_{ACTUAL,t} = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} \Delta C_{ijk,t} - GHG_{E,t} \qquad \textbf{(B.14)}$$

where:

$\Delta C_{ACTUAL,t}$ = actual net greenhouse gas removals by sinks; tonnes CO_2-e yr^{-1} in year *t*

$\Delta C_{ijk,t}$ = average annual change in carbon stock in living biomass of trees for stratum *i,* species *j,* sub-stratum k; tonnes CO_2 yr^{-1} in year *t*

$GHG_{E,t}$ = GHG emissions by sources within the project boundary as a result of the implementation of the A/R CDM project activity; tonnes CO_2-e yr^{-1} in year *t*

t = ranges from 1 to end of crediting period; years

i = stratum *i* (*I* = total number of strata)

j = species *j* (*J* = total number of species)

k = substratum *k* (*K* = total number of substrata)

a. Changes in carbon stocks of living biomass of trees

For the purpose of this methodology, the annual changes in carbon stock in the living biomass for year *t,* $\Delta C_{ijk,t}$, are estimated using equation:

$$\Delta C_{ijk,t} = \Delta C_{AB,ijk,t} + \Delta C_{BB,ijk,t} \qquad \textbf{(B.15)}$$

where:

$\Delta C_{ijk,t}$ = average annual change in carbon stock in living biomass of trees for stratum *i*, species *j*, sub-stratum (age class) *k*; tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{AB,ijk,t}$ = average annual changes in carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*

---

11 Please refer to <http://cdm.unfccc.int/methodologies/ARmethodologies.

12 http://cdm.unfccc.int/EB/024/eb24_repan19.pdf

$\Delta C_{BB,ijk,t}$ = average annual changes in carbon stock in below-ground biomass for stratum *i*, species *j,* sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*

The general formulae for estimating the changes in carbon stock in living biomass of trees of the A/R CDM project activity in year *t* is presented in the equation below. Annual changes in living biomass, at any given year, result from the difference in annual growth and loss. The decreases (or losses) result from the harvests of commercial wood and fuelwood and impacts from disturbance (e.g., fire, pest outbreaks).
For the purpose of ex-ante estimation of carbon stock changes, the impacts of disturbance need not be considered provided the disturbance is small and is primarily associated with the natural events such as fire or pest incidence. However, risk allowance shall be made in the estimates of GHG removals to account for natural disturbances.

$$\Delta C_{AB,ijk,t} = \Delta C_{G,AB,ijk,t} - \Delta C_{L,AB,ijk,t} \quad \textbf{(B.16)}$$

$$\Delta C_{BB,ijk,t} = \Delta C_{G,BB,ijk,t} - \Delta C_{L,BB,ijk,t} \quad \textbf{(B.17)}$$

where:

$\Delta C_{AB,ijk,t}$ = average annual changes in carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{BB,ijk,t}$ = average annual changes in carbon stock in below-ground biomass for stratum *i*, species *j,* sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{G,AB,ijk,t}$ = average annual increase in carbon in above-ground biomass due to biomass growth of trees for stratum *i*, species *j*, sub-stratum *k;* tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{L,AB,ijk,t}$ = average annual decrease in carbon in above-ground biomass due to biomass loss in stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{G,BB,ijk,t}$ = average annual increase in carbon in below-ground biomass due to biomass growth of trees for stratum *i*, species *j*, sub-stratum *k;* tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{L,BB,ijk,t}$ = average annual decrease in carbon in below-ground biomass due to biomass loss in stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*

a. 1 Gain in the living biomass of trees

The annual increase in living biomass can be estimated using biomass expansion factors. If local or national data on wood density or biomass expansion factors are not available, project participants can use the data from GPG for LULUCF for the land-use category and climatic region. The root-shoot ratio shall be obtained from national sources that closely reflect the conditions of the A/R CDM project activity. If national data are not available, the mean root-to-shoot value in the GPG for LULUCF shall be used.

$$\Delta C_{G,AB,\,ijk,t} = A_{ijk,t} \cdot I_{ijk,t} \cdot D_j \cdot BEF_{1j} \cdot CF_j \cdot \frac{44}{12} \quad \textbf{(B.18)}$$

$$\Delta C_{G,BB,\,ijk,t} = \Delta C_{G,AB,\,ijk,t} \cdot R_j \quad \textbf{(B.19)}$$

where:

$\Delta C_{G,AB,ijk,t}$ = average annual increase in carbon in above-ground biomass due to biomass growth of trees for stratum *i*, species *j*, sub-stratum *k;* tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{G,BB,ijk,t}$ = average annual increase in carbon in below-ground biomass due to biomass growth of trees for stratum *i*, species *j*, sub-stratum *k;* tonnes CO_2 yr^{-1} in year *t*

$A_{ijk,t}$ = area for stratum *i*, species *j*, sub-stratum *k*; hectares in year *t*

$I_{ijk,t}$ = average annual increment in merchantable volume for stratum *i*, species *j*, sub-stratum *k;* m^3 ha^{-1} yr^{-1} in year *t*

D_j = basic wood density for species *j*; t d.m. m^{-3} merchantable volume

BEF_{1j} = biomass expansion factor for conversion of merchantable volume for species *j* to above-ground tree biomass for species *j*; dimensionless

CF_j = carbon fraction of dry matter; tonnes C (tonne d. m.)$^{-1}$

R_j = root-shoot ratio appropriate for species *j*; dimensionless

$\frac{44}{12}$ = ratio of molecular weights of CO_2 and carbon; dimensionless

a.2 Losses in the living biomass

The annual decreases or losses of carbon in living biomass of trees result from (i) commercial harvest (ii) fuelwood harvest, and/or (iii) impacts of disturbance (e.g., fire, pest outbreaks), as represented in the equation below:

$$\Delta C_{L,AB,ijk,t} = \left(\Delta C_{L,AB,\,ijk,Harvest,t} + \Delta C_{L,AB,\,ijk,Fwood,t} + \Delta C_{L,AB,\,ijk,Dist,t}\right)\cdot\frac{44}{12} \qquad \textbf{(B.20)}$$

$$\Delta C_{L,BB,ijk,t} = \left(\Delta C_{L,BB,\,ijk,Harvest,t} + \Delta C_{L,BB,\,ijk,Fwood,t} + \Delta C_{L,BB,\,ijk,Dist,t}\right)\cdot\frac{44}{12} \qquad \textbf{(B.21)}$$

where:

$\Delta C_{L,AB,ijk,t}$ = average annual decrease in carbon in above-ground biomass due to biomass loss in stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{L,BB,ijk,t}$ = average annual decrease in carbon in below-ground biomass due to biomass loss in stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*

t = ranges from 1 to end of crediting period; years

$\Delta C_{L,AB,\,ijk,Harvest,t}$ = average annual decrease in carbon stock of above-ground biomass of trees due to commercial harvest for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*

$\Delta C_{L,AB,\,ijk,Fwood,t}$ = annual decrease in carbon stock of above-ground biomass of trees due to fuel wood collection/harvest for stratum *i*, species *j,* sub-stratum *k;* tonnes C yr^{-1} in year *t*

$\Delta C_{L,AB,\,ijk,Dist,t}$ = average annual decrease in carbon stock of above-ground biomass of trees due to disturbance for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*
Note: this can be ignored for small amounts in the *ex-ante* estimation)

$\Delta C_{L,BB,\,ijk,Harvest,t}$ = average annual decrease in carbon stock of below-ground biomass of trees due to commercial harvest for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*

$\Delta C_{L,BB,ijk,Fwood,t}$ = annual decrease in carbon stock of below-ground biomass of trees due to fuel wood collection/harvest for stratum *i*, species *j,* sub-stratum *k;* tonnes C yr^{-1} in year *t*

$\Delta C_{L,BB,ijk,Dist,t}$ = average annual decrease in carbon stock of below-ground biomass of trees due to disturbance for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*

$\frac{44}{12}$ = ratio of molecular weights of CO_2 and carbon; dimensionless

a.2.1 Loss in above-ground living biomass of trees from commercial harvest

The annual decrease of carbon stock in living biomass of trees (above-and below-ground) from the harvest of merchantable volume is estimated using the equation below.

$$\Delta C_{L,AB,ijk,Harvest,t} = A_{H,ijk,t} \cdot H_{ijk,t} \cdot D_j \cdot BEF_{jk} \cdot CF_j \qquad \textbf{(B.22)}$$

$$\Delta C_{L,BB,ijk,Harvest,t} = \Delta C_{L,AB,ijk,Harvest,t} \cdot R_{jk} \qquad \textbf{(B.23)}$$

where:

$\Delta C_{L,AB,ijk,Harvest,t}$ = average annual decrease in carbon stock in above-ground biomass of trees due to commercial harvest for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*

$\Delta C_{L,BB,ijk,Harvest,t}$ = average annual decrease in carbon stock in below-ground biomass of trees due to commercial harvest for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*

$A_{H,ijk}$ = area of harvest in stratum *i*, species *j*, sub-stratum *k*; ha yr^{-1} in year *t*

$H_{ijk,t}$ = amount of merchantable volume harvested in stratum *i,* species *j*, sub-stratum *k*; m^3 ha^{-1} in year *t*

D_j = basic wood density for species *j*; tonnes d.m. m^{-3} merchantable volume

BEF_{jk} = biomass expansion factor for conversion of harvested volume of species *j* sub-stratum *k* to above-ground biomass; dimensionless

R_{jk} = root-shoot ratio appropriate for species *j* sub-stratum *k*; dimensionless

CF_j = carbon fraction of dry matter; tonnes C $(\text{tonne d. m.})^{-1}$

a.2.2 Loss in living tree biomass from fuelwood harvest

The annual decrease of carbon stock in living biomass of trees (above-and below-ground) from fuel-wood harvest is estimated using the equation below.

$$\Delta C_{L,AB,ijk,Fwood,t} = A_{F,ijk} \cdot FW_{ijk,t} \cdot D_j \cdot BEF_{jk} \cdot CF_j \qquad \textbf{(B.24)}$$

$$\Delta C_{L,BB,ijk,Fwood,t} = \Delta C_{L,AB,ijk,Fwood,t} \cdot R_{jk} \qquad \textbf{(B.25)}$$

where:

$\Delta C_{L,AB,ijk,Fwood,t}$ = average annual decrease in carbon stock in above-ground biomass of trees due to fuelwood collection/harvest for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*

$A_{F,ijk}$ = area of harvest for fuelwood in stratum *i,* species *j,* sub-stratum *k*; ha yr^{-1} in year *t*
$FW_{ijk,t}$ = amount of fuelwood volume harvested for fuelwood in stratum *i,* species *j*, sub-stratum *k*; m^3 ha^{-1} in year *t*
D_j = basic wood density for species *j*; tonnes d.m. m^{-3} merchantable volume
BEF_{jk} = biomass expansion factor for conversion of harvested volume of species *j* sub-stratum *k* to above-ground biomass; dimensionless
R_{jk} = root-shoot ratio appropriate for species *j* sub-stratum *k*; dimensionless
CF_j = carbon fraction of dry matter; tonnes C (tonne d. m.)$^{-1}$

If no changes in below-ground biomass occur at the rotation harvest (e.g., roots are left on the field for coppicing), then R_{jk} should be set to zero for all age classes k > rotation. In this case, no increase in below-ground biomass is assumed to occur until the below-ground biomass is removed, and new plantations are established. Such an assumption leads to conservative *ex-ante* estimates.

a. 2.3 Loss of biomass due to disturbance

For the purpose of *ex-ante* estimation of carbon stock changes, the impacts of disturbance need not be considered provided the disturbance is expected to be small and is primarily associated with natural events such as fire or pest incidence. The overall risk allowance in the estimates of GHG removals is expected to account for natural disturbances.

b. Increase in emissions of greenhouse gases

In this methodology increases in emissions of greenhouse gases by sources are assumed to result from fossil fuel combustion, loss of biomass due to conversion of grassland to forests as a result of the A/R CDM activity, burning of biomass, and/or application of nitrogenous fertilizers. The increase in greenhouse gas emissions is estimated as follows:

$$GHG_{E,t} = E_{FuelBurn,\,t} + E_{Biomass\ Loss,t} + E_{Non-CO_2,BiomassBurn,t} + N_2O_{direct-N_{fertilizer},t} \qquad \textbf{(B.26)}$$

where:
$GHG_{E,t}$ = annual GHG emissions as a result of the implementation of the A/R CDM project activity within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$E_{FuelBurn,t}$ = CO_2 emissions from combustion of fossil fuels within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$E_{BiomassLoss,\,t}$ = GHG emissions from the loss of biomass in site preparation and conversion to A/R within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$E_{Non-CO_2,BiomassBurn,t}$ = non-CO_2 emission as a result of biomass burning within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$N_2O_{direct-N_{fertilizer},t}$ = direct N_2O emissions as a result of nitrogen application within the project boundary; tonnes CO_2-e yr^{-1} in year *t*

If the implementation of the A/R CDM project activity does not result in the burning of biomass (e.g for site preparation), the non-CO_2 greenhouse gas emissions need not be estimated.

If the implementation of the A/R CDM project activity does not result in the use of a significant amount of nitrogen fertilizers, these nitrous oxide emissions need not be estimated.

b. 1 Calculation of CO_2 emissions from burning fossil fuels

Emissions from fossil fuel combustion occur from the use of machinery in nursery, site preparation, thinning, harvesting, etc.. The IPCC 1996 Guidelines can be used to estimate the CO_2 emissions from the combustion of fossil fuels:

$$E_{FuelBurn,t} = (CSP_{diesel,t} \cdot EF_{diesel} + CSP_{gasoline,t} \cdot EF_{gasoline}) \cdot 0.001 \qquad \textbf{(B.27)}$$

where:

$E_{FuelBurn,t}$	=	CO_2 emissions from combustion of fossil fuels within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$CSP_{diesel,t}$	=	volume of diesel consumption; litre (l) yr^{-1} in year *t*
$CSP_{gasoline,t}$	=	volume of gasoline consumption; litre (l) yr^{-1} in year *t*
EF_{diesel}	=	emission factor for diesel; kg CO_2 l^{-1}
$EF_{gasoline}$	=	emission factor for gasoline; kg CO_2 l^{-1}
0.001	=	conversion from kg to tonnes of CO_2

Project participants should use national CO_2 emission factors. If these are not available they may use default emission factors as provided in the 1996 Revised IPCC Guidelines .

b. 2 Emissions from biomass loss due to conversion of grassland to forests

The annual loss of grassland living biomass due to the removal of grassland vegetation and other pre-existing vegetation to afforest or reforest the area is estimated using the equation below.

$$E_{BiomassLoss,t} = \sum_{i=1}^{I} A_i \cdot B_{w,i} \cdot (1 + R_G) \cdot CF \cdot \frac{44}{12} \qquad \textbf{(B.28)}$$

where:

$E_{Biomass\,Loss,t}$	=average annual decrease in grassland biomass due to conversion of grassland to forests in stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*
$A_{ijk,Conv,t}$	=annual area converted to forest in stratum *i*, species *j*, sub-stratum *k;* ha yr^{-1} in year *t*
$B_{w,i}$	=peak (maximum) above-ground biomass of grassland in stratum *i;* tonnes d.m. ha^{-1}
R_G	=root-shoot ratio appropriate for grassland; dimensionless
CF	=carbon fraction of dry matter; tonnes C (tonne d. m.)$^{-1}$
i	=stratum *i* (*I* = total number of strata)
$\frac{44}{12}$	=ratio of molecular weights of CO_2 and carbon; dimensionless

Note that the loss of biomass due to the removal of grass and other pre-existing vegetation occurs only when the area A_{ijk} is converted from grassland to forest through afforestation/reforestation. The estimates of $B_{w,i}$ and R_G shall be provided from national publications. In case these data are not available, project participants shall rely on default data provided in the GPG for LULUCF (Table 3.4.2 and Table 3A.1.8).

b. 3 Emissions from biomass burning

Emissions from biomass burning (fires) include not only CO_2 but also other greenhouse gases (in particular methane and nitrous oxide). These non-CO_2 emissions result from incomplete combustion of biomass. Such emissions can occur e.g. during the burning of pre-existing vegetation for site preparation or from forest fires.

The CO_2 emissions from biomass burning (fires) do not have to be accounted for since changes in carbon stock in the grassland in the living biomass are already included in the calculation of the decrease in carbon stocks in living biomass from removal of grassland to afforest or reforest. However, if biomass burning occurs during the site preparation before planting and/or replanting, this results in non-CO_2 emissions.

$$E_{Non-CO_2,BiomassBurn,t} = E_{BiomassBurn,N_2O,t} + E_{BiomassBurn,CH_4,t} \qquad \textbf{(B.29)}$$

$$E_{BiomassBurn,N_2O,t} = E_{BiomassBurn,C,t} \cdot N/C\ ratio \cdot EF_{N2O} \cdot GWP_{N2O} \cdot \frac{44}{28} \qquad \textbf{(B.30)}$$

$$E_{BiomassBurn,CH_4\,t} = E_{BiomassBurn,C,t} \cdot EF_{CH4} \cdot GWP_{CH4} \cdot \frac{16}{12} \qquad \textbf{(B.31)}$$

where:

$E_{Non-CO_2,BiomassBurn,t}$	=	non-CO_2 emission as a result of biomass burning within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$E_{BiomassBurn,N_2O,t}$	=	N_2O emission from biomass burning; tonnes CO_2-e yr^{-1} in year *t*
$E_{BiomassBurn,CH_4,t}$	=	CH_4 emission from biomass burning; tonnes CO_2-e yr^{-1} in year *t*
$E_{BiomassBurn,C,t}$	=	loss of carbon stock in above-ground biomass due to burning; tonnes C yr^{-1} in year *t*
$N/C\ ratio$	=	nitrogen/carbon ratio; dimensionless
EF_{N2O}	=	IPCC default emission ratio for N_2O (IPCC default: 0.0007); kg CO_2-e. (kg $C)^{-1}$
EF_{CH4}	=	IPCC default emission ratio for CH_4 (IPCC default: 0.0012); kg CO_2-e. (kg $C)^{-1}$
GWP_{N2O}	=	global warming potential for N_2O (IPCC default for the first commitment period: 310); kg CO_2 (kg $N_2O)^{-1}$
GWP_{CH4}	=	global warming potential for CH_4 (IPCC default for the first commitment period: 21); kg CO_2 (kg $CH_4)^{-1}$
$\frac{44}{28}$	=	ratio of molecular weights of N_2O and nitrogen; dimensionless
$\frac{16}{12}$	=	ratio of molecular weights of CH_4 and carbon; dimensionless

$$E_{BiomassBurn,C,t} = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} A_{burn,ijk,t} \cdot B_{ijk,t} \cdot CE \cdot CF \quad \textbf{(B.32)}$$

where:

$E_{BiomassBurn,C,t}$ = loss of carbon stock in above-ground biomass due to burning; tonnes C yr^{-1} in year t

$A_{burn,ijk,t}$ = annual area affected by biomass burning in stratum *i*, species *j*, sub-stratum *k;* ha yr^{-1}

$B_{ijk,t}$ = average above-ground biomass before burning for stratum *i*, species *j*, sub-stratum *k;* tonnes d.m. ha^{-1}
Notes: if the burning occurs during site preparation, $B_{ijk,t}$ indicates the above-ground biomass on grassland before burning. Otherwise it indicates the above-ground biomass of trees in year t.

CE = combustion efficiency; dimensionless (IPCC default = 0.5)

CF = carbon fraction of dry matter; tonnes C (tonne d.m)$^{-1}$

i = stratum *i* (*I* = total number of strata)

j = species *j* (*J* = total number of species)

k = substratum *k* (*K* = total number of substrata)

The combustion efficiencies may be chosen from Table 3.A.14 of GPG for 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 for LULUCF. The nitrogen-carbon ratio (*N/C ratio*) is approximated to be about 0.01. This is a default value that applies to leaf litter, but lower values would be appropriate for fuels with greater woody content, if data are available.

b.4 Calculation of nitrous oxide emissions from nitrogen fertilization practices

Nitrous oxide emissions from the use of nitrogenous fertilizers application practices can be estimated using the equations below.

$$N_2O_{direct-N_{fertilizer},t} = \left(F_{SN,t} + F_{ON,t}\right) \cdot EF_i \cdot \frac{44}{28} \cdot GWP_{N2O} \quad \textbf{(B.33)}$$

$$F_{SN,t} = N_{SF-Fert,t} \cdot \left(1 - FRAC_{GASF}\right) \quad \textbf{(B.34)}$$

$$F_{ON,t} = N_{ON-Fert,t} \cdot \left(1 - FRAC_{GASM}\right) \quad \textbf{(B.35)}$$

where:

$N_2O_{direct-N_{fertilizer},t}$ = direct N_2O emissions as a result of nitrogen application within the project boundary; tonnes CO_2-e yr^{-1} in year t

$F_{SN,t}$ = annual amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_X; tonnes N yr^{-1} in year t

$F_{ON,t}$ = annual amount of organic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_X; tonnes N yr^{-1} in year *t*

$N_{SF-Fert,t}$ = annual amount of synthetic fertilizer nitrogen applied; tonnes N yr^{-1} in year *t*

$N_{ON-Fert,t}$ = annual amount of organic fertilizer nitrogen applied; tonnes N yr^{-1} in year *t*

EF_1 = emission factor for emissions from N inputs; tonnes N_2O-N (tonnes N input)$^{-1}$

$FRAC_{GASF}$ = fraction that volatilises as NH_3 and NO_X for synthetic fertilizers (IPCC default: 0.01) ; dimensionless

$FRAC_{GASM}$ = fraction that volatilises as NH_3 and NO_X for organic fertilizers (IPCC default: 0.02); dimensionless

GWP_{N_2O} = global warming potential for N_2O (IPCC default: 310); kg CO_2 (kg N_2O)$^{-1}$

$\frac{44}{28}$ = ratio of molecular weights of N_2O and nitrogen; dimensionless

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 fertiliser nitrogen that are emitted as NO_X and NH_3 are 0.1 and 0.2, respectively as per 1996 IPCC Guideline. Project participants may use scientifically-established specific emission factors that are more appropriate for their projects. Specific good practice guidance on how to derive specific emission factors is given in Box 4.1 of GPG 2000.

8. Leakage

Leakage is assumed to occur as a result of increased emissions from fossil fuel combustion (mobile combustion) outside the project boundary (e.g., personnel, seedling and product transportation) and of the displacement of economic activities to areas outside the project that lead to deforestation and land use change for agriculture/non-agricultural purposes, harvest of fuelwood for meeting domestic energy needs, and use of lands as pastures for grazing/fodder collection.
Considering the small proportion of harvest from A/R CDM project activities relative to the size of the market for wood, the market effects of A/R CDM project activities are unlikely to be significant, even for large-scale A/R CDM activities. Moreover, if the project participants utilize the wood from A/R CDM activities in the captive industrial or commercial value chain, the market effects are not likely to exist at all. For these reasons, it is reasonable to ignore the market effects of the A/R CDM project activities.

$$LK_t = LK_{Vehicle,CO_2,t} + LK_{Activity\_Disp,t} \quad \textbf{(B.36)}$$

where:

LK_t = increase of GHG emissions outside the project boundary; tonnes CO_2-e yr^{-1} in year *t*

$LK_{Vehicle,CO_2,t}$ = increase in CO_2 emissions outside the project boundary due to fossil fuel combustion from vehicles; tonnes CO_2-e yr^{-1} in year *t*

$LK_{Activity\_Disp,t}$ = increase in GHG emissions outside the project boundary resulting from displacement of economic activities; tonnes CO_2-e yr^{-1} in year *t*

a. Increase in emissions from fossil fuel combustion

Increase in GHG emissions outside the project boundary may be caused by fuel combustion from the vehicles used in the transportation of seedling, labour, staff and harvest products to and/or from project sites and markets (while avoiding double-counting with emissions accounted under $E_{FuelBurn}$ above). The CO_2 emissions can be estimated using the bottom-up approach described in GPG 2000.

$$LK_{Vehicle,CO_2,t} = \sum_{v=1}^{V}\sum_{f=1}^{F}\frac{EF_{vf} \cdot FuelConsumption_{vf,t}}{1000} \qquad \textbf{(B.37)}$$

$$FuelConsumption_{vf,t} = n_{vf,t} \cdot k_{vf,t} \cdot e_{vf} \qquad \textbf{(B.38)}$$

where:

$LK_{Vehicle,CO_2,t}$	=	increase in CO_2 emissions outside the project boundary due to fossil fuel combustion from vehicles; tonnes CO_2-e yr^{-1} in year *t*
EF_{vf}	=	emission factor for vehicle type v with fuel type *f*; kg CO_2 $litre^{-1}$
$FuelConsumption_{vf,t}$	=	consumption of fuel type *f* of vehicle type *v*; litres in year *t*
$n_{vf,t}$	=	number of vehicles type *v* with fuel type *f* in year *t*
$k_{vf,t}$	=	kilometers traveled by each of vehicle type *v* with fuel type *f*; km in year *t*
e_{vf}	=	average fuel consumption of vehicle type v with fuel type f; litres km^{-1}
v	=	vehicle type (*V* = total number of vehicles)
f	=	fuel type (*F* = total number of fuels)

Country-specific emission factors shall be used as per availability. Default emission factors provided in the IPCC 1996 Guidelines and updated in the GPG 2000 shall be used if no locally available data exists.

b. Determination of activity displacement

Activity displacement occurs when the economic activities associated with land uses within the project area shift to areas outside the project increase GHG emissions in areas outside the project boundary. Determination of the presence or absence of activity displacement shall be done prior to adopting the methods and procedures proposed to measure the activity displacement under this methodology.

b. 1 No activity displacement

No displacement of activities associated with the project is expected from the project and $LK_{Activity\_Disp,\ t} = 0$ if[13]:

13 As per EB22, Annex 15 (http://cdm.unfccc.int/EB/Meetings/022/eb22_repan15.pdf), "pre-project GHG emissions by sources which are displaced outside the project boundary in order to enable an afforestation or reforestation project activity under the CDM shall not be included under leakage if the displacement does not increase these emissions with respect to the pre-project conditions". In this context, CH_4 emissions from enteric fermentation of displaced livestock are excluded from leakage as these emissions would continue to occur in the pre-project land use, provided it is demonstrated that the land use and livestock population in the project area has not increased relative to the pre-project scenario (see applicability conditions).

- A proposed A/R CDM project activity provides the same quantities of products in comparison to those provided under the baseline scenario. Project participants shall evaluate the product supplies from the project with those from the baseline scenario to determine the balance between the product supplies of both scenarios. For example, if the proposed A/R CDM project activity provides the same amount of fodder/grazing, fuelwood, and other products that were produced prior to the project, no activity displacement can be expected to occur as a result of the implementation of the A/R CDM project activity. Suitable evidence shall be presented at the time of project validation;
- Leakage prevention activities are implemented as part of the project so that activity displacement from the project is prevented. The evidence on the leakage prevention activities implemented in the project shall be presented at the time of project validation;
- Area outside the project serves as temporary (seasonal) substitute to provide the foregone goods from the project. For example, implementation of more efficient pasture management by organizing seasonal or rotational low intensive grazing or fodder collection management without involving land use change and loss of vegetation. The evidence supporting the more efficient pasture management should include a demonstration that it is based on efficient management methods and not due to practices that increase GHG emissions by sources, e.g. due to the use of fertilizers;
- Pre-project activities are displaced to the areas outside the project boundary that have lower biomass compared to the areas of the project from which land use activities are displaced as a result of the project. The evidence in this regard should be in the form of official records demonstrating that the areas in which economic activities are displaced have at least 50% less biomass than the area of the project from which the activity (ies) displacement occurred.

In situations other than those described above, activity displacement and land use change is assumed to occur outside the project. The assessment and quantification of such activity displacement shall be undertaken using the methods outlined below.

b.2 Activity displacement

If the displacement of households or the shifting of preproject activities results in biomass losses that can reasonably be attributed to the project activity, then emissions from activity displacement occur. The displacement of economic activities from an A/R CDM project activity to areas outside the project boundary can have potential impacts on the land use in terms of deforestation resulting from the loss of vegetation and conversion to agriculture and other land uses or the degradation of vegetation due to prolonged and unregulated harvest of forest products such as fuelwood and fodder (including grazing).

The activity displacement is linked to the type of pre-project land use and tenure status of households whose activities are expected to displace as a result of the implementation of a proposed A/R CDM project activity. The households displaced are likely to comprise a mix of landed households that have tenure to land and households that are landless. Therefore, under this methodology, pre-project land use and land tenure status of households are considered as major determinants influencing the activity displacement.

Under this methodology, household is the unit of measurement to measure the activity displacement. Due to inherent difficulties of relating to what extent the subsequent actions undertaken by displaced households can be directly attributable to the A/R CDM project activity, the emission estimates focus on the direct land use impacts of displacement as an immediate aftermath of the project implementation. Therefore, project participants are requested to track the displacement of activities after one full year of displacement.

It is possible that activity displacement can be from one or more land use activities (conversion to agriculture/other uses, and/or fuelwood collection). The steps and procedures outlined below to quantify leakage from activity displacement are relevant to different project and geographic contexts either as stand alone activities or a combination of one or more activities. If more than one activity is relevant in the project context, the steps and procedures of individual modules can be integrated into household surveys to quantify leakage from activity displacement.
The categories of activities considered under activity displacement are represented below:

- Deforestation/land use change – conversion of forest land outside the project boundary to agriculture, grazing and other land uses
- Degradation of biomass resources – from the prolonged harvest of fuelwood

$$LK_{Activity\_Disp,t} = LK_{AD\_Def,t} + LK_{AD\_Fuel,t} \quad \textbf{(B.39)}$$

where:

$LK_{Activity\_Disp,t}$ = increase in GHG emissions outside the project boundary resulting from displacement of economic activities; tonnes CO_2-e yr^{-1} in year t

$LK_{AD\_Def,t}$ = emissions from deforestation and land use change to agriculture and other uses due to displacement of households; tonnes CO_2-e yr^{-1} in year t

$LK_{AD\_Fuel,t}$ = emissions from fuelwood use due to displacement of households; tonnes CO_2-e yr^{-1} in year t

Among the households expected to displace, this methodology differentiates between households that remain within the vicinity of the project (resident households that are displaced to areas within the vicinity of the project, e.g., up to 5 km radius) and those that emigrate from the project area (emigrant households). All displaced households that do not qualify as resident households are categorized as emigrant households.

b.2.1 Leakage from deforestation and land use change to agriculture and/or other land uses

If the implementation of an A/R CDM project activity is expected to result in the displacement of people and/or economic activities that result in land use and/or land cover changes outside the project boundary, the increase in emissions associated with such change shall be estimated. The determination of whether or not leakage occurs from the shifts in land use/cover change shall be done as a prerequisite to adopting the steps and procedures outlined for the estimation of leakage.
If the carbon stocks of areas in which households resettle relative to those areas in which households resided prior to shifting is at least 50 % lower, then $LK_{AD\_Def,t} = 0$. Additionally, households may decide to abandon the pre-project activities by selling their lands, which are subsequently brought under the project activity after 3 to 5 year period and in which case the displaced households may decide to pursue other forms of livelihood that is not linked to the pre-project land use, then $LK_{AD\_Def,t} = 0$.
Leakage from agricultural activities needs to be assessed if household land use for agricultural activities is shifted to areas that have a carbon stock that is higher than half 50% of the pre-project carbon stock of their project. In this case and within 3 to 5 years of displacement from the areas in which households were displaced, the household decisions on land use can lead to clearance of land outside the project; if carbon stocks of these lands can be estimated (e.g. in the case of resident households remaining in the vicinity of the project area; see below), the loss of average carbon stocks of these areas is assumed; if the carbon stocks of these lands is unknown (in the case of emigrant

households), then the biomass carbon loss is assumed to be due to deforestation of mature forest with regional average carbon stock (from GPG for LULUCF default data, literature or original measurements).
This methodology proposes integrated household surveys to capture the household and community impacts of the displacement of land use to areas that have higher carbon stock relative to the pre-project lands. The pre-project land use and tenure status determine the household and community characteristics of land uses, and as household surveys take into account the tenure status of households, the structured and standardized household survey methods adequately capture the household and community characteristics. Therefore, this methodology does not foresee the need to assess the community impacts of leakage as the household surveys provide detailed, consistent and uniform data for leakage assessment from the major activity displacement categories.
For the purpose of leakage assessment from land use change, displaced households are categorized into resident (households that shift to areas within the 5 kilometer radius of the project boundary) and emigrant households (that shift to areas elsewhere outside 5 km radius). The emissions from land use/cover change associated with resident and emigrant households are represented as below.

$$LK_{AD\_Def,t} = LK_{AD\_Def_{resident,t}} + LK_{AD\_Def_{emigrant,t}} \qquad \textbf{(B.40)}$$

where:

$LK_{AD\_Def,t}$ = emissions from deforestation and land use change to agriculture and other uses due to displacement of households; tonnes CO_2-e yr^{-1} in year t

$LK_{AD\_Def_{resident,t}}$ = emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to resident households; tonnes CO_2-e yr^{-1} in year t

$LK_{AD\_Def_{emigrant,t}}$ = emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to emigrant households; tonnes CO_2-e yr^{-1} in year t

The following step-wise approach is proposed to facilitate the estimation of leakage from conversion to agricultural/other uses.

Step 1: Prior to start of a proposed A/R CDM project activity, information on total number of households residing within the project boundary shall be collected from official records. A list of households displaced or expected to displace as a result of the proposed A/R CDM project activity shall be prepared.

Step 2: Information on factors influencing the land uses of households such as tenure status, types of pre-project land uses, average area of households under the pre-project land uses shall be collected and recorded. If data from official records on land uses are not available, household survey data shall be used to collect the relevant data to assess the land use patterns and land use changes.

Step 3: Depending on the number of households affected, a sampling strategy shall be designed for a household survey. The sampling strategy should be representative of resident households in the project vicinity. Depending on the number of households displaced as a result of the A/R CDM project activity and that reside within the project vicinity, 5 to 10% of resident households, with a minimum of 50 households shall be selected using random or stratified sampling methods. If the number of households expected to be displaced are less than 50, then the survey should include all households to avoid selection and sampling bias associated with small sample surveys.

Step 4: For the purpose of survey, structured questionnaires and/or participatory appraisal methods covering the aspects of land uses and other economic activities shall be used. The survey questionnaires shall be pre-tested to ensure the consistent results.

Step 5: Based on the data from the household survey, and information collected on land uses from other sources such as satellite imagery, aerial photographs, and/or regional maps, area subjected to land use/cover change shall be estimated. The strata subject to land use change shall be compared with the strata prior to conversion to assess the extent of land use/cover change.

$$Area_{Def,t} = AF_{m_1} - AF_{m_2} \quad \textbf{(B.41)}$$

$$MAD_h = \frac{AF_{t1} - AF_{t2}}{nH_r} \quad \textbf{(B.42)}$$

where:

$Area_{Def,t}$	=	area deforested from land use change due to displacement of households; hectares in the year t
AF_{t_2}, AF_{t_1}	=	area of land use at year t_2 and year t_1, respectively; hectares
MAD_h	=	mean area subject to land use/cover change per resident sample household h; hectares
nH_r	=	number of sample households resident in the vicinity of the project

Step 6: Emissions shall be estimated as the product of area subjected to land use/cover change and the mean carbon stock in the living biomass of the lands to where the pre-project activities areas are likely to be shifted to. The mean carbon stock of living biomass *MC* (above ground and below ground biomass) shall be estimated from the official records or using the procedures outlined in GPG for LULUCF. An expansion factor of 1.2 to 1.5 depending upon the density of vegetation shall be used to convert the mean carbon stock of living biomass to carbon stock that can represent all pools (above ground biomass, below ground biomass, deadwood, litter, and soil). In situations where demonstrable constraints exits in the estimation of carbon stock of the areas receiving the pre-project activities, the mean carbon of mature forest (Table 3A.1.4 in GPG for LULUCF) that best represents the project area shall be used.

Step 7: The GHG emissions from land use/cover change attributable to the displaced resident households shall be estimated as follows.

$$LK_{AD\_Def_{resident}} = \sum_{h=1}^{H} MAD_h \cdot MC \cdot \frac{44}{12} \cdot \frac{NH_r}{nH_r} \quad \textbf{(B.43)}$$

$$MC = B_{LB} \cdot CF \cdot EF_{all\_pools} \quad \textbf{(B.44)}$$

where:

$LK_{AD\_Def_{resident,t}}$	=	emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to resident households; tonnes CO_2-e yr^{-1} in year t

MAD_h = mean area subject to land use/cover change per resident sample household *h*; hectares

MC = mean carbon stock per ha in the area subject to land use/cover change; tonnes C ha^{-1}

B_{LB} = living biomass of trees (above-ground and below-ground biomass) per ha in the area subject to land use/cover change; tonnes d.m. ha^{-1}

CF = carbon fraction for biomass in the area subject to land use/cover change; tonnes C (tonne d.m.)$^{-1}$

$EF_{all-pools}$ = expansion factor (1.2 to 1.5) to convert the carbon stock of living biomass of trees to carbon stock representing all pools depending on vegetation density (low vegetation density areas should use lower end of expansion factor and vice versa).

NH_r = total number of displaced households resident in the project vicinity

nH_r = number of sample households resident in the vicinity of the project.

h = household *h* (*H* = total of households)

$\frac{44}{12}$ = ratio of molecular weights of CO_2 and carbon; dimensionless

Step 8: Information on the number of households emigrated shall be collected from official records and the data from household surveys on resident households shall be used as proxy to estimate the emissions associated with these households. Considering the difficulties in ascertaining information on the land use of emigrant household, the leakage associated with the emigrant household is set equal to the mean area impacted by a resident sample household, multiplied with the mean mature forest carbon stock. Data from GPG for LULUCF Table 3A.1.4 can be used to estimate the mean carbon stock if other sources of data are unavailable.

$$LK_{AD\_Def_{emigrant}} = MAD_h \cdot MC \cdot \frac{44}{12} \cdot NH_e \qquad \textbf{(B.45)}$$

where:

$LK_{AD\_Def_{emigrant,t}}$ = annual increase in emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to emigrant households; tonnes CO_2-e yr^{-1} in year *t*

MAD_h = mean area subject to land use/cover change per resident sample household *h*; hectares

MC = mean carbon stock per ha in the area subject to land use/cover change; tonnes C ha^{-1}

NH_e = total number of emigrant households

$\frac{44}{12}$ = ratio of molecular weights of CO_2 and carbon; dimensionless

b.2.2 Leakage from fuelwood collection

A large proportion of rural households depend on fuelwood for domestic energy purposes such as cooking and heating. A very large number of displaced households may depend on the non-project

area for meeting their fuel wood supplies. Considering the limitations of fuel choice, households may be forced to harvest fuelwood unsustainably for long-periods until they have suitable domestic energy alternatives. The continuous harvest of fuelwood leads to degradation of biomass resources and could potentially contribute to leakage emissions.
The assessment of fuelwood collection as a displaced activity shall be made prior to consideration of the aspects outlined below to assess the displacement of fuelwood collection:

- Leakage from fuelwood collection is considered zero ($LK_{AD\_Fuel,t} = 0$), if $Fuel_{BL,t} < Fuel_{PR,t}$
- The amount of fuelwood available from agricultural lands and other bona fide sources such as agricultural lands shall be ascertained, if $Fuel_{BL,t} < Fuel_{AG,t}$, then $LK_{AD\_Fuel,t} = 0$
- In case $LK_{AD\_Fuel,t} < 2\%$ of the actual net GHG removals by sinks under the project, then leakage from fuel wood is considered insignificant and is not required to be accounted[14].

where:

$LK_{AD\_Fuel,t}$	=	emissions from fuelwood use due to displacement of households; tonnes CO_2-e yr^{-1} in year *t*
$Fuel_{BL,t}$	=	average annual quantity of fuelwood use prior to project; tonnes d.m. yr^{-1} in year *t*
$Fuel_{PR,t}$	=	average annual quantity of fuelwood permitted for collection or supplied from the project; tonnes d.m. yr^{-1} in year *t*
$Fuel_{AG,t}$	=	average annual quantity of fuelwood available for collection or supplied from agricultural land; tonnes d.m. yr^{-1} in year *t*

The relevant steps outlined for estimation of GHG emissions from deforestation/land use change, along with the steps outlined below shall be considered for the estimation of leakage emissions from displacement of fuelwood collection activity

Step 1: The household survey data collected on resident sample households and discussed above can be used to estimate the fuelwood consumption. From household survey/participatory appraisal data, the average size of household and per capita fuelwood consumption in the sample household shall be estimated.

Step 2: Data on fuel wood consumption, sources of fuelwood supply, and patterns of fuelwood/charcoal consumption shall be estimated or collected from the household survey data and official records/market studies/fuelwood studies in the region over the previous 5 to10 year period in order to estimate the per capita fuel wood consumption, which is assumed to remain constant over the entire crediting period.

$$PFC_t = \frac{FG_t \cdot D \cdot BEF_2}{P_t} \qquad \textbf{(B.46)}$$

where:

PFC_t	=	per capita annual fuelwood consumption; tonnes d.m $(person)^{-1}$ yr^{-1} in year t Note: As per equation 3.2.8 of GPG of LULUCF, the per capita fuelwood consumption is converted into tonnes d.m $(person)^{-1}$ yr^{-1} by dividing the population of the region.
FG_t	=	annual volume of fuelwood use; m^3 yr^{-1}

14 As per Annex 15, EB 22.

D	=	basic wood density; tonnes d.m. m^{-3}
BEF_2	=	biomass expansion factor for converting volumes of extracted roundwood to total above-ground biomass (including bark); dimensionless
P_t	=	population of the region; number of persons in year t

Step 3: Information on average annual growth of human population in the region in which the project is located shall be collected from official records. Data from official records, secondary studies and household survey data on resident sample households can be utilized to estimate the amount of fuelwood consumed or expected to be relevant to the displaced resident households.

$$LK_{AD\_Fuel_{resident,t}} = \sum_{h=1}^{H} HS \cdot PFC_t \cdot (1 - FCA) \cdot CF \cdot \frac{44}{12} \cdot (1 + PG)^t \cdot \frac{NH_r}{nH_r} \quad \textbf{(B.47)}$$

where:

$LK_{AD\_Fuel_{resident,t}}$	=	annual emissions from fuel gathering outside the project boundary attributable to resident households; tonnes CO_2-e yr^{-1} in year t
HS	=	average size of resident household; number of persons per household
FCA	=	proportion of per capita fuelwood consumption from agricultural/ private lands including purchases, to the total per capita annual fuelwood consumption from all sources (estimated from household survey data and scaled between 0 to 1), dimensionless
CF	=	carbon fraction of dry biomass; tonnes C (tonne d.m.)$^{-1}$
PG	=	annual human population growth, in percent
NH_r	=	total number of displaced households that are resident in the project vicinity
nH_r	=	number of resident sample households.
t	=	time in years from the start date of the proposed A/R CDM project activity
h	=	household h (H = total number of households)
$\frac{44}{12}$	=	ratio of molecular weights of CO_2 and carbon; dimensionless

Step 4: It is not feasible to obtain information on fuelwood consumption of emigrant households. Therefore, the annual fuelwood consumption of emigrant households is assumed to be equal to that of the displaced resident households. The population growth rate is not relevant to the emigrant households as the demographic patterns of these households vary from those of the resident holds. Therefore, population growth is not applied to the fuelwood consumption estimates of the emigrant households.

$$LK_{AD\_Fuel_{emigarnt,t}} = HS \cdot PFC_t \cdot (1 - FCA) \cdot CF \cdot NH_e \cdot \frac{44}{12} \quad \textbf{(B.48)}$$

where:

$LK_{AD\_Fuel_{emigrant,t}}$	=	annual emissions from fuel gathering outside the project boundary attributable to emigrant households; tonnes CO_2-e yr^{-1} in year t
HS	=	average size of resident household; number of persons per household

FCA	=	proportion of per capita fuelwood consumption from agricultural/ private lands including purchases, to the total per capita annual fuelwood consumption from all sources (estimated from household survey data and scaled between 0 to 1), dimensionless
CF	=	carbon fraction of dry biomass; tonnes C (tonne d.m.)$^{-1}$
PG	=	annual human population growth, in percent
NH_r	=	total number of displaced households that are resident in the project vicinity
NH_e	=	total number of emigrant households
$\frac{44}{12}$	=	ratio of molecular weights of CO_2 and carbon; dimensionless

Step 5: The total emissions from fuelwood consumption of resident and emigrant households can be represented as below.

$$LK_{AD\_Fuel,\,t} = LK_{AD\_Fuel_{resident},t} + \quad LK_{AD\_Fuel_{emigrant},\,t} \qquad \textbf{(B.49)}$$

where:

$LK_{AD\_Fuel,t}$	=	annual emissions from fuelwood use due to displacement of households; tonnes CO_2-e yr^{-1} in year *t*
$LK_{AD\_Fuel\ resident,\,t}$	=	annual emissions from fuel gathering outside the project boundary attributable to resident households; tonnes CO_2-e yr^{-1} in year *t*
$LK_{AD\_Fuel\ emigrant,\,t}$	=	annual emissions from fuel gathering outside the project boundary attributable to emigrant households; tonnes CO_2-e yr^{-1} in year *t*

Step 6: If $LK_{AD\_Fuel,t}$ results to be larger than 5 % of net actual GHG removals by sinks, fuel wood collection has to be assessed according to the modalities outlined for the quantification of activity displacement, taking into account all carbon pools (EB22, Annex 15).

9. Ex ante net anthropogenic GHG removal by sinks

The estimation of the net anthropogenic greenhouse gas removals by sinks follows the generic formulation:

$$C_{AR-CDM,t} = \Delta C_{ACTUAL,t} - \Delta C_{BSL,t} - LK_t \qquad \textbf{(B.50)}$$

where:

$C_{AR-CDNM,t}$	=	net anthropogenic greenhouse gas removals by sinks; tonnes CO_2-e for year *t*
$\Delta C_{ACTUAL,t}$	=	actual net greenhouse gas removals by sinks; tonnes CO_2-e for year *t*
$\Delta C_{BSL,t}$	=	baseline net greenhouse gas removals by sinks; tonnes CO_2-e for year *t*
LK_t	=	leakage; tonnes CO_2-e for year *t*

The calculation of lCER's and tCER's should follow and be performed in accordance with the guidance from EB 22 Annex 15.

10. Uncertainties

The approach provided in section III.10 below should be applied.

11. Data needed for ex ante estimations

The data requirements in this methodology can be met from the following major sources – international data; national level data; project level data, and published data and expert judgment. It is recommended that key parameters, such as average wood volume, basic wood density, biomass expansion factors, root to shoot ratio be investigated by sound research if data is unavailable from scientifically referenced publications. The data to calculate the project area shall have been acquired prior to the submission of the proposed A/R CDM project activity.

The auxiliary data to guide the stratification of the project area, such as soil map, previous land uses, shall be the latest developed by the national, regional or local authorities and institutions. Precipitation data, if used, shall cover a time series of at least the five years prior to submission of the proposed A/R CDM project activity.

National data on peak carbon stock in above-ground biomass of grassland, maximum carbon stock in above-ground biomass in afforested or reforested areas, average annual increase in carbon stock in above-ground biomass in afforested or reforested areas, root to shoot ratio shall be those published in reliable sources or national reports. There is no restriction regarding the vintage of these data; however, it is recommendable that they are not older than 10 years.

IPCC data: the IPCC default emission factors, and other data (annual increases in carbon stock in above-ground biomass, peak carbon stock in above-ground biomass in grassland and afforested or reforested areas, root-to-shoot ratios) shall be those in the GPG 2000, GPG for LULUCF and IPCC 2006 Guidelines to be published. Data from the 1996 Guidelines shall be used if no updated data are provided in the GPG reports or 2006 Guidelines.
Project participants shall ensure that the spatial resolution of the data is adequate for the specific conditions of the proposed A/R CDM project activity. Some areas within the project boundary may have a spatial configuration that imposes restrictions on the spatial resolution of the data to be used. Auxiliary data (such as soil maps, land use/land-cover maps etc.) shall also be compatible with the spatial resolution of the remotely sensed data, to allow integration of the data into a Geographic Information System.

Table II.2: Data/parameter, their vintage, geographical scale and possible data sources

Data / parameter	Description	Vintage	Geographical scale	Data sources
Historical land use/cover data	Determining baseline approach and demonstrating land eligibility	Earliest possible up to current	Local	Publications, forestry inventory, local government, interviews
Land use/cover map	Demonstrating land eligibility and stratification	Around 1990 & most recent	Local	Forest inventory
Satellite imagery	Demonstrating land eligibility and stratification	1989/1990 & most recent	Local	e.g. Landsat imagery
Landform map	Stratification of area	Most recent	Local	Local government
Soil map	Stratification of area	Most recent	Local	Local government regional agencies
National and sector policies	Additionality consideration	Most recent	National	Official publications
UNFCCC decisions		1997 up to now	Global	UNFCCC website
Forest thresholds (height, crown cover, minimum area)	Land eligibility criteria	Most updated	National	Designated national authority UNFCCC records
Incentives and barriers to A/R for industrial/ commercial use	Baseline consideration	Compliant with sector policies & local practices	Local	National or local documentation
Demand and supply of wood resources for industrial/commercial use	Baseline consideration	Compliant with sector policies & local practices	Local / National	National or local publications; data on wood imports
A/R Tool for the assessment and demonstration of additionality	Additionality consideration	Most updated	Global	UNFCCC website; Additionality Tool (EB21, Annex 16)
Investment cost	Land purchase, rental, machinery, equipment, buildings, fences, site preparation, nursery, planting, weeding, pesticides, fertilization, consultation, etc. That occur during establishment period	Most recent data, taking into account market risk	Project	Local/national statistics, published / survey data
Operations and maintenance costs	Costs of thinning, pruning, harvesting, replanting, fuel, transportation, repairs, fire and disease control, patrol, administration	Most recent date, taking into account market risk	Local	Local statistics, published data / survey

Data / parameter	Description	Vintage	Geographical scale	Data sources
Transaction costs	Including costs of project preparation, validation, registration, monitoring etc	Most updated	Local	Project data
Revenues	Those from timber, fuelwood, non-wood products, with and without cers revenues etc	Most recent,	Local	Project data/ local published data / survey
Barrier analysis	Additionality consideration	Most recent considering Risks	Local/ national /regional	Local/national official publications/ project data
0.001	Conversion from kg to tonnes of CO_2	Constant	Global default	Official publications
$\frac{44}{28}$	Ratio of molecular weights of N_2O and nitrogen; dimensionless	Constant	Global default	Official publications
$\frac{44}{12}$	Ratio of molecular weights of CO_2 and carbon; dimensionless	Constant	Global default	Official publications
$A_{ijk,t}$	Area for stratum *i*, species *j*, sub-stratum *k*; hectares in year *t*	Most updated	Project	Calculated
$A_{ijk,Conv,t}$	Annual area converted to forest in stratum *i*, species *j*, sub-stratum *k;* ha yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$A_{ARB,ij}$	Area of stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*; hectare (ha)	Most updated	Project	Calculated
$A_{burn,ijk,t}$	Annual area affected by biomass burning in stratum *i*, species *j*, sub-stratum *k;* ha yr^{-1}	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$A_{F,ijk}$	Area of harvest for fuelwood in stratum *i*, species *j*, sub-stratum *k*; ha yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
AF_{t_2}, AF_{t_1}	Area of land use at year t_2 and year t_1, respectively; hectares	Most updated	Local	Calculated
$A_{H,ijk}$	Area of harvest in stratum *i,* species *j* sub-stratum *k*; ha yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$Area_{Def,t}$	Area deforested from land use change due to displacement of households; ha	Most updated	Local	Estimated *ex-ante* & measured *ex-post*
$B_{ijk,t}$	Average above-ground biomass before burning for stratum *i*, species *j*, sub-stratum *k;* tonnes d.m. ha^{-1}	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$B_{w,i}$	Peak (maximum) above-ground biomass of grassland in stratum *i;* tonnes d.m. ha^{-1}	Most updated	Local/national / global	Local/national GPG for LULUCF/ official publications
BEF_{1j}	Biomass expansion factor for	Most updated	Local/national	Local/national/

Data / parameter	Description	Vintage	Geographical scale	Data sources
	conversion of annual net increment (including bark) in merchantable volume to total above-ground biomass increment for species *j;* dimensionless		/global default	GPG for LULUCF/ publications
$BEF_{2,j}$	Biomass expansion factor for conversion of merchantable volume to above-ground tree biomass for species *j*; dimensionless	Most updated	Local/national /global default	Local/national/ GPG for LULUCF/ publications
B_{LB}	Living biomass of trees (above-ground and below-ground biomass) per ha in the area subject to land use/cover change; tonnes d.m. ha^{-1}	Most updated	Local	Estimate
$\Delta C_{AB,ijk,t}$	Average annual changes in carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$\Delta C_{ACTUAL,t}$	Actual net greenhouse gas removals by sinks; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$\Delta C_{BB,ijk,t}$	Average annual changes in carbon stock in below-ground biomass for stratum *i*, species *j,* sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Calculated
$\Delta C_{ijk,t,\ ETB}$	Sum of annual changes in the carbon stocks of living biomass (above- and below-ground) of pre-existing trees in stratum *i,* substratum *j,* species *k*; t CO_2 yr^{-1}	Most updated	Project	Calculated
$\Delta C_{ijk,t}$	Average annual change in carbon stock in living biomass of trees for stratum *i,* species *j,* sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$\Delta C_{ARB,ij,t}$	Average annual change in carbon stock in the living biomass of trees for stratum *i*, species *j* under the baseline scenario with *A/R activities implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Calculated

Data / parameter	Description	Vintage	Geographical scale	Data sources
$\Delta C_{ARB,G,ij,t}$	Average annual increase in carbon stock due to biomass growth of living trees for stratum *i,* species *j* under the baseline scenario with *A/R implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Calculated
$\Delta C_{ARB,L,ij,t}$	Average annual decrease in carbon stock due to biomass loss of living trees for stratum *i,* species *j* under the baseline scenario with *A/R implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Calculated
$\Delta C_{ARB,t}$	Sum of carbon stock changes in living biomass of trees, under the baseline scenario with *A/R activities implemented during the pre-project period*; tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Calculated
$\Delta C_{BSL,t}$	Sum of the carbon stock chanes in living biomass of grassland (above and below-ground bio-mass) under the baseline sce-nario; tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Calculated
$\Delta C_{G,AB,ijk,t}$	Average annual increase in carbon in above-ground biomass due to biomass growth of trees for stratum *i*, species *j*, sub-stratum *k;* tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$\Delta C_{L,AB,ijk,t}$	Average annual decrease in carbon in above-ground biomass due to biomass loss in stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$\Delta C_{G,BB,ijk,t}$	Average annual increase in carbon in below-ground biomass due to biomass growth of trees for stratum *i*, species *j*, sub-stratum *k;* tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Calculated
$\Delta C_{GLB,t}$	Sum of the carbon stock changes in the living biomass of grassland (above and below-ground biomass) under the baseline scenario - *maintenance*	Most updated	Project	Calculated

Data / parameter	Description	Vintage	Geographical scale	Data sources
	of grassland in its state; tonnes CO_2 yr^{-1} in year *t*			
$\Delta C_{L,BB,ijk,t}$	Average annual decrease in carbon in below-ground biomass due to biomass loss in stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*	Most updated	Project	Calculated
$\Delta C_{L,AB,ijk,Fwood,t}$	Annual decrease in carbon stock of above-ground biomass of trees due to fuel wood collection/harvest for stratum *i*, species *j,* sub-stratum *k;* tonnes C yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$\Delta C_{L,AB,ijk,Dist,t}$	Average annual decrease in carbon stock of above-ground biomass of trees due to disturbance for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$\Delta C_{L,AB,ijk,Harvest,t}$	Average annual decrease in carbon stock of above-ground biomass of trees due to commercial harvest for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$\Delta C_{L,BB,ijk,Harvest,t}$	Average annual decrease in carbon stock of below-ground biomass of trees due to commercial harvest for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*	Most updated	Project	Calculated
$\Delta C_{L,AB,ijk,Fwood,t}$	Average annual decrease in carbon stock in above-ground biomass of trees due to fuelwood	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$\Delta C_{L,BB,ijk,Fwood,t}$	Annual decrease in carbon stock of below-ground biomass of trees due to fuel wood collection/harvest for stratum *i*, species *j,* sub-stratum *k;* tonnes C yr^{-1} in year *t*	Most updated	Project	Calculated
$\Delta C_{L,BB,ijk,Dist,t}$	Average annual decrease in carbon stock of below-ground biomass of trees due to disturbance for stratum *i*, species *j*, sub-stratum *k*; tonnes C yr^{-1} in year *t*	Most updated	Project	Calculated

Data / parameter	Description	Vintage	Geographical scale	Data sources
C_{ARB,ij,t_2}	Total carbon stock in living biomass of trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period* calculated at time t_2; tonnes C	Most updated	Project	Calculated
C_{ARB,ij,t_1}	Total carbon stock in living biomass of trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period* calculated at time t_1; tonnes C	Most updated	Project	Calculated
$C_{ARB,AB,ij}$	Carbon stock in above-ground biomass for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period;* tonnes C	Most updated	Project	Calculated
$C_{ARB,BB,ij}$	Carbon stock in below-ground biomass for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period;* tonnes C	Most updated	Project	Calculated
$C_{AR-CDM,t}$	Net anthropogenic greenhouse gas removals by sinks; tonnes CO_2-e for year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
CE	Combustion efficiency; dimensionless (IPCC default =0.5)	Default	Global	IPCC
CF	Carbon fraction of dry matter; tonnes C (tonne d.m)$^{-1}$	Most updated	Local/national /global default	Local/national/ GPG for LULUCF/ publications
CF_j	Carbon fraction of dry matter for species *j*; tonnes C (tonne d.m.)$^{-1}$	Most updated	Local/national /global default	Local/national GPG for LULUCF/ official publications
$CSP_{diesel,t}$	Volume of diesel consumption; litre (l) yr^{-1} in year t	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$CSP_{gasoline,t}$	Volume of gasoline consumption; litre (l) yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
D_j	Basic wood density for species *j*; tonnes d.m. m^{-3}	Most updated	Local/national /global default	Local/national/ GPG for LULUCF/ publications
DBH_t, H_t	Growth model or yield table that gives the expected tree dimensions as a function of tree age under the baseline scenario with *A/R implemented during the pre-project period*	Most updated	Local/national /global	Local/national GPG for LULUCF/ official publications

Data / parameter	Description	Vintage	Geographical scale	Data sources
$E_{FuelBurn,t}$	CO_2 emissions from combustion of fossil fuels within the project boundary; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$E_{BiomassLoss,t}$	GHG emissions from the loss of biomass in site preparation and conversion to A/R within the project boundary; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$E_{Non-CO_2,BiomassBurn,t}$	Non-CO_2 emission as a result of biomass burning within the project boundary; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$E_{N2O\,direct-N_{fertilizer},t}$	Direct N_2O emissions as a result of nitrogen application within the project boundary; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$E_{Biomass\,Burn,N_2O,t}$	N_2O emission from biomass burning; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$E_{Biomass\,Burn,CH_4,t}$	CH_4 emission from biomass burning; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$E_{BiomassBurn,C,t}$	Loss of carbon stock in above-ground biomass due to burning; tonnes C yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
EF_1	Emission factor for emissions from N inputs; tonnes N_2O-N (tonnes N input)$^{-1}$	Default	National/ Global	IPCC
EF_{diesel}	Emission factor for diesel; kg CO_2 l^{-1}	Most updated	National/ global default	IPCC
$EF_{gasoline}$	Emission factor for gasoline; kg CO_2 l^{-1}	Most updated	National/ global default	IPCC
EF_{CH4}	IPCC default emission ratio for CH_4 (IPCC default: 0.0012); kg CO_2-e. (kg C)$^{-1}$	Default	Global	IPCC
EF_{N2O}	IPCC default emission ratio for N_2O (IPCC default: 0.0007); kg CO_2-e. (kg C)$^{-1}$	Default	Global	IPCC
EF_{vf}	Emission factor for vehicle type *v* with fuel type *f*; kg CO_2 litre^{-1}	Most updated	National/ Global	IPCC Guidelines, GPG 2000, national GHG inventory
$EF_{all-pools}$	Expansion factor (1.2 to 1.5) to convert the carbon stock of living biomass of trees to carbon stock representing all pools depending on vegetation density	Most updated	Local	Estimate

Data / parameter	Description	Vintage	Geographical scale	Data sources
e_{vf}	Average fuel consumption of vehicle type *v* with fuel type *f*; litres km^{-1}	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$f_j(DBH, H)$	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* under the baseline scenario with *a/r implemented during the pre-project period*	Most updated	Local/national/global	Local/national GPG for LULUCF/ official publications
FCA	Proportion of per capita fuelwood consumption from agricultural/ private lands including purchases, to the total per capita annual fuelwood consumption from all sources (estimated from household survey data and scaled between 0 to 1), dimensionless	Most updated	Local	Estimate
FG_t	Annual volume of fuelwood use; m^3 yr^{-1}	Most updated	Local	Local government, publications/ survey
$F_{ON,t}$	Annual amount of organic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_X; tonnes N yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$F_{SN,t}$	Annual amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_X; tonnes N yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$FRAC_{GASF}$	Fraction that volatilises as NH_3 and NO_X for synthetic fertilizers; dimensionless	Default	National/ Global	IPCC
$FRAC_{GASM}$	Fraction that volatilises as NH_3 and NO_X for organic fertilizers; dimensionless	Default	National/ Global	IPCC
$FuelConsumption_{vf,t}$	Consumption of fuel type *f* of vehicle type *v*; litres in year t	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$FW_{ijk,t}$	Amount of fuelwood volume harvested for fuelwood in stratum *i,* species *j*, sub-stratum *k*; m^3 ha^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
f	Fuel type	Most updated	Project	Calculated
$G_{ARB,ij,t}$	Average annual increment of total dry biomass of living trees for stratum *i*, species *j* under	Most updated	Project	Calculated

Data / parameter	Description	Vintage	Geographical scale	Data sources
	the baseline scenario with *A/R implemented during the pre-project period;* tonnes d.m. ha^{-1} yr^{-1} in year *t*			
$G_{ARB,w,ij,t}$	Average annual above-ground biomass increment of trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*; tonnes d.m. ha^{-1} yr^{-1} in year *t*	Most updated	Project	Calculated
$GHG_{E,t}$	GHG emissions by sources within the project boundary as a result of the implementation of the A/R CDM project activity; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
GWP_{CH_4}	Global warming potential for CH_4 (IPCC default for the first commitment period: 21); kg CO_2 (kg CH_4)$^{-1}$	Default	Global	IPCC
GWP_{N_2O}	Global warming potential for N_2O (IPCC default for the first commitment period: 310); kg CO_2 (kg N_2O)$^{-1}$	Default	Global	IPCC
$H_{ijk,t}$	Amount of merchantable volume harvested in stratum *i*, species *j*, sub-stratum *k*; m^3 ha^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
HS	Average size of resident household; number of persons per household	Most updated	Local	Estimated from survey
$I_{ARB,v,ij,t}$	Average annual increment in merchantable volume for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*; m^3 ha^{-1} yr^{-1} in year *t*	Most updated	Local to Global default	Estimate/Calculated
$I_{ijk,t}$	Average annual increment in merchantable volume for stratum *i*, species *j*, sub-stratum *k;* m^3 ha^{-1} yr^{-1} in year *t*	Most updated	Project	Calculated
$k_{vf,t}$	Kilometers traveled by each of vehicle type *v* with fuel type *f*; km in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
LK_t	Increase of GHG emissions outside the project boundary; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Calculated

Data / parameter	Description	Vintage	Geographical scale	Data sources
$LK_{Vehicle,CO_2,t}$	Increase in CO_2 emissions outside the project boundary due to fossil fuel combustion from vehicles; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$LK_{Activity\_Disp,t}$	Increase in GHG emissions outside the project boundary resulting from displacement of economic activities; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$LK_{AD\_Def,t}$	Emissions from deforestation and land use change to agriculture and other uses due to displacement of households; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Local	Estimated *ex-ante* & measured *ex-post*
$LK_{AD\_Fuel,t}$	Emissions from fuelwood use to displacement of households; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Local	Estimated *ex-ante* & measured *ex-post*
$LK_{AD\_Def\ emigrant,t}$	Emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to emigrant households; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Local	Estimated *ex-ante* & measured *ex-post*
$LK_{AD\_Def\ resident,t}$	Emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to resident households; tonnes CO_2-e yr^{-1} in year *t*	Most updated	Local	Estimated *ex-ante* & measured *ex-post*
MAD_h	Mean area subject to land use/cover change per resident sample household *h*; hectares	Most updated	Local	Local government, publications/ survey
MC	Mean carbon stock per ha in the area subject to land use/cover change; tonnes C ha^{-1}	Most updated	Local	Estimate
$N/C\ ratio$	Nitrogen/carbon ratio; dimensionless	Default	Global	IPCC/Official publications
$n_{vf,t}$	Number of vehicles type *v* with fuel type *f* in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
NH_e	Total number of emigrant households	Most updated	Local	Local government/ publications/survey
NH_r	Total number of displaced households resident in the project vicinity	Most updated	Local	Calculated from survey

Data / parameter	**Description**	**Vintage**	**Geographical scale**	**Data sources**
$N_{ON-Fert,t}$	Annual amount of organic fertilizer nitrogen applied; tonnes N yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
$N_{SF-Fert,t}$	Annual amount of synthetic fertilizer nitrogen applied; tonnes N yr^{-1} in year *t*	Most updated	Project	Estimated *ex-ante* & measured *ex-post*
nH_r	Number of sample households resident in the vicinity of the project	Most updated	Local	Calculated
PFC_t	Per capita annual fuelwood consumption; tonnes d.m $(person)^{-1}$ yr^{-1} in year *t*	Most updated	Local	Local government/ publications/survey
P_t	Population of the region; number of persons in year *t*	Most updated	Local	Local government, publications
PG	Annual human population growth, in percent	Most updated	Local	Estimate
R_j	Root-shoot ratio relevant to the increments of species *j*; dimensionless	Most updated	Local/national /global default	Local/national GPG for LULUCF/ official publications
R_G	Root-shoot ratio appropriate for pre-existing non-tree vegetation; dimensionless	Most updated	Local/national /global	Local/national GPG for LULUCF/ official publications
T	Number of years between times t_2 and t_1; years	Most updated	Project	Calculated
t	Ranges from 1 to length of the crediting period	Most updated	Project	Calculated
U_c	Combined percentage uncertainty; %	Most updated	Project	Calculated
U_i	Percentage uncertainties associated with each of the parameters and activity data, *i* =1,2,…,n; %	Most updated	Project	Calculated
U_s	Percentage uncertainty of each parameter; %	Most updated	Project	Calculated
U_S	Percentage uncertainty of emission by sources or removal by sinks; %	Most updated	Project	Calculated
U_{si}	Percentage uncertainty of each emission by sources or removal by sinks; %	Most updated	Project	Calculated
$V_{ARB,ij}$	Merchantable volume of stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period;* m^3 ha^{-1}	Most updated	Project	Calculated
v	Vehicle type	Most updated	Project	Calculated
μ	Mean value; dimensionless	Most updated	Project	Calculated

Data / parameter	Description	Vintage	Geographical scale	Data sources
σ	Standard deviation of each parameter; dimensionless	Most updated	Project	Calculated

12. Other information

- void -

Section III: Monitoring methodology description

1. Monitoring project boundary and project implementation

a. Monitoring of the project boundary

The project boundary delineates the A/R CDM project activity as a distinct land use in relation to the land uses in the adjoining area. During the crediting period, a combination of field surveys and/or remote sensing methods shall be used to monitor the proposed A/R CDM activity within the project boundary.

The project boundary shall be verified using field-based methods and/or GPS systems. The methods used in monitoring of the project boundary shall be subjected to quality assurance/quality control procedures. The project participants shall be trained on the quality control/quality assurance procedures associated with the monitoring of the project boundary.

Project participants shall follow the steps outlined below in order to monitor the area planted under the A/R CDM project activity in each stratum:

- Field surveys shall be undertaken to verify that the delineated project boundary is congruent with the description presented in the AR-CDM-PDD.
- Confirmation that afforested/reforested sites within the project boundary correspond to the list of sites presented in the AR-CDM-PDD.
- The spatial extent and location of the species planted under the A/R project activity, in each stratum, shall be recorded.
- As per the availability of remote sensing data of adequate resolution, project participants can assess the area planted and compare the changes observed in the planted area using remote sensing data and the data from ground checks, field monitoring, and from planting records.
- Any discrepancies between the area reported and the area estimated under the proposed A/R CDM project activity in any part of the strata or sub-strata along with the species planted, including the areas of mortality due to natural factors (e.g. fire and pests) and anthropogenic factors shall be recorded and reported.

b. Monitoring of the forest establishment

In order to ensure that the planting quality and forest establishment conforms to the prescribed silvicultural practices relevant to the region, the CDM-AR-PDD shall provide the information on the monitoring activities implemented during the early stage of the forest establishment covering the 3-5 year period of the planting activity.

- Activities related to site preparation and vegetation affected as part of site preparation shall be recorded.
- Information on the number of species planted, area of stratum, and planting layout as per the management plan shall be prepared
- Any deviation in the implementation in relation to the management or silvicultural plan and the information on such deviation shall be recorded and the justification shall be presented in the monitoring report.
- Survival rates of A/R areas in various sub-strata and strata of the project during the initial months of the project shall be recorded
- The planted areas affected by natural and anthropogenic disturbances and seedlings planted by species as part of the gap planting during the year 2 and year 3 shall be recorded as during the assessment.

c. Monitoring of the forest management activities

As part of monitoring of the forest management activities, inputs (e.g. fertilizer application) and outputs (e.g., harvests) of the A/R CDM project activities, which reflect in the GHG removals by sinks of the proposed A/R CDM project shall be recorded. The following categories of operations shall be recoded in the project database and reported to the DOE at the time of verification:

- Schedule of fertilization and the types and quantity of fertilizer applied.
- Species-wise thinning and harvest regimes prescribed and followed, and the biomass removed from the operations, including the damage (if any occurred as part of thinning and harvesting).
- Schedule of replanting, coppicing and other management implemented to ensure the land use in its intended purpose.
- Quantity of fossil fuels used in the forest management and operations during each year of the project.
- Natural or anthropogenic disturbances (including the fire or other catastrophic events) by date, location, species, volume of biomass lost or affected, and the preventive or curative measures, if any implemented
- Biomass burning practices, if any, carried out during the monitoring interval and the reasons for the activity.
- Information on the forest protection practices such as fire breaks, control burning, and closure to prevent anthropogenic activities that impact the standing biomass.

2. Stratification and sampling design for ex-post calculations

The strata of the project in terms of their numbers and boundaries may change after the implementation of the project as described under the *ex ante stratification* outlined in Section II.3. For this reason, strata should be monitored at regular intervals. If a change in the number and area of the project strata occurs, the sample frame should be adjusted accordingly. Furthermore, *ex post* stratification also holds significance for merging the strata that have close similarities in terms of stocking levels or other criteria that lead to greater similarities in the carbon stock changes identified during *ex ante* stratification. The procedures for monitoring project strata and for implementing sampling frame are outlined below.

a. *Ex post* stratification of project area

The *ex post* stratification shall consider monitoring of the project strata and their boundaries in order to account for the changes occurring in the strata due to disturbances and management activities in the period subsequent to *ex-ante* stratification. Monitoring of strata shall be done using a Geographical Information System (GIS), which allows for integrating data from different sources (including data from GPS and remote sensing methods). The monitoring of strata and stand boundaries is critical to the verification of the area of stratum *i,* sub-stratum *k*, which reflects in the actual bet GHG removals by sinks. The need for *ex post* stratification shall be evaluated at each monitoring event and changes in strata should be reported to the DOE for verification. The stratification map should be of adequate scale and should reflect the variables considered under the *ex post* monitoring.

a.1 Factors to be considered in the ex post stratification

The stratum reflects the characteristics of proposed A/R activity, stand type, age class, and planting year, and other characteristics that are specific to it. The maps of suitable scale should be used to delineate a sub-stratum and stratum levels. The potential anthropogenic and natural influences should be taken into account in *ex post* stratification for the purpose of evaluating variables influencing actual GHG removals by sinks. The factors to be considered in the ex-post stratification are outlined below.

- Catastrophic disturbances such as fire, pest, or disease outbreaks that modify the homogeneous character of a stratum;
- The influence of grassland vegetation on stand development, for example, level of competition or shrub and herb weed growth that has changed during the period subsequent to ex ante stratification and could impact the growth of young stands should be taken into account;
- Management and silvicultural activities such as planting, thinning, harvesting, coppicing, replanting etc. implemented at different intervals and locations than those proposed at the start of the project;
- Changes in local factors that lead to different planting regimes than those planned at the time of *ex ante* stratification leading to differences in the composition of strata and the carbon stocks associated with them.
- Information on land use, tenure and institutional issues that were either not available at the time of *ex ante* stratification or were not taken into account at the earlier stage of stratification should be taken into account in the *ex post* stratification;
- Additional information on site characteristics or other variables not considered during the *ex ante* stratification of grassland should be considered during ex post stratification.

The ex post stratification implemented taking into account above factors and any other additional information is expected form the basis for the sampling frame required for monitoring of the stands. The procedures of sampling frame are outlined below.

b. Sampling frame

The monitoring of the stratum *Aijk,t* (area of stratum *i,* species *j* at sub-stratum *k* (age class) level data permits transparent and accurate calculation of the net anthropogenic GHG removals by sinks. The sampling framework specifies the sample size, plot size, and plot location in order make an unbiased assessment of carbon stock changes under the project.

b.1 Sample size

Permanent sampling plots should be used for sampling to monitor changes in carbon stocks over the crediting period as they take into account the high covariance between observations at successive sampling events. The plots should be treated in the same way as other lands within the project boundary (e.g., during site and soil preparation, weeding, fertilization, irrigation, thinning, etc.). The number of permanent plots needed for monitoring depends on the accuracy desired, variability of the carbon stock, composition of the species and costs associated with sampling. This methodology adopts a maximum permissible error of ±10% of the mean, at the 95% confidence level. The samples size (n) can be estimated as per the Neyman criterion of fixed levels of costs and accuracy. The number of plots in each stratum/sub-stratum shall be calculated using the following equation.

$$n = \left(\frac{t_\alpha}{E}\right)^2 \cdot \left(\sum_{i=1}^{I} W_i \cdot s_i \cdot \sqrt{C_i}\right) \cdot \left(\sum_{i=1}^{I} W_i \cdot \frac{s_i}{\sqrt{C_i}}\right) \qquad \textbf{(M.1)}$$

where:

n	=	sample size (number of sample plots required for monitoring)
t_α	=	t value for a significance level of α (0.05) or confidence level of 95%
N_i	=	number of sample units for stratum *i*, calculated by dividing the area of stratum *i* by the area of each plot
N	=	total number of sample units of all stratum levels, $N = \sum N_i$
s_i	=	standard deviation of stratum *i*
E	=	allowable error (±10% of the mean)
C_i	=	cost to select a plot of the stratum *i*
i	=	stratum *i* (total number of strata I)

$$W_i = \frac{N_i}{N}$$

The number of plots shall be allocated among the strata as per the equation below.

$$n_i = n \cdot \frac{W_i \cdot \frac{s_i}{\sqrt{C_i}}}{\sum_{i=1}^{I} W_i \cdot \frac{s_i}{\sqrt{C_i}}} \qquad \textbf{(M.2)}$$

where:

n_i	=	number of sample units (permanent sample plots) per stratum, that are allocated proportional to $W_h \cdot \frac{s_i}{\sqrt{C_i}}$
C_i	=	cost to select a plot of the stratum *i*
n	=	sample size (number of sample plots required for monitoring)
s_i	=	standard deviation of stratum *i*
i	=	stratum *i* (total number of strata I)

$W_i = N_i / N$

b.2 Sample plot size

The plot size depends on the density of stands and spatial heterogeneity of the sub-stratum levels. As the size is related to number of trees, diameter, and variance of carbon stock among the plots, it is difficult to set a standard common size. Large sized plots will be useful in achieving desired accuracy. The permanent sample plots could be square, rectangular or circular shape.
The plot area has major influence on sampling intensity, time, and resources spent in the measurements. Increasing the plot area decreases the variability between two samples. Thus, by increasing the sample plot area, variation among plots can be reduced permitting the use of small sample size at the same accuracy. Therefore, the size of plots could range between 100 m^2 for dense stands and 1000 m^2 for open stands.

b.3 Location of sample plots

The location of sample plots should be done using plot centres as reference points. The geographical position, administrative location, stratum, stand, and series number of plots and their location within the sub-strata and strata should be recorded, represented on the map and archived. The plots should be systematically located with a random start in each stratum or sub-stratum and could be accomplished with the help of GPS or by adopting standard field operating procedures of forest inventory. In situations where GPS is not readily available, the plot description should follow the standard forest survey and inventory practices.
The total stratum area is divided by the number of plots to estimate the average area represented by one sample plot. Each sub-stratum or site is divided by the average area per plot to obtain the number of plots rounded to the nearest integer.

b.4 Treatment of sample plots

All plots within a stratum/sub-stratum are managed in the same way and their layout and treatment should not lead to a differentiated treatment. Any changes occurring in the sample plots and the type of management practices and disturbance observed in the sample plots should be recorded and considered in evaluating carbon stock changes.

b.5 Management of sample plot data

The geo-referenced spatial data base shall be updated periodically taking into account the influence of the *ex post* stratification. The quality assurance and quality control measures should be applied in order to maintain the consistency of the monitoring data over the crediting period.

c. Monitoring interval

Monitoring interval depends on the growth rate and variability observed in the above-ground carbon stock. The verification and certification events should not coincide with peaks in carbon stocks. As per the paragraph 12 of appendix B in decision 19/CP.9, the time of thinning, harvest and other silvicultural activities shall be taken into account in adopting the monitoring interval. Depending on the rate of carbon accumulation in the living biomass, the first monitoring interval could be 3-5 years, after which the monitoring interval coincides with the verification interval, which is expected to occur at 5-year intervals until the end of the crediting period.
Project participants should determine the monitoring frequency taking into account the growth rate of species in the project activity: Within a 5 year monitoring interval, the fast growing species may allow early verification relative to slow growing species.
Data needed for the monitoring of emission sources and leakage should be collected and analyzed at least annually.

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

The ex-ante baseline scenario defined prior to the start of the proposed A/R CDM project activity shall be valid for the entire crediting period. Therefore, this methodology does not require the monitoring of baseline scenario during the crediting period and thereby avoids the costs to be incurred on baseline monitoring.

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

Under this methodology there is no need for collecting data to estimated baseline net GHG removals by sinks.

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

a. Carbon stock changes

As per the provisions of the baseline methodology, carbon stocks in dead wood, litter, and soil pools are not monitored under this methodology. Therefore, changes in carbon stocks equal the carbon stock changes in above-ground and below-ground biomass within the project boundary. This methodology recommends estimating the changes in the above-ground biomass and below-ground biomass using either allometric equation or Biomass Expansion Factor (BEF) methods. Allometric equation method should receive precedence over the *BEF* method. However, if allometric equations do not exist, BEF method could be used. In case it is impossible to calculate the changes in carbon stock due to absence of allometric equations and the parameters of the BEF method, the project specific biomass allometric equations can be established. Considering the cost and time intensiveness of the destructive sampling, it should only be pursued in the absence of local/regional allometric equations and parameters of the BEF method.
The changes in the carbon stocks of above-ground and below-ground biomass are estimated as follows.

$$\Delta C_{ijk,t} = (\Delta C_{AB,ijk,t} + \Delta C_{BB,ijk,t}) \cdot \frac{44}{12} \qquad \textbf{(M.3)}$$

$$\Delta C_{AB,ijk,t} = \frac{C_{AB,ijk,m_2} - C_{AB,ijk,m_1}}{T} \qquad \textbf{(M.4)}$$

$$\Delta C_{BB,ijk,t} = \frac{C_{BB,ijk,m_2} - C_{BB,ijk,m_1}}{T} \qquad \textbf{(M.5)}$$

where:

$\Delta C_{ijk,t}$ = verifiable changes in carbon stock in living biomass of trees for stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{AB,ijk,t}$ = changes in carbon stock in above-ground biomass of trees for stratum *i*, species *j*, sub-, stratum *k*; tonnes CO_2 yr^{-1} in year *t*

$\Delta C_{BB,ijk,t}$ = changes in carbon stock in below-ground biomass of trees for stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year *t*

C_{AB,ijk,m_2} = carbon stock in above-ground biomass of trees for stratum *i*, species *j*, sub-stratum *k* calculated at monitoring point m_2; tonnes C

C_{AB,ijk,m_1} = carbon stock in above-ground biomass of trees for stratum *i*, species *j*, sub-stratum *k* calculated at monitoring point m_1; tonnes C

C_{BB,ijk,m_2} = carbon stock in below-ground biomass of trees for stratum *i*, species *j*, sub-stratum *k* calculated at monitoring point m_2; tonnes C

C_{BB,ijk,m_1} = carbon stock in below-ground biomass of trees for stratum *i*, species *j*, sub-stratum *k,* calculated at monitoring point m_1; tonnes C

T	=	number of years between monitoring point m_2 and m_1, which in this methodology is 5 years.
$\frac{44}{12}$	=	ratio of molecular weights of CO_2 and carbon; dimensionless

a.1 Use of allometric equations

The tree biomass can be estimated as a relationship between biomass and *DBH*, or *DBH* and tree height *H* to calculate biomass as an intermediate step in the estimation of biomass.

Step 1: For plot level measurements, plots shall be located, their identity verified by comparing the identification in the project database and monitoring plan. The measurements of diameter at breast height (*DBH*) and tree height (*H*) shall be collected. For tree height, trees above minimum *DBH* shall be selected. The minimum *DBH* may vary from 2.5 cm to 10 cm.

Step 2: Allometric equation relating the diameter at the breast height and tree height is represented as below.

$$TB_{AB,ijk,m} = f\ (DBH, H) \quad \textbf{(M.6)}$$

where:

$TB_{AB,tree,ijk,m}$	=	above-ground biomass of a tree in stratum *i*, species *j*, sub-stratum *k*; kg tree^{-1} at monitoring time *m*
$f(DBH, H)$	=	an allometric equation for species *j* linking above-ground tree biomass (kg tree^{-1}) to the diameter at breast height (*DBH*) and possibly tree height (*H*) in plots for stratum *i,* species *j,* sub-stratum *k*

The allometric equations used for the ex post estimates should preferably be the same as used for the ex-ante estimates baseline methodology and be selected according to the same hierarchical order of data sources.

Step 3: The carbon stock per tree in above-ground biomass shall be estimated using allometric equations applied to the tree measurements

$$TC_{AB,ijk,tree,m} = TB_{AB,ijk,tree,m} \cdot CF_j \quad \textbf{(M.7)}$$

where:

$TB_{AB,tree,ijk,m}$	=	above-ground biomass of a tree in stratum *i*, species *j*, sub-stratum *k*; kg tree^{-1} at monitoring time *m*
$TC_{AB,ijk,tree,m}$	=	carbon stock in above-ground biomass per tree in stratum *i*, species *j*, sub-stratum *k*; kg C tree^{-1} at monitoring time *m*
CF_j	=	carbon fraction of species *j*, tonnes C (tonne d.m.)$^{-1}$; IPCC default = 0.5.

Step 4: The carbon stock in living biomass of trees in each plot shall be summed up and extrapolated to a per ha basis by multiplying the carbon stock per plot with the plot expansion factor *XF*:

$$PC_{AB,ijk,plot,m} = \frac{\sum_{tr=1}^{TR} TC_{AB,ijk,tree,m} \cdot XF}{1000} \quad \textbf{(M.8)}$$

$$XF = \frac{10'000}{AP} \quad \textbf{(M.9)}$$

$$PC_{BB,ijk,plot,m} = PC_{AB,ijk,plot,m} \cdot R_j \quad \textbf{(M.10)}$$

where:

$PC_{AB,ijk,plot,m}$	=	plot level carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes C ha^{-1} at monitoring time *m*
$TC_{AB,ijk,tree,m}$	=	carbon stock in above-ground biomass per tree in stratum *i*, species *j*, sub-stratum *k*; kg C $tree^{-1}$ at monitoring time *m*
XF	=	plot expansion factor from per plot values to per hectare values, ha^{-1}
AP	=	plot area; m^2
$PC_{BB,ijk,plot,m}$	=	plot level carbon stock in below-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes C ha^{-1} at monitoring time *m*
R_j	=	root-shoot ratio appropriate to increments for species *j*; dimensionless
tr	=	tree (TR = number of trees in the plot)

Step 5: Mean carbon stock within each stratum shall be calculated by averaging the carbon stock across plots in a stratum.

$$MC_{AB,ijk,m} = \frac{\sum_{p_{ijk}=1}^{P_{ijk}} PC_{AB,ijk,plot,m}}{P_{ijk}} \quad \textbf{(M.11)}$$

$$MC_{BB,ijk,m} = \frac{\sum_{p_{ijk}=1}^{P_{ijk}} PC_{BB,ijk,plot,m}}{P_{ijk}} \quad \textbf{(M.12)}$$

where:

$MC_{AB,ijk,m}$	=	mean carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes C ha^{-1} at monitoring time *m*
$MC_{BB,ijk,m}$	=	mean carbon stock in below-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes C ha^{-1} at monitoring time *m*
$PC_{AB,ijk,plot,m}$	=	plot level carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes C ha^{-1} at monitoring time *m*
$PC_{BB,ijk,plot,m}$	=	plot level carbon stock in below-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes C ha^{-1} at monitoring time *m*

p_{ijk} = plot in stratum *i*, species *j*, sub-stratum *k* (P_{ijk} = total number of plots in stratum *i*, species *j*, sub-stratum *k*); dimensionless

Step 6: The carbon stock in living biomass is calculated from the area of each stratum *i*, species *j* and substratum *k* at time *t* and the mean carbon stock in above-ground biomass and below-ground biomass per unit area, given by:

$$C_{AB,ijk,m} = A_{ijk,m} \cdot MC_{AB,ijk,m} \quad \textbf{(M.13)}$$

$$C_{BB,ijk,m} = A_{ijk,m} \cdot MC_{BB,ijk,m} \quad \textbf{(M.14)}$$

where:

$C_{AB,ijk,m}$ = changes in carbon stock in above-ground biomass for stratum *i*, species *j,* sub-stratum *k*; tonnes C at monitoring time *m*

$C_{BB,ijk,m}$ = changes in carbon stock in below-ground biomass for stratum *i*, species *j,* sub-stratum *k*; tonnes C at monitoring time *m*

$A_{ijk,m}$ = area of stratum *i*, species *j,* sub-stratum *k;* hectare (ha) at monitoring time *m*

$MC_{AB,ijk,m}$ = mean carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes C ha^{-1} at monitoring time *m*

$MC_{BB,ijk,m}$ = mean carbon stock in below-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes C ha^{-1} at monitoring time *m*

a.2 Use of BEF method

The estimation of carbon stock of the above-ground biomass in each stratum shall be carried out using plot level data and available local yield data and expansion factors as follows:

***Step 1**: Estimation of living biomass of trees using BEF*

Measurements of the diameter at breast height (*DBH*) above a minimum diameter of 2.5 to 10 cm and height of trees in the permanent sample plot shall be used to estimate the merchantable volume. The biomass expansion factor (*BEF*) and root-to-shoot ratio (*R*) required for conversion of merchantable volume into above-ground biomass and below-ground biomass should preferably be the same as used for the ex-ante estimates baseline methodology and be selected according to the same hierarchical order of data sources.

$$TB_{AB,ijk,tree,m} = V_{ijk,m} \cdot D_j \cdot BEF_{jk} \quad \textbf{(M.15)}$$

$$TB_{BB,ijk,tree,m} = TB_{AB,ijk,tree,m} \cdot R_j \quad \textbf{(M.16)}$$

where:

$TB_{AB,ijk,tree,m}$ = above-ground biomass per tree of stratum *i*, species j, sub-stratum *k*; tonnes d.m. $tree^{-1}$ at monitoring time *m*

$TB_{BB,ijk,tree,m}$ = below-ground biomass per tree of stratum *i*, species j, sub-stratum *k*; tonnes d.m. $tree^{-1}$ at monitoring time *m*

$V_{ijk,m}$	=	merchantable volume per tree (diameter DBH and height H) in stratum *i*, species j, sub-stratum *k* (age class); m^3 $tree^{-1}$ at monitoring time *m*
D_j	=	basic wood density for species *j*; tonnes d.m. m^{-3} merchantable volume
BEF_{jk}	=	biomass expansion factor for conversion of merchantable volume to above-ground tree biomass for species j, sub-stratum *k*; dimensionless
R_j	=	root-to-shoot ratio appropriate for species *j*; dimensionless

The *BEF* and the root-shoot ratio (*R*) are age or density dependent, therefore, it is desirable to use age or density-dependent equations (i.e. volume per ha). Stem wood volume can be small in young stands and *BEF* can be very large, while for old stands *BEF* is significantly smaller. Therefore care shall be exercised in using average *BEF* value as it may show significant variation for both young stands and old stands.

Step 2: *Estimation of the carbon stock of living biomass of trees in one permanent sample plot*

The living biomass of trees in one single permanent plot is the sum of the living biomass of measured trees within the sample plot and converted to carbon stock by multiplying the carbon fraction of the biomass.

$$PC_{AB,ijk,plot,m} = \sum_{tr=1}^{TR} TB_{AB,ijk,tree,m} \cdot CF_j \qquad \textbf{(M.17)}$$

$$PC_{BB,ijk,plot,m} = \sum_{tr=1}^{TR} TB_{BB,ijk,tree,m} \cdot CF_j \qquad \textbf{(M.18)}$$

where:

$PC_{AB,ijk,plot,m}$	=	plot level carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes C ha^{-1} at monitoring time *m*
$PC_{BB,ijk,plot,m}$	=	plot level carbon stock in below-ground biomass for stratum *i*, species *j*, sub-stratum *k*; tonnes C ha^{-1} at monitoring time *m*
$TB_{AB,ijk,tree,m}$	=	above-ground biomass per tree of stratum *i*, species j, sub-stratum *k*; tonnes d.m. $tree^{-1}$ at monitoring time *m*
$TB_{BB,ijk,tree,m}$	=	below-ground biomass per tree of stratum *i*,species j, sub-stratum *k*; tonnes d.m. $tree^{-1}$ at monitoring time *m*
CF_j	=	carbon fraction of species *j*, tonnes C (tonne d.m.)$^{-1}$; IPCC default = 0.5.

Step 3*:* Repeat step 5 and step 6 outlined under the allometric method above (Section III.5.a.1) to estimate the carbon stock in living trees

b. GHG emissions by sources

The A/R project activity can result in the increase of GHG emissions, in particular CO_2, CH_4 and N_2O emissions. This methodology provides guidance for the monitoring of the increases in greenhouse gas emissions from fossil fuel combustion, loss of biomass from the conversion of grassland, non-

CO_2 emissions from biomass burning (if practiced to clear the land to afforest or reforest), and nitrous oxide emissions from fertilizer application, if significant, and estimates the GHGs emissions based on project monitoring data and IPCC emission factors.
The changes in GHG emissions caused by these practices can be calculated from the monitoring data and by selecting appropriate emission factors. The increase in greenhouse gas emissions (GHG_E) by sources is represented as follows:

$$GHG_{E,t} = E_{FuelBurn,t} + E_{BiomassLoss,t} + E_{Non-CO_2,BiomassBurn,t} + N_2O_{direct-N_{fertilizer},t} \quad \textbf{(M.19)}$$

where:

$GHG_{E,t}$	=	annual GHG emissions as a result of the implementation of the A/R CDM project activity within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$E_{FuelBurn,t}$	=	CO_2 emissions from combustion of fossil fuels within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$E_{BiomassLoss,t}$	=	GHG emissions from the loss of biomass in site preparation and conversion to A/R within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$E_{Non-CO_2,BiomassBurn,t}$	=	non-CO_2 emission as a result of biomass burning within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$N_2O_{direct-N_{fertilizer},t}$	=	direct N_2O emissions as a result of nitrogen application within the project boundary; tonnes CO_2-e yr^{-1} in year *t*

The A/R project activities that result in emissions from the use of fossil fuels, shall be monitored and the emissions be calculated. However, not all A/R project activities burn biomass or use nitrogenous fertilizers. If implementation of the A/R project activity results in the burning of biomass, it shall be monitored and the greenhouse gas emissions from biomass burning shall be estimated.
Likewise, if the implementation of the A/R project activity results in the use of nitrogen fertilizers, and if it is significant, estimation of the N_2O emissions shall be done using the steps outlined below.

b.1 CO_2 emissions from burning of fossil fuels

Emissions from fossil fuel burning occur e.g., from the use of machinery in nursery, site preparation, thinning, and harvest. The data on operations are monitored and the data collected to estimate the emissions from the fossil fuel use as per the steps outlined below.

Step 1: The type and amount of fossil fuels using in project activities such as site preparation, planting, thinning, harvesting shall be monitored and recorded, e.g. from log books, sales records, etc.

Step 2: The project activities that use fossil fuels shall be identified and the parameters of activities such as number of hours of machines operation, fuel consumption per hour of the machines, types of vehicles used, distance traveled and the fuel economy in kilometers per hour, amount of timber thinned or harvested etc. shall be monitored and recorded based on, e.g. from log books, sales records, etc.

Step 3*:* The emission factors of the fuels used in the project should be chosen. If national/regional emission factors are not readily available, IPCC default emission factors can be used.

Step 4: The operation-wise GHG emissions shall be calculated. The IPCC 1996 Guidelines can be used to estimate the CO_2 emissions from combustion of fossil fuels using the equation below

$$E_{FuelBurn,t} = (CSP_{diesel,t} \cdot EF_{diesel} + CSP_{gasoline,t} \cdot EF_{gasoline}) \cdot 0.001 \qquad \textbf{(M.20)}$$

where:

$E_{FuelBurn,t}$	=	CO_2 emissions from combustion of fossil fuels within the project boundary; tonnes CO_2-e yr^{-1} in year t
$CSP_{diesel,t}$	=	volume of diesel consumption; litre (l) yr^{-1} in year t
$CSP_{gasoline,t}$	=	volume of gasoline consumption; litre (l) yr^{-1} in year t
EF_{diesel}	=	emission factor for diesel; kg CO_2 l^{-1}
$EF_{gasoline}$	=	emission factor for gasoline; kg CO_2 l^{-1}
0.001	=	conversion from kg to tonnes of CO_2

b.2. Emissions from loss of biomass in site preparation and conversion of grassland

The loss of biomass due to the removal of grass and pre-existing non-tree vegetation occurs when the area A_{ijk} is converted from grassland to forest. Some proportion of biomass that disappears during the conversion of grassland to forests and site preparation and other vegetation re-grows even if some biomass is removed during site preparation.

A conservative approach is followed in this methodology by treating the biomass loss as equal to the peak biomass of the pre-existing non-tree vegetation. The amount of biomass loss is monitored based on the area affected, biomass associated with the area, and the carbon fraction of the biomass using the steps outlined below.

Step 1: The peak biomass of pre-existing non-tree vegetation on lands to be afforested/reforested is estimated from the field data or local studies. The estimates of $B_{w,i}$ and R_G provided in the national publications shall be used. In case these data are unavailable, project participants shall rely on default data provided in the GPG for LULUCF or use destructive sampling.

Step 2: The CO_2 emissions from biomass loss are estimated using the following equation.

$$E_{BiomassLoss,t} = \sum_{i=1}^{I} A_i \cdot B_{w,i} \cdot (1 + R_G) \cdot CF \cdot \frac{44}{12} \qquad \forall\ t = 1 \qquad \textbf{(M.21)}$$

$$E_{BiomassLoss,t} = 0 \qquad \forall\ t > 1 \qquad \textbf{(M.22)}$$

where:

$E_{Biomass\ Loss,t}$	=	average annual decrease in grassland biomass due to conversion of grassland to forests in stratum *i*, species *j*, sub-stratum *k*; tonnes CO_2 yr^{-1} in year t
A_i	=	area of stratum *i;* ha
$B_{w,i}$	=	peak (maximum) above-ground biomass of pre-existing non-tree vegetation in stratum *i;* tonnes d.m. ha^{-1}

R_G	=	root-shoot ratio appropriate for pre-existing non-tree vegetation; dimensionless
CF	=	carbon fraction of dry biomass in pre-existing non-tree vegetation; tonnes C (tonnes d.m)$^{-1}$
i	=	stratum i (total number of strata I)
$\frac{44}{12}$	=	ratio of molecular weights of CO_2 and carbon; dimensionless

b.3 Emissions from biomass burning

Emissions from biomass burning include not only CO_2 but also other greenhouse gases (in particular methane and nitrous oxide). These non-CO_2 emissions result from incomplete combustion of the biomass, as a consequence of biomass burning for site preparation of forest fires.
The CO_2 emissions from biomass burning (fires) do not have to be accounted for since changes in the loss of carbon stock in the grassland in the living biomass are already included in the calculated part of the emissions from biomass loss. The following steps are used for monitoring and estimating the non-CO_2 emissions from biomass burning.

Step 1: To estimate the biomass per unit area affected in the burning, the average biomass of the area shall be estimated. The above-ground tree and shrub biomass per unit area shall be estimated using available shrub and tree allometric equations. The non-tree biomass shall be estimated by collecting the non-tree biomass in circular/squares frames and the dry to wet ratio of the biomass is estimated using standards non-tree biomass sampling procedures. The total biomass per unit area can thus be estimated adding up all the above-ground biomass.

Step 2: The monitoring data on the area affected by burning shall be collected by surveying the area subjected to burn; this data on affected area is used along with the biomass per unit area to estimate the amount of biomass burnt.

Step 3: The combustion efficiencies shall be chosen from Table 3.A.14 of IPCC GPG for LULUCF. If no relevant combustion efficiency is found, the IPCC default of 0.5 should be used. The general default value of nitrogen/carbon ratio (N/C ratio) of 0.01 applicable to leaf litter could be used if no suitable data are available. Emission factors provided in Tables 3.A 15 and 3.A.16 of IPCC GPG for LULUCF shall be referred for additional guidance.

Step 4: The GHG emissions from the biomass burn shall be estimated based on the revised IPCC 1996 Guidelines for LULUCF and IPCC GPG for LULUCF using the equations below.

$$E_{Non-CO_2,BiomassBurn,t} = E_{BiomassBurn,N_2O,t} + E_{BiomassBurn,CH_4,t} \quad \textbf{(M.23)}$$

$$E_{BiomassBurn,N_2O,t} = E_{BiomassBurn,C,t} \cdot N/C\ ratio \cdot EF_{N2O} \cdot GWP_{N2O} \cdot \frac{44}{28} \quad \textbf{(M.24)}$$

$$E_{BiomassBurn,CH_4\,t} = E_{BiomassBurn,C,t} \cdot EF_{CH4} \cdot GWP_{CH4} \cdot \frac{16}{12} \quad \textbf{(M.25)}$$

where:

$E_{Non-CO_2,BiomassBurn,t}$	=	non-CO_2 emission as a result of biomass burning within the project boundary; tonnes CO_2-e yr^{-1} in year t

$E_{BiomassBurn,N_2O,t}$ = N_2O emission from biomass burning; tonnes CO_2-e yr^{-1} in year *t*
$E_{BiomassBurn,CH_4,t}$ = CH_4 emission from biomass burning; tonnes CO_2-e yr^{-1} in year *t*
$E_{BiomassBurn,C,t}$ = loss of carbon stock in above-ground biomass due to burning; tonnes C yr^{-1} in year *t*
$N/C\ ratio$ = nitrogen/carbon ratio; dimensionless
EF_{N2O} = IPCC default emission ratio for N_2O of biomass burning (IPCC default: 0.0007); kg CO_2-e. (kg C)$^{-1}$
EF_{CH4} = IPCC default emission ratio for CH_4 of biomass burning (IPCC default: 0.0012); kg CO_2-e. (kg C)$^{-1}$
GWP_{N_2O} = global warming potential for N_2O (IPCC default for the first commitment period: 310); kg CO_2 (kg N_2O)$^{-1}$
GWP_{CH_4} = global warming potential for CH_4 (IPCC default for the first commitment period: 21); kg CO_2 (kg CH_4)$^{-1}$
$\frac{44}{28}$ = ratio of molecular weights of N_2O and nitrogen; dimensionless
$\frac{16}{12}$ = ratio of molecular weights of CH_4 and carbon; dimensionless

$$E_{BiomassBurn,C,t} = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} A_{burn,ijk,t} \cdot B_{ijk,t} \cdot PP_{ijk,t} \cdot CE \cdot CF \qquad \textbf{(M.26)}$$

where:
$E_{BiomassBurn,C,t}$ = loss of carbon stock in above-ground biomass due to burning; tonnes C yr^{-1} in year *t*
$A_{burn,ijk,t}$ = annual area affected by biomass burning in stratum *i*, species *j*, sub-stratum *k;* ha yr^{-1} in year *t*
$B_{ijk,t}$ = average above-ground biomass before burning for stratum *i*, species *j*, sub-stratum *k;* tonnes d.m. ha^{-1}
<u>Note</u>: if the burning occurs during site preparation, $B_{ijk,t}$ indicates the above-ground biomass on grassland before burning. Otherwise it indicates the above-ground biomass of established forest in year *t*.
$PP_{ijk,t}$ = proportion of biomass burned, dimensionless
CE = combustion efficiency; dimensionless (IPCC default =0.5)
CF = carbon fraction of dry matter; tonnes C (tonne d.m)$^{-1}$
i = stratum *i* (*I* = total number of strata)
j = species *j* (*J* = total number of species)
k = substratum *k* (*K* = total number of substrata)

b. 4 Calculation of nitrous oxide emissions from nitrogen fertilization practices

Step 1: The quantity of nitrogenous synthetic and organic fertilizers and their periodicity in the project boundary shall be monitored and recorded, e.g. based on log books, sales records, etc.

Step 2: The emission factors for N_2O are collected from GPG 2000 and 1996 IPCC Guideline. The default emission factor from GPG 2000 on applied N shall be use if national emission factors are unavailable.

Step 3: Nitrous oxide emissions from the use of nitrogenous fertilizers application practices can be estimated using the equations below.

$$N_2O_{direct-N_{fertilizer},t} = \left(F_{SN,t} + F_{ON,t}\right) \cdot EF_i \cdot \frac{44}{28} \cdot GWP_{N2O} \quad \textbf{(M.27)}$$

$$F_{SN,t} = N_{SF-Fert,t} \cdot \left(1 - FRAC_{GASF}\right) \quad \textbf{(M.28)}$$

$$F_{ON,t} = N_{ON-Fert,t} \cdot \left(1 - FRAC_{GASM}\right) \quad \textbf{(M.29)}$$

where:

$N_2O_{direct-N_{fertilizer},t}$	=	direct N_2O emissions as a result of nitrogen application within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$F_{SN,t}$	=	annual amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_X; tonnes N yr^{-1} in year *t*
$F_{ON,t}$	=	annual amount of organic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_X; tonnes N yr^{-1} in year *t*
$N_{SF-Fert,t}$	=	annual amount of synthetic fertilizer nitrogen applied; tonnes N yr^{-1} in year *t*
$N_{ON-Fert,t}$	=	annual amount of organic fertilizer nitrogen applied; tonnes N yr^{-1} in year *t*
EF_1	=	emission factor for emissions from N inputs; tonnes N_2O-N (tonnes N input)$^{-1}$
$FRAC_{GASF}$	=	fraction that volatilises as NH_3 and NO_X for synthetic fertilizers (IPCC default value: 0.01); dimensionless
$FRAC_{GASM}$	=	fraction that volatilises as NH_3 and NO_X for organic fertilizers (IPCC default value: 0.02); dimensionless
GWP_{N2O}	=	global warming potential for N_2O (IPCC default: 310); kg CO_2 (kg N_2O)$^{-1}$
$\frac{44}{28}$	=	ratio of molecular weights of N_2O and nitrogen; dimensionless

As noted in GPG 2000, the default emission factor (EF1) of 1.25 % of applied N should be used when country-specific factors are unavailable. The default values for the fractions of synthetic and organic fertiliser nitrogen that are emitted as NO_X and NH_3 are 0.1 and 0.2, respectively as per 1996 IPCC Guideline. Project participants may use scientifically established specific emission factors that are more appropriate for their project. Specific good practice guidance on how to derive specific emission factors can be found in Box 4.1 of GPG 2000.
Emission ratios for methane and nitrous oxide are provided in Table 3A.1.15 in the GPG for LULUCF. The mean emission ratio provided for biomass burning in savannas for methane (IPCC default value: 0.012) and for nitrous oxide (IPCC default value: 0.007) can be used, if national data are not available.

c. Actual net GHG removals by sinks

The actual net greenhouse gas removals by sinks represent the sum of the changes in the carbon stocks in the carbon pools considered under this methodology minus the sum of all GHG emissions by sources increased due to the implementation of the project activity.

$$\Delta C_{ACTUAL,t} = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} \Delta C_{ijk,t} - GHG_{E,t} \qquad \textbf{(M.30)}$$

where:

$\Delta C_{ACTUAL,t}$ = actual net greenhouse gas removals by sinks; tonnes CO_2-e yr^{-1} for year t
i = stratum i (I = total number of strata)
j = species j (J = total number of species)
k = substratum k (K = total number of substrata)

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

Table III.1: Data to be collected or used in order to monitor the verifiable changes in carbon stock in the carbon pools within the project boundary from the proposed A/R CDM project activity, and how this data will be archived:

ID number	Data Variable	Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.01	Stratum ID	Stratification map	Alpha-numeric		Before the start of the project	100%	Each stratum has a particular combination of soil type, climate, and possibly tree species
2.1.1.02	Sub-stratum ID	Stratification map	Alpha-numeric		Before the start of the project	100%	Each sub-stratum 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 accuracy
2.1.1.04	Accuracy		%		Before the start of the project	100%	For the purpose of QA/QC and measuring and monitoring accuracy
2.1.1.05	Standard deviation of each stratum			e	Before the start of the project	100%	For each stratum and sub-stratum, calculated from 2.1.1.03 – 2.1.1.05
2.1.1.06	Number of sample plots			c	Before the start of the project	100%	Plot ID shall be provided to each permanent sample plot
2.1.1.07	Sample plot ID	Project and plot map	Alpha numeric		Before the start of the project	100%	Numeric series ID will be assigned to each permanent sample plot

ID number	Data Variable	Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.08	Plot location	Project and plot map; GPS		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 CDM-AR PDD
2.1.1.10	Age of plantation	Plot measurement	year	m	5 years	100%sampling plot	Counted since the planted year
2.1.1.11	Number of trees	Plot measurement	number	m	5 years	100% of trees on plots	Counted in plot measurement
2.1.1.12	Diameter at Breast Height(DBH)	Plot measurement	cm	m	5 year	100% trees on plots	Measured at each monitoring interval
2.1.1.13	Mean DBH	Calculated from 2.1.1.12	cm	c	5 years	100% of sampling plots	Calculated from 2.1.1.11 and 2.1.1.12
2.1.1.14	Tree height	Plot measurement	m	m	5 year	100% trees on plots	Monitoring at each monitoring time per sampling method
2.1.1.15	Mean tree height	Calculated from 2.1.1.14	m	c	5 year	100% trees in plots	Calculated from 2.1.1.11 and 2.1.1.14
2.1.1.16	Merchantable volume	Calculated or plot measurement	m^3/ha	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	Local-derived, national GHG inventory, GPG for LULUCF	t d.m. m^{-3}	e	5 year	100% of plots	Local-derived and species-specific value have the priority
2.1.1.18	Biomass expansion fac-	Local-derived,	dimensionless	e	5 year	100% of plots	Local-derived and species-

ID number	Data Variable	Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
	tor (BEF)	national inventory, GPG for LULUCF					specific value have the priority
2.1.1.19	Carbon fraction	Local/national, IPCC	$t\ C.\ (t\ d.m)^{-1}$	e	5 year	100% of plots	Local-derived and species-specific value have the priority
2.1.1.20	Root-shoot ratio	Local, national, IPCC	dimensionless	e	5 year	100% of plots	Locally-derived and species-specific value have the priority
2.1.1.21	Carbon stock in above-ground biomass of tree	Calculated from equation	$kg\ C\ tree^{-1}$	c	5 year	100% sampling plot	Calculated
2.1.1.22	Carbon stock in below – ground biomass of tree	Calculated from equation	$kg\ C\ tree^{-1}$	c	5 year	100% sampling plot	Calculated
2.1.1.23	Carbon stock in above-ground biomass of plots	Calculated from equation	$t\ C\ ha^{-1}$	c	5 year	100% sampling plot	Calculated
2.1.1.24	Carbon stock in below-ground biomass of plots	Calculated from equation	$t\ C\ ha^{-1}$	c	5 year	100% sampling plot	Calculated
2.1.1.25	Mean carbon stock in above-ground biomass per unit area per stratum per species	Calculated from plot data	$t\ C\ ha^{-1}$	c	5 year	100% of stratum and sub-stratum	Calculated from 2.1.1.06 to 2.1.1.23
2.1.1.26	Mean carbon stock in below-ground biomass per unit area per stratum per species	Calculated from plot data	$t\ C\ ha^{-1}$	c	5 year	100% of stratum and sub-stratum	Calculated from 2.1.1.06 to 2.1.1.20
2.1.1.27	Area of stratum and sub-stratum	Stratification map and data	ha	m	5 year	100%	Actual area of each stratum and sub-stratum

ID number	Data Variable	Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.28	Carbon stock in above-ground biomass of stratum per species	Calculated from equation	t C	c	5 year	100% of stratum and sub-stratum	Calculated
2.1.1.29	Carbon stock in below-ground biomass of stratum per species	Calculated from equation	t C	c	5 year	100% of stratum and sub-stratum	Calculated
2.1.1.30	Carbon stock change in above-ground biomass per stratum per species	Calculated from equation	t C yr^{1}	c	5 year	100% strata and sub-strata	Calculated
2.1.1.31	Carbon stock change in below-ground biomass per stratum per species	Calculated from equation	t C yr^{1}	c	5 year	100% strata and sub-strata	Calculated
2.1.1.32	Total carbon stock change	Calculated from equation	t CO_2-e yr^{-1}	c	5 year	100% project area	Summing up carbon stock change in 2.1.1.30 and 2.1.1.31 for all stratum, sub-stratum and tree species

Table III.2: Data to be collected or used in order to monitor the GHG emissions by the sources, measured in units of CO_2 equivalent, that are increased as a result of the implementation of the proposed A/R CDM project activity within the project boundary, and how this data will be archived:

ID Number	Data Variable	Source of data	Data unit	Measured (m) Calculated (c) estimated (e)	Recording frequency	Pro-portion of data monitored	Comment
2.1.2.01	Amount of diesel consumed in machinery use for site preparation, thinning or loggings	On-site Monitoring	litre	m	Annually	100%	Monitoring 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 preparation, thinning or loggings	On-site monitoring	litre	m	Annually	100%	Monitoring either gasoline 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 Guide-lines, national GHG inventory	kg/litre	e	At the begin-ning of the project	100%	National inventory value should have priority
2.1.2.04	Emission factor for gasoline	GPG 2000, IPCC Guide-lines, national GHG inventory	kg/litre	e	At the begin-ning of project	100%	National inventory value should have priority
2.1.2.05	Emission from fossil fuel use within project boundary	Calculated from equation	t CO_2-e yr^{-1}	e	Annually	100%	Calculated using equations
2.1.2.06	Area affected by biomass burning	Measured during implementation if prac-ticed	ha	m	Annually	100%	Measured for different stratum
2.1.2.07	Mean above-ground biomass stock before burning	Local or national data, GPG for LULUCF	t d.m. ha^{-1}	e		100%	Sampling survey for different strata and sub-strata before burning

ID Number	Data Variable	Source of data	Data unit	Measured (m) Calculated (c) estimated (e)	Recording frequency	Pro-portion of data monitored	Comment
2.1.2.08	Proportion of biomass burned	Measured after biomass burning	dimensionless	m	Annually	100%	Sampling survey for different strata and sub-strata after burning
2.1.2.09	Biomass combustion efficiency	GPG for LULUCF, national GHG inventory	dimensionless	e	Before the start of the project	100%	IPCC default value (IPCC default: 0.05) should be used if no appropriate value available
2.1.2.10	Carbon fraction	Local, national, IPCC	$t\ C\ (t\ d.m.)^{-1}$	e	5 year	100%	
2.1.2.11	Loss of above-ground biomass carbon due to biomass burning	Calculated from equation	$t\ C\ yr^{-1}$	c	5 year	100%	Calculated from equation
2.1.2.12	N/C ratio	GPG LULUCF, national GHG inventory	kg N/kg C	e	Before the start of the project	100%	IPCC default value (IPCC default: 0.001) should be used if no appropriate value is available
2.1.2.13	N_2O emission from biomass burning	Calculated using equation	$t\ CO_2$-e yr^{-1}	c	5 year	100%	Calculated using equation
2.1.2.14	CH_4emission from biomass burning	Calculated using equation	$t\ CO_2$-e yr^{-1}	c	5 year	100%	Calculated using equation
2.1.2.15	Increase in non-CO_2 emission as a result of biomass burning	Calculated using equation	$t\ CO_2$-e yr^{-1}	c	5 year	100%	Calculated using equation
2.1.2.16	Amount of synthetic fertilizer N applied per unit area	Project monitoring data	$kg\ N\ ha^{-1}\ yr^{-1}$	m	Annually	100%	For different tree species and/or management intensity

ID Number	Data Variable	Source of data	Data unit	Measured (m) Calculated (c) estimated (e)	Recording frequency	Pro-portion of data monitored	Comment
2.1.2.17	Amount of organic fertilizer N applied per unit area	Project monitoring data	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 fertilized	Project monitoring data	ha yr^{-1}	m	Annually	100%	For different tree species and management
2.1.2.19	Amount of synthetic fertilizer N applied	Calculated from project data	t N yr^{-1}	c	Annually	100%	Calculated using equation
2.1.2.20	Amount of organic fertilizer N applied	Calculated using equation	t N yr^{-1}	c	Annually	100%	Calculated using equation
2.1.2.21	Fraction that volatilizes as NH_3 and NO_X for synthetic fertilizers	GPG 2000, GPG for LULUCF, IPCC Guide-lines, national GHG inventory	Dimensionless	e	Before start of monitoring	100%	IPCC default value (IPCC default: 0.01) should be used if no appropriate data is avail-able
2.1.2.22	Fraction that volatilizes as NH_3 and NO_X for organic fertilizers	GPG 2000, GPG for LULUCF, IPCC national GHG inventory	Dimensionless	e	Before start of monitoring	100%	IPCC default value (IPCC default: 0.02) should be used if no appropriate data is avail-able
2.1.2.23	Emission factor for emis-sion from N input	GPG 2000, GPG for LULUCF IPCC Guide-lines, national GHG inventory	N_2O N-$input^{-1}$	e	Before start of monitoring	100%	IPCC default value (1.25%) should be used if no appropriate data is available
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
2.1.2.25	Total increase in GHG emission	Calculated using equation	t CO_2-e yr^{-1}	c	Annually	100%	Calculated using equation

7. Leakage

Leakage is assumed to occur as a result of increased GHG emissions from:

- fossil fuel combustion (mobile combustion) outside the project boundary (e.g., personnel, seedlings and product transportation)
- displacement of economic activities to areas outside the project that lead to deforestation and land use change for agriculture/non-agricultural purposes, including the harvest of fuelwood for meeting domestic energy needs.

$$LK_t = LK_{Vehicle,CO_2,t} + LK_{Activity\_Disp,t} \quad \textbf{(M.31)}$$

where:

LK_t = increase of GHG emissions outside the project boundary; tonnes CO_2-e yr^{-1} in year t

$LK_{Vehicle,CO_2,t}$ = increase in CO_2 emissions outside the project boundary due to fossil fuel combustion from vehicles; tonnes CO_2-e yr^{-1} in year t

$LK_{Activity\_Disp,t}$ = increase in GHG emissions outside the project boundary resulting from displacement of economic activities; tonnes CO_2-e yr^{-1} in year t

a. Increase in emissions from fossil fuel

Increase in GHG emissions outside the project boundary may be caused by fuel combustion in the vehicles used in the transportation of seedling, labour, staff and harvest products to and/or from project sites and markets (while avoiding double-counting with emissions accounted under $E_{FuelBurn}$ above).

Step 1: Information on the vehicle types used and distance traveled outside the project boundary in connection with the activities of the proposed A/R CDM project activity shall be collected from the monitoring data and project records, e.g. from log books, sales records, etc.

Step 2: Country specific emission factors shall be selected. In the absence of country specific emissions factors, emissions from IPCC 1996 or IPCC GPG 2000 guidelines on the GHG emissions assessment shall be used.

Step 3: From the monitored project data on the project activities, vehicles used, and fuel consumed in the project related travel outside the project boundary, the CO_2 emissions are estimated. The bottom-up approach described in GPG 2000 could be used to calculate the CO_2 emissions.

$$LK_{Vehicle,CO_2,t} = \sum_v \sum_f \frac{EF_{vf} \cdot FuelConsumption_{vf,t}}{1000} \quad \textbf{(M.32)}$$

$$FuelConsumption_{vf,t} = n_{vf,t} \cdot k_{vf,t} \cdot e_{vf} \quad \textbf{(M.33)}$$

where:

$LK_{Vehicle,CO_2,t}$ = increase in CO_2 emissions outside the project boundary due to fossil fuel combustion from vehicles; tonnes CO_2-e yr^{-1} in year t

EF_{vf}	=	emission factor for vehicle type v with fuel type *f*; kg CO_2 litre^{-1}
$FuelConsumption_{vf,t}$	=	consumption of fuel type *f* of vehicle type *v*; litres in year *t*
$n_{vf,t}$	=	number of vehicles type *v* with fuel type *f* in year *t*
$k_{vf,t}$	=	kilometers traveled by each of vehicle type *v* with fuel type *f*; km in year *t*
e_{vf}	=	average fuel consumption of vehicle type v with fuel type f; litres km^{-1}
v	=	refers to vehicle type
f	=	refers to fuel type

b. Determination of activity displacement

Activity displacement occurs when the economic activities associated with land uses within the project area shift to areas outside the project, increasing GHG emissions in areas outside the project boundary. Determination of the presence or absence of activity displacement is necessary to estimate the leakage associated with activity displacement under this methodology. Determination of the occurrence of leakage shall be done using household survey data collected from sample households through structured household interviews.

b.1 No activity displacement

No displacement of activities associated with the project is expected from the project and $LK_{Activity\_Disp,\ t} = 0$ if[15]:

- A proposed A/R CDM project activity provides the same quantities of products in comparison to those provided under the baseline scenario. Project participants shall evaluate the product supplies from the project with those from the baseline scenario to determine the balance between the product supplies of both scenarios. For example, if the proposed A/R CDM project activity provides the same amount of fodder/grazing, fuelwood, and other products that were produced prior to the project, no activity displacement can be expected to occur as a result of the implementation of the A/R CDM project activity. Suitable evidence shall presented at the time of project validation
- Leakage prevention activities are implemented as part of the project so that activity displacement from the project is prevented. The evidence on the leakage prevention activities implemented in the project shall be presented at the time of project validation.
- Area outside the project serves as temporary (seasonal) substitute to provide the foregone goods from the project. For example, implementation of more efficient pasture management by organizing seasonal or rotational low intensive grazing or fodder collection management without involving land use change and loss of vegetation. The evidence supporting the more efficient pasture management should include a demonstration that it is based on efficient management methods and not due to practices that increase GHG emissions by sources, e.g. due to the use of fertilizers.

15 As per EB22, Annex 15 (http://cdm.unfccc.int/EB/Meetings/022/eb22_repan15.pdf), "pre-project GHG emissions by sources which are displaced outside the project boundary in order to enable an afforestation or reforestation project activity under the CDM shall not be included under leakage if the displacement does not increase these emissions with respect to the pre-project conditions". In this context, CH_4 emissions from enteric fermentation of displaced livestock are excluded from leakage as these emissions would continue to occur in the pre-project land use, provided it is demonstrated that the land use and livestock population in the project area has not increased relative to the pre-project scenario (see applicability conditions).

- Pre-project activities are displaced to the areas outside the project boundary that have lower biomass compared to the areas of the project from which land use activities are displaced as a result of the project. The evidence in this regard should be in the form of official records demonstrating that the areas in which economic activities are displaced have at least 50% less biomass than the area of the project from which the activity (ies) displacement occurred.

In situations other than those described above, activity displacement and land use change is assumed to occur outside the project, the assessment and quantification of such activity displacement shall be undertaken using the methods outlined below.

b.2 Activity displacement

If the displacement of households or the shifting of preproject activities results in biomass losses that can reasonably be attributed to the project activity, then emissions from activity displacement occur. Displacement of economic activities from project to areas outside the project shall be monitored in terms of deforestation resulting from loss of vegetation cover and conversion to agriculture and other land uses; and degradation of vegetation due to prolonged and unregulated harvest of forest products such as fuelwood and fodder (including grazing).
Under this methodology, household is the unit of measurement to measure the activity displacement. Activity displacement is linked to the type of pre-project land use and tenure status of households whose activities are expected to displace as a result of implementation of A/R CDM project. Therefore, monitoring of leakage involves not only the monitoring the activities on both sides of project boundary but also monitoring the households whose activities have been displaced through household surveys. The households displaced are likely to comprise mix of landed households that have tenure to land and households that are landless. Therefore, under this methodology, pre-project land use and land tenure status of households are considered as major determinants influencing the activity displacement.
Due to difficulties of relating the actions of displaced households that are directly attributable to the project, the direct land use impacts may require time to manifest. Therefore, project participants are requested to monitor the displacement of activities after one full year of displacement and at the year 5 after the project implementation, which will coincide with the verification of the project..
It is possible that activity displacement can be from one or more land use activities (conversion to agriculture/other uses, grazing, and/or fuelwood collection). If more than one activity is relevant in the project context, the steps and procedures of individual modules could be integrated into household surveys to quantify leakage from the activity displacement as separate or related activities. The categories of activities considered under activity displacement are represented below:

- Deforestation/land use change – conversion of forest land outside the project boundary to agriculture and other land uses
- Degradation of biomass resources – from the prolonged harvest of fuelwood

$$LK_{Activity\_Disp,t} = LK_{AD\_Def,t} + LK_{AD\_Fuel,t} \quad \textbf{(M.34)}$$

where:

$LK_{Activity\_Disp,t}$ = increase in GHG emissions outside the project boundary resulting from displacement of economic activities; tonnes CO_2-e yr^{-1} in year *t*

$LK_{AD\_Def,t}$ = emissions from deforestation and land use change to agriculture and other uses due to displacement of households; tonnes CO_2-e yr^{-1} in year *t*

$LK_{AD\_Fuel,t}$ = emissions from fuelwood use due to displacement of households; tonnes CO_2-e yr^{-1} in year *t*

From among the households expected to displace, this methodology differentiates between households that remain within the vicinity of the project (resident households that are displaced to areas within the vicinity of the project, e.g., up to 5 km radius) and those that emigrate from project area (emigrant households). All displaced households that do not qualify as resident households are categorized as emigrant households.

(i) Leakage from deforestation and land use change to agriculture and/or other land uses

Determination of whether or not leakage occurs from the shifts in land use/land cover change shall be done as a prerequisite to adopting the steps and procedures outlined for the estimation of leakage. The determination of leakage occurrence shall be made based on the monitoring of activities of the displaced households and the land use of the area outside the project.
Leakage from agricultural activities needs to be assessed if household land use for agricultural activities is shifted to areas that have a carbon stock that is higher than half 50% of the pre-project carbon stock of their project. In this case and within 3 to 5 years of displacement from the areas in which households were displaced, the household decisions on land use can lead to clearance of land outside the project; if carbon stocks of such lands can be estimated (e.g. in the case of resident households), the loss of average carbon stocks of these areas is assumed; if the carbon stocks of these lands is unknown (in the case of emigrant households), then the biomass carbon loss is assumed to be due to deforestation of mature forest with regional average carbon stock (from GPG for LULUCF default data, literature or original measurements).
Leakage due to conversion of land is not attributable to the CDM-A/R project activity if the conversion of land occurs 5 or more years after the displacement of the activity to areas outside the project boundary.
For the purpose of leakage assessment from land use change, displaced households are categorized into resident (households that shift to areas within the 5 kilometer radius of the project boundary) and emigrant households (that shift to areas elsewhere outside 5 km radius). The emissions from land use/cover change associated with resident and emigrant households are represented as below.

$$LK_{AD\_Def,t} = LK_{AD\_Def_{resident,t}} + LK_{AD\_Def_{emigrant,t}} \quad \textbf{(M.35)}$$

where:

$LK_{AD\_Def,t}$ = emissions from conversion of land use/land cover outside the project boundary to agriculture/other land uses; tonnes CO_2-e for year *t*

$LK_{AD\_Def_{resident,t}}$ = emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to resident households; tonnes CO_2-e for year *t*

$LK_{AD\_Def_{emigrant,t}}$ = emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to emigrant households; tonnes CO_2-e for year *t*

The following steps shall be used in the monitoring and calculation of leakage from the monitored data on the conversion to agricultural/other uses.

Step 1: Information on total number of households residing within the project boundary shall be collected from official records. A list of households displaced as a result of project shall be prepared from the data collected from the official sources or project database.

Step 2: Information on the tenure status, type of pre-project land use, average area of households under the pre-project land use shall be collected and recorded. If data from official records on land use are not available, household survey data shall be used to supplement the relevant data to assess the land use patterns and land use change.

Step 3: Depending on the number of households affected, a sampling strategy shall be designed for the conduct of a household survey. The sample should be representative of resident households in the project vicinity. Depending on the number of households displaced as a result of the A/R project and that reside within the project vicinity, 5 to 10% of resident households, with a minimum of 50 households shall be selected using random or stratified sampling methods. If the number of households displaced is less than 50, then the survey should include all households to avoid selection and sampling bias associated with small sample surveys.

Step 4: An integrated household survey shall be conducted to monitor the household and community impacts on land use. As household survey takes into account the tenure status of households, the standardized household survey methods can capture the household and community characteristics. The household survey shall be conducted one year after the project implementation in order to capture maximum information on land use and household economic activities displaced as a result of the A/R CDM project

Step 5: For the purpose of the survey, structured questionnaires and/or participatory appraisal methods covering the aspects of land use and other economic activities can be used. The survey questionnaires shall be pre-tested to ensure the consistent results.

Step 6: From the household survey data and information collected on land use from other sources such as satellite imagery, aerial photographs, and/or regional maps, the area subjected to land use/cover change shall be estimated. The mean area subject to land use/ cover change shall be calculated from the project data, data on the displacement of households and their economic activities from the official records,

$$Area_{Def,t} = AF_{m_1} - AF_{m_2} \quad \textbf{(M.36)}$$

$$MAD_h = \frac{AF_{t1} - AF_{t2}}{nH_r} \quad \textbf{(M.37)}$$

where:

$Area_{Def,t}$	=	area deforested from land use change due to displacement of households; hectares in the year t
AF_{t_2}, AF_{t_1}	=	area of land use at year t_2 and year t_1, respectively; hectares
MAD_h	=	mean area subject to land use/cover change per resident sample household h; hectares
nH_r	=	number of sample households resident in the vicinity of the project.

Step 7: Emissions shall be estimated as the product of area subjected to land use/cover change and the mean carbon stock in the living biomass of the lands to where the pre-project activities areas are likely to be shifted to. The mean carbon stock of living biomass *MC* (above ground and below ground biomass) shall be estimated from the official records or using the procedures outlined in GPG for LULUCF. An expansion factor of 1.2 to 1.5 depending upon the density of vegetation shall be used to convert the mean carbon stock of living biomass to carbon stock that can represent all pools (above ground biomass, below ground biomass, deadwood, litter, and soil). In situations where demonstrable constraints exits in the estimation of carbon stock of the areas receiving the pre-project activities, the mean carbon of mature forest (Table 3A.1.4 in GPG for LULUCF) that best represents the project area shall be used..

Step 8: The GHG emissions from the land use/cover change attributable to displaced resident households shall be estimated as follows.

$$LK_{AD\_Def\ resident} = \sum_{h=1}^{H} MAD_h \cdot MC \cdot \frac{44}{12} \cdot \frac{NH_r}{nH_r} \qquad \textbf{(M.38)}$$

where:

$LK_{AD\_Def\ resident,\,t}$ = emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to resident households; tonnes CO_2-e yr^{-1} in year *t*

MAD_h = mean area subject to land use/cover change per resident sample household *h*; hectares

MC = mean carbon stock per ha in the area subject to land use/cover change; tonnes C ha^{-1}

B_{LB} = living biomass of trees (above-ground and below-ground biomass) per ha in the area subject to land use/cover change; tonnes d.m. ha^{-1}

CF = carbon fraction for biomass in the area subject to land use/cover change; tonnes C (tonnes d.m.)$^{-1}$

$EF_{all-pools}$ = expansion factor (1.2 to 1.5) to convert the carbon stock of living biomass of trees to carbon stock representing all pools depending on vegetation density (low vegetation density areas should use lower end of expansion factor and vice versa).

NH_r = total number of displaced households resident in the project vicinity

nH_r = number of sample households resident in the vicinity of the project.

h = household *h* (*H* = total of households)

$\frac{44}{12}$ = ratio of molecular weights of CO_2 and carbon; dimensionless

Step 9: Information on the number of households emigrated shall be collected from official records and the data from household surveys on resident households shall be used as proxy to estimate the emissions associated with these households. Considering the difficulties in ascertaining information on the land use of emigrant household, the leakage associated with the emigrant household is set equal to the mean area impacted by a resident sample household, multiplied with the mean mature forest carbon stock. Data from GPG for LULUCF Table 3A.1.4 can be used to estimate the mean carbon stock if other sources of data are unavailable.

$$LK_{AD\_Def\ emigrant} = MAD_h \cdot MC \cdot \frac{44}{12} \cdot NH_e \qquad \textbf{(M.39)}$$

where:

$LK_{AD\_Def\ emigrant,\ t}$ = annual increase in emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to emigrant households; tonnes CO_2-e yr^{-1} in year *t*

MAD_h = mean area subject to land use/cover change per resident sample household *h*; hectares

MC = mean carbon stock per ha in the area subject to land use/cover change; tonnes C ha^{-1}

NH_e = total number of emigrant households

$\frac{44}{12}$ = ratio of molecular weights of CO_2 and carbon; dimensionless

(ii) Leakage from fuelwood collection

The assessment of fuelwood collection as a displaced activity shall be made prior to consideration of the aspects outlined below to assess the displacement of fuelwood collection:

- Leakage from fuelwood collection is considered is zero ($LK_{AD\_Fuel,t} = 0$); if $Fuel_{BL,t} < Fuel_{PR,t}$
- The amount of fuelwood available from agricultural lands and other bona fide sources such as agricultural lands shall be ascertained, if $Fuel_{BL,t} < Fuel_{AG,t}$, then $LK_{AD\_Fuel,t} = 0$
- In case $LK_{AD\_Fuel,t} < 2\%$ of net GHG removals by sinks under the project, then leakage from fuel wood is considered insignificant and is not required to be accounted[16].

where:

$LK_{AD\_Fuel,t}$ = emissions from fuelwood use due to displacement of households; tonnes CO_2-e yr^{-1} in year *t*

$Fuel_{BL,t}$ = average annual quantity of fuelwood use prior to project; tonnes d.m. yr^{-1} in year *t*

$Fuel_{PR,t}$ = average annual quantity of fuelwood permitted for collection or supplied from the project; tonnes d.m. yr^{-1} in year *t*

$Fuel_{AG,t}$ = average annual quantity of fuelwood available for collection or supplied from agricultural land; tonnes d.m. yr^{-1} in year *t*

The steps outlined below shall be considered for the estimation of leakage emissions from displacement of fuelwood collection activity. The following steps shall be followed in the monitoring and measurement of leakage from fuelwood collection.

Step 1: Household survey data collected on the resident sample households and from official records shall be used to estimate the fuelwood consumption of households. From the household survey/participatory appraisal data, average size of household and per capita fuelwood consumption in the sample household shall be estimated.

16 As per Annex 15, EB 22.

Step 2: Data on fuel wood consumption, sources of fuelwood supply, and patterns of fuelwood/charcoal consumption shall be collected from household survey data and official records/market studies/fuelwood studies in the region over the previous 5 to10 year period to estimate the per capita fuel wood consumption, which is assumed to remain constant over the entire crediting period.

$$PFC_t = \frac{FG_t \cdot D \cdot BEF_2}{P_t} \qquad \textbf{(M.40)}$$

where:

PFC_t	=	per capita annual fuelwood consumption; tonnes d.m (person)$^{-1}$ yr^{-1} in year t Note: As per equation 3.2.8 of GPG of LULUCF, the per capita fuelwood consumption is converted into tonnes d.m (person)$^{-1}$ yr^{-1} by dividing the population of the region.
FG_t	=	annual volume of fuelwood use; m^3 yr^{-1}
D	=	basic wood density; tonnes d.m. m^{-3}
BEF_2	=	biomass expansion factor for converting volumes of extracted roundwood to total above-ground biomass (including bark); dimensionless
P_t	=	population of the region; number of persons in year *t*

Step 3: From the official records, information on average annual growth of human population in the region of the project. The data from official records, secondary studies and household survey data on resident sample households could be utilized to estimate the amount of fuelwood consumed or expected to be consumed by displaced resident households.

$$LK_{AD\_Fuel_{resident},t} = \sum_{h=1}^{H} HS \cdot PFC_t \cdot (1 - FCA) \cdot CF \cdot \frac{44}{12} \cdot (1 + PG)^t \cdot \frac{NH_r}{nH_r} \qquad \textbf{(M.41)}$$

where:

$LK_{AD\_Fuel_{resident},t}$	=	annual emissions from fuel gathering outside the project boundary attributable to resident households; tonnes CO_2-e yr^{-1} in year *t*
HS	=	average size of resident household; number of persons per household
FCA	=	proportion of per capita fuelwood consumption from agricultural/ private lands including purchases, to the total per capita annual fuelwood consumption from all sources (estimated from household survey data and scaled between 0 to 1), dimensionless
CF	=	carbon fraction of dry biomass; tonnes C (tonne d.m.)$^{-1}$
PG	=	annual human population growth, in percent
NH_r	=	total number of displaced households that are resident in the project vicinity
nH_r	=	number of resident sample households.
t	=	time in years from the start date of the proposed A/R CDM project activity
h	=	household *h* (*H* = total number of households)
$\frac{44}{12}$	=	ratio of molecular weights of CO_2 and carbon; dimensionless

Step 4: It is infeasible to obtain information on fuelwood consumption of emigrant households. Therefore, the annual fuelwood consumption of emigrant households is assumed to be equal the displaced resident households. Equal treatment of resident and emigrant households leads to a transparent and conservative assessment of leakage associated with both categories of households.

$$LK_{AD\_Fuel_{emigarnt},t} = HS \cdot PFC_t \cdot (1 - FCA) \cdot CF \cdot NH_e \cdot \frac{44}{12} \qquad \textbf{(M.42)}$$

$LK_{AD\_Fuel_{emigrant},t}$ = annual emissions from fuel gathering outside the project boundary attributable to emigrant households; tonnes CO_2-e yr^{-1} in year *t*
HS = average size of resident household; number of persons per household
FCA = proportion of per capita fuelwood consumption from agricultural/ private lands including purchases, to the total per capita annual fuelwood consumption from all sources (estimated from household survey data and scaled between 0 to 1), dimensionless
CF = carbon fraction of dry biomass; tonnes C (tonne d.m.)$^{-1}$
PG = annual human population growth, in percent
NH_r = total number of displaced households that are resident in the project vicinity
NH_e = total number of emigrant households
$\frac{44}{12}$ = ratio of molecular weights of CO_2 and carbon; dimensionless

Step 5: The total emissions from fuelwood consumption of resident and emigrant households shall be summed to calculate the leakage associated with fuelwood consumption.

$$LK_{AD\_Fuel,t} = LK_{AD\_Fuel_{resident},t} + LK_{AD\_Fuel_{emigrant},t} \qquad \textbf{(M.43)}$$

where:
$LK_{AD\_Fuel,t}$ = annual emissions from fuelwood use due to displacement of households; tonnes CO_2-e yr^{-1} in year *t*
$LK_{AD\_Fuel_{resident},t}$ = annual emissions from fuel gathering outside the project boundary attributable to resident households; tonnes CO_2-e yr^{-1} in year *t*
$LK_{AD\_Fuel_{emigrant},t}$ = annual emissions from fuel gathering outside the project boundary attributable to emigrant households; tonnes CO_2-e yr^{-1} in year *t*

Step 6: If $LK_{AD\_Fuel,t}$ results to be larger than 5 % of net actual GHG removals by sinks, fuel wood collection has to be assessed according to the modalities outlined for the quantification of activity displacement, taking into account all carbon pools (EB22, Annex 15)

Accounting of monitored leakage in the project

After establishing the leakage at the end of year 1 of the project implementation, the leakage shall be monitored prior to the first verification of the project to evaluate the validity of the estimates of leakage made at the end of year 1

- If the leakage estimated in year 5 does not vary by more than 20% of the value estimated in year 1, then the higher value of the leakage estimated in year 1 and year 5 shall be applicable for the crediting period.
- If the leakage estimated in year 5 is found to be 20% higher than the year 1 leakage estimate by more than 20%, then the leakage estimated from the monitoring data in year 5 shall be applicable for the crediting period.
- The leakage is assumed to stabilize between the years 1 and 5, therefore, no further monitoring of leakage is required after year 5 or first verification period, which ever occurs earlier.

8. Data to be collected and archived for leakage

Table III.3: Data and information that will be collected in order to monitor leakage of the proposed A/R CDM project activity:

ID number	Data Variable	Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.1.01	Number of vehicle type used	Project monitoring data	number		Annually	100%	Monitoring number of each vehicle type used
3.1.02	Emission factor for road transportation	GPG 2000, IPCC Guidelines,	kg CO_2-e t^{-1}	E	Annually	100%	National or local value has the priority
3.1.03	Kilometers travelled by vehicles	Project monitoring data	km	M	Annually	100%	Monitoring kilometers for each vehicle type and fuel type used
3.1.04	Fuel consumption per km	Local/ national/ IPCC	litre km^{-1}	E	5 years	100%	Estimated for each vehicle type and fuel type used
3.1.05	Fuel consumption for road transportation	Calculated using equation	litre	C	Annual	100%	Calculated using equation
3.1.06	No of households /activities displaced	Official records/ survey	number	E	Year 1	100%	Number of households and their activities displaced
3.1.07	Hectares deforested due to displacement	Records/Monitoring of project leakage	ha	M	Years 1,5	100% of sampling households	Monitoring area deforested
3.1.08	Mean carbon stock of the forest/geographic region in which the project located (t CO_2-e)	GPG for LULUCF (Table 3A.1.4), literature or measurement	tonnes CO_2-e/ha	E	Year 1		GPG for LULUCF cited value should be multiplied by 1.83 to convert from biomass to t CO_2-e.
3.1.09	Number of resident households	Official sources & survey	numeric	e	Year 1	100% of sampling	Data collected from official sources or surveys

ID number	Data Variable	Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
						households	
3.1.11	Number of households emigrated from project area	Official records/ project data	numeric	M	Years 1	100% of sampling households	Surveys and monitoring
3.1.12	Area subjected to conversion to agri/other in the region	Official sources & survey	ha	E	Year 1,5		Data collected from official sources or surveys
3.1.13	Mean area converted to agri/other uses per resident household	Calculated	ha	C	Year 1,5	100% of sampling households	Calculated using leakage relevant equation
3.1.14	Leakage due to conversion to agri/other use of resident households	Calculated using equation	t CO_2-e	C	Years 1,5	100% of sampling households	Calculated using relevant equation
3.1.15	Leakage from conversion to agri/other associated with emigrant household	Calculated using equation	t CO_2-e	C	Years 1		Default value (IPCC default: 0.025) as a proportion of conversion of land by resident households Calculated using relevant equation
3.1.16	Changes in land use adjoining the project boundary	Monitoring of project leakage	ha	M	Years 1,5		Monitoring of leakage
3.1.17	GHG emissions due to conversion to agri/other	Calculated using equation	t CO_2-e/ ha	C	Years 1,5	100% of sampling households	Calculated using leakage equation
3.1.18	Household size	Calculated from survey data	number	C	Year 1	100% of sampling	Estimated based on household survey

ID number	Data Variable	Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
						households	
3.1.19	Per capita fuelwood consumption per year	Calculated from survey data	tonnes	E	Year 1	100% of sampling households	Based on survey or secondary data
3.1.20	Fuelwood use from agricul-ture/other sources	Survey data /secondary data	tonnes	C	Years 1,5	100% of sampling households	Based on official data or secondary data
3.1.21	Human population growth	Official records	percent	E	Year 1		Based on official data or secondary data
3.1.22	Fuelwood use of resident household	Survey data /secondary data	tonnes	C	Years 1,5	100% of sampling households	Based on official data or secondary data
3.1.23	Fuelwood use of emigrant household	Survey data/ secondary data	tonnes	C	Years 1		Based on official data or secondary data
3.1.24	Leakage due to fuelwood from resident household	Calculated using equation	tonnes CO_2e	C	Years 1,5	100% of sampling households	Calculated using leakage equation
3.1.25	Leakage due to fuelwood from emigrant household	Calculated using equation	tonnes CO_2e	C	Years 1		Calculated using leakage equation
3.1.26	GHG emissions per project area due to fuelwood use	Calculated using equation	tonnes CO_2e	C	Years 1,5	100% of sampling households	Calculated using leakage equation
3.1.33	GHG emissions per project from activity displacement	Calculated using equation	tonnes CO_2-e	C	Years 1,5	100% of sampling households	Calculated using leakage equation

9. Ex post net anthropogenic GHG removal by sinks

The net anthropogenic greenhouse gas removals by sinks can be calculated follows following the generic equation:

$$C_{AR-CDM,t} = \Delta C_{ACTUAL,t} - \Delta C_{BSL,t} - LK_t \quad \textbf{(M.44)}$$

where:

$C_{AR-CDNM,t}$	=	net anthropogenic greenhouse gas removals by sinks; tonnes CO_2-e for year *t*
$\Delta C_{ACTUAL,t}$	=	actual net greenhouse gas removals by sinks; tonnes CO_2-e for year *t*
$\Delta C_{BSL,t}$	=	baseline net greenhouse gas removals by sinks; tonnes CO_2-e for year *t*
LK_t	=	leakage; tonnes CO_2-e for year *t*

The calculation of lCER's and tCER's should follow and be performed in accordance with the guidance from EB 22 Annex 15 as outlined below.
t-CERs reflect the *existing stock change at the time of verification* minus project emissions minus leakage (t CO_2):

$$t - CER(t_v) = C_P(t_v) - C_B(t_v) - \sum_{0}^{t_v} E_t - \sum_{0}^{t_v} LK_t \quad \textbf{(M.45)}$$

$$C_P(t_v) - \sum_{0}^{t_v} E_t = \sum_{1}^{t_v} \Delta C_{Actual,\,t} \quad \textbf{(M.46)}$$

$$C_B(t_v) = \sum_{1}^{t_v} \Delta C_{BSL,\,t} \quad \textbf{(M.47)}$$

l-CERs reflect the *increment of the stock change* at the time of verification minus project emissions minus leakage compared to the existing stock change at the previous time of verification (t CO_2):

$$l - CER(t_v) = \left[C_P(t_v) - C_P(t_v - \kappa)\right] - \left[C_B(t_v) - C_B(t_v - \kappa)\right] - \sum_{t_{v-\kappa}}^{t_v} E_t - \sum_{t_{v-\kappa}}^{t_v} LK_t \quad \textbf{(M.48)}$$

$$C_P(t_v) - C_P(t_v - \kappa) - \sum_{t_{v-\kappa}}^{t_v} E_t = \sum_{t_{v-\kappa}}^{t_v} \Delta C_{Actual,\,t} \quad \textbf{(M.49)}$$

$$C_B(t_v) - C_B(t_v - \kappa) = \sum_{t_{v-\kappa}}^{t_v} \Delta C_{BSL,\,t} \quad \textbf{(M.50)}$$

where:

t-CER(t_v)	t-CERs issued at year of verification t_v (t CO_2)
l-CER(t_v)	l-CERs issued at year of verification t_v (t CO_2)

$C_P(t_v)$	existing carbon stocks at the year of verification t_v (t CO_2)
$C_B(t_v)$	estimated carbon stocks of the baseline scenario at year of verification t_v (t CO_2)
$E(t)$	annual project emissions (t CO_2)
$LK(t)$	annual leakage (t CO_2)
t_v	year of verification
κ	time span between two verification occasions (year)

10. Uncertainties

a. Uncertainty assessment

The methodology uses methods from IPCC GPG for LULUCF, GPG 2000, as well as the modalities and procedures for A/R CDM project activities to estimate baseline net GHG removal by sinks, leakage, actual net GHG removal by sinks and net anthropogenic removal by sinks. In the context of this methodology, the major sources of uncertainties related to changes in carbon stock in the living biomass pool include: natural factors such as fire and pest breaks; stand variables such as variation in the yield tables, allometric equations, biomass expansion factors (BEFs), wood density, and carbon fraction; and the errors contributed by the measurement.

The Tier 1 and Tier 2 methods (GPG for LULUCF) provide insight into the individual categories and GHG contribute to the uncertainty in total removals and emissions of the project. It is good practice to use Tier 1 methods since theses are spreadsheet based.

The Tier 1 method for combining uncertainties uses error propagation equation introduced in GPG 2000. It applies where there is no significant correlation among data and where uncertainties are relatively small (standard deviation less than about 30% of the mean). It is good practice to calculate error estimates in terms of standard error, standard deviation or range

$$U_s(\%) = \frac{\frac{1}{2}(95\%ConfidenceIntervalWith)}{\mu}\cdot 100 \quad \textbf{(M.51)}$$

$$= \frac{\frac{1}{2}(4\sigma)}{\mu}\cdot 100 \quad \textbf{(M.52)}$$

where:

U_s	= percentage uncertainty of each parameter; %
μ	= mean value
σ	= standard deviation of each 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[17]. It is good practice to calculate error estimates in terms of standard error, standard deviation or range

The uncertainties of increase in emission and carbon stock in above- and below-ground biomass pools of a proposed A/R CDM project activity and leakage that are the product of activity data and

17 GPG LULUCF Chapter 5.2 and Chapter 3.2

parameters (half the 95% confidence interval divided by the total and expressed as a percentage) are then estimated using equation[18]:

$$U_S = \sqrt{U_1^2 + U_2^2 + \cdots U_n^2} \quad \textbf{(M.53)}$$

where:

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

Uncertainty arising from field measurement can be assessed using same way as above. The total percentage uncertainty can be estimated using following simple error propagation equations[19]:

$$U_c = \frac{\sqrt{(U_{s1} \cdot C_{s1})^2 + (U_{s2} \cdot C_{s2})^2 + \cdots + (U_{sn} \cdot C_{sn})^2}}{\left| C_{s1} + C_{s2} + \cdots + C_{sn} \right|} \quad \textbf{(M.54)}$$

where:

U_c = combined percentage uncertainty; %
U_{si} = percentage uncertainty of each emission by sources or removal by sinks; %
C_{si} = mean value of each emission by sources or removal by sinks

b. Measures to reduce uncertainty

To develop a credible plan for measuring and monitoring carbon stock change in the project context, steps must be taken to control for errors in the sampling and data analysis. To provide confidence to all stakeholders that the reported GHG removals by sinks meet the measurement standards, a quality assurance and quality control (QA/QC) plan shall be implemented. This includes procedures to verify field data and techniques used to analyze the data. To insure continuity, same procedures shall be used during the project life and data are archived using acceptable methods.

The QA/QC procedures should aim to develop procedures for the collection of reliable field measurements. To ensure that the net anthropogenic GHG removals by sinks are estimated and monitored accurately, quality assurance and quality control (QA/QC) procedures such as (1) collection of field data; (2) verification of the data collected; (3) data entry and analysis; and (4) data storage shall be implemented. QA/QC procedures ensure that the target error estimate is met.

b.1 Quality assurance of field monitoring

Collecting reliable field data is an important step in the quality assurance. The personnel involved in the project monitoring should be fully trained in data collection and analyses. The data collection and organization shall be based on the Standard Operating Procedures (SOPs) developed for the purpose. These SOPs should contain provisions for documentation and verification so that continuity in the field monitoring is maintained and measurements can be verified.

In order to ensure consistency in field monitoring and measurements, the team members shall be made aware of all procedures of data collection. It is recommended that test plots be used to develop

18 Equation 5.2.1 in GPG LULUCF
19 Refers to equation 5.2.2 in GPG LULUCF

standard operating procedures. The monitoring and data collection documents should list names of all personnel and their responsibilities.

b.2 Data collection

The quality of field data collection shall be verified by undertaking random checks of 10 to 15% of the plots, including their re-measurement by a senior member of the monitoring team. In case errors are found, they shall be corrected and recorded for each stratum. The errors identified shall be recorded as a percentage of errors on all the verified plots to estimate the measurement error. Since measurement error also contributes to the desired accuracy of the plot and stratum level estimates, care should be exercised in minimizing the error. To ensure the collection of accurate field data the following steps shall be implemented:

- The field-team members shall be made aware of the procedures on field data collection.
- The field teams shall install test plots and measure relevant carbon pools using the standard operating procedures.
- The measurements shall be checked by qualified personnel in order to correct the errors.
- The document shall list all names of the field team and the project leader and should be certified by the team

b.3 Verification of field data

The personnel involved in the measurement of carbon pools should be fully trained in the field data collection and analyses. Standard Operating Procedures shall be developed for each step of the field measurements and followed so that measurements are comparable over time. Each team shall re-measure the trees in at least one plot done by another team. The re-measurement of permanent plots helps to verify that the measurement procedures are conducted properly. During the re-measurement the key items to be checked are the location and measurement of the diameter of each tree in the plot. The results of re-measurements shall be compared to each other and problems identified shall be discussed with the members of teams. If deviations from re-measurements by the different teams are significant, both teams shall return to the site and re-measure the plot in conjunction. Accordingly, the errors shall be corrected and the corrected field sheets are included with the original. If any of such errors are caused by different interpretations of the Standard Operation Procedures, they shall be jointly revised to ensure clearer guidance. This procedure shall be repeated during the field data collection.

b.4 Data entry and analysis

To minimize the errors in the entry of field and laboratory data, the data entry process shall be reviewed by a senior member of the monitoring team and compared with independent data sources to ensure consistency. The discussion between the monitoring and data entry personnel should be undertaken before the data analysis in order to resolve any anomalies in the data.

11. Other information

Default values used in elaborating the new methodology

CF Carbon fraction of dry matter default = 0.5 tonnes C (tonnes d.m.)$^{-1}$

$GWPN_2O$ Global Warming Potential for N_2O = 310 kg CO_2-e. (kg N_2O)$^{-1}$

$GWPCH_4$	Global Warming Potential for CH_4 = 21 kg CO_2-e. (kg CH_4) $^{-1}$
ERN_2O	Emission ratio for N_2O in biomass burning = 0.007 (kg CO_2-e. (kg C)$^{-1}$)
$ERCH_4$	Emission ratio for CH_4 in biomass burning = 0.012 (kg CO_2-e. (kg C^{-1})
CE	Average combustion efficiency of biomass = 0.5
N/C	N/C ratio of biomass = 0.01 kg N (kg C) $^{-1}$
EF1	Emission factor for emissions from N fertilization = 0.0125 kg N_2O-N (kg N input) $^{-1}$
FracGASF	Fraction that volatilizes as NH_3 and NO_X for synthetic fertilizers = 0.1
FracGASM	Fraction that volatilizes as NH_3 and NO_X for organic fertilizers = 0.2

Source: IPCC, 1996 Guidelines, IPCC GPG-LULUCF, GPG-2000 for energy, GPG-2000 for agriculture

Section IV: Lists of variables, acronyms and references

Table IV.1: List of variables used in equations

Variable	SI Unit	Description
$A_{burn,ijk,t}$	ha yr^{-1}	annual area affected by biomass burning in stratum *i*, species *j*, sub-stratum *k*
AF_{m2}, AF_{m1}	hectares (ha)	area of land use at monitoring point m_2 and m_1, respectively
$Area_{Def,t}$	hectares (ha)	area deforested from land use change due to displacement of households
$A_{F,ijk}$	ha yr^{-1} in year *t*	area of harvest for fuelwood in stratum *i*, species *j*, sub-stratum *k*
$A_{H,ijk}$	ha yr^{-1} in year *t*	area of harvest in stratum *i*, species *j*, sub-stratum *k*
A_{ij}	hectare (ha)	area of stratum *i*, species *j*
$A_{burn,ijk,t}$	ha yr^{-1} in year t	annual area affected by biomass burning in stratum *i*, species *j*, sub-stratum *k*
A_{ijk}	ha yr^{-1} in year *t*	annual area of harvest in stratum *i*, species *j*, sub-stratum *k*
$A_{ijk,t}$	hectare (ha)	area for stratum *i*, species *j*, sub-stratum *k* in hectares in year *t*
$A_{ijk,m}$	hectare (ha) at monitoring time *m*	area of stratum *i*, species *j*, sub-stratum *k*
$A_{ijk,Conv,t}$	ha yr^{-1} in year *t*	annual area converted to A/R in stratum *i*, species *j*, sub-stratum *k*
$A_{ARB,ij}$	hectare (ha)	area of stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*
AP	m^2	plot area
$B_{ijk,t}$	tonnes d.m. ha^{-1}	average above-ground biomass before burning for stratum *i*, species *j*, sub-stratum *k*
$B_{w,i}$	tonnes d.m. ha^{-1}	peak (maximum) above-ground biomass of pre-existing non-tree vegetation in stratum *i*
BEF_{1j}	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 conversion of merchantable volume to above-ground tree biomass for species *j*
BEF_j	dimensionless	biomass expansion factor for conversion of merchantable volume for species *j* to above-ground tree biomass for species *j*
BEF_{jk}	dimensionless	biomass expansion factor for conversion of harvested volume of species *j* sub-stratum *k* to above-ground biomass for species *j* sub-stratum *k*
B_{LB}	tonnes d.m. ha^{-1}	living biomass of trees (above-ground and below-ground biomass) per ha in the area subject to land use/cover change
B_i	tonnes d.m. ha^{-1}	average above-ground grassland biomass before burning for stratum *i*
$\Delta C_{AB,ijk,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual changes in carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*
C_{AB,ijk,m_2}	tonnes C	carbon stock in above-ground biomass of trees for stratum *i*, species *j*, sub-stratum *k* calculated at monitoring point m_2
C_{AB,ijk,m_1}	tonnes C	carbon stock in above-ground biomass of trees for stratum *i*, species *j*, sub-stratum *k* calculated at monitoring point m_1
$\Delta C_{AB,ijk,m}$	tonnes C at monitoring time *m*	changes in carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*

Variable	SI Unit	Description
$\Delta C_{BB,ijk,t}$	tonnes CO_2 yr^{-1} in year t	changes in carbon stock in below-ground biomass of trees for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{L,AB,ijk,Dist,t}$	tonnes C yr^{-1} in year *t*	average annual decrease in carbon stock of above-ground biomass of trees due to disturbance for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{L,AB,ijk,Fwood,t}$	tonnes C yr^{-1} in year *t*	annual decrease in carbon stock of above-ground biomass of trees due to fuel wood collection/harvest for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{L,AB,ijk,Harvest,t}$	tonnes C yr^{-1} in year *t*	average annual decrease in carbon stock of above-ground biomass of trees due to commercial harvest for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{ACTUAL,t}$	tonnes CO_2-e yr^{-1} in year *t*	actual net greenhouse gas removals by sinks
C_{BB,ijk,m_2}	tonnes C	carbon stock in below-ground biomass of trees for stratum *i*, species *j*, sub-stratum *k* calculated at monitoring point m_2
C_{BB,ijk,m_1}	tonnes C	carbon stock in below-ground biomass of trees for stratum *i*, species *j*, sub-stratum *k,* calculated at monitoring point m_1
$\Delta C_{BB,ijk,m}$	tonnes C at monitoring time *m*	changes in carbon stock in below-ground biomass for stratum *i*, species *j,* sub-stratum *k*
$\Delta C_{ARB,ij,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual change in carbon stock in the living biomass of trees for stratum *i*, species *j* under the baseline scenario with *A/R activities implemented during the pre-project period*
$C_{ARB,AB,ij}$	tonnes C	carbon stock in above-ground biomass for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*
$C_{ARB,BB,ij}$	tonnes C	carbon stock in below-ground biomass for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*
$\Delta C_{ARB,G,ij,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual increase in carbon stock due to biomass growth of living trees for stratum *i,* species *j* under the baseline scenario with *A/R implemented during the pre-project period*
$\Delta C_{ARB,L,ij,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual decrease in carbon stock due to biomass loss of living trees for stratum *i,* species *j* under the baseline scenario with *A/R implemented during the pre-project period*
$\Delta C_{ARB,t}$	tonnes CO_2 yr^{-1} in year *t*	sum of carbon stock changes in living biomass of trees under the baseline scenario with *A/R activities implemented during the pre-project period*
$\Delta C_{AR-CDM,t}$	tonnes CO_2-e in year *t*	net anthropogenic greenhouse gas removals by sinks
$\Delta C_{BB,ijk,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual changes in carbon stock in below-ground biomass for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{BSL,t}$	tonnes CO_2 yr^{-1} in year *t*	sum of the carbon stock changes in living biomass of grassland (above and below-ground biomass) under the baseline scenario
$\Delta C_{G,AB,ijk,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual increase in carbon in above-ground biomass due to biomass growth of trees for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{G,BB,ijk,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual increase in carbon in below-ground biomass due to biomass growth of trees for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{L,AB,ijk,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual decrease in carbon in above-ground biomass due to biomass loss in stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{L,BB,ijk,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual decrease in carbon in below-ground biomass due to biomass loss in stratum *i*, species *j*, sub-stratum *k*

Variable	SI Unit	Description
$\Delta C_{L,BB,ijk,Dist,t}$	tonnes C yr^{-1} in year t	average annual decrease in carbon stock of below-ground biomass of trees due to disturbance for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{L,BB,ijk,Fwood,t}$	tonnes C yr^{-1} in year t	annual decrease in carbon stock of below-ground biomass of trees due to fuel wood collection/harvest for stratum *i*, species *j,* sub-stratum *k*
$\Delta C_{L,BB,ijk,Harvest,t}$	tonnes C yr^{-1} in year t	average annual decrease in carbon stock of below-ground biomass of trees due to commercial harvest for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{GLB,t}$	tonnes CO_2 yr^{-1} in year t	sum of the carbon stock changes in the living biomass of grassland (above and below-ground biomass) under the baseline scenario - *maintenance of grassland in its state*
$\Delta C_{ijk,t,ETB}$	tonnes CO_2 yr^{-1},	sum of annual changes in the carbon stocks of living biomass (above- and below-ground) of pre-existing trees in stratum *i* substratum *j* species *k*:
$\Delta C_{ijk,t}$	tonnes CO_2 yr^{-1} in year t	average annual change in carbon stock in living biomass of trees for stratum *i,* species *j,* sub-stratum *k*
$C_{AB,ij}$	tonnes C	carbon stock in above-ground biomass for stratum *i*, species *j*
$C_{AB,ijk,t}$	tonnes C in year t	carbon stock in above-ground biomass of trees in stratum *i,* species *j*, sub-stratum *k*
$C_{ACTUAL,t}$	tonnes CO_2-e in year t	actual net greenhouse gas removals by sinks
C_{ARB,ij,t_2}	tonnes C	total carbon stock in living biomass of trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period* calculated at time t_2
C_{ARB,ij,t_1}	tonnes C	total carbon stock in living biomass of trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period* calculated at time t_1
$C_{AR\text{-}CDM,t}$	tonnes CO_2-e in year t	net anthropogenic greenhouse gas removals by sinks
$C_{BB,ij}$	tonnes C	carbon stock in below-ground biomass for stratum *i*, species *j*
$C_{BB,ijk,t}$	tonnes C in year t	car bon stock in below-ground biomass of trees in stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{BSL,t}$	tonnes CO_2-e in year t	baseline net greenhouse gas removals by sinks
$C_B(t_v)$	t CO_2	estimated carbon stocks of the baseline scenario at year of verification t_v
CE	dimensionless	combustion efficiency (IPCC default =0.5)
CF	tonnes C (tonne d.m)$^{-1}$	carbon fraction of dry matter
CF_j	tonnes C (tonne d.m.)$^{-1}$	carbon fraction of dry matter for species *j*
C_i	Local currency	cost to select a plot of the stratum *i*
$C_{ijk,tree}$	tonnes C $tree^{-1}$	carbon stock of living biomass of trees in stratum *i*, species *j*, sub-stratum *k*
$C_P(t_v)$	t CO_2	existing carbon stocks at the year of verification t_v
C_{si}	dimensionless	mean value of each emission by sources or removal by sinks
$CSP_{diesel,t}$	litre (l) yr^{-1} in yr t	volume of diesel consumption
$CSP_{gasoline,t}$	litre (l) yr^{-1} in yr t	volume of gasoline consumption

Variable	SI Unit	Description
$\Delta C_{AB,ijk,t}$	tonnes CO_2 yr^{-1} in year t	average annual changes in carbon stock in above-ground biomass for stratum *i,* species *j*, sub-stratum *k*
$\Delta C_{ACTUAL,t}$	tonnes CO_2-e yr^{-1} in year *t*	actual net greenhouse gas removals by sinks
$\Delta C_{ARB,ij,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual change in carbon stock of living biomass of trees for stratum *i*, species *j* in the absence of the project activity, under the baseline scenario with A/R implemented during the pre-project period
$\Delta C_{ARB,t}$	tonnes CO_2 yr^{-1} in year t	sum of annual changes in carbon in living biomass of trees, under the baseline scenario with A/R implemented during the pre-project period
$\Delta C_{BB,ijk,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual changes in carbon stock in below-ground biomass for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{BSL,t}$	tonnes CO_2 yr^{-1} in year *t*	baseline net GHG removals by sinks
$\Delta C_{G,ij,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual increase in carbon stock due to biomass growth of living trees for stratum *i*, species *j* under the baseline scenario A/R implemented during the pre-project period
$\Delta C_{G,ijk,t}$	tonnes CO_2 yr^{-1}in year *t*	average annual increase in carbon due to biomass growth of trees for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{GLB,t}$	tonnes CO_2 yr^{-1} in year t	sum of the changes in carbon in grassland living biomass (above and below-ground biomass) under the baseline scenario maintenance of grassland in its state
$\Delta C_{ijk,t}$	tonnes CO_2 yr^{-1} in year t	average annual change in carbon stock in living biomass of trees for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{ij,t}$	tonnes CO_2 yr^{-1} in year *t*	average annual change in carbon stock in the living biomass of trees for stratum *i*, species *j* in the absence of the project activity
$\Delta C_{L,ijk,t}$	tonnes CO_2 yr^{-1}in year *t*	average annual decrease in carbon due to biomass loss in stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{L,ijk,t,Dist}$	tonnes C yr^{-1} in year t	average annual decrease in carbon stock in biomass of trees due to disturbance for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{L,ijk,t,Fwood}$	tonnes C yr^{-1} in year *t*	annual carbon decrease in carbon stock of biomass due to fuel wood collection/harvest for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{L,ijk,t,Harvest}$	tonnes C yr^{-1} in year *t*	average annual decrease in carbon stock in biomass of trees due to commercial harvest for stratum *i*, species *j*, sub-stratum *k*
$\Delta C_{L,ij,t}$	tonnes CO_2 yr^{-1}in year t	average annual decrease in carbon stock due to biomass loss of living trees for stratum *i*, species *j* under the baseline scenario A/R implemented during the pre-project period
DBH_t, H_t	m^3 / ha	growth model or yield table that gives the expected tree dimensions as a function of tree age
D_j	tonnes d.m. m^{-3}	wood density for species *j*
E	DBH_t, H_t	growth model or yield table that gives the expected tree dimensions as a function of tree age under the baseline scenario with *A/R implemented during the pre-project period*
$E(t)$	t CO_2	annual project emissions
$E_{FuelBurn,t}$	tonnes CO_2-e yr^{-1} in year t	CO_2 emissions from combustion of fossil fuels within the project boundary
$E_{BiomassLoss,t}$	tonnes CO_2-e yr^{-1} in year	GHG emissions from the loss of biomass in site preparation and conversion to A/R within the project boundary

Variable	SI Unit	Description
$E_{Non-CO_2,BiomassBurn,t}$	tonnes CO_2-e yr^{-1} in year t	non-CO_2 emission as a result of biomass burning within the project boundary
$E_{N2O\,direct-N_{fertilizer},t}$	tonnes CO_2-e yr^{-1} in year t	direct N_2O emissions as a result of nitrogen application within the project boundary
$E_{BiomassBurn,CH_4,t}$	tonnes CO_2-e yr^{-1} in year *t*	CH_4 emission from biomass burning
$E_{BiomassBurn,N_2O,t}$	tonnes CO_2-e yr^{-1} in year *t*	N_2O emission from biomass burning
$E_{BiomassBurn,C,t}$	tonnes C yr^{-1} in year *t*	loss of carbon stock in above-ground biomass due to burning
e_{vf}	km^{-1}	average fuel consumption of vehicle type *v* with fuel type *f* litres km^{-1}
$EF_{all-pools}$	dimensionless	expansion factor (1.2 to 1.5) to convert the carbon stock of living tree biomass to carbon stock representing all pools depending on vegetation density
EF_{CH4}	kg CO_2-e. (kg C)$^{-1}$	IPCC default emission ratio for CH_4 (IPCC default: 0.0012)
EF_{diesel}	kg CO_2 l^{-1}	emission factor for diesel
$EF_{gasoline}$	kg CO_2 l^{-1}	emission factor for gasoline
EF_{N2O}	kg CO_2-e. (kg C)$^{-1}$	IPCC default emission ratio for N_2O (IPCC default: 0.0007)
EF_{vf}	kg CO_2 litre^{-1}	emission factor for vehicle type *v* with fuel type *f*
EF_1	(tonnes N input)$^{-1}$	emission factor for emissions from N inputs tonnes N_2O-N
f	number	refers to fuel type
$f_f(DBH,H)$	dimensionless	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*
FCA	dimensionless	proportion of per capita fuelwood consumption from agricultural/ private lands including purchases, to the total per capita annual fuelwood consumption from all sources (estimated from household survey data and scaled between 0 to 1),
FG_t	m^3 yr^{-1}	annual volume of fuelwood use
F_{ON}	tonnes N yr^{-1}	annual amount of organic fertilizer nitrogen applied ad*j*usted for volatilization as NH_3 and NO_X
F_{SN}	tonnes N yr^{-1}	annual amount of synthetic fertilizer nitrogen applied ad*j*usted for volatilization as NH_3 and NO_X
$FRAC_{GASF}$	dimensionless	fraction that volatilises as NH_3 and NO_X for synthetic fertilizers
$FRAC_{GASM}$	dimensionless	fraction that volatilises as NH_3 and NO_X for organic fertilizers
$FuelConsumption_{vf}$	litres in year t	consumption of fuel type *f* of vehicle type *v*
$FW_{ijk,t}$	m^3 ha^{-1} in year t	amount of fuelwood volume harvest in stratum *i*, species *j*, sub-stratum *k*
$G_{ARB,ij,t}$	tonnes d.m. ha^{-1} yr^{-1} in year *t*	average annual increment of total dry biomass of living trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*
$G_{ARB,w,ij,t}$	tonnes d.m. ha^{-1} yr^{-1} in year *t*	average annual above-ground biomass increment of trees for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*

Variable	SI Unit	Description
$G_{TOTAL,ij,t}$	tonnes d.m. ha^{-1} yr^{-1} in year t	average annual increment of total dry biomass of living trees for stratum *i*, species *j*
$G_{w,ij}$	tonnes d.m. ha^{-1} yr^{-1} in year t	average annual above-ground biomass increment of trees for stratum *i*, species *j*
GHG_E	tonnes CO_2-e yr^{-1}	annual GHG emissions as a result of the implementation of the A/R CDM project activity within the project boundary
$GHG_{E,t}$	tonnes CO_2-e yr^{-1} in year t	GHG emissions by sources within the project boundary as a result of the implementation of the A/R CDM project activity
GWP_{CH_4}	kg CO_2 (kg CH_4)$^{-1}$	global warming potential for CH_4 (IPCC default for the first commitment period: 21)
GWP_{N_2O}	kg CO_2 (kg N_2O)$^{-1}$	global warming potential for N_2O (IPCC default for the first commitment period: 310)
$H_{ijk,t}$	m^3 ha^{-1} in year *t*	amount of merchantable volume harvested in stratum *i,* species *j*, sub-stratum *k*
HS	number of persons per household	average size of resident household
$I_{ARB,v,ij,t}$	m^3 ha^{-1} yr^{-1} in year *t*	average annual increment in merchantable volume for stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*
$I_{ijk,t}$	m^3 ha^{-1} yr^{-1} in year *t*	average annual increment in merchantable volume for stratum *i*, species *j,* sub-stratum *k*
$k_{vf,t}$	km in year t	kilometers traveled by each of vehicle type *v* with fuel type *f*
L	number	total number of strata
l-CER(t_v)	t CO_2	l-CERs issued at year of verification t_v
$LK_{Activity\_Disp,t}$	tonnes CO_2-e yr^{-1} in year t	increase in GHG emissions outside the project boundary resulting from displacement of economic activities
$LK_{AD\_Def\ emigrant,t}$	tonnes CO_2-e in year t	emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to emigrant households
$LK_{AD\_Def\ resident,t}$	tonnes CO_2-e in year	emissions from conversion of land use/land cover outside the project boundary to agriculture/other land use attributable to resident households
$LK_{AD\_Def,t}$	tonnes CO_2-e yr^{-1} in year t	emissions from deforestation and land use change to agriculture and other uses due to displacement of households
$LK_{AD\_Fuel,t}$	tonnes CO_2-e in year t	emissions from fuelwood use due to displacement of households
LK_t	tonnes CO_2-e yr^{-1} in year t	increase of GHG emissions outside the project boundary
$LK_{Vehicle,CO_2,t}$	tonnes CO_2-e yr^{-1} in year t	increase in CO_2 emissions outside the project boundary due to fossil fuel combustion from vehicles
MAD_h	hectares (ha)	mean area subject to land use/cover change per resident sample household *h*
MC	tonnes C ha^{-1}	mean carbon stock per ha in the area subject to land use/cover change
$MC_{AB,ijk,m}$	tonnes C ha^{-1} at monitoring time *m*	mean carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*
$MC_{BB,ijk,m}$	tonnes C ha^{-1} at monitoring time *m*	mean carbon stock in below-ground biomass for stratum *i*, species *j*, sub-stratum *k*
n	number	sample size (number of sample plots required for monitoring)

Variable	SI Unit	Description
N	number	number of total sample units (all stratum)
$N/Cratio$	dimensionless	nitrogen/carbon ratio
$N_{ON-Fert}$	tonnes N yr^{-1}	annual amount of organic fertilizer nitrogen applied
n_h	number	number of sample units (permanent sample plots) per stratum, that is allocated proportional to stratum *i*
N_i	number	number of sample units for stratum *i,* calculated by dividing the area of stratum *i*
NH_e	number	total number of emigrant households
nH_r	dimensionless	number of sample household resident in the vicinity of the project.
NH_r	dimensionless	total number of displaced households resident in the project vicinity
$N_{SF-Fert,t}$	tonnes N yr^{-1} in year t	annual amount of synthetic fertilizer nitrogen applied
n_{vf}	number	number of vehicles type *v* with fuel type *f*
$N_2O_{direct-N_{fertilizer}}$	tonnes CO_2-e yr^{-1}	direct N_2O emissions as a result of nitrogen application within the project boundary
p	number	1,2,3,…*P* number of sample plots in stratum *i*, species *j*, sub-stratum *k*
P_{ijk}	number plots $stratum^{-1}$	number of sample plots in stratum *i*, species *j*, sub-stratum *k*
$PP_{ijk,t}$	dimensionless	proportion of biomass burned in year *t*
$PC_{AB,ijk,plot,m}$	tonnes C ha^{-1} at monitoring time *m*	plot level carbon stock in above-ground biomass for stratum *i*, species *j*, sub-stratum *k*
$PC_{BB,ijk,plot,m}$	tonnes C ha^{-1} at monitoring time *m*	plot level carbon stock in below-ground biomass for stratum *i*, species *j*, sub-stratum *k*
PG	dimensionless	annual human population growth, in percent
PFC_t	tonnes d.m $(person)^{-1}$ yr^{-1} in year t	per capita annual fuelwood consumption
ps	ha	plot size
P_t	number of persons in year t	population of the region
R_G	dimensionless	root-shoot ratio appropriate for pre-existing non-tree vegetation
R_j	dimensionless	root-shoot ratio relevant to the increments of for species *j*
R_{jk}	dimensionless	root-shoot ratio appropriate for species *j*, sub-stratum *k*
s_i	dimensionless	standard deviation of stratum *i*
t	years	ranges from 1 to length of the crediting period
T	years	number of years between times t_2 and t_1
$t\text{-}CER(t_v)$	t CO_2	t-CERs issued at year of verification t_v
tr	number	number of trees in the plot
TR	number	number of trees measured within the sample plot number trees $plot^{-1}$
t_v	dimensionless	year of verification
t_α	number	*t* value for a significance level of α (0.05) or confidence level of 95%
$TB_{AB,tree,ijk,m}$	tonnes d.m. $tree^{-1}$ at monitoring time *m*	above-ground biomass of a tree in stratum *I*, species *j*, sub-stratum *k*
$TB_{BB,ijk,tree,m}$	tonnes d.m. $tree^{-1}$ at	below-ground biomass per tree of stratum *i*, species *j* and sub-stratum

Variable	SI Unit	Description
	monitoring time *m*	*k*
U_c	%	combined percentage uncertainty,
U_i	dimensionless	percentage uncertainties associated with each of the parameters and activity data, *i* =1,2,…,n
U_s	dimensionless	percentage uncertainty of each parameter, %
U_S	dimensionless	percentage uncertainty of emission by sources or removal by sinks
U_{si}	%	percentage uncertainty of each emission by sources or removal by sinks,
v		refers to vehicle type
$V_{ARB,ij}$	$m^3\ ha^{-1}$	merchantable volume of stratum *i*, species *j* under the baseline scenario with *A/R implemented during the pre-project period*
V_{ij}	m^3 ha-^{1}	merchantable volume of stratum *i,* species *j*
$V_{ijk,m}$	m^3 ha-^{1}	merchantable volume per tree (diameter DBH and height H) in stratum
v	number	refers to vehicle type
XF	dimensionless	plot expansion factor from per plot values to per hectare values
μ	dimensionless	mean value
σ	dimensionless	standard deviation of each parameter
0.001	t CO_2/kg CO_2	conversion from kg to tonnes of CO_2
$\frac{16}{12}$	dimensionless	ratio of molecular weights of CH_4 and carbon dimensionless
$\frac{44}{12}$	dimensionless	ratio of molecular weights of CO_2 and carbon
$\frac{44}{28}$	dimensionless	ratio of molecular weights of N_2O and nitrogen dimensionless

2. Acronyms

Acronym	Description
A/R	Afforestation/Reforestation
C	Carbon
CO_2	Carbon Dioxide
CO_2-e	Carbon Dioxide equivalent
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CF	Carbon Fraction
CH_4	Methane
d.m.	Dry Matter
DBH	Diameter at Breast Height
EB	Executive Board
GHG	Greenhouse Gas
GPG for LULUCF	Good Practice Guidance for Land use, Land-use Change and Forestry
GPG2000	Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories
GPS	Global Positioning System
GWP	Global Warming Potential
H	Tree Height

Acronym	Description
IPCC	Intergovernmental Panel on Climate Change
lCER	long-term Certified Emission Reduction
LULUCF	Land Use Land-Use Change and Forestry
N_2O	Nitrous Oxide
PDD	Project Design Document
QA	Quality Assurance
QC	Quality Control
tCER	temporary Certified Emission Reduction