# Revised Approved afforestation and reforestation baseline methodology AR-AM0001

## "Reforestation of degraded land"

**Source**

This methodology is based on the draft CDM-AR-PDD "Facilitating Reforestation for Guangxi Watershed Management in Pearl River Basin, China" whose baseline study, monitoring and verification plan and project design document were prepared by the Institute of Forest Ecology and Environment, the Chinese Academy of Forestry, Joanneum Research (Austria), Guangxi Forestry Inventory and Design, (China), and World Bank reviewers. For more information regarding the proposal and its consideration by the Executive Board please refer to case ARNM0010: "Facilitating Reforestation for Guangxi Watershed Management in Pearl River Basin, China" on http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html.

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

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

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

### 2. Applicability

This methodology is applicable to project activities with the following conditions:

- The project activity does not lead to a shift of pre-project activities outside the project boundary, i.e. the land under the proposed A/R CDM project activity can continue to provide at least the same amount of goods and services as in the absence of the project activity;
- Lands to be reforested are severely degraded with the vegetation indicators (tree crown cover and height) below thresholds for defining forests, as communicated by the DNA consistent with decision 11/CP.7 and 19/CP.9, and the lands are still degrading;
- Environmental conditions and human-caused degradation do not permit the encroachment of natural forest vegetation;
- Lands will be reforested by direct planting and/or seeding;
- Site preparation does not cause significant longer term net emissions from soil carbon;
- Plantation may be harvested with either short or long rotation and will be regenerated either by direct planting or natural sprouting;
- Carbon stocks in soil organic matter, litter and deadwood can be expected to decrease more due to soil erosion and human intervention or increase less in the absence of the project activity, relative to the project scenario;
- Grazing will not occur within the project boundary in the project case;
- The application of the procedure for determining the baseline scenario in section II.4 leads to the conclusion that the baseline approach 22(a) (existing or historical changes in carbon stocks in the carbon pools with the project boundary) is the most appropriate choice for determination of the baseline scenario and that the land would remain degraded in the absence of the project activity.

**3. Selected carbon pools:**

**Table 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 |
| Soil organic carbon | No | Conservative approach under applicability condition |

**4. Summary of baseline and monitoring methodologies**

Baseline methodology steps:
The methodology is applicable for a proposed A/R project activity on degraded and degrading abandoned land.

The eligibility of land as an A/R CDM project activity is demonstrated using archives and/or maps of land use/cover and/or satellite image around 1990 and for a recent date before the start of the A/R CDM project activity, as well as a supplementary survey of land use in cases where land cover alone is not sufficient to distinguish between forest and non-forest (e.g., bare land that may be forest due to forest regeneration under way). This methodology applies approach 22(a) as a general baseline approach for the proposed A/R CDM project activity, taking into account historic land use/cover changes, national, local and sectoral policies that influence land use within the boundary of the proposed A/R CDM project activity, economical attractiveness of the project relative to the baseline, and barriers for implementing project activities in absence of CDM finance.

The proposed A/R CDM project area is stratified based on local site classification map/table, the most updated land use/cover maps and/or satellite image, soil map, vegetation map, landform map as well as supplementary surveys, and the baseline scenario is determined separately for each stratum. For strata without growing trees, this methodology conservatively assumes that the carbon stock in above-ground and below-ground biomass would in the absence of the project activity remain constant, i.e., the baseline net GHG removals by sinks are zero. For strata with a few growing trees, the baseline net GHG removals by sinks are estimated based on methods in GPG-LULUCF[1]. Only the carbon stock changes in above-ground and below-ground biomass (in living trees) are estimated. The omission of the other pools (soil organic matter, dead wood and litter) is considered to be conservative because it can be justified that these other pools would decrease more or increase less in the absence of the proposed A/R CDM project activity, relative to the project scenario. The loss of non-tree living biomass on the site due to competition from planted trees or site preparation is accounted as a emission within the project boundary, in a conservative manner.

[1] Throughout this document, "GPG-LULUCF" means the Good Practice Guidance for Land Use, Land Use Change and Forestry from the Intergovernmental Panel on Climate Change (2003). This document is available at the following URL: http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.htm.

*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*[2].

Monitoring methodology steps:

This methodology includes the following elements:

- The overall performance of the proposed A/R CDM project activity, including the integrity of the project boundary and the success of forest establishment and forest management activities;
- The actual net GHG removals by sinks, increase in GHG emissions within the project boundary due to nitrogen fertilization, machinery use in site preparation, thinning and logging, removing of existing non-tree vegetation and biomass burning in any slash and burn site preparation;
- Leakage due to vehicle use for transportation staff, seedlings, timber and non forest products, as a result of the implementation of the proposed A/R CDM project activity;
- A Quality Assurance/Quality Control plan, including field measurements, data collection verification, data entry and archiving, as an integral part of the monitoring plan of the proposed A/R CDM project activity, to ensure the integrity of data collected and improve the monitoring efficiency.

The baseline net GHG removals by sinks does not need to be measured and monitored over time. However, the methodology checks and re-assesses these assumptions if a renewal of the crediting period is chosen. This methodology stratifies the project area based on local climate, existing vegetation, site class and tree species and/or years to be planted with the aid of land use/cover maps, satellite images, soil map, GPS and field survey. This methodology uses permanent sample plots to monitor carbon stock changes in living biomass pools. The methodology first determines the number of plots needed in each stratum/sub-stratum to reach the targeted precision level of ±10% of the mean at the 95% confidence level. GPS is used to locate plots.

## Section II. Baseline methodology description

### 1. Eligibility of land

The eligibility of land is treated under the 'additionality section' below.

### 2. Project boundary

The A/R CDM project activity may contain more than one discrete parcel of land. Each discrete parcel of land shall have a unique geographical identification. The boundary shall be defined for each discrete parcel. The discrete parcels of lands may be defined by polygons, and to make the boundary geographically verifiable and transparent, the GPS coordinate for all corners of each polygon shall be measured, recorded, archived and listed as an attachment of the CDM-AR-PDD.
Furthermore, the project boundary includes the emission sources and gases listed in the table below.

[2] Throughout this document, "A/R additionality tool" refers to the document approved by the Executive Board of the CDM and available at <http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html.>

**Table 2: Gases considered from emissions by sources other than resulting from changes in carbon pools:**

| Source | Gas | Included/ excluded | Justification / Explanation |
|---|---|---|---|
| Burning of fossil fuels | $CO_2$ | Included | |
| | $CH_4$ | Excluded | Potential emission is negligibly small |
| | $N_2O$ | Excluded | Potential emission is negligibly small |
| Burning of biomass | $CO_2$ | Included | However accounted as part of changes in carbon pools |
| | $CH_4$ | Included | |
| | $N_2O$ | Included | |
| Use of fertilizers… | $CO_2$ | Excluded | Not applicable |
| | $CH_4$ | Excluded | Not applicable |
| | $N_2O$ | Included | |

**3. Ex-ante stratification**

In general, the ex-ante stratification may be different from the ex-post stratification, however, they the procedures set out in section III.2, “Stratification and sampling for ex-post calculations”, should also be applied for ex-ante stratification.

**4. Procedure for selection of most plausible baseline scenario**

Project participants should determine the most plausible baseline scenario with the following steps:

**Step 1:** Identify and list plausible alternative land uses including alternative future public or private activities on the degraded lands such as any similar A/R activity or any other feasible land development activities, considering relevant national and or sectoral land-use policies that would impact the proposed project area, and land records, field surveys, data and feedback from stakeholders, and other appropriate sources.

**Step 2:** Demonstrate that under the plausible scenarios identified in Step 1, the most plausible scenario is that the project areas would remain abandoned and degrading in absence of the project activity, by assessing the attractiveness of the plausible alternative land uses in terms of benefits to the project participants, consulting with stakeholders for existing and future land use, and identifying barriers for alternative land uses. This can be done in at least one of the following ways:

- **Generally**: By demonstrating that similar lands, in the vicinity, are also not, and are not planned to be used for these alternative land uses. Show that apparent 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;
- **Specifically for any agricultural alternative land uses**: Demonstrate that the project lands are legally restricted to forestry purposes only, and that these restrictions are generally complied with in the vicinity of the project area. Alternatively, use step 2 of the A/R “Tool for the demonstration and assessment of additionality” to demonstrate that alternative agricultural land uses are financially non-viable.

**Step 3:** To support the findings above, demonstrate that the lands to be planted[3] are really "degraded":

Analyze the historical and existing land use/cover changes in a social-economic context and identify key factors that influence the land use/cover changes over time, using 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, land-owner interviews, as well as collection of data from other sources. The historical degradation feature can be indicated by assessing one of the following indicators:

- Vegetation degradation, e.g.,
  - The crown cover of non-tree vegetation has decreased in the recent past for reasons other than sustainable harvesting activities;
- Soil degradation, e.g.,
  - Soil erosion has increased between two time points in the recent past;
  - Soil organic matter content has decreased between two time points in the recent past.

In addition, demonstrate that no natural encroachment of trees would occur by,

- Demonstration of lack of on-site seed pool that may results in natural regeneration;
- Demonstration of lack of external seed sources that may result in natural regeneration;
- Demonstration of lack of possibility of seed sprouting and growth of young trees;
- Demonstration of lack of possible natural regeneration activity, by use of supplementary surveys on the project areas as well as similar surrounding areas for two different years that cover a minimum time period of ten years;
- Any other evidence that demonstrates the impossibility of natural encroachment in a credible and verifiable way.

Demonstrate that national and/or sectoral land-use policies or regulations that create policy driven market distortions which give comparative advantages to afforestation/reforestation activities and that have been adopted before 11 November 2001 do not influence the areas of the proposed A/R CDM project activity (e.g., because the policy is not implemented, the policy does not target this area, or because there are prohibitive barriers to the policy in this area, etc[4]. If the policies (implemented before 11 Nov 2001) significantly impact the project area, then the baseline scenario cannot be "degraded land" and this methodology cannot be used.

This methodology is not applicable if project proponents can not clearly show in the application of Steps 1 to 3 that the baseline approach 22(a) (existing or historical changes in carbon stocks in the carbon pools with the project boundary) and the scenario "lands to be planted are degraded lands and will continue to degrade in absence of the project" is the most appropriate plausible baseline scenario.

To ensure transparency regarding the condition of degraded lands, all information used in the analysis and demonstration shall be archived and verifiable.

[3] This section interprets the term "degradation" only in the context of non-forest land, subject of this methodology. Degradation of existing forests is not covered. Therefore the definition of degradation is more constrained than in the IPCC report on "Definitions and Methodological Options to Inventory Emissions from Direct Human-induced Degradation of Forests and Devegetation of Other Vegetation Types, see <http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/degradation.htm>.

[4] This is to comply with a ruling of the Executive Board of the CDM, see annex 3 of the sixteenth meeting of the Board at <http://cdm.unfccc.int/EB/Meetings>.

**5. Estimation of baseline net GHG removals by sinks**

To determine the baseline net GHG removals by sinks, the following steps are necessary:

a) Determination of the sum of carbon stock changes for each stratum:

- For those strata without growing trees, the sum of carbon stock changes in above-ground and below-ground biomass is set as zero;
- For those strata with growing trees, the sum of carbon stock changes in above-ground and below-ground biomass is determined based on the projection of their number and growth, based on growth models (yield tables), allometric equations, and local or national or IPCC default parameters (detail below in this section).

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

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

The baseline net greenhouse gas removals by sinks can be calculated by:

$$\Delta C_{BSL,t} = \sum_i \sum_j \Delta C_{ij,t} \quad \textbf{(1)}$$

where:

| | |
|---|---|
| $\Delta C_{BSL,t}$ | the sum of the changes in carbon stocks in the living biomass of trees for year *t*, tonnes $CO_2$ $yr^{-1}$ for year *t* |
| $\Delta Cij$,t | average annual carbon stock change in living biomass of trees for stratum *i* species *j*, tonnes $CO_2$ yr-1 for year *t* |
| $\Delta C_{ij,baseline,t}$ | average annual carbon stock change in living biomass of trees for stratum *i* species *j* in the absence of the project activity, tonnes $CO_2$ $yr^{-1}$ for year *t* |
| *i* | strata |
| *j* | tree species |
| *t* | 1 to length of crediting period |

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

**(a) Method 1 (Carbon gain-loss method )**[5]

$$\Delta C_{ij,t} = (\Delta C_{G,ij,t} - \Delta C_{L,ij,t}) \quad \textbf{(2)}$$

where:

| | |
|---|---|
| $\Delta Cij$,t | average annual carbon stock change in living biomass of trees for stratum *i* species *j*, tonnes $CO_2$ yr-1 for year *t* |
| $\Delta C_{G,ij,t}$ | average annual increase in carbon due to biomass growth of living trees for stratum *i* species *j*, tonnes $CO_2$ $yr^{-1}$ for year *t* |

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

| | |
|---|---|
| $\Delta C_{L,ij,t}$ | average annual decrease in carbon due to biomass loss of living trees for stratum *i* species *j*, tonnes $CO_2$ $yr^{-1}$ for year *t*. To be conservative for the baseline scenario, $\Delta C_{L,ij} = 0$ in this methodology. |

$$\Delta C_{G,ij,t} = A_{ij} \cdot G_{TOTAL,ij,t} \cdot CF_j \cdot 44/12 \quad (3)$$

where:

| | |
|---|---|
| $\Delta CG,ij,t$ | average annual increase in carbon due to biomass growth of living trees for stratum *i* species *j*, tonnes $CO_2$ yr-1 for year *t* |
| $A_{ij}$ | area of stratum *i* species *j*, hectare (ha) |
| $G_{TOTAL,ij,t}$ | average annual increment of total dry biomass of living trees for stratum *i* species *j*, tonnes of dry matter, $ha^{-1}$ $yr^{-1}$ for year *t* |
| $CF_j$ | the carbon fraction for species *j*, tonnes C (tonne d.m.)$^{-1}$ |
| *44/12* | ration of molecular weights of $CO_2$ and carbon, dimensionless |

$$G_{TOTAL,ij,t} = G_{w,ij,t} \cdot (1 + R_j) \quad (4)$$

$$G_{w,ij,t} = I_{v,ij,t} \cdot D_j \cdot BEF_{1,j} \quad (5)$$

where:

| | |
|---|---|
| $G_{TOTAL,ij,t}$ | average annual increment of total dry biomass of living trees for stratum *i* species *j*, tonnes of dry matter, $ha^{-1}$ $yr^{-1}$ for year *t* |
| $G_{w,ij,t}$ | average annual aboveground dry biomass increment of living trees for stratum *i* species *j*, tonnes d.m. $ha^{-1}$ $yr^{-1}$ for year *t* |
| $R_j$ | Root-shoot ratio appropriate to increments for species *j*, dimensionless |
| $I_{v,ij,t}$ | average annual increment in merchantable volume for stratum *i* species *j*, $m^3$ $ha^{-1}$ $yr^{-1}$ for year *t* |
| $D_j$ | basic wood density for species *j*, tonnes d.m. $m^{-3}$ |
| $BEF_{1,j}$ | biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total aboveground biomass increment for species *j*, dimensionless |

**(b) Method 2 (stock change method)** [6]

$$\Delta C_{ij,t} = (C_{2,ij} - C_{1,ij}) / T \cdot 44/12 \quad (6)$$

$$C_{ij} = C_{AB,ij} + C_{BB,ij} \quad (7)$$

$$C_{AB,ij} = A_{ij} \cdot V_{ij} \cdot D_j \cdot BEF_{2,j} \cdot CF_j \quad (8)$$

$$C_{BB,ij} = C_{AB,ij} \cdot R_j \quad (9)$$

where:

| | |
|---|---|
| $\Delta Cij,t$ | average annual carbon stock change in living biomass of trees for stratum *i* species *j*, tonnes $CO_2$ $yr^{-1}$ for year *t* |

[6] GPG-LULUCF Equation 3.2.3

| | |
|---|---|
| $C_{2,ij}$ | total carbon stock in living biomass of trees for stratum *i* species *j*, calculated at time 2, tonnes C |
| $C_{1,ij}$ | total carbon stock in living biomass of trees for stratum *i* species *j*, calculated at time 1, tonnes C |
| $T$ | number of years between times 2 and 1 |
| $C_{AB,ij}$ | carbon stock in aboveground biomass for stratum *i* species *j*, tonnes C |
| $C_{BB,ij}$ | carbon stock in belowground biomass for stratum *i* species *j*, tonnes C |
| $A_{ij}$ | area of stratum *i* species *j*, hectare (ha) |
| $V_{ij}$ | merchantable volume of stratum *i* species *j*, $m^3$ $ha^{-1}$ |
| $D_j$ | basic wood density for species *j*, tonnes d.m. $m^{-3}$ merchantable volume |
| $BEF_{2,j}$ | biomass expansion factor for conversion of merchantable volume to aboveground tree biomass for species *j*, dimensionless |
| $CF_j$ | the carbon fraction for species *j*, tonnes C (tonne d.m.)$^{-1}$ |
| $R_j$ | Root-shoot ratio species *j*, dimensionless |

The time points 1 and 2, for which the stock are estimated taken to determine the $\Delta C_{ij}$ must be broadly representative of the typical age of the trees under the baseline scenario during the crediting period. For example, if the trees are already mature at the start of the project , it is not appropriate to select time point 1 and 2 that corresponds to the juvenile fast growth stage.

$C_{AB,ij}$ can be estimated through the use of an allometric equations and a growth model or yield table.

$$C_{AB,ij} = A_{ij} \cdot CF_j \cdot f_j(DBH, H) \quad \textbf{(10)}$$

where:

| | |
|---|---|
| *CAB,ij* | carbon stock in aboveground biomass for stratum *i* species *j*, tonnes C |
| $f_i(DBH,H)$ | an allometric equation linking aboveground biomass of living trees (d.m. $ha^{-1}$) to mean diameter at breast height (DBH) and possibly tree height (H). |
| *DBH(t), H(t)* | a growth model or yield table that gives the expected tree dimensions as a function of tree age |
| $A_{ij}$ | area of stratum *i* species *j*, hectare (ha) |
| $CF_j$ | the carbon fraction for species *j*, tonnes C (tonne d.m.)$^{-1}$ |

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

a) existing local and species specific;
b) national and species specific (e.g. from national GHG inventory);
c) species specific from neighbouring countries with similar conditions. In the case of a large country that encompasses very different biome types, c might be preferable to b;
d) globally species specific (e.g. GPG-LULUCF).

If species specific information is not available information for similar species. (e.g., shape of trees, broadleaved vs deciduous etc) can be used, with data source priority as listed for species specific information.

When choosing from global or national databases because local data are limited, it shall be confirmed

with any available local data that this choice of values does not lead to underestimating the baseline net GHG removals by sinks, as far as can be judged. Local data used for confirmation may be drawn from the literatures and local forestry inventory or measured directly by project participants especially for BEF and root-shoot ratios that are age- and species- dependent.
Attention should be given to the fact that trees under the baseline scenario are trees outside forest and the biomass expansion factors for trees outside forest is generally higher than for forest trees.

## 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*[7].

## 7. Ex ante actual net GHG removal by sinks

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

### (a) Verifiable changes in carbon stocks in the carbon pools

The average annual carbon stock change in aboveground biomass and belowground biomass in living trees between two monitoring events for stratum *i* species *j* ($\Delta C_{ij,project}$) shall be estimated using one of two methods described in section II.5, i.e., equation (2) to (10).
However, when method 1 (Carbon gain-loss method) is used, the following equations shall be used to calculate the average annual decrease in carbon due to biomass loss in living trees for stratum *i* - species *j* ($\Delta C_{L,ij}$)[8]

$$\Delta C_{L,ij} = L_{fellings,ij} + L_{fuelwood,ij} + L_{otherloss,ij} \quad (12)$$

$$L_{fellings,ij} = H_{ij} \cdot D_j \cdot BEF_{2,j} \cdot CF_j \quad (13)$$

$$L_{fuelwood,ij} = FG_{ij} \cdot D_j \cdot BEF_{2,j} \cdot CF_j \quad (14)$$

$$L_{otherloss,ij} = A_{disturbance,ij} \cdot F_{disturbance,ij} \cdot B_{w,ij} \cdot CF_j \quad (15)$$

where:

| | |
|---|---|
| $\Delta C_{L,ij}$ | average annual decrease in carbon due to biomass loss in living trees for stratum *i* species *j*, tonnes C $yr^{-1}$ |
| $L_{fellings,ij}$ | Annual carbon loss due to commercial fellings for stratum *i* species *j*, tonnes C $yr^{-1}$ |
| $L_{fuelwood,ij}$ | annual carbon loss due to fuelwood harvesting of trees for stratum *i* species *j*, tonnes C $yr^{-1}$. Note: double counting between $L_{fellings,ij}$ and $L_{fuelwood,ij}$ must be avoided. Collection of fuelwood from the ground (from dead wood and litter pools) is not relevant, because |

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

8 Refers to GPG-LULUCF Equation 3.2.6, Equation 3.2.7, Equation 3.2.8 and Equation 3.2.9

| | |
|---|---|
| | these pools are omitted from the accounting. |
| $L_{other\ losses,ij}$ | annual natural losses of carbon in living trees for stratum *i* species *j*, tonnes C $yr^{-1}$ |
| $H_{ij}$ | annually extracted merchantable volume for stratum *i* species *j*, $m^3$ $yr^{-1}$ |
| $D_j$ | basic wood density for species *j*, tonnes d.m. $m^{-3}$ merchantable volume |
| $BEF_{2,j}$ | biomass expansion factor for converting merchantable volumes of extracted roundwood to total aboveground biomass (including bark) for stratum *i* species *j*, dimensionless |
| $CF_j$ | Carbon fraction of dry matter for species *j* , tonnes C (tonne d.m.)$^{-1}$ |
| $FG_{ij}$ | Annual volume of fuel wood harvesting of living trees for stratum *i* species *j*, $m^3$ $yr^{-1}$ |
| $A_{\ disturbance,ij}$ | Areas affected by disturbances in stratum *i* species *j*, ha $yr^{-1}$ |
| $F_{\ disturbance,ij}$ | the fraction of the biomass in living trees for stratum *i* species *j* affected by disturbance, dimensionless |
| $B_{W,ij}$ | average biomass stock of living trees for stratum *i* species *j*, tonnes d.m. $ha^{-1}$ |

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

**(b) GHG emissions by sources**

The A/R CDM project activity may cause GHG emissions within the project boundary, in particular . The emission of $CO_2$, $CH_4$ and $N_2O$ from following sources, also contained in Table 1 above, may occur as a result of the proposed A/R CDM project activity[9]:

- Emissions of greenhouse gases from combustion of fossil fuels for site preparation, thinning and logging;
- Decrease in carbon stock in living biomass of existing non-tree vegetation, caused either by competition of planted trees or site preparation including slash and burn;
- Emissions of non-$CO_2$ greenhouse gases from biomass burning for site preparation (slash and burn activity);
- $N_2O$ emissions caused by nitrogen fertilization application.

The GHG emission as a result of the implementation of the proposed A/R CDM project activity within the project boundary are estimated as follows:

$$GHG_E = E_{FuelBurn} + E_{biomassloss} + E_{Non-CO_2,BiomassBurn} + N_2O_{direct-N_{fertilizer}} \quad \textbf{(16)}$$

where:

| | |
|---|---|
| $GHG_E$ | the GHG emissions as a result of the implementation of the A/R CDM project activity within the project boundary, tonnes $CO_2$-e $yr^{-1}$ |
| $E_{FuelBurn}$ | the $CO_2$ emissions from combustion of fossil fuels within the project boundary, tonnes $CO_2$-e $yr^{-1}$ |
| $E_{biomassloss}$ | the $CO_2$ emissions as a result of a decrease in carbon stock in living biomass of existing non-tree vegetation, tonnes $CO_2$-e $yr^{-1}$. This is an initial loss, and therefore accounted once upfront as part of the first monitoring interval. |
| $E_{Non-CO2,\ BiomassBurn}$ | Non-$CO_2$ emission as a result of biomass burning within the project boundary, tonnes $CO_2$-e $yr^{-1}$ |
| $N_2O_{direct-N_{fertilizer}}$ | $N_2O$ emission as a result of direct nitrogen application within the project |

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

boundary, tonnes $CO_2$-e $yr^{-1}$

***(i) Calculation of GHG emissions from burning fossil fuels***

This most likely results from machinery use during site preparation and logging. The IPCC 1996 Guidelines could be used to estimate $CO_2$ emissions from combustion of fossil fuels:

$$E_{FuelBurn} = (CSP_{diesel} \cdot EF_{diesel} + CSP_{gasoline} \cdot EF_{gasoline}) \cdot 0.001 \quad \textbf{(17)}$$

where:

| | |
|---|---|
| $E_{FuelBurn}$ | $CO_2$ emissions from combustion of fossil fuels within the project boundary, tonnes $CO_2$-e $yr^{-1}$ |
| $CSP_{diesel}$ | volume of diesel consumption, litre (l) $yr^{-1}$ |
| $CSP_{gasoline}$ | volume of gasoline consumption, litre (l) $yr^{-1}$ |
| $EF_{diesel}$ | emission factor for diesel, kg $CO_2$ $l^{-1}$ |
| $EF_{gasoline}$ | emission factor for gasoline, kg $CO_2$ $l^{-1}$ |
| *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.

***(ii) Calculation of the decrease in carbon stock in living biomass of existing non-tree vegetation***

It is assumed that all existing non-tree vegetation will disappear due to site preparation including slash and burn, or competition from planted trees. This is a conservative assumption because there will be some non-tree vegetation in the project scenario. Some vegetation may re-grow even if all non-tree vegetation is removed during the site preparation (overall plough or site burning). The non-tree vegetation carbon loss will be accounted once during the crediting period, as part of the first monitoring interval.

$$E_{biomassloss} = \sum_i A_i \cdot B_{non-tree,i} \cdot CF_{non-tree} \cdot 44/12 \quad \textbf{(18)}$$

where:

| | |
|---|---|
| $E_{biomassloss}$ | $CO_2$ emissions as a result of a decrease in carbon stock in living biomass of existing non-tree vegetation, tonnes $CO_2$-e $yr^{-1}$. This is an initial loss, and therefore accounted once upfront as part of the first monitoring interval |
| $A_i$ | area of stratum *i*, ha $yr^{-1}$ |
| $B_{non-tree,i}$ | average non-tree biomass stock on land to be planted before the start of a proposed A/R CDM project activity for stratum *i*, tonnes d.m. $ha^{-1}$ |
| $CF_{non-tree}$ | the carbon fraction of dry biomass in non-tree vegetation, tonnes C (tonne d.m.)$^{-1}$ |
| *44/12* | ration of molecular weights of $CO_2$ and carbon, dimensionless |

***(iii) Calculation of emissions from biomass burning***

If slash and burn occurs during site preparation before planting and/or replanting, this results in non-$CO_2$ emissions ($CO_2$ emission has been covered in B) above). Based on GPG for LULUCF[10], this type of emission can be estimated as follows:

$$E_{Non-CO_2,BiomassBurn} = E_{BiomassBurn,N_2O} + E_{BiomassBurn,CH_4} \quad \mathbf{(19)}$$

where:

| | |
|---|---|
| $E_{Non\text{-}CO2,\ BiomassBurn}$ | the increase in Non-$CO_2$ emission as a result of biomass burning in slash and burn, tonnes $CO_2$-e $yr^{-1}$ |
| $E_{BiomassBurn,\ N2O}$ | $N_2O$ emission from biomass burning in slash and burn, tonnes $CO_2$-e $yr^{-1}$ |
| $E_{BiomassBurn,\ CH4}$ | $CH_4$ emission from biomass burning in slash and burn, tonnes $CO_2$-e $yr^{-1}$ |

$$E_{BiomassBurn,N_2O} = E_{BiomassBurn,C} \cdot (N/C\,ratio) \cdot ER_{N20} \cdot \frac{44}{28} \cdot GWP_{N2O} \quad \mathbf{(20)}$$

$$E_{BiomassBurn,CH_4} = E_{BiomassBurn,C} \cdot ER_{CH4} \cdot 16/12 \cdot GWP_{CH4} \quad \mathbf{(21)}$$

where[11]:

| | |
|---|---|
| $E_{BiomassBurn,C}$ | loss of carbon stock in aboveground biomass due to slash and burn, t C $yr^{-1}$ |
| *N/C ratio* | Nitrogen-Carbon ratio, dimensionless |
| *44/28* | ration of molecular weights of $N_2O$ and nitrogen, dimensionless |
| *16/12* | ration of molecular weights of $CH_4$ and carbon, dimensionless |
| $ER_{N2O}$ | IPCC default emission ratio for $N_2O$ = 0.007 |
| $ER_{CH4}$ | IPCC default emission ratio for $CH_4$ = 0.012 |
| $GWP_{N2O}$ | Global Warming Potential for $N_2O$, kg $CO_2$e (kg $N_2O$)$^{-1}$ (IPCC default = 310, valid for the first commitment period) |
| $GWP_{CH4}$ | Global Warming Potential for $CH_4$ , kg $CO_2$e (kg $CH_4$)$^{-1}$ (valid for the first commitment period) |

$$E_{BiomassBurn,C} = \sum_i A_{burn,i} \cdot B_i \cdot CE \cdot CF \quad \mathbf{(22)}$$

where:

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

The combustion efficiencies may be chosen from Table 3.A.14 of GPG-LULUCF. If no appropriate combustion efficiency can be used, the IPCC default of 0.5 should be used, see section 3.2.1.4.2.2 in

[10] Refers to equation 3.2.20 in GPG for LULUCF

[11] Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF and Equation 3.2.19 in GPG LULUCF

GPG LULUCF. The nitrogen-carbon ratio (N/C ratio) is approximated to be about 0.01. This is a general default value that applies to leaf litter, but lower values would be appropriate for fuels with greater woody content, if data are available.

***(iv) Calculation of nitrous oxide emissions from nitrogen fertilization practices***[12]

$$N_2O_{direct-N_{fertilizer}} = \left[(F_{SN} + F_{ON}) \cdot EF_1\right] \cdot 44/28 \cdot GWP_{N2O} \qquad (23)$$

$$F_{SN} = N_{SN-Fert} \cdot (1 - Frac_{GASF}) \qquad (24)$$

$$F_{ON} = N_{ON-Fert} \cdot (1 - Frac_{GASM}) \qquad (25)$$

where:

| | |
|---|---|
| $N_2O_{direct-N_{fertilizer}}$ | the direct $N_2O$ emission as a result of nitrogen application within the project boundary, tonnes $CO_2$-e $yr^{-1}$ |
| $F_{SN}$ | mass of synthetic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_X$, tonnes N $yr^{-1}$ |
| $F_{ON}$ | [Annual] mass of organic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_X$, tonnes N $yr^{-1}$ |
| $N_{SN-Fert}$ | mass of synthetic fertilizer nitrogen applied, tonnes N $yr^{-1}$ |
| $N_{ON-Fert}$ | mass of organic fertilizer nitrogen applied, tonnes N $yr^{-1}$ |
| $EF_1$ | Emission Factor for emissions from N inputs, tonnes $N_2O$-N (tonnes N input)$^{-1}$ |
| $Frac_{GASF}$ | the fraction that volatilises as $NH_3$ and $NO_X$ for synthetic fertilizers, dimensionless |
| $Frac_{GASM}$ | the fraction that volatilises as $NH_3$ and $NO_X$ for organic fertilizers, dimensionless |
| *44/28* | ration of molecular weights of $N_2O$ and nitrogen, dimensionless |
| $GWP_{N2O}$ | Global Warming Potential for $N_2O$, kg $CO_2e$ (kg $N_2O$)$^{-1}$ (IPCC default = 310, valid for the first commitment period) |

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 in 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 is given in Box 4.1 of GPG 2000.

**(c) Actual net GHG removals by sinks**

The actual net greenhouse gas removals are calculated as follows:

$$\Delta C_{ACTUAL} = \sum_i \sum_j \Delta C_{ij} - GHG_E \qquad (26)$$

where:

| | |
|---|---|
| $\Delta C_{ACTUAL}$ | actual net greenhouse gas removals by sinks, tonnes $CO_2$-e $yr^{-1}$ |
| $\Delta C_{ij}$ | average annual carbon stock change in living biomass of trees for stratum *i* species *j*, tonnes $CO_2$ $yr^{-1}$. |

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

| | |
|---|---|
| $GHG_E$ | GHG emissions by sources within the project boundary as a result of the implementation of an A/R CDM project activity, tonnes $CO_2$-e $yr^{-1}$ |

## 8. Leakage

In choosing parameters and making assumptions project participants should retain conservative approach, i.e. if different values for a parameter are plausible, a value that does not lead to an underestimation of leakage emissions should be applied.

According to applicability conditions for this methodology, the land used for reforestation is abandoned and can under the proposed A/R CDM project activity continue to provide at least the same amount of goods and services. Consequently, as a result of the A/R CDM project activity, agricultural or pastoral activities will not be displaced from the project sites to other locations.

Similarly, the A/R CDM project activity will not result in any reduction of reforestation activities or increasing of deforestation activities outside of the project boundary. Under the baseline scenario, local farmers may collect a limited amount fuel (mainly shrub and grass) from the project sites. Dead wood and some living branch biomass from the A/R CDM project activity can continue to be collected by local farmers as fuelwood without compromising the growth of trees established under the project. Thus, as the result of the project activities, local farmers will not have to collect additional fuelwood on lands outside the project boundary.

The identified potential leakage of the proposed A/R CDM project activity may be GHG emissions caused by vehicle fossil fuel combustion due to transportation of seedling, labours, staff and harvest products to and/or from project sites (while avoiding double-counting with emission accounted for in $E_{FuelBurn}$ above). The $CO_2$ emissions can be estimated using bottom-up approach described in GPG 2000[13].

$$LK_{Vehicle,CO_2} = \sum_i \sum_j (EF_{ij} \cdot FuelConsumption_{ij}) / 1000 \qquad \textbf{(27)}$$

$$FuelConsumption_{ij} = n_{ij} \cdot k_{ij} \cdot e_{ij} \qquad \textbf{(28)}$$

where:

| | |
|---|---|
| $LK_{Vehicle,CO2}$ | total GHG emissions due to fossil fuel combustion from vehicles, tonnes $CO_2$-e $yr^{-1}$ |
| $i$ | vehicle type |
| $j$ | fuel type |
| $EF_{ij}$ | emission factor for vehicle type $i$ with fuel type $j$, kg$CO_2$/litre |
| $FuelConsumption_{ij}$ | consumption of fuel type $j$ of vehicle type $i$, litres |
| $n_{ij}$ | number of vehicles |
| $k_{ij}$ | kilometres travelled by each of vehicle type $i$ with fuel type $j$, km |
| $e_{ij}$ | average fuel consumption of vehicle type $i$ with fuel type $j$, litres/km |

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

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

**9. Ex ante net anthropogenic GHG removal by sinks**

The net anthropogenic GHG removals by sinks is the actual net GHG removals by sinks minus the baseline net GHG removals by sinks minus leakage, therefore, the following general formula can be used to calculate the net anthropogenic GHG removals by sinks of an A/R CDM project activity ($C_{AR\text{-}CDM}$), in tonnes $CO_2$-e $yr^{-1}$:

$$C_{AR-CDM} = C_{ACTUAL} - C_{BSL} - LK_{Vehicle,CO2} \quad \textbf{(29)}$$

where:

| | |
|---|---|
| $C_{AR\text{-}CDM}$ | net anthropogenic greenhouse gas removals by sinks, tonnes $CO_2$-e $yr^{-1}$ |
| $C_{ACTUAL}$ | actual net greenhouse gas removals by sinks, tonnes $CO_2$-e $yr^{-1}$ |
| $C_{BSL}$ | baseline net greenhouse gas removals by sinks, tonnes $CO_2$-e $yr^{-1}$ |
| $LK_{Vehicle,CO2}$ | total GHG emissions as leakage due to fossil fuel combustion from vehicles, tonnes $CO_2$-e $yr^{-1}$ |

**10. Uncertainties**

The approach provided in section III.11 below should be applied.

**11. Data needed for ex ante estimations**

| Data/Parameters | Descriptions | Vintage | Resolution | Sources |
|---|---|---|---|---|
| Historical land use/cover data | Determining baseline approach<br>Demonstrating eligibility of land | Earliest possible up to now | Local | Publications, national or regional forestry inventory, local government, interview |
| Land use/cover map | Demonstrating eligibility of land, stratifying land area | Around 1990 and most recent date | Regional local | Forestry inventory |
| Satellite image | Demonstrating eligibility of land, stratifying land area | 1989/1990 and most recent date | Local | e.g. Landsat |
| Landform map | Stratifying land area | most recent date | 1:10000 | Local government |
| Soil map | Stratifying land area | most recent date | highest available scale | Local government and institutional agencies |
| National and sectoral policies | Additionality consideration | Before 1998 | National and sectoral | |
| UNFCCC decisions | | 1997 up to now | Internation al | UNFCCC website |
| IRR, NPV cost benefit ratio, or unit cost of service | Indicators of investment analysis | Most recent date | Local | Calculation |

| | | | | |
|---|---|---|---|---|
| Investment costs | Including land purchase or rental, machinery, equipments, buildings, fences, site and soil preparation, seedling, planting, weeding, pesticides, fertilization, supervision, training, technical consultation, etc. that occur in the establishment period | Most recent date, taking into account market risk | Local | Local statistics, published data and/or survey |
| Operations and maintenance costs | Including costs of thinning, pruning, harvesting, replanting, fuel, transportation, repairs, fire and disease control, patrolling, administration, etc. | Most recent date, taking into account market risk | Local | Local statistics, published data and/or survey |
| Transaction costs | Including costs of project preparation, validation, registration, monitoring, etc. | Most recent date | National and inter-national | |
| Revenues | Those from timber, fuelwood, non-wood products, with and with-out CER revenues, etc. | Most recent date, taking into account market risk | National and local | Local statistics, published data and/or survey |
| $\Delta C_{BSL}$ | Baseline net GHG removals by sinks | | | |
| $\Delta C_{ij}$ | average annual carbon stock change in living biomass of trees | | Stratum, species | estimated |
| $\Delta C_{G,ij}$ | average annual increase in carbon due to biomass growth | Most recent | Global default to local | GPG-LULUCF, national and local forestry inventory |
| $C_{L,ij}$ | average annual decrease in carbon due to biomass loss | Most recent | Global default to local | GPG-LULUCF, national and local forestry inventory |
| $A_{ij}$ | Area of stratum and species | | Stratum and species | |
| $G_{TOTAL,ij}$ | annual average increment rate in total biomass per hectare for stratum | Most recent | Global default to local | GPG-LULUCF, national and local forestry inventory |
| *CF* | Carbon fraction | | Global default to local | GPG-LULUCF, national GHG inventory |
| *44/12* | ration of molecular weights of $CO_2$ and carbon | | Global default | IPCC |

| | | | |
|---|---|---|---|
| $G_{w,ij}$ | average annual aboveground biomass increment | Global default to local | GPG-LULUCF, national GHG inventory |
| $R_j$ | Root-shoot ratio for tree species | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $L_{v,ij}$ | average annual net increment in volume suitable for industrial processing | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $D_j$ | Species specific basic wood density | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $BEF_{1,j}$ | Species specific biomass expansion factor for conversion of annual net increment (including bark) to aboveground biomass increment | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $BEF_{2,j}$ | Species specific biomass expansion factor for conversion of merchantable volume to aboveground tree biomass | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $C_{2,ij}$ | Total carbon stock in living biomass of trees, calculated at time 2 | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $C_{1,ij}$ | Total carbon stock in living biomass of trees, calculated at time 1 | Global default to local and species specific | GPG-LULUCF, national GHG inventory, local survey |
| $V_{ij}$ | Merchantable volume | Local and species specific | Forestry inventory, yield table, local survey |
| $\Delta C_{ACTUAL}$ | Actual net greenhouse gas removals by sinks | Project specific | Calculated |
| $C_{AB,ij}$ | Carbon stock in aboveground biomass | Local and species specific | Calculated |
| $C_{BB,ij}$ | Carbon stock in belowground biomass | Local and species specific | Calculated |
| $GHG_E$ | Increase in GHG emissions by the sources within the project boundary as a result of the implementation of an A/R CDM project activity | Project specific | Calculated |

| | | | |
|---|---|---|---|
| $f_j(DBH,H)$ | Allometric equation | National, local, species specific | Forestry inventory, published data, local survey |
| $L_{fellings,ij}$ | Annual carbon loss due to commercial fellings | | Calculated |
| $L_{fuelwood,ij}$ | Annual carbon loss due to fuelwood gathering of trees | | Calculated |
| $L_{other\ losses,ij}$ | Annual natural losses of carbon in living trees | | Calculated. |
| $H_{ij}$ | Annually extracted volume | Stratum | Monitoring |
| $FG_{ij}$ | Annual volume of harvested fuel wood | Stratum | Monitoring |
| $A_{\ disturbance,ij}$ | Areas affected by disturbances | Stratum | Monitoring |
| $F_{\ disturbance,ij}$ | The fraction of the biomass in living trees for stratum *i* species *j* affected by disturbance | Stratum | Monitoring |
| $B_{W,j}$ | Average biomass stock of living trees | Stratum | Local survey |
| $E_{FuelBurn}$ | Emissions from burning of fossil fuels | | Estimated |
| $E_{biomassloss}$ | Decrease in carbon stock in living biomass of existing non-tree vegetation | | Estimated |
| $E_{Non\text{-}CO2,BiomassBurn}$ | The increase in non-$CO_2$ emission as a result of biomass burning within the project boundary | | Estimated |
| $N_2O_{direct-N_{fertilizer}}$ | The increase in $N_2O$ emission as a result of direct nitrogen application within the project boundary | | Estimated |
| $CSP_{diesel}$ | Amount of diesel consumption | Project | Monitored |
| $CSP_{gasoline}$ | Amount of gasoline consumption | Project | Monitored |
| $EF_{diesel}$ | Emission factor for diesel | Global to national | IPCC Guideline, GPG 2000, national inventory |
| $EF_{gasoline}$ | Emission factor for gasoline | Global to national | IPCC Guideline, GPG 2000, national inventory |

| | | | | |
|---|---|---|---|---|
| $B_{non\text{-}tree,i}$ | Average biomass stock on land to be planted, before the start of a proposed A/R CDM project activity | | Stratum | Local survey |
| $CF_{non\text{-}tree}$ | The carbon fraction of dry biomass in non-tree vegetation | | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $E_{BiomassBurn,C}$ | Loss of carbon due to slash and burn | | Stratum | Estimated |
| $E_{BiomassBurn,\ N2O}$ | $N_2O$ emission from biomass burning in slash and burn | | | |
| $E_{BiomassBurn,\ CH4}$ | $CH_4$ emission from biomass burning in slash and burn | | | |
| $B_i$ | Average stock in living biomass before burning | Most updated | Site specific | Survey |
| $A_{burn,i}$ | Area of slash and burn | | Site specific | Survey |
| $CE$ | Average biomass combustion efficiency | | Global and national default | IPCC GPG-2000, national GHG inventory |
| $N/C$ ratio | | | Global | IPCC |
| $N_2O_{\ direct\text{-}Nfertilizer}$ | Emission of $N_2O$ caused by nitrogen fertilization | | | Estimated |
| $F_{SN}$ | Annual amount of synthetic fertilizer nitrogen adjusted for volatilization as $NH_3$ and $NO_X$ | | | Estimated |
| $F_{ON}$ | Annual amount of organic fertilizer nitrogen adjusted for volatilization as $NH_3$ and $NO_X$ | | | Estimated |
| $EF_1$ | Emission factor for emissions from N inputs | | Global default | GPG 2000 |
| $Frac_{GASF}$ | The fraction that volatilises as $NH_3$ and $NO_X$ for synthetic fertilizers | | Global default | IPCC Guideline |
| $Frac_{GASM}$ | The fraction that volatilises as $NH_3$ and $NO_X$ for organic fertilizers | | Global default | IPCC Guideline |
| $N_{SN\text{-}Fert}$ | Amount of synthetic fertilizer nitrogen applied | | Project | Monitored |
| $N_{SN\text{-}Fert}$ | Amount of organic fertilizer nitrogen applied | | Project | Monitored |
| $LK$ | Total GHG emissions caused by transportation | | | |

| | | | |
|---|---|---|---|
| $LK_{Vehicle,CO2}$ | $CO_2$ emissions caused by transportation | | |
| $LK_{Vehicle,N2O}$ | $N_2O$ emissions caused by transportation | | |
| $LK_{Vehicle,CH4}$ | $CH_4$ emissions caused by transportation | | |
| $EF_{ij}$ | Emission factor for vehicle type *i* with fuel type *j* | Global, national | GPG-2000, IPCC 1996 Guideline, national GHG inventory |
| $FuelConsumption_{ij}$ | Consumption of fuel type *j* of vehicle type *i* | Project | Estimated |
| $e_{ij}$ | Average liters consumed per kilometer travelled for vehicle type *i* with fuel type *j* | Global to national | GPG-2000, IPCC 1996 Guideline, national GHG inventory |
| $k_{ij}$ | Kilometers traveled by each of vehicle type *i* with fuel type *j* | Project | Monitored |
| $n_{ij}$ | Number of vehicles | Project | Monitored |

## 12. Other information

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

## Section III: Monitoring methodology description

### 1. Monitoring project boundary and project implementation

#### (a) Monitoring the boundary of the proposed A/R CDM project activity

This is meant to demonstrate that the actual planting area conforms with the planting area outlined in the project plan. The following activities are foreseen:

- Field survey concerning the actual boundary within which reforestation activity has occurred, site by site;
- Measuring geographical positions (latitude and longitude of each corner of polygon sites) using GPS;
- Checking whether the actual boundary is consistent with the description in the CDM-AR-PDD;
- If the actual boundary falls outside of the designed boundary in CDM-AR-PDD, additional information for lands beyond the designed boundary in CDM-AR-PDD shall be provided; the eligibility of these lands as a part of the A/R CDM project activity shall be justified; and the projected baseline scenario shall be demonstrated to be applicable to these lands. Otherwise, these lands shall not be accounted as a part of the A/R CDM project activity. Such changes in boundary shall be communicated to the DOE and subject to validation during the project, e.g. during the first verification event;
- Input the measured geographical positions into GIS system and calculate the eligible area of each stratum and sub-stratum;
- The project boundary shall be monitored periodically all through the crediting period, including through remote sensing as applicable. If the forest area changes during the crediting period, for instance, because deforestation occurs on the project area, the specific location and area of the deforested land shall be identified. Similarly, if the planting on certain lands within the project boundary fails these lands shall be documented.

#### (b) Monitoring of forest establishment

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

- Confirm that site and soil preparations are implemented based on practice documented in CDM-AR-PDD. If pre-vegetation is removed, e.g., slash and burn of pre-existing vegetation, emissions associated shall be accounted (described in section below);
- Confirm that site preparation does not cause significant longer term net emissions from soil carbon;
- Survival checking:
  - The initial survival rate of planted trees shall be counted three months after the planting, and re-planting shall be conducted if the survival rate is lower than 90 percent;
  - Final checking three years after the planting;
  - The checking of the survival rate may be conducted using permanent sample plots;
- Weeding checking: check and confirm that the weeding practice is implemented as described in the CDM-AR-PDD;
- Survey and check that species and planting for each stratum and sub-stratum are in line with the CDM-AR-PDD.

**(c) Monitoring of forest management**

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

- Thinning: specific location, area, tree species, thinning intensity, biomass removed;
- Harvesting: harvested location, area, tree species, biomass removed;
- Fertilization: tree species, location, amount and type of fertilizer applied, etc.;
- Checking and confirming that harvested lands are re-planted or re-sowed immediately after harvesting if direct planting or seeding is used;
- Checking and ensuring that good conditions exist for natural regeneration if harvested lands are allowed to regenerate naturally.

**2. Stratification and sampling for ex-post calculations**

**(a) Stratification**

Project areas are usually heterogeneous in terms of micro-climate, soil condition and vegetation cover in addition to different trees species and forest establishment year. Therefore it is necessary to stratify the project area. This can increase the accuracy of the measuring and monitoring in a cost-effective manner. Stratification of the project area into relatively homogeneous units can either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit. The pre-stratification can be implemented using steps as follows:

**Step 1***:* Assessing the key factors influencing carbon stocks in the above- and below-biomass pools. These factors may include soil features, micro-climate, landform (e.g., elevation, slope gradient), tree species to be planted, year to be planted, human management, etc.

**Step 2***:* Collecting local information of key factors identified in step 1, e.g.:
- local site classification maps and/or tables;
- the most updated land use/cover maps and/or satellite images / aerial photography;
- Soil types, parent rocks and preferably soil maps;
- landform information and/or maps;
- soil erosions intensity;
- other information relevant to key factors identified above.

Data sources may include archives, records, statistics, study reports and publications of national, regional or local governments, institutes and/or agencies, and literature.

**Step 3:** Preliminary stratification: The stratification shall be conducted in a hierarchical order that depends on the significance of key factors on carbon stock changes or the extent of difference of the key factors across the project area. Only once higher level stratification is complete shall stratification at the next level down commence. At each level in the hierarchy, stratification shall be conducted within the strata determined at the upper level. For example, if there is a significant climatic difference within the project boundary, the stratification process may begin with stratification according to difference of the climate. If the key factor in the second level is soil type, then strata determined in the first level may be further stratified based on difference of soil type. Preferably, the stratification can be carried out on GIS platform by overlaying information/maps collected, and in this case the hierarchical order may not necessary.

**Step 4:** Carrying out a supplementary sampling survey on site specifications for each preliminary stratum, e.g.:

- Existing trees if any: species, age class, number of trees, mean diameter at breast height (DBH) and/or height by measuring randomly selected plots with an area of 400 $m^2$ (at least three plots for each preliminary stratum);
- Non-tree vegetation: crown cover and mean height for herbaceous vegetation and shrubs by measuring randomly selected plots with an area of 4 $m^2$ (at least 10 plots for each preliminary stratum). For stratum with growing trees, the plots can be sub-plots of plots for measuring trees;
- Site and soil factors: soil type, soil depth, slope gradient, intensity of soil erosion, underground water level, etc. and sampling soils for soil organic matter determination;
- Human intervention: prescribed burning, logging, grazing, fuel collecting, medicine collection and others;
- Conducting variation analysis for key factors investigated above. If the variation is large within each preliminary stratum, more intense field investigation shall be conducted and/or further stratification shall be considered in step 5.

**Step 5:** Conducting a further stratification based on supplementary information collected from step 4 above, by checking whether or not each preliminary stratum is sufficiently homogenous or the difference among preliminary strata is significant. The degree of homogeneity may vary from project to project and may be assessed based on stratum size in the context of the project, the degree of natural variability and the significance of the variability to the project and baseline scenarios. A stratum within which there is a significant variation in any of vegetation type, soils and human intervention shall be divided into two or more strata. On the other hand, strata with similar features shall be merged into one stratum. Distinct strata should differ significantly from each other in terms of their baseline and/or project carbon calculation. For example, sites with different species and age classes of trees already growing shall form a separate stratum. Sites with a more intensive collection of fuelwood might also be a separate stratum. On the other hand, site and soil factors may not warrant a separate stratum as long as all lands have a baseline of continued degradation, with little to no vegetation growing, and with no human intervention, and as long as the carbon accumulation in above-ground and below-ground biomass is similar in the project scenario.

**Step 6**: Sub-stratification: Create sub-strata for each stratum based on tree species to be planted and/or on planting year described in CDM-AR-PDD.

**Step 7**: Create stratification map, preferably using a Geographical Information System (GIS).
The GIS will be useful for integrating the data from different sources which can then be used to identify and stratify the project area. In addition, post stratification shall be considered after the first monitoring event, because there are possible changes of project boundaries, tree species arrangement and planting year in comparison to the CDM-AR-PDD. For example, it may be that within one stratum the estimated changes in carbon stocks point to the existence of two sub-populations. Also, two different strata may be similar enough to allow their merging into one stratum. The following factors shall be considered in the post-stratification:

- Data from monitoring of forest establishment and project boundary, e.g., actual project boundary, site and soil preparation, tree species and planting year;
- Data from monitoring of forest management, e.g., actual thinning and fertilization;

Variation in carbon stock changes for each stratum and substratum after the first monitoring event. Strata or substrata shall be grouped into one strata or substrata if they have similar carbon stock, carbon stock change and spatial variation.

**(b) Sampling**

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

***(i) Determining sample size***

The number of plots depends on species variation, accuracy and monitoring interval. In this methodology the total sum of samples (n) is estimated as per a criterion of Neyman of fixed levels of accuracy and costs, according to Wenger (1984)[14]:

$$n = \left(\frac{t}{E}\right)^2 \left[\sum_{h=1}^{L} W_h \cdot s_h \cdot \sqrt{C_h}\right] \cdot \left[\sum_{h=1}^{L} W_h \cdot s_h \Big/ \sqrt{C_h} \cdot \right] \quad (1)$$

$$n_h = n \cdot \frac{W_h \cdot s_h \big/ \sqrt{C_h}}{\sum_{h=1}^{L} W_h \cdot s_h \big/ \sqrt{C_h}} \quad (2)$$

where:

| | |
|---|---|
| $L$ | total number of strata |
| $t$ | t value for a confidence level (95%) |
| $E$ | allowable error (±10% of the mean) |
| $s_h$ | standard deviation of stratum h |
| $n_h$. | number of samples per stratum that is allocated proportional to $W_h \cdot s_h \big/ \sqrt{C_h}$ . |
| $W_h$ | $N_h/N$ |
| $N$ | number of total sample units (all stratum), $N = \sum N_h$ |
| $N_h$ | number of sample units for stratum h, calculated by dividing the area of stratum h by area of each plot |
| $C_h$ | cost to select a plot of the stratum h |

The standard deviation of each stratum ($s_h$) can be determined through local forest inventory on similar site, either using growth volume or tree biomass data. Alternatively, if these data are unavailable, standard deviation of soil condition in each stratum can be used, as soil conditions that are surveyed in the stratification process are major determinants of tree growth within each stratum. The t value for 95% confidence is approximately equal to 2 when the number of sample plot is over 30. As the first step, use 2 as the t value and if the resulting n is less than 30, use the new n to get a new t value and conduct recalculation. This process can be repeated until the calculated n is stabilized. The allowable error is a value on a per-plot basis and can be estimated as ±10% of the expected mean

[14] Wenger, K.F. (ed). 1984. Forestry handbook (2nd edition). New York: John Wiley and Sons.

biomass carbon stock per plot in living trees at the end of a rotation, which can be estimated as part of the ex-ante estimation of the actual net GHG removals by sinks described in the baseline methodology.
It is possible to reasonably modify the sample size after the first monitoring event based on the actual variation of the carbon stock changes determined from taking the n samples.

***(ii) Randomly locating sampling plots***

To avoid subjective choice of plot locations (plot centres, plot reference points, movement of plot centres to more "convenient" positions), the permanent sample plots shall be located systematically with a random start, which is considered good practice in GPG-LULUCF. This can be accomplished with the help of a GPS in the field. The geographical position (GPS coordinate), administrative location, stratum and sub-stratum series number of each plots shall be recorded and archived. The size of plots depends on the density of trees, in general between 100 $m^2$ for dense stands and 1000 $m^2$ for open stands.

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

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

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

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

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

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

**5. Calculation of ex post actual net GHG removal by sinks**
*(Note: Calculation of increase in GHG emissions by the sources within the project boundary as a result of the implementation of an A/R CDM project activity)*
*In choosing parameters and making assumptions project participants should retain conservative approach, i.e. when different values of a parameter are plausible, a value that does not lead to overestimation of the net GHG removals by sinks should be applied.*

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

$$\Delta C_{ACTUAL,t} = \sum_i \sum_j \sum_k \Delta C_{ijk,t} - GHG_{E,t} \quad \textbf{(3)}$$

where:

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

| | |
|---|---|
| $\Delta C_{ijk,t}$ | verifiable changes in carbon stock change in carbon pools for stratum *i* sub-stratum *j* species *k*, tonnes $CO_2$ $yr^{-1}$ for year *t* |
| $GHG_{E,t}$ | increase in GHG emissions by the sources within the project boundary as a result of the implementation of an A/R CDM project activity, tones $CO_2$-e $yr^{-1}$ in year *t* |
| *t* | 1 to end of crediting period |

**(a) Verifiable changes in carbon stocks in the carbon pools**

Since carbon stock changes in pools of soil organic matter, litter and dead wood are ignored in this methodology, the verifiable changes in carbon stock equal to the carbon stock changes in aboveground biomass and belowground biomass within the project boundary, estimated using equation [15]

$$\Delta C_{ijk,t} = (\Delta C_{AB,ijk,t} + \Delta C_{BB,ijk,t}) \cdot 44/12 \quad \textbf{(4)}$$

$$\Delta C_{AB,ijk,t} = (C_{AB,m_2,ijk} - C_{AB,m_1,ijk}) / T \quad \textbf{(5)}$$

$$\Delta C_{BB,ijk,t} = (C_{BB,m_2,ijk} - C_{BB,m_1,ijk}) / T \quad \textbf{(6)}$$

where:

| | |
|---|---|
| $\Delta C_{ijk,t}$ | verifiable changes in carbon stock in living biomass for stratum *i* sub-stratum *j* species *k*, tonnes $CO_2$ $yr^{-1}$ in year *t* |
| $\Delta C_{AB,ijk,t}$ | changes in carbon stock in aboveground biomass for stratum *i* sub-stratum *j* species *k*, tonnes C $yr^{-1}$ in year *t* |
| $\Delta C_{BB,ijk,t}$ | changes in carbon stock in belowground biomass for stratum *i* sub-stratum *j* species *k*, tonnes C $yr^{-1}$ in year *t* |
| $C_{AB,m2,ijk}$ | carbon stock in aboveground biomass for stratum *i* sub-stratum *j* species *k*, calculated at monitoring point $m_2$, tonnes C |
| $C_{AB,\ m1,ijk}$ | carbon stock in aboveground biomass for stratum *i* sub-stratum *j* species *k*, calculated at monitoring point $m_1$, tonnes C |
| $C_{BB,m2,ijk}$ | carbon stock in belowground biomass for stratum *i* sub-stratum *j* species *k*, calculated at monitoring point $m_2$, tonnes C |
| $C_{BB,\ m1,ijk}$ | carbon stock in belowground biomass for stratum *i* sub-stratum *j* species *k*, calculated at monitoring point $m_1$, tonnes C |
| *44/12* | ration of molecular weights of carbon and $CO_2$, dimensionless |
| *T* | number of years between monitoring point $m_2$ and $m_1$, which in this methodology is 5 years. |

For the first monitoring, the first biomass measurement could be omitted, because it is zero.

The total carbon stock in living biomass for each stratum and sub-stratum in each monitoring point (m) is calculated from the area of each stratum and sub-stratum and mean carbon stock in aboveground biomass and belowground biomass per unit area, given by:

$$C_{AB,m,ijk} = A_{ijk} \cdot MC_{AB,m,ijk} \quad \textbf{(7)}$$

$$C_{BB,m,ijk} = A_{ijk} \cdot MC_{BB,m,ijk} \quad \textbf{(8)}$$

[15] Refers to GPG-LULUCF Equation 3.2.3

where:

| | |
|---|---|
| $\Delta C_{AB,ijk,t}$ | changes in carbon stock in aboveground biomass for stratum *i* sub-stratum *j* species *k*, tonnes C $yr^{-1}$ in year *t* |
| $\Delta C_{BB,ijk,t}$ | changes in carbon stock in belowground biomass for stratum *i* sub-stratum *j* species *k*, tonnes C $yr^{-1}$ in year *t* |
| $A_{ijk}$ | area of stratum *i* sub-stratum *j* species *k*, hectare (ha) |
| $MC_{AB,m,ijk}$ | mean carbon stock in aboveground biomass per unit area for stratum *i* sub-stratum *j* species *k*, tonnes C $ha^{-1}$ |
| $MC_{BB,m,ijk}$ | mean carbon stock in belowground biomass per unit area for stratum *i* sub-stratum *j* species *k*, tonnes C $ha^{-1}$ |

The mean carbon stock in aboveground biomass and belowground biomass per unit area is estimated based on field measurements on permanent plots. This can be estimated using two methods, i.e., Biomass Expansion Factors (BEF) method and Allometric Equations method.

***BEF Method***

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

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

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

**Step 4:** Converting the volume of the commercial component of trees into carbon stock in aboveground biomass and belowground biomass via basic wood density, BEF root-shoot ratio and carbon fraction, given by[16]:

[16] Refers to GPG LULUCF Equation 4.3.1

$$MC_{AB} = V \cdot D \cdot BEF \cdot CF \quad \textbf{(9)}$$

$$MC_{BB} = MC_{AB} \cdot R \quad \textbf{(10)}$$

where:

| | |
|---|---|
| $MC_{AB}$ | mean carbon stock in aboveground biomass, tonnes C $ha^{-1}$ |
| $MC_{BB}$ | mean carbon stock in belowground biomass, tonnes C $ha^{-1}$ |
| $V$ | merchantable volume, $m^3$ $ha^{-1}$ |
| $D$ | volume-weighted average wood density, tonnes d.m. $m^{-3}$ merchantable volume |
| $BEF$ | biomass expansion factor for conversion of biomass of merchantable volume to aboveground biomass, dimensionless. |
| $CF$ | carbon fraction, tonnes C (tonne d.m.)$^{-1}$, IPCC default value = 0.5. |
| $R$ | Root-shoot ratio, dimensionless |

***Allometric method***

**Step 1:** As with the step 1 in BEF method, the diameter and preferably height of all trees above some minimum diameter is measured.

**Step 2:** Choosing or establishing appropriate allometric equations.

$$B_{AB} = f(DBH, H) \quad \textbf{(11)}$$

where:

| | |
|---|---|
| $B_{AB}$ | aboveground biomass, tonnes d.m. $ha^{-1}$ |
| $f_i(DBH,H)$ | an allometric equation linking aboveground biomass (d.m. $ha^{-1}$) to diameter at breast height (DBH) and possibly tree height (H). |

The allometric equations are preferably local-derived and species-specific. When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of GPG LULUCF, are used, it is necessary to verify by destructively harvesting, within the project area but outside the sample plots, a few trees of different sizes and estimate their biomass and then compare against a selected equation. If the biomass estimated from the harvested trees is within about ±10% of that predicted by the equation, then it can be assumed that the selected equation is suitable for the project. If this is not the case, it is recommended to develop local allometric equations for the project use. For this, a sample of trees, representing different size classes, is destructively harvested, and its total biomass is determined. The number of trees to be destructively harvested and measured depends on the range of size classes and number of species—the greater the heterogeneity the more trees are required. If resources permit, the carbon content can be determined in the laboratory. Finally, allometric equations are constructed relating the biomass with values from easily measured variables, such as the DBH and total height (see Chapter 4.3 in GPG LULUCF). Also generic allometric equations can be used, as long as it can be proven that they are wrong on the conservative side, i.e., they underestimate carbon sequestration.

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

$$MC_{AB} = B_{AB} \cdot CF \quad \textbf{(12)}$$

where:

| | |
|---|---|
| $MC_{AB}$ | mean carbon stock in aboveground biomass, tonnes C $ha^{-1}$ |
| $B_{AB}$ | aboveground biomass, tonnes d.m. $ha^{-1}$ |
| $CF$ | carbon fraction, tonnes C (tonne d.m.)$^{-1}$, IPCC default value = 0.5. |

**Step 4**: Estimating carbon stock in belowground biomass using above described equation **(10)** and total carbon stock in biomass.

**(b) GHG emissions by sources**

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

$$GHG_{E,t} = E_{FuelBurn,t} + E_{biomassloss,t} + E_{Non-CO_2,BiomassBurn,t} + N_2O_{direct-N_{fertilizer},t} \quad \textbf{(13)}$$

where:

| | |
|---|---|
| $GHG_{E,t}$ | the increase in GHG emission as a result of the implementation of the proposed A/R CDM project activity within the project boundary, tonnes $CO_2$-e $yr^{-1}$ in year $t$ |
| $E_{FuelBurn,t}$ | the increase in GHG emission as a result of burning of fossil fuels within the project boundary, tonnes $CO_2$-e $yr^{-1}$ in year $t$ |
| $E_{biomassloss,t}$ | Decrease in carbon stock in living biomass of existing non-tree vegetation tonnes $CO_2$-e $yr^{-1}$ in year $t$ |
| $E_{Non-CO2,BiomassBurn,t}$ | the increase in Non-$CO_2$ emission as a result of biomass burning within the project boundary, tonnes $CO_2$-e $yr^{-1}$ in year $t$ |
| $N_2O_{direct-N_{fertilizer},t}$ | the increase in $N_2O$ emission as a result of direct nitrogen application within the project boundary, tonnes $CO_2$-e $yr^{-1}$ in year $t$ |

***(i) GHG emissions from burning of fossil fuel***

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

**Step 1:** Monitoring the type and amount of fossil fuels consumed in site preparation and/or logging.

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

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

**Step 3:** Estimating of GHG emissions resulted from the burning of fossil fuel during site preparation and logging. Although some non-$CO_2$ GHG (CO, $CH_4$, NMVOCs) may be released during combustion process, all the released carbon are accounted as $CO_2$ emissions based on the Revised 1996 IPCC Guidelines for energy:

$$E_{FuelBurn,t} = (CSP_{diesel,t} \cdot EF_{diesel} + CSP_{gasoline,t} \cdot EF_{gasoline}) \cdot 0.001 \quad (14)$$

where:

| | |
|---|---|
| $E_{FuelBurn,t}$ | the increase in GHG emission as a result of burning of fossil fuels within the project boundary, tonnes $CO_2$-e $yr^{-1}$ in year $t$ |
| $CSP_{diesel,t}$ | amount of diesel consumption, litre (l) $yr^{-1}$ in year $t$ |
| $CSP_{gasoline,t}$ | amount of gasoline consumption, 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 kg to tonnes |

***(ii) Decrease in carbon stock in living biomass of existing non-tree vegetation***

It is assumed that all existing non-tree vegetation will disappear due to site preparation including slash and burn, or competition from planted trees.

**Step 1:** Measuring and estimating the above- and below-ground biomass of existing non-tree vegetation. This task shall be conducted before the start of project activity. The herbaceous plants can be measured by simple harvesting techniques. A small frame (either circular or square), usually encompassing about 0.5-1.0 $m_2$ or less, is used to aid this task. The material inside the frame is cut to ground level and weighed, and the underground part is also dug and weighed. Well-mixed samples are then collected and oven dried to determine dry-to-wet matter ratios. These ratios are then used to convert the entire sample to oven-dry matter. For shrubs, destructive harvesting techniques can also be used to measure the living biomass. An alternative approach, if the shrubs are large, is to develop local shrub allometric equations based on variables such as crown area and height or diameter at base of plant or some other relevant variable (e.g., number of stems in multi-stemmed shrubs). The equations would then be based on regressions of biomass of the shrub versus some logical combination of the independent variables. The independent variable or variables would then be measured in the sampling plots (Refers to Chapter 4.3 in GPG LULUCF).

**Step 2:** Estimating decrease in carbon stock of existing non-tree vegetation

$$E_{biomassloss,t} = \sum_i A_i \cdot B_{non-tree,i} \cdot CF_{non-tree} \cdot 44/12 \quad \forall t = 1 \quad (15)$$

$$E_{biomassloss,t} = 0 \quad \forall t > 1$$

where:

| | |
|---|---|
| $E_{biomassloss,t}$ | Decrease in carbon stock in living biomass of existing non-tree vegetation tonnes $CO_2$-e $yr^{-1}$ in year $t$ |
| $A_i$ | area of stratum $i$, ha |
| $B_{non-tree,i}$ | average biomass stock of non-tree vegetation on land to be planted before the start of a proposed A/R CDM project activity for stratum $i$, tonnes d.m. $ha^{-1}$ |
| $CF_{non-tree}$ | the carbon fraction of dry biomass in non-tree vegetation, tonnes C (tonne d.m.)$^{-1}$ |
| *44/12* | ration of molecular weights of $CO_2$ and carbon, dimensionless |

***(iii) GHG emissions from biomass burning***

Slash and burn or removal of pre-existing vegetation occurs traditionally in some regions during site preparation before planting and/or replanting. Since $CO_2$ emission has already in above bullet, only non-$CO_2$ emissions are accounted here.

**Step 1:** Estimating the mean aboveground biomass stock per unit area before slash and burn. The degraded land or logged land is usually dominated by herbaceous plants and shrubs. Therefore this value can be obtained from step 1 of the last bullet.

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

**Step 3:** Estimating of GHG emissions resulted from the slash and burn based on revised IPCC 1996 Guideline for LULUCF and GPG LULUCF:

$$E_{Non-CO_2,BiomassBurn,t} = E_{BiomassBurn,N_2O} + E_{BiomassBurn,CH_4} \quad \forall t = 1 \qquad \textbf{(16)}$$

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

where:

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

$$E_{BiomassBurn,N_2O} = E_{BiomassBurn,C} \cdot (N/C\,ratio) \cdot ER_{N2O} \cdot 44/28 \cdot GWP_{N2O} \qquad \textbf{(17)}$$

$$E_{BiomassBurn,CH_4} = E_{BiomassBurn,C} \cdot ER_{CH4} \cdot 16/12 \cdot GWP_{CH4} \qquad \textbf{(18)}$$

where[17]:

| | |
|---|---|
| $E_{BiomassBurn,\,N2O}$ | $N_2O$ emission from biomass burning in slash and burn, tonnes $CO_2$-e $yr^{-1}$ |
| $E_{BiomassBurn,\,CH4}$ | $CH_4$ emission from biomass burning in slash and burn, tonnes $CO_2$-e $yr^{-1}$ |
| $E_{BiomassBurn,C}$ | loss of aboveground biomass carbon due to slash and burn, t C $yr^{-1}$ |
| *N/C ratio* | nitrogen-carbon ratio, dimensionless |
| *44/28* | ration of molecular weights of $N_2O$ and nitrogen, dimensionless |
| *16/12* | ration of molecular weights of $CH_4$ and carbon, dimensionless |
| $ER_{N2O}$ | IPCC default emission ratio for $N_2O$ = 0.007 |
| $ER_{CH4}$ | IPCC default emission ratio for $CH_4$ = 0.012 |
| $GWP_{N2O}$ | Global Warming Potential for $N_2O$, kg $CO_2e$ (kg $N_2O)^{-1}$ (IPCC default = 310, valid for the first commitment period) |
| $GWP_{CH4}$ | Global Warming Potential for $CH_4$ , kg $CO_2e$ (kg $CH_4)^{-1}$ (valid for the first commitment period) |

[17] Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF and Equation 3.2.19 in GPG LULUCF

$$E_{BiomassBurn,C} = \sum_i A_{burn,i} \cdot B_i \cdot CE \cdot CF \quad (19)$$

where:

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

**(iv) Nitrous oxide emissions from nitrogen fertilization practices**

Only direct $N_2O$ emissions from nitrogen fertilization are monitored and estimated in this methodology, because indirect $N_2O$ emissions (e.g., leaching and runoff) are smaller in forest than in agricultural land and the emission factor used in the 1996 IPCC Guidelines appears to be high (GPG LULUCF). The method of 1996 IPCC Guideline, GPG-2000 and GPG LULUCF can be used to estimate the direct $N_2O$ emissions.

**Step 1:** Monitoring and estimating the amount of nitrogen in synthetic and organic fertilizer used within the project boundary;

$$N_{SN-Fert,t} = \sum_k A_k \cdot N_{SN-Fert,k,t} \cdot 0.001 \quad (20)$$

$$N_{ON-Fert,t} = \sum_k A_k \cdot N_{ON-Fert,k,t} \cdot 0.001 \quad (21)$$

where:

| | |
|---|---|
| $N_{SN-Fert,t}$ | total use of synthetic fertiliser within the project boundary, tonnes N $yr^{-1}$ in year *t* |
| $N_{ON-Fert,t}$ | total use of organic fertiliser within the project boundary, tonnes N $yr^{-1}$ in year *t* |
| $A_k$ | area of tree species *k* with fertilization, ha $yr^{-1}$ |
| $N_{SN-Fert,k,t}$ | use of synthetic fertiliser per unit area for tree species *k*, kg N $ha^{-1}$ $yr^{-1}$ in year *t* |
| $N_{ON-Fert,k,t}$ | use of organic fertiliser per unit area for tree species *k*, kg N $ha^{-1}$ $yr^{-1}$ in year *t* |
| *0.001* | conversion kg N to tonnes N |

**Step 2:** Choosing the fractions of synthetic and organic fertiliser nitrogen that is emitted as $NO_X$ and $NH_3$, and emission factors. As noted in GPG 2000 and 1996 IPCC Guideline, the default emission factor is 1.25 % of applied N, and this value should be used when country-specific factors are unavailable. Project developer may develop specific emission factors that are more appropriate for their project. Specific good practice guidance on how to derive specific emission factors is given in Box 4.1 of GPG 2000. The default values for the fractions of synthetic and organic fertiliser nitrogen that are emitted as $NO_X$ and $NH_3$ are 0.1 and 0.2 respectively in 1996 IPCC Guideline[18].

**Step 3:** Calculating direct $N_2O$ emissions from nitrogen fertilization[19]

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

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

$$N_2O_{direct-N_{fertilizer},t} = \left[(F_{SN} + F_{ON}) \cdot EF_1\right] \cdot 44/28 \cdot GWP_{N20} \quad \textbf{(22)}$$

$$F_{SN} = N_{SN-Fert,t} \cdot (1 - Frac_{GASF}) \quad \textbf{(23)}$$

$$F_{ON} = N_{ON-Fert,t} \cdot (1 - Frac_{GASM}) \quad \textbf{(24)}$$

where:

| | |
|---|---|
| $N_2O_{direct-N_{fertilizer},t}$ | the direct $N_2O$ emission as a result of nitrogen application within the project boundary during monitoring interval, tonnes $CO_2$-e $yr^{-1}$ in year *t* |
| $F_{SN}$ | Amount of synthetic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_X$, tonnes N $yr^{-1}$ |
| $F_{ON}$ | Annual amount of organic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_X$, tonnes N $yr^{-1}$ |
| $N_{SN-Fert}$ | Amount of synthetic fertilizer nitrogen applied, tonnes N $yr^{-1}$ |
| $N_{SN-Fert}$ | Amount of organic fertilizer nitrogen applied, tonnes N $yr^{-1}$ |
| $EF_1$ | Emission Factor for emissions from N inputs, tonnes $N_2O$-N (tonnes N $input)^{-1}$ |
| $Frac_{GASF}$ | the fraction that volatilises as $NH_3$ and $NO_X$ for synthetic fertilizers, dimensionless |
| $Frac_{GASF}$ | the fraction that volatilises as $NH_3$ and $NO_X$ for organic fertilizers, dimensionless |
| *44/28* | ration of molecular weights of $N_2O$ and nitrogen, dimensionless |
| $GWP_{N2O}$ | Global Warming Potential for $N_2O$, kg $CO_2$e (kg $N_2O)^{-1}$ (IPCC default = 310, valid for the first commitment period) |

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

**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 | Pro-portion of data monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.1.01 | Stratum ID | Stratifica-tion map | Alpha nu-meric | | 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 | Stratum ID | Stratifica-tion map | Alpha nu-meric | | 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 precision control |
| 2.1.1.04 | Precision level | | % | | Before the start of the project | 100% | For the purpose of QA/QC and measuring and monitoring precision control |
| 2.1.1.05 | Standard deviation of each stratum | | | e | Before the start of the project | 100% | Used for estimating numbers of sample plots of each stratum and sub-stratum |
| 2.1.1.06 | Number of sample plots | | | c | Before the start of the project | 100% | For each stratum and sub-stratum, calcu-lated from 2.1.1.03-2.1.1.05 using equa-tion (1)-(2) |
| 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 | Pro-portion of data monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.1.08 | Plot location | Project and plot map and GPS locating | | m | 5 years | 100% | Using GPS to locate before start of the project and at time of each field meas-urement |
| 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 meas-urement | year | m | 5 years | 100% sam-pling plot | Counted since the planted year |
| 2.1.1.11 | Number of trees | Plot meas-urement | number | m | 5 years | 100% trees in plots | Counted in plot measurement |
| 2.1.1.12 | Diameter at breast height (DBH) | Plot measure-ment | cm | m | 5 year | 100% trees in plots | Measuring at each monitoring time per sampling method |
| 2.1.1.13 | Mean DBH | Calculated from 2.1.1.12 | cm | c | 5 year | 100% of sampling plots | Calculated from 2.1.1.11 and 2.1.1.12 |
| 2.1.1.14 | Tree height | Plot measure-ment | m | m | 5 year | 100% trees in plots | Measuring 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% of sampling plots | Calculated from 2.1.1.11 and 2.1.1.14 |

| ID number | Data Variable | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Pro-portion of data monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.1.16 | Merchant-able volume | Calculated or plot measure-ment | $m^3 \cdot ha^{-1}$ | 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 den-sity | Local-derived, national inventory, GPG for LULUCF | t d.m. $m^{-3}$ | e | 5 year | 100% of sampling plots | Local-derived and species-specific value have the priority |
| 2.1.1.18 | Biomass expansion factor (BEF) | Local-derived, national inventory, GPG for LULUCF | dimen-sionless | e | 5 year | 100% of sampling plots | Local-derived and species-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 sampling plots | Local-derived and species-specific value have the priority |
| 2.1.1.20 | Root-shoot ratio | Local-derived, national inventory, GPG for LULUCF | Dimen-sionless | e | 5 year | 100% of sampling plots | Local-derived and species-specific value have the priority |

| ID number | Data Variable | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Pro-portion of data monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.1.21 | Carbon stock in above-ground biomass of plots | Calculated from equa-tion | $t\ C\ ha^{-1}$ | c | 5 year | 100% of sampling plots | Calculated from equation (9) via 2.1.1.16-2.1.1.19, or from equation (11) and (12) via 2.1.1.13, 2.1.1.15 and 2.1.1.19 |
| 2.1.1.22 | Carbon stock in below-ground biomass of plots | Calculated from equa-tion | $t\ C\ ha^{-1}$ | c | 5 year | 100% of sampling plots | Calculated from equation (10) via 2.1.1.20-2.1.1.21, or equation (10) via 2.1.1.19 and 2.1.1.21 |
| 2.1.1.23 | Mean Car-bon 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 strata and sub-strata | Calculated from 2.1.1.06-2.1.1.21 |

| ID number | Data Variable | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Pro-portion of data monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.1.24 | Mean Car-bon 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 strata and sub-strata | Calculated from 2.1.1.06 and 2.1.1.22 |
| 2.1.1.25 | Area of stratum and sub-stratum | Stratifica-tion map and data | ha | m | 5 year | 100% of strata and sub-strata | Actual area of each stratum and sub-stra-tum |
| 2.1.1.26 | Carbon stock in above-ground biomass of stratum per species | Calculated from equa-tion (7) | t C | c | 5 year | 100% of strata and sub-strata | Calculated from equation (7) via 2.1.1.23 and 2.1.1.25 |
| 2.1.1.27 | Carbon stock in below-ground biomass of r stratum per species | Calculated from equa-tion (8) | t C | c | 5 year | 100% of strata and sub-strata | Calculated from equation (8) 2.1.1.24 and 2.1.1.25 |

| ID number | Data Variable | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Pro-portion of data monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.1.28 | Carbon stock change in above-ground biomass of stratum per species | Calculated from equa-tion (5) | $t\ C\ yr^{-1}$ | c | 5 year | 100% of strata and sub-strata | Calculated from equation (5) via 2.1.1.26 |
| 2.1.1.29 | Carbon stock change in below-ground biomass of stratum per species | Calculated from equa-tion (6) | $t\ C\ yr^{-1}$ | c | 5 year | 100% of strata and sub-strata | Calculated from equation (6) 2.1.1.27 |
| 2.1.1.30 | Total carbon stock change | Calculated from equa-tion (4) | $t\ CO_2\text{-}e\ yr^{-1}$ | c | 5 year | 100% project area | Summing up carbon stock change in 2.1.1.28 and 2.1.1.29 for all strata, sub-strata and tree species |

**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) or estimated (e) | Recording frequency | Proportion of data to be monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.2.01 | Amount of diesel consumed in machinery use for site prep, thinning or logging | On-site monitoring | litre | m | annually | 100% | Measuring either diesel consumption per unit area for site preparation, or per unit volume logged or thinned |
| 2.1.2.02 | Amount of gasoline consumed in machinery use for site prep, thinning or logging | On-site monitoring | litre | m | annually | 100% | Measuring either diesel consumption per unit area for site preparation, or per unit volume logged or thinned |
| 2.1.2.03 | Emission factor for diesel | GPG 2000, IPPCC Guidelines, national inventory | kg/ litre | e | At beginning of the project | 100% | National inventory value should has priority |

| ID number | Data variable | Source of data | Data unit | Measured (m), calculated (c) or estimated (e) | Recording frequency | Proportion of data to be monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.2.04 | Emission factor for gasoline | GPG 2000, IPPCC Guidelines, national inventory | kg/ litre | e | At beginning of the project | 100% | National inventory value should has priority |
| 2.1.2.05 | Emission from fossil fuel use within project boundary | Calculated from equation (14) | t $CO_2$-e $yr^{-1}$ | e | annually | 100% | Calculating using equation (14) via 2.1.2.01-2.1.2.04 |
| 2.1.2.06 | Area of slash and burn | Measured during implementation | ha | m | annually | 100% | Measured for different strata and sub-strata |
| 2.1.2.07 | Mean biomass stock per unit area before slash and burn | Measured before slash and burn | t d.m. $ha^{-1}$ | m | Annually | 100% | Sampling survey for different strata and sub-strata before slash and burn |
| 2.1.2.08 | Proportion of biomass burnt | Measured after slash and burn | dimensionless | m | Annually | 100% | Sampling survey after slash and burn |
| 2.1.2.09 | Biomass combustion efficiency | GPG LULUCF National inventory | dimensionless | e | Before the start of the project | 100% | IPCC default value (0.5) is used if no appropriate value |

| ID number | Data variable | Source of data | Data unit | Measured (m), calculated (c) or estimated (e) | Recording frequency | Proportion of data to be monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.2.10 | Carbon fraction | Local, national, IPCC | t C.(t d.m.)$^{-1}$ | e | 5 year | 100% | 2.1.1.19 can be used if no appropriate value |
| 2.1.2.11 | Loss of above-ground biomass carbon due to slash and burn | Calculated using equation (19) | t C yr$^{-1}$ | c | 5 year | 100% | Calculated using equation (19) |
| 2.1.2.12 | N/C ratio | GPG LULUCF National inventory, publications | dimensionless | e | Before the start of the project | 100% | IPCC default value (0.01) is used if no appropriate value |
| 2.1.2.13 | $N_2O$ emission from biomass burn | Calculated using equation (17) | t $CO_2$-e yr$^{-1}$ | c | 5 year | 100% | Calculated using equation (17) via 2.1.2.11-2.1.2.12 |
| 2.1.2.14 | $CH_4$ emission from biomass burn | Calculated using equation (18) | t $CO_2$-e yr$^{-1}$ | c | 5 year | 100% | Calculated using equation (18) via 2.1.2.11 |
| 2.1.2.15 | the increase in Non-$CO_2$ emission as a result of biomass burning in slash and burn | Calculated using equation (16) | t $CO_2$-e yr$^{-1}$ | c | 5 year | 100% | Calculated using equation (16) via 2.1.2.11, 2.1.2.13, 2.1.2.14 |

| ID number | Data variable | Source of data | Data unit | Measured (m), calculated (c) or estimated (e) | Recording frequency | Proportion of data to be monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.2.16 | Amount of synthetic fertilizer N applied per unit area | Monitoring activity | kg N $ha^{-1}$ $yr^{-1}$ | m | annually | 100% | For different tree species and/or management intensity |
| 2.1.2.17 | Amount of organic fertilizer N applied per unit area | Monitoring activity | kg N $ha^{-1}$ $yr^{-1}$ | m | annually | 100% | For different tree species and/or management intensity |
| 2.1.2.18 | area of land with N applied | Monitoring activity | ha $yr^{-1}$ | m | annually | 100% | For different tree species and/or management intensity |
| 2.1.2.19 | Amount of synthetic fertilizer N applied | Calculated using equation (20) | t N $yr^{-1}$ | c | annually | 100% | Calculated using equation (20) via 2.1.2.16 and 2.1.2.18 |
| 2.1.2.20 | Amount of organic fertilizer N applied | Calculated using equation (21) | t N $yr^{-1}$ | c | annually | 100% | Calculated using equation (21) via 2.1.2.17 and 2.1.2.18 |
| 2.1.2.21 | Fraction that volatilises as $NH_3$ and $NO_X$ for synthetic fertilizers | GPG 2000, GPG LULUCF, IPCC Guideline National inventory | dimensionless | e | Before start of monitoring | 100% | IPCC default value (0.1) is used if no more appropriate data |

| ID number | Data variable | Source of data | Data unit | Measured (m), calculated (c) or estimated (e) | Recording frequency | Proportion of data to be monitored | Comment |
|---|---|---|---|---|---|---|---|
| 2.1.2.22 | Fraction that volatilises as $NH_3$ and $NO_X$ for organic fertilizers | GPG 2000, GPG LULUCF, IPCC Guidelines National inventory | dimensionless | e | Before start of monitoring | 100% | IPCC default value (0.2) is used if no more appropriate data |
| 2.1.2.23 | Emission factor for emission from N input | GPG 2000, GPG LULUCF, IPCC Guidelines National inventory | $N_2O$ N-input$^{-1}$ | e | Before start of monitoring | 100% | IPCC default value (1.25%) is used if no more appropriate data |
| 2.1.2.24 | Direct $N_2O$ emission of N input | Calculated using equation (22) | t $CO_2$-e yr$^{-1}$ | c | annually | 100% | Calculated using equation (22) via 2.1.2.19-2.1.2.23 |
| 2.1.2.25 | Total increase in GHG emission | Calculated using equation (13) | t $CO_2$-e yr$^{-1}$ | c | annually | 100% | Calculated using equation (13) via 2.1.2.05, 2.1.2.11, 2.1.2.15 and 2.1.2.24 |

**7. Leakage**

The leakage represents the increase in GHG emissions by sources which occurs outside the boundary of an A/R CDM project activity which is measurable and attributable to the A/R CDM project activity. Land used for reforestation is abandoned, economical unattractive land rather than forested land, agricultural land or grazing land, thus, as the result of an A/R CDM project activity, deforestation, agricultural or pastoral activities will not be displaced from the project sites to other locations. As per the conditions in section B, the proposed A/R CDM project activity will provide as the same amount of fuel for local people, so the there is no displace of fuel collection. However, in the context of A/R activities, fossil fuel combustion from vehicles use due to the transportation of seedling, labours, staff, harvest products, to and/or from project sites, as a result of the proposed A/R CDM project activity, emits greenhouse gases. This can be monitored and estimated using IPCC bottom-up approach.

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

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

**Step 3:** Estimating the $CO_2$ emissions using bottom-up approach described in GPG 2000 for energy sector[20].

$$LK_t = \sum_i \sum_j (EF_{ij} \cdot FuelConsumption_{ij,t}) \cdot 0.001 \quad \textbf{(25)}$$

$$FuelConsumption_{ij,t} = n_{ij,t} \cdot k_{ij,t} \cdot e_{ij,t} \quad \textbf{(26)}$$

where:

| | |
|---|---|
| $LK_t$ | $CO_2$ emissions due to fossil fuel combustion from vehicles, tonnes $CO_2$-e $yr^{-1}$ in year *t* |
| *i* | vehicle type |
| *j* | fuel type |
| $EF_{ij}$ | emission factor for vehicle type *i* with fuel type *j*, kg $CO_2$-e $l^{-1}$ |
| $FuelConsumption_{ij}$ | consumption of fuel type *j* of vehicle type *i*, litre $yr^{-1}$ in year *t* |
| $n_{ij}$ | number of vehicle type *i* used, $yr^{-1}$ in year *t* |
| $k_{ij}$ | kilometres travelled annually by each of vehicle type *i* with fuel type *j*, km $yr^{-1}$ in year *t* |
| $e_{ij}$ | average litres consumed per kilometre travelled for vehicle type *i* with fuel type *j*, litre $km^{-1}$in year *t* |

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

**8. Data to be collected and archived for leakage**

**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 | Pro-portion of data monitored | Comment |
|---|---|---|---|---|---|---|---|
| 3.1.01 | Number of each vehicle type used | Monitoring of project activity | num-ber | | Annually | 100% | Monitoring number of each vehicle type used |
| 3.1.02 | Emission factors for road trans-portation | GPG 2000, IPCC Guidelines, national inventory | kg $CO_2$-e $l^{-1}$ | e | Annually | 100% | National or local value has the priority |
| 3.1.03 | Kilometres travelled by vehicles | Monitoring of project activity | km | m | Annually | 100% | Monitoring kilometres for each vehicle type and fuel type used |
| 3.1.04 | Fuel con-sumption per km | Local data, national data, IPCC | litre $km^{-1}$ | e | 5 years | 100% | estimated for each vehicle type and fuel type used |
| 3.1.05 | Fuel con-sumption for road trans-portation | Calculated using equation (27) | litre | c | Annually | 100% | Calculated using equation (27) via 3.1.01, 3.1.03, 3.1.04 |
| 3.1.06 | Leakage due to vehicle use for transpor-tation | Calculated using equation (26) | t $CO_2$-e $yr^{-1}$ | c | Annually | 100% | Calculated using equation (26) via 3.1.02, 3.1.05 |

**9. Ex post net anthropogenic GHG removal by sinks**

The net anthropogenic GHG removals by sinks is the actual net GHG removals by sinks minus the baseline net GHG removals by sinks minus leakage, therefore, following general formula can be used to calculate the net anthropogenic GHG removals by sinks of an A/R CDM project activity ($C_{AR-CDM}$), in tonnes $CO_2$-e $yr^{-1}$:

$$C_{AR-CDM} = \Delta C_{ACTUAL} - \Delta C_{BSL} - LK_{Vehicle,CO2} \quad \textbf{(27)}$$

where:

| | |
|---|---|
| $C_{AR-CDM}$ | net anthropogenic greenhouse gas removals by sinks, tonnes $CO_2$-e $yr^{-1}$ |
| $C_{ACTUAL}$ | actual net GHG removals by sinks, tonnes $CO_2$-e $yr^{-1}$ |
| $C_{BSL}$ | baseline net GHG removals by sinks, tonnes $CO_2$-e $yr^{-1}$ |
| $LK_{Vehicle,CO2}$ | total GHG emissions due to fossil fuel combustion from vehicles, tonnes $CO_2$-e $yr^{-1}$ |

**Ways of calculating t-CER and l-CER:**

t-CERs reflect the *existing stock change at the time of verification* minus project emissions minus leakage (t $CO_2$):

$$t-CER(t_v) = C_P(t_v) - C_B(t_v) - \sum_{0}^{t_v} E_t - \sum_{0}^{t_v} LK_t \quad \textbf{(28)}$$

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

$$C_B(t_v) = \sum_{1}^{t_v} \Delta C_{BSL,t}$$

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 $CO_2$):

$$l-CER(t_v) = [C_P(t_v) - C_P(t_v - \kappa)] - [C_B(t_v) - C_B(t_v - \kappa)] - \sum_{t_{v-\kappa}}^{t_v} E_t - \sum_{t_{v-\kappa}}^{t_v} LK_t \quad \textbf{(29)}$$

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

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

where:

| | |
|---|---|
| $t\text{-}CER(t_v)$ | t-CERs issued at year of verification $t_v$ (t $CO_2$) |
| $l\text{-}CER(t_v)$ | 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 |
| $\kappa$ | Time span between two verification occasions (year) |

**10. Uncertainties**

**(a) Uncertainties to be considered**

This methodology uses methods from IPCC GPG-LULUCF, GPG 2000, as well as related rules for A/R CDM project activities to estimate the baseline net GHG removals by sinks, the leakage, the actual net GHG removals by sinks and the net anthropogenic GHG removals by sinks. Potential uncertainties arise from emission factors and sampling surveys. These uncertainties and their countermeasures are elaborated below.

**(i)** Uncertainties arising from, for example, biomass expansion factors (BEFs) or basic wood density would result in uncertainties in the estimation of both the baseline net GHG removals by sinks and the actual net GHG removals by sinks, especially when global default values are used. This methodology recommends project participants to identify key parameters that would significantly influence the estimation results, and to try to develop local values for key factors using various data sources including direct measurement, and/or to choose conservative values.

**(ii)** Uncertainties arising from sample survey (statistical uncertainties): The sampling error for each stratum may result from large spatial variability. Therefore an appropriate sampling protocol is necessary, including sufficient number of samples, variation and uncertainty analysis, sound quality control and quality assurance.

**(b) Uncertainty assessment**

The percentage uncertainty on the estimate of certain parameters and data (yield table values, biomass expansion factors, wood density, carbon fraction and other biophysical parameters) can be assessed from the sample standard deviation of measured sample values, using half the 95% confidence interval width divided by the estimated value, i.e.[21],

$$U_s(\%) = \frac{\frac{1}{2}(95\% ConfidenceIntervalWidth)}{\mu} \cdot 100 \quad \textbf{(30)}$$

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

where:

| | |
|---|---|
| $U_s$ | percentage uncertainty on the estimate of the mean parameter value, % |
| $\mu$ | sample mean value of the parameter |
| $\sigma$ | sample standard deviation of the parameter |

[21] Box 5.2.1 in GPG LULUCF

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[22].

The percentage uncertainties on quantities that are the product of several terms are then estimated using the following equation[23]:

$$U_S = \sqrt{U_1^2 + U_2^2 + \cdots U_n^2} \quad \textbf{(31)}$$

where:

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

The percentage uncertainty on quantities that are the sum or difference of several terms can be estimated using following simple error propagation equation[24]:

$$U_c = \frac{\sqrt{(U_{s1} \cdot C_{s1})^2 + (U_{s2} \cdot C_{s2})^2 + \cdots + (U_{sn} \cdot C_{sn})^2}}{\left|C_{s1} + C_{s2} + \cdots + C_{sn}\right|} \quad \textbf{(32)}$$

where:

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

This methodology can basically reduce uncertainties through:

**(i)** Proper stratification of the project area into relatively homogeneous strata;
**(ii)** In setting values for BEFs and root-shoot ratios.

[22] GPG LULUCF Chapter 5.2 and Chapter 3.2
[23] Equation 5.2.1 in GPG LULUCF
[24] Refers to equation 5.2.2 in GPG LULUCF

## Section IV: Lists of variables, acronyms and references

### 1. List of variables used in equations:

| Parameters | Unit | Descriptions |
|---|---|---|
| IRR, NPV cost benefit ratio, or unit cost of service | | Indicators of investment analysis |
| $\Delta C_{BSL}$ | | Baseline net GHG removals by sinks |
| $\Delta C_{ij}$ | | average annual carbon stock change in living biomass of trees |
| $\Delta C_{G,ij}$ | | average annual increase in carbon due to biomass growth |
| $C_{L,ij}$ | | average annual decrease in carbon due to biomass loss |
| $A_{ij}$ | ha | Area of stratum and species |
| $G_{TOTAL,ij}$ | | annual average increment rate in total biomass per hectare for stratum |
| $CF$ | | carbon fraction |
| $44/12$ | | ration of molecular weights of $CO_2$ and carbon |
| $G_{w,ij}$ | | average annual aboveground biomass increment |
| $R_j$ | | Root-shoot ratio for tree species |
| $L_{v,ij}$ | | average annual net increment in volume suitable for industrial processing |
| $D_j$ | | Species specific basic wood density |
| $BEF_{1,j}$ | | Species specific biomass expansion factor for conversion of annual net increment (including bark) to aboveground biomass increment |
| $BEF_{2,j}$ | | Species specific biomass expansion factor for conversion of merchantable volume to aboveground tree biomass |
| $C_{2,ij}$ | | total carbon stock in living biomass of trees, calculated at time 2 |
| $C_{1,ij}$ | | total carbon stock in living biomass of trees, calculated at time 1 |
| $V_{ij}$ | | merchantable volume |
| $\Delta C_{ACTUAL}$ | | actual net greenhouse gas removals by sinks |
| $C_{AB,ij}$ | | carbon stock in aboveground biomass |
| $C_{BB,ij}$ | | carbon stock in belowground biomass |

| | |
|---|---|
| $GHG_E$ | increase in GHG emissions by the sources within the project boundary as a result of the implementation of an A/R CDM project activity |
| $f_j(DBH,H)$ | allometric equation |
| $L_{fellings,ij}$ | annual carbon loss due to commercial fellings |
| $L_{fuelwood,ij}$ | annual carbon loss due to fuelwood gathering of trees |
| $L_{other\ losses,ij}$ | annual natural losses of carbon in living trees |
| $H_{ij}$ | annually extracted volume |
| $FG_{ij}$ | Annual volume of harvested fuel wood |
| $A_{\ disturbance,ij}$ | Areas affected by disturbances |
| $F_{\ disturbance,ij}$ | the fraction of the biomass in living trees for stratum *i* species *j* affected by disturbance |
| $B_{W,j}$ | average biomass stock of living trees |
| $E_{FuelBurn}$ | emissions from burning of fossil fuels |
| $E_{biomassloss}$ | Decrease in carbon stock in living biomass of existing non-tree vegetation |
| $E_{Non\text{-}CO2,BiomassBurn}$ | the increase in non-$CO_2$ emission as a result of biomass burning within the project boundary |
| $N_2O_{direct-N_{fertilizer}}$ | The increase in $N_2O$ emission as a result of direct nitrogen application within the project boundary |
| $CSP_{diesel}$ | amount of diesel consumption |
| $CSP_{gasoline}$ | amount of gasoline consumption |
| $EF_{diesel}$ | emission factor for diesel |
| $EF_{gasoline}$ | emission factor for gasoline |
| $B_{non\text{-}tree,i}$ | average biomass stock on land to be planted, before the start of a proposed A/R CDM project activity |
| $CF_{non\text{-}tree}$ | the carbon fraction of dry biomass in non-tree vegetation |
| $E_{BiomassBurn,C}$ | loss of carbon due to slash and burn |
| $E_{BiomassBurn,\ N2O}$ | $N_2O$ emission from biomass burning in slash and burn |
| $E_{BiomassBurn,\ CH4}$ | $CH_4$ emission from biomass burning in slash and burn |
| $B_i$ | average stock in living biomass before burning |
| $A_{burn,i}$ | area of slash and burn |

| | |
|---|---|
| *CE* | average biomass combustion efficiency |
| *N/C ratio* | |
| $N_2O_{\text{direct-Nfertilizer}}$ | Emission of $N_2O$ caused by nitrogen fertilization |
| $F_{SN}$ | Annual amount of synthetic fertilizer nitrogen adjusted for volatilization as $NH_3$ and $NO_X$ |
| $F_{ON}$ | Annual amount of organic fertilizer nitrogen adjusted for volatilization as $NH_3$ and $NO_X$ |
| $EF_1$ | Emission Factor for emissions from N inputs |
| $Frac_{GASF}$ | the fraction that volatilises as $NH_3$ and $NO_X$ for synthetic fertilizers |
| $Frac_{GASM}$ | the fraction that volatilises as $NH_3$ and $NO_X$ for organic fertilizers |
| $N_{SN\text{-}Fert}$ | Amount of synthetic fertilizer nitrogen applied |
| $N_{SN\text{-}Fert}$ | Amount of organic fertilizer nitrogen applied |
| *LK* | total GHG emissions caused by transportation |
| $LK_{Vehicle,CO2}$ | $CO_2$ emissions caused by transportation |
| $LK_{Vehicle,N2O}$ | $N_2O$ emissions caused by transportation |
| $LK_{Vehicle,CH4}$ | $CH_4$ emissions caused by transportation |
| $EF_{ij}$ | emission factor for vehicle type *i* with fuel type *j* |
| $FuelConsumption_{ij}$ | consumption of fuel type *j* of vehicle type *i* |
| $e_{ij}$ | average litres consumed per kilometre travelled for vehicle type *i* with fuel type *j* |
| $k_{ij}$ | kilometres travelled by each of vehicle type *i* with fuel type *j* |
| $n_{ij}$ | number of vehicles |

**2. References:**

All references are quoted in footnotes.