# Approved afforestation and reforestation baseline methodology AR-AM0004

## "Reforestation or afforestation of land currently under agricultural use"

**Source**

This methodology is based on the draft CDM-AR-PDD "Reforestation around Pico Bonito National Park, Honduras", whose baseline study, monitoring and verification plan and project design document were prepared by the Fundación Parque Nacional de Pico Bonito (FUPNAPIB), Ecologic Development Fund, Winrock International, USAID MIRA and the World Bank (BioCarbon Fund).

For more information regarding the proposal and its consideration by the Executive Board please refer to case ARNM0019: "Reforestation around Pico Bonito National Park, Honduras" 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 the following project activities:

- Afforestation or reforestation of degraded land, which is subject to further degradation or remains in a low carbon steady state, through assisted natural regeneration, tree planting, or control of pre-project grazing and fuel-wood collection activities (including in-site charcoal production).
- The project activity can lead to a shift of pre-project activities outside the project boundary, e.g. a displacement of agriculture, grazing and/or fuel-wood collection activities, including charcoal production;

The conditions under which the methodology is applicable are:

- Lands to be afforested or reforested are degraded and the lands are still degrading or remain in a low carbon steady state.
- Site preparation does not cause significant longer term net decreases of soil carbon stocks or increases of non-$CO_2$ emissions from soil.
- Carbon stocks in soil organic carbon, litter and dead wood 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.
- Flooding irrigation is not permitted;
- Soil drainage and disturbance are insignificant, so that non $CO_2$-greenhouse gas emissions from this these types of activities can be neglected;
- The amount of nitrogen-fixing species (NFS) used in the AR CDM project activity is not significant, so that greenhouse gas emissions from denitrification can be neglected in the estimation of actual net greenhouse gas removals by sinks.

- The AR CDM project activity is implemented on land where there are no other on-going or planned AR activities (no afforestation/reforestation in the baseline).

## 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 description

**Baseline methodology steps**

i. The project boundary is defined for all eligible discrete parcels of land to be afforested or reforested that are under the control of the project participants at the starting date of the project activity or expected to become under the control of the project participants during the implementation of the project activity during the crediting period.

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

iii. The baseline scenario is determined by the following steps:

Step 1. Demonstration that the proposed AR CDM project activity meets the conditions under which the methodology is applicable and that baseline approach 22(a) can be used.

Step 2. Delineation of the project boundary.

Step 3. Analysis of historical land use, local and sectoral land-use policies or regulations and land use alternatives.

Step 4. Stratification of the AR CDM project area:

- Stratification according to pre-existing conditions and baseline projections;
- Stratification according to the planned AR CDM project activity;
- Final *ex ante* stratification;

Step 5. Determination of the baseline land-use / land-cover for each stratum.

Step 6. Determination of baseline carbon stock changes in each stratum.

iv. The *ex ante* calculation of baseline net GHG removals by sinks is performed by strata. For strata without growing trees or shrubs, the methodology assumes that the carbon stock of the baseline scenario remains constant, i.e., the baseline net removal by sinks is zero, which is conservative due to the prevailing environmental conditions or anthropogenic pressures that are degrading the land and impeding spontaneous forest regeneration.

For strata with growing trees and/or shrubs, the baseline carbon stock change is estimated based on methods developed in IPCC 2003 Good Practice Guidance (GPG) for Land Use, Land-Use Change and Forestry (LULUCF)[1]. Only the carbon stock change in living biomass is estimated. The omission of the other carbon pools is considered as a conservative approach because these pools are likely to decrease or remain constant in the absence of the proposed AR CDM project activity, relative to the project scenario.

v. Additionality is demonstrated using the latest version of the "tool for demonstration and assessment of additionality for afforestation and reforestation CDM project activities" approved by the CDM Executive Board.

vi. The *ex ante* actual net GHG removal by sinks is estimated for each type of stand to be created with the AR CDM project activity. Stand types are represented by 'stand models' that are a description of the species planted or regenerated and the management prescribed (species, fertilization, thinning, harvesting, etc.). Carbon stock changes and the increase of GHG emissions resulting from fertilization, site preparation (biomass burning) and fossil fuel consumption are estimated using methods developed in IPCC GPG-LULUCF.

vii. Leakage emissions, including carbon stock decreases outside the project boundary, are accounted for the following sources: fossil fuels consumption for transport of staff, products and services; displacement of pre-project croplands, grazing and fuel-food collection activities; increased consumption of wood posts for fencing.

**Monitoring methodology steps**

i. The project implementation is monitored, including the afforested/reforested area, forest establishment and forest management.

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

iii. Baseline net GHG removals by sinks are not monitored in this methodology. The *ex ante* estimate is 'frozen' for the entire crediting period.

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

v. Leakage due to activity displacement (crops, grazing and fuel-wood collection activities), increased fossil fuel and fencing post consumption are monitored.

---

[1] Hereinafter referred as "IPCC GPG-LULUCF"

## Section II. Baseline methodology description

### 1 Project boundary

The boundary of the proposed AR CDM project activity shall be defined as follows:

a) The project boundary shall geographically delineate and encompass all anthropogenic GHG emissions by sources and removals by sinks on lands under the control of the project participants that are significant and reasonably attributable to the proposed AR CDM project activity. The sources and gases included in this methodology are listed in Table 2 below.

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

| Sources | Gas | Included/ excluded | Justification / Explanation |
|---|---|---|---|
| Use of fertilizers | $CO_2$ | No | Not applicable |
| | $CH_4$ | No | Not applicable |
| | $N_2O$ | Yes | Main gas of this source |
| Combustion of fossil fuels used in on-site vehicles | $CO_2$ | Yes | Main gas of this source |
| | $CH_4$ | No | Potential emission is negligibly small |
| | $N_2O$ | No | Potential emission is negligibly small |
| Burning of biomass | $CO_2$ | No | However, carbon stock decreases due to burning are accounted as a carbon stock change |
| | $CH_4$ | Yes | Non-$CO_2$ gas emitted from biomass burning |
| | $N_2O$ | Yes | Non-$CO_2$ gas emitted from biomass burning |

b) 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.

c) Discrete parcels of land not under the control of the project participants at the start date of the proposed AR CDM project activity but expected to come under the control of the project participants during the crediting period may be included within the project boundary if all of the following conditions are met:

- The total area (hectares) of these parcels of land not yet under the control of the project participants is clearly defined in the CDM-AR-PDD; and
- A justification of how these parcels of land will come under the control of the project participants is provided in the CDM-AR-PDD; and
- The candidate land areas among which the particular parcels of land will be chosen have been identified and are unambiguously identified in the CDM-AR-PDD with GPS coordinates and maps; and
- All candidate land areas have been included in the baseline assessment and it can be

shown that they are not different from the land areas already under the control of the project participants at the start of the proposed AR CDM project activity in terms of land eligibility, baseline net greenhouse gas removal by sinks, actual net greenhouse gas removal by sinks, leakage, socio-economic and environmental impacts.

## 2 Eligibility of land

This methodology uses the latest version of the mandatory tool: "Procedures to define the eligibility of lands for afforestation and reforestation project activities" approved by the CDM Executive Board[2] to demonstrate land eligibility within the project boundary.

## 3 *Ex ante* stratification

In this methodology, stratification is achieved in three steps: Step 1 stratifies the project area according to pre-existing natural conditions and baseline projections into $m_{BL}$ strata; Step 2 stratifies the project area according to projected AR CDM project activities into $m_{PS}$ strata; and step 3 achieves the final *ex ante* stratification by combining the results of step 2 with ongoing treatment and stratum boundary monitoring. In all three steps, the minimum contiguous area required for an area of land to be identified as a stratum, or as part of a larger stratum consisting of several discontinuous areas of land, shall be equal to the minimum forest area designated by the DNA of the host country.

***Step 1:*** Stratification according to pre-existing conditions and baseline projections:

a) Define the factors influencing carbon stock changes in above-ground and below-ground biomass pools. These factors may include soil, climate, previous land use, existing vegetation type, degree of anthropogenic pressure in the baseline scenario, etc.

b) Collect local site classification maps/tables, the most updated land use/cover maps, satellite images, soil maps, vegetation maps, landform maps, and literature reviews of site information concerning key factors identified above.

c) Collect information on pre-project distribution of ruminant animals.

d) Collect information on pre-project production of crops

e) Do a preliminary stratification based on the collected information.

f) Carry out supplementary sampling for site specifications for each stratum, including as appropriate:

   - Area cover for herbaceous plants and crown cover, height and DBH for shrubs and trees (preferably species or cohort specific), respectively;
   - Deforestation processes and the time elapsed since;
   - Present and past land tenure and land use;
   - Likely land use in the absence of an AR CDM project activity;
   - Present/potential vegetation types, alternatively, site and soil factors: soil type, soil depth, slope gradient, slope face, underground water level, etc.;
   - Animal pressure, e.g. grazing.

g) Do the final stratification of the baseline scenario based on supplementary information collected from f) above. Distinct strata should differ significantly in terms of their baseline net greenhouse gas removals by sinks. For example, separate strata could consist of sites: totally

[2] Hereinafter referred as "AR eligibility tool" (http://cdm.unfccc.int/EB/Meetings/022/eb22_repan16.pdf)

deprived of trees or shrubs; with some trees or shrubs already present; subject to intensive agriculture, grazing or collection of fuel wood. 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.

h) For highly variable landscapes the option exists to carry out a systematic unbiased sampling to determine the percentage of the project area occupied by each stratum. At each plot, based on the site specifications found, the plot shall be assigned to one of the strata identified in paragraph f. Sampling intensity in this step shall be the greater of 100 plots, or 1 plot per 5 hectares of project area. The proportions defined will be applied across the project area to define baseline condition. Subsequent sampling for determination of baseline carbon shall take place in each of the defined strata.

***Step 2:*** Stratification according to the planned AR CDM project activity:

a) Define the '<u>stand models</u>' to be implemented in the project area by specifying:

- The species or species combination (cohorts) to be planted together in one single location and at the same date to create a 'stand';
- The growth assumptions for each species, combination of species in the stand model;
- Planting, fertilization, thinning, harvesting, coppicing, and replanting cycle scheduled for each stand model, by specifying:
  - The age class when the above management activities will be implemented;
  - The quantities and types of fertilizers to be applied;
  - The volumes to be thinned or harvested;
  - The volumes to be left on site (harvest residues becoming dead wood) or extracted.

b) Define the establishment timing of each stand model by specifying:

- The planting date;
- The area to be planted (ha);
- The geographical location (coordinates of the polygons) for each stand model.

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

***Step 3:*** Final *ex ante* stratification:

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

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

Note: In the equations used in this methodology, the letter *i* is used to represent a stratum and the letter *m* for the total number of strata.

$m_{BL}$ is the number of *ex ante* defined baseline strata as determined with step 1. $m_{BL}$ remains fixed for the entire crediting period.

$m_{PS}$ is the number of strata in the project scenario as determined *ex ante* with step 2. *Ex post* adjustments of the strata in the project scenario (*ex post* stratification) may be needed if unexpected disturbances occur during the crediting period (e.g. due to fire, pests or disease outbreaks), affecting differently different parts of an originally homogeneous stratum or stand, or when forest management (planting, thinning, harvesting, replanting) occurs at different intensities, dates and spatial locations than originally planned.

## 4 Procedure for selection of most plausible baseline scenario

The baseline scenario is determined by the following steps:

***Step 1:*** Demonstrate that the proposed AR CDM project activity meets the conditions under which the proposed methodology is applicable, and that baseline approach 22(a) can be used.

***Step 2:*** Define the project boundary as described in Section II.2 above[3]

***Step 3:*** Analyze historical land use, local and sectoral land-use policies or regulations and land use alternatives

a) Analyze the historical and existing land-use / land-cover changes in the context of the socio-economic conditions prevailing within the boundary of the proposed AR CDM project activity and identify key factors that influence the land-use / land-cover changes over time, using multiple sources of data including archives, maps or satellite images of land use/cover data prepared before 31.12.1989 (reforestation) or at least 50 years old (afforestation) and before the start of the proposed AR CDM project activity, supplementary field investigation, land-owner interviews, as well as studies and data collected from other sources.

b) Show that historical and current land-use/land-cover change has led to progressive degradation of the land over time including a decrease or steady state at a reduced level of the carbon stocks in the carbon pools. Provide indicators of land degradation and carbon stock decrease/steady state that can be verified and sustain the choice of these indicators using appropriate and credible sources of information, such as scientific literature and studies or data collected in the project area or similar areas.

The historical degradation feature can be indicated by:

1. Vegetation degradation. For example:

- The land was forest at time points in the past and non-forest at more recent time points;
- There was a forest at time points in the past, but attempts to re-establish the forest through seeding have failed;
- There was higher crown cover of non-tree vegetation at time points in the past and lower crown cover at more recent time points.

2. Soil degradation. For example::

[3] As outlined in Section II.1, this methodology uses the latest version of the mandatory tool: "Procedures to define the eligibility of lands for afforestation and reforestation project activities" approved by the CDM Executive Board to demonstrate land eligibility within the project boundary.

- Lower soil erosion at time points in the past than in more recent time points;
- Higher soil organic matter content at time points in the past than in more recent time points;
- Less desertification at time points in the past than in more recent time points.

These indicators do not represent all cases of land degradation but are appropriate for the proposed methodology. Other indicators may be used.

c) Identify and briefly describe national, local and sectoral land-use policies or regulations adopted before 11 November 2001 that may influence land-use / land-cover change and demonstrate that they do not influence the areas of the proposed AR CDM project activity (e.g., because the policy does not target this area, or because there are barriers to the policy implementation in this area, etc). 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 any further.

d) Identify alternative land uses including alternative future public or private activities on the degraded lands including any similar AR activity or any other feasible land development activities, that are not in contradiction with the identified local, national and/or sectoral land-use policies and regulations and that could be implemented within the boundary of the proposed AR CDM project activity. In doing so, use land records, field surveys, data and feedback from stakeholders, and other appropriate sources.

e) Demonstrate that land use/cover within the boundary of the proposed AR CDM project activity would not change and/or lead to further degradation and carbon stock decrease in absence of the proposed project activity, e.g., by assessing the relative attractiveness of alternative land uses in terms of benefits to the local economy and communities' subsistence, consulting with stakeholders for existing and future land use, and identifying barriers for alternative land uses.

If the analyses above indicate for the baseline land use that the land area within the boundary of the proposed AR CDM project activity is likely to change its current status (i.e. degraded and/or subject to further degradation), then this methodology is not applicable. . However, if the analysis shows that a change can only occur as a result of the implementation of the proposed AR CDM activity, continue with the next step.

***Step 4***: Stratify the AR CDM project area as explained in section II.3 above

***Step 5:*** Determine the baseline land-use / land-cover scenario for each stratum

Analyze the possibility of self-encroachment of trees[4] under the current conditions by, e.g.:

- Survey and identification of trees growing on site.
- Identification of on-site or external seed pools/sources that may result in natural regeneration.
- Identification of the possibility of seed sprout and growth into trees with the potential height, crown cover and area crossing the threshold values used in the national definition of forest, under the current conditions.

If no or only sparse natural regeneration with no potential to become a forest can be identified, continue with section II.5 below. Otherwise, the proposed AR CDM project activity is not different from the baseline scenario[5].

---

[4] A woody perennial with a single main stem or, in the case of coppice, with several stems, having a more or less definite crown (TBRFA 2000).

## 5 Estimation of baseline net GHG removals by sinks

### Baseline strata without trees or woody perennials

The baseline net greenhouse gas removals by sinks is the sum of the changes in carbon stocks in the carbon pools within the project boundary that would have occurred in the absence of an AR CDM project activity. As per the conditions under which the proposed methodology is applicable (described in section I.2), lands to be afforested or reforested are degraded lands, either abandoned or subjected to pre-project grazing activity or agricultural crop activity, with vegetation having area, crown cover and tree high values below the thresholds used in the national definition of forest, and the lands are still degrading or remaining in a low carbon steady state. For this reason, in all baseline strata where:

a) no growing trees or woody perennials exist, and

b) no trees or other woody perennials will start to grow at any time during the crediting period, or

c) no trees or other woody perennials will reach the threshold for the national definition of forest due to ongoing cutting and burning cycles that are part of shifting cultivation systems,

the baseline net greenhouse gas removals by sinks are expected to be negative due to ongoing degradation. For these strata the methodology conservatively assumes that baseline net greenhouse gas removal by sinks is zero:

$$C_{BSL} = 0 \text{ for all } t^* \leq t_{cp} \quad \textbf{(1)}$$

where:

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

$t^*$ = number of years elapsed since the start of the AR project activity; yr

$t_{cp}$ = year at which the first crediting period ends; yr

This baseline methodology accounts for above-ground and below-ground biomass only. Therefore, for all strata that do not satisfy the conditions listed above, the baseline net greenhouse gas removals by sinks can be calculated by:

$$C_{BSL} = \Delta C_{B,LB} \quad \textbf{(2)}$$

where:

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

$\Delta C_{BLB}$ = baseline sum of the changes in living biomass carbon stocks (above- and below-ground); t $CO_2$-e.

[5] If pre-existing natural vegetation and natural seed sources can develop and become a forest according to the national definition of forest but the land is not used for the purpose of establishing a forest, the area may still be eligible for AR CDM project activities and the baseline different from the project scenario (e.g. shifting cultivation areas). However, under such particular circumstances, the development of vegetation should be taken into account as the most likely baseline scenario.

Note: In this methodology Eq. 2 is used to estimate baseline net greenhouse gas removal by sinks for the period of time elapsed between project start (*t=1*) and the year *t=t*, t** being the year for which baseline net greenhouse gas removals by sinks are estimated.

**Estimation of $\Delta C_{BLB}$ (changes in living biomass carbon stocks in the baseline):**

$$\Delta C_{BLB} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{BL}} \Delta C_{B,ikt} \tag{3}$$

where:

| | | |
|---|---|---|
| $\Delta C_{BLB}$ | = | baseline sum of the changes in living biomass carbon stocks (above- and below-ground); t $CO_2$-e. |
| $\Delta C_{B,ikt}$ | = | baseline annual carbon stock change in living biomass for stratum *i*, stand model k, time *t*; t $CO_2$-e. $yr^{-1}$ |
| *i* | = | 1, 2, 3, … $m_{BL}$ baseline strata |
| *k* | = | 1, 2, 3, … *K* stand model |
| *t* | = | 1, 2, 3, …*t** years elapsed since the start of the AR CDM project activity |

To be symmetric Eq. 3 will be used for both the baseline and the actual net GHG removals by sinks, the subscript *k* referencing stand model is included. Stand model is the term used for stratum within the project. For the *ex ante* baseline estimation $k = 0$.[6]

For those strata without growing trees, or with trees and non-tree vegetation as part of an agricultural cycle that are not accumulating carbon due to the predictable cutting and burning, $\Delta C_{B,ikt} = 0$. For those strata with a few growing trees, $\Delta C_{B,ikt}$ 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 )[7]

$$\Delta C_{ikt} = \Delta C_{G,ikt} - \Delta C_{L,ikt} \tag{4}$$

where:

| | | |
|---|---|---|
| $\Delta C_{ikt}$ | = | annual carbon stock change in living biomass for stratum *i,* for stand model *k,* time *t*; t $CO_2$-e. $yr^{-1}$ |
| $\Delta C_{G,ikt}$ | = | annual increase in carbon stock due to biomass growth for stratum *i,* for stand model *k,* time *t*; t $CO_2$-e. $yr^{-1}$ |
| $\Delta C_{L,ikt}$ | = | annual decrease in carbon stock due to biomass loss for stratum *i,* for stand model *k*, time *t;* t $CO_2$-e. $yr^{-1}$ |

Note: This methodology conservatively assumes that $\Delta C_{L,ikt} = 0$ for the baseline scenario[8].

[6] Within a baseline stratum, the vegetation type (=stand model) should be similar as a criterion for stratification

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

$$\Delta C_{G,ikt} = A_{ijt} \cdot C_{TOTAL,ikt} \quad \textbf{(5)}$$

where:

$\Delta C_{G,ikt}$ = annual increase in carbon *stock* due to biomass growth for stratum *i,* for stand model *k,* time *t*; t $CO_2$-e. $yr^{-1}$

$A_{ijt}$ = area of stratum *i,* for stand model *k*, at time *t*; hectare (ha)

$C_{TOTAL,ikt}$ = annual average increment rate in total biomass in units of dry matter for stratum *i* for stand model *k*, time t; t d.m. $ha^{-1}$ $yr^{-1}$

Note: The area of a stratum *i* planted with species *j* has a time notation because depending on baseline land use/cover projections stand models *k* may appear at different dates within the same stratum. As well, $G_{TOTALikt}$ can be estimated as a constant annual average value.

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

$$\Delta C_{TOTAL,ikt} = \sum_{j}^{J} G_{w,ijt} \cdot (1 + R_j) \cdot CF_j \cdot \frac{44}{12} \quad \textbf{(6)}$$

$$\Delta G_{w,ijt} = I_{v,ijt} \cdot D_j \cdot BEF_{1,j} \quad \textbf{(7)}$$

where:

$C_{TOTAL,ikt}$ = annual average increment rate in total biomass for stratum *i* for stand model *k*, time t; t d.m. $ha^{-1}$ $yr^{-1}$

$G_{w,ijt}$ = average annual above-ground biomass increment for stratum *i,* species *j*, at time *t*; t d.m. $ha^{-1}$ $yr^{-1}$

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

$CF_j$ = the carbon fraction for species *j*; t C (t d.m.)$^{-1}$

$I_{v,ijt}$ = average annual increment in merchantable volume for stratum *i,* species *j*; $m^3$ $ha^{-1}$ $yr^{-1}$

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

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

Note:

(i) $G_{TOTALikt}$ can be estimated as a constant annual average value

(ii) Care should be taken that the root-shoot ratio may change as a function of the above-ground biomass present at time (*t*) (see IPCC GPG, 2003, Annex 3.A1, Table 3A1.8)

(iii) $I_{vijt}$ is estimated as 'current annual increment – CAI'. The 'mean annual increment' – MAI in the forestry jargon – can only be used if its use leads to conservative estimates.

---

[8] This assumption implies that all baseline woody biomass is assumed to remain living during the entire crediting period. This is conservative because the proportion of living biomass that will die or will be harvested is not deduced from the estimation of baseline net GHG removals by sinks.

**B) Method 2 (stock change method)** [9]

$$\Delta C_{ikt} = \frac{C_{ikt2} - C_{ikt1}}{T} \cdot \frac{44}{12} \qquad \textbf{(8)}$$

$$C_{ikt} = C_{AB,ijt} + C_{BB,ijt} \qquad \textbf{(9)}$$

$$C_{AB,ijt} = A_{ijt} \cdot V_{ijt} \cdot D_j \cdot BEF_{2,j} \qquad \textbf{(10)}$$

$$C_{BB,ijt} = C_{AB,ijt} \cdot R_j \qquad \textbf{(11)}$$

where:

| | | |
|---|---|---|
| $\Delta C_{ikt}$ | = | annual carbon stock change in living biomass for stratum *i,* for stand model *k,* time *t*; t $CO_2$-e. $yr^{-1}$ |
| $C_{ikt}$ | = | carbon stock in living biomass for stratum *i,* stand model *k*, time *t*; t C |
| $C_{ikt2}$ | = | total carbon stock in living biomass for stratum *i,* species *j*, calculated at time $t = t_2$; t C |
| $C_{ikt1}$ | = | total carbon stock in living biomass for stratum *i,* species *j*, calculated at time $t = t_1$; t C |
| $T$ | = | number of years between times $t_2$ and $t_1$ $(T = t_2 - t_1)$ |
| $A_{ikt}$ | = | area of stratum *i*, for stand model *k*, at time *t*; hectare (ha) |
| $C_{AB,ijt}$ | = | carbon stock in above-ground biomass for stratum *i,* species *j*, at time *t;* t C |
| $C_{BB,ijt}$ | = | carbon stock in below-ground biomass for stratum *i,* species *j*, at time *t;* t C |
| $V_{ijt}$ | = | average merchantable volume of stratum *i,* species *j*, at time *t;* $m^3$ $ha^{-1}$ |
| $D_j$ | = | basic wood density of species *j*; t d.m. $m^{-3}$ merchantable volume |
| $BEF_{2,j}$ | = | biomass expansion factor for conversion of merchantable volume to above-ground tree biomass for species *j*; dimensionless |
| $R_j$ | = | root-shoot ratio for species *j*; dimensionless |

Note: Stratification criteria shall include age classes so that $V_{ijt}$ should have low variances within stratum *i,* species *j*, time *t.*

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

$$C_{AB,ijt} = A_{ikt} \cdot nTR_{ijt} \cdot CF_j \cdot f_j(DBH_t, H_t) \qquad \textbf{(12)}$$

where:

| | | |
|---|---|---|
| $C_{AB,ijt}$ | = | carbon stock in above-ground biomass for stratum *i,* species *j*, at time *t;* t C |
| $A_{ikt}$ | = | area of stratum *i,* stand model *k*, at time *t;* hectare (ha) |
| $nTR_{ijt}$ | = | number of trees in stratum *i*, species *j*, at time *t*; dimensionless $ha^{-1}$ |

[9] GPG-LULUCF Equation 3.2.3

$CFj$ = carbon fraction for species j, t C (t d.m.)$^{-1}$

$f_i(DBH_t,H_t)$ = allometric equation linking above-ground biomass of living trees (d.m. ha$^{-1}$) to mean diameter at breast height (DBH) and possibly mean tree height (H) for species j; dimensionless

Note: Mean DBH and H values should be estimated for stratum i, species j, at time t using a growth model or yield table that gives the expected tree dimensions as a function of tree age. The allometric relationship between above-ground biomass and DBH and possibly H is a function of the species considered.

To be conservative, this methodology does not account for living biomass losses due to harvesting and mortality in the baseline scenario and does account for them in the project scenario. Therefore when using method 2 for the baseline (and make its use consistent with the assumption $\Delta C_{L,ij} = 0$ made in Eq. 4 of method 1), $V_{ijt}$ shall not consider volume reductions due to harvesting and mortality. For the choice of methods there is no priority, and it will mainly depend on the kind of parameters available. $V_{ijt}$ and $I_{v,itj}$ shall be estimated based on number of trees and national/local growth curve/table that is usually covered by national/local forestry inventory. $D_j$, $BEF_{1,j}$, $BEF_{2,j}$, $CF_j$ and $R_j$ are regional and species specific and shall be chosen with priority from higher to lower order as follows:

a) Existing local and species specific.

b) National and species specific (e.g. from national GHG inventory).

c) Species specific from neighboring countries with similar conditions. Sometimes c) might be preferable to b); this case shall be substantiated in the PDD.

d) Globally species specific (e.g. GPG-LULUCF).

If none of the above works, then start again from a, but replace ‘species specific’ with ‘similar species’. (e.g., shape of trees, broadleaved vs. deciduous etc).

When choosing from global or national databases because local data are limited, it shall be confirmed with any available local data that the chosen values for the baseline are not a significant underestimate of the baseline net removals by sinks, as far as can be judged. Local data used for confirmation may be drawn from the literature and local forestry inventory

## 6 Additionality

This methodology uses the latest version of the ‘Tool for the demonstration and assessment of additionality in afforestation and reforestation CDM project activities’ approved by the CDM Executive Board[10].

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

The actual net greenhouse gas removals by sinks represent the sum of the verifiable changes in carbon stocks in the carbon pools within the project boundary, minus the increase in greenhouse emissions by sources measured in $CO_2$ equivalents within the project boundary that are a result of the implementation of an AR CDM project activity. Therefore,

$$C_{ACTUAL} = \Delta C_{P,LB} - GHG_E \qquad \textbf{(13)}$$

where:

[10] Hereinafter referred as ‘AR additionality tool’ (http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html)

$C_{ACTUAL}$ = actual net greenhouse gas removals by sinks; t $CO_2$-e.

$\Delta C_{P,LB}$ = sum of the changes in living biomass carbon stocks (above- and below-ground); t $CO_2$-e.

$GHG_E$ = sum of the increases in GHG emissions by sources within the project boundary as a result of the implementation of an AR CDM project activity; t $CO_2$-e.

Note: In this methodology Eq. 13 is used to estimate actual net greenhouse gas removal by sinks for the period of time elapsed between project start (*t=1*) and the year *t=t*, t** being the year for which actual net greenhouse gas removals by sinks are estimated.

### 7.1 Estimation of actual $\Delta C_{P,LB}$ (changes in living biomass carbon stocks in the project scenario):

In general, the changes in living biomass stocks in the project can be given by:

$$\Delta C_{P,LB} = \Delta C_{P,LB_T} - E_{biomassloss} \quad \textbf{(14)}$$

where:

$\Delta C_{P,LB}$ = sum of the changes in living biomass carbon stocks (above- and below-ground); t $CO_2$-e.

$\Delta C_{P,LB\,T}$ = sum of the changes in living tree biomass carbon stocks (above- and below-ground); t $CO_2$-e.

$E_{biomassloss}$ = decrease in the carbon stock in the living biomass carbon pools of non-tree vegetation in the year of site preparation, up to time *t**; t $CO_2$-e.

**Treatment of pre-existing vegetation**

Given the conditions under which the proposed methodology is applicable (described in section I.3), pre-existing carbon stocks in the living biomass are most likely not significant (< 2% of the anticipated actual net GHG removals by sinks). The methodology nevertheless considers the two following possible situations:

a) The carbon stocks in the living biomass of pre-existing non-tree and tree vegetation are not significant:

- Carbon stock changes in the living biomass of pre-existing non-tree and tree vegetation are not included in the *ex ante* calculation of actual carbon stock changes, regardless if the pre-existing non-tree and tree vegetation is left standing or is harvested.
- If the pre-existing vegetation is burned for land preparation before planting, non-$CO_2$ emissions are estimated from the total above-ground biomass (details in section 2 below) and included in the calculation of actual net GHG removal by sinks if they are significant (> 2% of actual net GHG removals by sinks)
- To be conservative the biomass of the pre-existing vegetation would be set as the maximum biomass over the slash and burn/fallow cycle.

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

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

a) If the baseline is shifting agriculture or another form of agriculture/fallow cycle, a conservative approach of setting the baseline stock to be equal to the maximum stock over the cycle. It is assumed all this stock will disappear in the year of site preparation. The stocks are assumed to be burned:

- Non-$CO_2$ emissions are calculated from the carbon stock in the above-ground biomass of non-tree and tree vegetation (details in section 6.2 below).
- 100% carbon stock loss in the above-ground and below-ground biomass is assumed and estimated using Eq. 15 for both the non-tree component and the young trees.

b) Otherwise if for land preparation before planting non-tree and tree vegetation is burned (and not harvested) then:

- Non-$CO_2$ emissions are calculated from the carbon stock in the above-ground biomass of non-tree and tree vegetation (details in section 7.2.2 below).
- 100% carbon stock loss in the above-ground and below-ground biomass is assumed and estimated using the methods outlined in Eq. 16 ff. below for the tree component and Eq. 15 for the non-tree component.

c) Or, If the tree vegetation is partially or totally harvested before burning then:

- The carbon stock decrease in the harvested above-ground and below-ground tree biomass is estimated using the methods outlined below.
- The above-ground biomass of the harvested trees is subtracted from the total above-ground biomass estimate used for the calculation of non-$CO_2$ emissions from burning.
- Carbon stock changes in the living biomass (above-ground and below-ground) of pre-existing trees that are left standing are not included in the *ex ante* calculation of actual carbon stock changes. This is a conservative assumption because the trees will continue to grow. *Ex post* these trees will be measured in the monitoring plots; any change in the carbon stocks in these trees due to grow or mortality will be duly accounted.

All existing non-tree vegetation is assumed to disappear in the year of site preparation, to account for slash and burn or future competition from planted trees. This is a conservative assumption because there will be some non-tree vegetation in the project scenario. Some vegetation may re-grow even if all non-tree vegetation is removed during the site preparation (overall site burning). The carbon stock decrease is estimated as follows:

$$E_{biomassloss} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{BL}}\sum_{k=1}^{K_P} A_{ikt} \cdot B_{pre,ikt} \cdot CF_{pre} \cdot \frac{44}{12} \qquad \textbf{(15)}$$

where:

$E_{biomassloss}$ = decrease in the carbon stock in the living biomass carbon pools of non-tree vegetation in the year of site preparation, up to time $t^*$; t $CO_2$-e.

$A_{ikt}$ = area of stratum *i*, stand model *k*, time *t*; ha

$B_{pre,ikt}$ = average pre-existing stock non-tree pre-project biomass on land to be planted before the start of a proposed A/R CDM project activity for baseline stratum *i*, stand model *k*, time *t*; t d.m. $ha^{-1}$

| | | |
|---|---|---|
| $CF_{pre}$ | = | the carbon fraction of dry biomass in pre-existing vegetation, t C (t d.m.)$^{-1}$ |
| $i$ | = | 1, 2, 3, ... $m_{BL}$ strata in the baseline |
| $k$ | = | 1, 2, 3, … $K_P$ stand models in the project scenario |
| $t$ | = | 1, 2, 3, ...$t^*$ years elapsed since the start of the AR project activity |

**Treatment of trees**

For clarification, trees refer to all woody biomass that occurs as a result of the A/R project.

The methodology and equations for estimating *ex ante* actual changes in the living biomass carbon stocks are similar to the ones used for the estimation of baseline changes in the living biomass carbon stocks, with the following main differences:

a) Harvesting and mortality are taken into account

b) Baseline strata (defined based on pre-existing vegetation, among others) differ for the project implementation (based on type of baseline stratum where activity takes place, stand model and possibly cohorts of the same stand model)

c) Stand models are different as defined in step 2 of Section II.2.

$$\Delta C_{P,LB_T} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{BL}}\sum_{k=1}^{K_P}\Delta C_{P,LB,ikt} \qquad \textbf{(16)}$$

where:

| | | |
|---|---|---|
| $\Delta C_{P,LB}$ | = | sum of the changes in living biomass carbon stocks in the project scenario (above- and below-ground); t $CO_2$-e. |
| $\Delta C_{LB,ikt}$ | = | annual carbon stock change in living biomass for stratum *i,* stand model *k*, time *t;* t $CO_2$-e. yr$^{-1}$ |
| $i$ | = | 1, 2, 3, ... $m_{BL}$ strata in the baseline |
| $k$ | = | 1, 2, 3, … $K$ stand models in the project scenario |
| $t$ | = | 1, 2, 3, ...$t^*$ years elapsed since the start of the AR project activity |

Annual carbon stock changes in the living biomass ($\Delta C_{LB,ikt}$) are estimated using one of the two methods described in section II.5. In addition:

**A) Method 1 (Carbon gain-loss method )** [11]

The following equations shall be used to calculate the average annual decrease in carbon stocks due to biomass loss for stratum *i,* stand model *k,* time *t* ($\Delta C_{L,ikt}$)

$$\Delta C_{L,ikt} = L_{hr,ikt} + L_{fw,ikt} + L_{ot,ikt} \qquad \textbf{(17)}$$

where:

| | | |
|---|---|---|
| $\Delta C_{L,ikt}$ | = | average annual decrease in carbon stocks due ot biomass loss for stratum *i*, stand model *k*, time *t*; t $CO_2$-e. yr$^{-1}$ |

[11] Refers to GPG-LULUCF Equation 3.2.6, Equation 3.2.7, Equation 3.2.8 and Equation 3.2.9

| | | |
|---|---|---|
| $L_{hr,ikt}$ | = | annual carbon loss due to commercial harvesting for stratum *i*, stand model *k*, time *t*; t $CO_2$-e. $yr^{-1}$ |
| $L_{fw,ikt}$ | = | annual carbon loss due to fuel wood gathering for stratum *i*, species *j*, time *t*; $CO_2$-e. $yr^{-1}$ |
| $L_{ot,ikt}$ | = | annual natural losses (mortality) of carbon for stratum *i*, species *j*, time *t*; $CO_2$-e. $yr^{-1}$ |

and:

$$L_{hr,ikt} = A_{ikt} \cdot \sum_{j=1}^{J} H_{ijt} \cdot D_j \cdot BEF_{2,j} \cdot CF_j \cdot \frac{44}{12} \quad \textbf{(18)}$$

$$L_{fw,ikt} = A_{ijt} \cdot \sum_{j=1}^{J} FG_{ijt} \cdot D_j \cdot BEF_{2,j} \cdot CF_j \cdot \frac{44}{12} \quad \textbf{(19)}$$

$$L_{ot,ikt} = Adist_{ikt} \cdot \sum_{j=1}^{J} B_{w,j} \cdot M_{ijt} \cdot CF_j \cdot \frac{44}{12} \quad \textbf{(20)}$$

where:

| | | |
|---|---|---|
| $L_{hr,ikt}$ | = | annual carbon loss due to commercial harvesting for stratum *i*, stand model *k*, time *t*; t $CO_2$-e. $yr^{-1}$ |
| $L_{fw,ikt}$ | = | annual carbon loss due to fuel wood gathering for stratum *i*, species *j*, time *t*; $CO_2$-e. $yr^{-1}$ |
| $L_{ot,ikt}$ | = | annual natural losses (mortality) of carbon for stratum *i*, species *j*, time *t*; $CO_2$-e. $yr^{-1}$ |
| $j$ | = | 1,2,3…*J* tree species |
| $H_{ijt}$ | = | annually extracted merchantable volume for stratum *i,* species *j*, time *t*; $m^3$ $ha^{-1}$ $yr^{-1}$ |
| $D_j$ | = | wood density for species *j*; t d.m. $m^{-3}$ merchantable volume |
| $BEF_{2,j}$ | = | biomass expansion factor for converting merchantable volumes of extracted round wood to total above-ground biomass (including bark) for stratum *i,* species *j*, time *t*; dimensionless |
| $CF_j$ | = | carbon fraction of dry matter for species *j*; t C (t d.m.)$^{-1}$ |
| $FG_{ijt}$ | = | annual volume of fuel wood harvesting for stratum *i,* species *j*, time *t*; $m^3$ $ha^{-1}$ $yr^{-1}$ |
| $A_{ikt}$ | = | area of stratum *i,* stand model *k*, at time *t;* hectare (ha) |
| $Adist_{ikt}$ | = | forest areas affected by disturbances in stratum *i,* stand model *k*, time *t*; ha $yr^{-1}$ |
| $B_{w,ijt}$ | = | average above-ground biomass stock for stratum *i,* species *j*, time *t*; t d.m. $ha^{-1}$ |
| $M_{ijt}$ | = | % mortality caused by disturbance in stratum *i,* species *j*, time *t*; dimensionless |

Note: The time notation *t* is given here assuming that in most cases project participants are able to define a harvesting schedule (volumes and years of harvesting as per step 2 in section II.2). The use of a constant average annual harvesting volume should be used only under particular circumstances and should be justified in the PDD.

This methodology allows for the assumption of no disturbances in the *ex ante*[12] estimation of actual net GHG removals by sinks, which implies that $Adist_{ikt}$ is set as zero and therefore $L_{ot,ikt} = 0$. This assumption can be made in project circumstances where expected disturbances (e.g. fire, pest and disease outbreaks) are of low frequency and intensity, and therefore difficult to predict. However, the factor $Adist_{ikt}$ should be estimated when natural tree mortality due to competition and/or disturbances is likely to occasion significant carbon losses. In such cases, $Adist_{ikt}$ can be estimated as an average annual percentage of $A_{ikt}$ to express a yearly mortality percentage due to competition (usually between 0% and 2% of $A_{ikt}$) or disturbances.

**B) Method 2 (stock change method)** [13]

The 'stand models' as defined in section II.3, step 2 shall be developed and presented in the PDD in a way that the values of $V_{ikjt}$ (average merchantable volume of stratum *i,* species *j*, stand model k, at time *t*) used in Eq. 10 represent the actual average merchantable volume of stratum *i,* species *j*, stand model *k*, at time *t* after deduction of harvested volumes and mortality:

$$V_{ikt2} = V_{ikt1} \cdot (1 - Mf_{ikT}) + \sum_{j=1}^{J_k} (I_{v,ijT} - H_{ijT} - FG_{ijT}) \cdot T \qquad \textbf{(21)}$$

$$Mf_{ikT} = \left( \frac{Adist_{ikT}}{A_{ikT}} \right) \qquad \textbf{(22)}$$

where:

$V_{ikt1}$ = average merchantable volume of stratum *i,* stand model *k*, at time $t = t_1$; $m^3\ ha^{-1}$

$V_{ikt2}$ = average merchantable volume of stratum *i,* stand model *k*, at time $t = t_2$; $m^3\ ha^{-1}$

$Mf_{ikT}$ = mortality factor = percentage of $V_{ikt1}$ died during the period *T*; dimensionless

$I_{v,ijT}$ = average annual net increment in merchantable volume for stratum *i,* species *j* during the period *T*; $m^3\ ha^{-1}\ yr^{-1}$

$H_{ijT}$ = average annually harvested merchantable volume for stratum *i,* species *j*, during the period *T*; $m^3\ ha^{-1}\ yr^{-1}$

$FG_{ijT}$ = average annual volume of fuel wood harvested for stratum *i,* species *j*, during the period *T*; $m^3\ ha^{-1}\ yr^{-1}$

$T$ = number of years between times $t_2$ and $t_1$ $(T = t_2 - t_1)$

$Adist_{ijT}$ = average annual area affected by disturbances for stratum *i,* species *j*, during the period *T*; $ha\ yr^{-1}$

$A_{ijT}$ = average annual area for stratum *i,* species *j*, during the period *T*; $ha\ yr^{-1}$

$j$ = $1,2,3…J_k$ tree species in stand model *k*

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

**7.2 Estimation of $GHG_E$ (increase in GHG emissions by sources within the project boundary as a result of the implementation of an AR CDM project activity):**

[12] *Ex post* monitoring of disturbances will not be necessary, as the effect of disturbances in carbon stocks will be captured through the monitoring of permanent sample plots.

[13] GPG-LULUCF Equation 3.2.3

An AR CDM project activity may increase GHG emissions, in particular $CO_2$, $CH_4$ and $N_2O$. The list below contains factors that may be attributable to the increase of GHG emissions[14]:

- Emissions of greenhouse gases by burning of fossil fuels resulting from site preparation, thinning and logging.
- Emissions of greenhouse gases by biomass burning from site preparation (slash and burn activity).
- $N_2O$ emissions caused by nitrogen fertilization practices.
- $CH_4$ emission as a result of flood irrigation. As per the conditions of applicability of this methodology (see section I.3) this source of GHG emissions can be ignored in this methodology.

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

$$GHG_E = E_{FuelBurn} + E_{BiomassBurn} + N_2O_{direct-N_{fertilizer}} \tag{23}$$

where:

$GHG_E$ = increase in GHG emission as a result of the implementation of the proposed AR CDM project activity within the project boundary; t $CO_2$-e.

$E_{FuelBurn}$ = increase in GHG emission as a result of burning of fossil fuels within the project boundary; t $CO_2$-e.

$E_{BiomassBurn}$ = increase in GHG emission as a result of biomass burning within the project boundary; t $CO_2$-e.

$N_2O_{direct-N_{fertilizer}}$ = increase in $N_2O$ emission as a result of direct nitrogen application within the project boundary; t $CO_2$-e.

Note: In this methodology Eq. 23 is used to estimate the increase in GHG emission for the period of time elapsed between project start (*t=1*) and the year *t=t*, t** being the year for which actual net greenhouse gas removals by sinks are estimated.

### 7.2.1 Estimation of $E_{FuelBurn}$ (GHG emissions from burning of fossil fuels):

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

$$E_{FuelBurn} = E_{Vehicle,CO_2} \tag{24}$$

and:

$$E_{Vehicle,CO_2} = \sum_{t=1}^{t^*} \sum_{x} \sum_{y} (EF_{xy} \cdot FuelConsumption_{xyt}) \tag{25}$$

where:

$E_{FuelBurn}$ = total GHG emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$

$E_{Vehicle,CO2}$ = total $CO_2$ emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$

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

$x$ = vehicle type

$y$ = fuel type

$EF_{xy}$ = $CO_2$ emission factor for vehicle type $x$ with fuel type $y$; dimensionless

$FuelConsumption_{xyt}$ = recorded consumption of fuel type $y$ of vehicle type $x$ at time $t$; liters

If the consumption of fuel is not recorded, it can be estimated by:

$$FuelConsumption_{xyt} = n_{xyt} \cdot k_{xyt} \cdot e_{xyt} \quad \textbf{(26)}$$

$n_{xyt}$ = number of vehicles

$k_{xyt}$ = kilometers traveled by each of vehicle type $x$ with fuel type $y$ at time $t$; km

$e_{xyt}$ = fuel efficiency of vehicle type $x$ with fuel type $y$ at time $t$; liters $km^{-1}$

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

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

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

### 7.2.2 Estimation of $E_{BiomassBurn}$ (GHG emissions from biomass burning):

Slash and burn occurs traditionally in some regions during site preparation before planting and/or replanting, and this practice results in $CO_2$ and non-$CO_2$ emissions. Based on revised IPCC 1996 Guideline for LULUCF, this type of emissions can be estimated (whenever double counting of carbon stock losses is avoided) as follows.

$$E_{BiomassBurn} = E_{BiomassBurn,CO_2} + E_{BiomassBurn,N_2O} + E_{BiomassBurn,CH_4} \quad \textbf{(27)}$$

where:

$E_{BiomassBurn}$ = total GHG emission from biomass burning in slash and burn; t $CO_2$-e.

$E_{BiomassBurn,CO2}$ = $CO_2$ emission from biomass burning in slash and burn; t $CO_2$-e.

$E_{BiomassBurn, N2O}$ = $N_2O$ emission from biomass burning in slash and burn; t $CO_2$-e.

$E_{BiomassBurn, CH4}$ = $CH_4$ emission from biomass burning in slash and burn; t $CO_2$-e.

and:

$$E_{BiomassBurn,CO_2} = \sum_{t=1}^{t^*}\sum_{i=1}^{S_{PS}}\sum_{k=1}^{K}(A_{B,ikt\_sb} \cdot B_{ikt} \cdot PBB_{ikt} \cdot CE \cdot CF) \cdot \frac{44}{12} \qquad \textbf{(28)}$$

where:

$E_{BiomassBurn,CO2}$ = $CO_2$ emission from biomass burning in slash and burn; t $CO_2$-e.

$A_{B,ikt\_sb}$ = area of slash and burn for stratum *i*, stand model *k*, time *t*; ha

$B_{ikt}$ = average above-ground biomass stock before burning for stratum *i* as determined for the respective baseline stratum, stand model *k*, time *t*; t d.m. $ha^{-1}$

$PBB_{ikt}$ = average proportion of biomass burnt for stratum *i*, stand model *k*, time *t*; dimensionless

*CE* = average biomass combustion efficiency (IPCC default = 0.5); dimensionless

*CF* = carbon fraction (IPCC default = 0.5); t C (t d.m.)$^{-1}$

*i* = 1, 2, 3, ... $S_{PS}$ strata of the project activity

*k* = 1, 2, 3, … *K* stand models in the project scenario

*t* = 1, 2, 3, ...*t** years elapsed since the start of the AR project activity

Emissions of non-$CO_2$ gases are given by[15]:

$$E_{BiomassBurn,N_2O} = E_{BiomassBurn,CO_2} \cdot \frac{12}{44} \cdot (N/C\,ratio) \cdot ER_{N_2O} \cdot \frac{44}{28} \cdot GWP_{N_2O} \qquad \textbf{(29)}$$

$$E_{BiomassBurn,CH_4} = E_{BiomassBurn,CO_2} \cdot \frac{12}{44} \cdot ER_{CH_4} \cdot \frac{16}{12} \cdot GWP_{CH_4} \qquad \textbf{(30)}$$

where:

$E_{BiomassBurn,CO2}$ = $CO_2$ emission from biomass burning in slash and burn; t $CO_2$-e.

$E_{BiomassBurn,\ N2O}$ = $N_2O$ emission from biomass burning in slash and burn; t $CO_2$-e.

$E_{BiomassBurn,\ CH4}$ = $CH_4$ emission from biomass burning in slash and burn; t $CO_2$-e.

*N/C ratio* = nitrogen-carbon ratio (IPCC default _= 0.01); dimensionless

$ER_{N2O}$ = emission ratio for $N_2O$ (IPCC default value = 0.007); t $CO_2$-e./t C

$ER_{CH4}$ = emission ratio for $CH_4$ (IPCC default value = 0.012); t $CO_2$-e./t C

$GWP_{N2O}$ = Global Warming Potential for $N_2O$ (= 310 for the first commitment period); t $CO_2$-e./t $N_2O$

$GWP_{CH4}$ = Global Warming Potential for $CH_4$ (= 21 for the first commitment period); t $CO_2$-e./t $CH_4$

The combustion efficiencies *CE* may be chosen from Table 3.A.14 of IPCC 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

15 Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF and Equation 3.2.19 in IPCC GPG-LULUCF

available. Emission factors for use with above equations are provided in Tables 3.A 15 and 3.A.16 of IPCC GPG-LULUCF.

### 7.2.3 Estimation of $N_2O_{direct-N_{fertilizer}}$ (nitrous oxide emissions from nitrogen fertilization):

Emissions of nitrous oxide from nitrogen fertilization is given by[16]:

$$N_2O_{direct-N_{fertilizer}} = \sum_{t=1}^{t^*}(F_{SN_t} + F_{ON_t}) \cdot EF_1 \cdot \frac{44}{28} \cdot GWP_{N_2 0} \qquad \textbf{(31)}$$

$$F_{SN\,t} = N_{SN-Fert,\,t} \cdot (1 - Frac_{GASF}) \qquad \textbf{(32)}$$

$$F_{ON\,t} = N_{ON-Fert,\,t} \cdot (1 - Frac_{GASM}) \qquad \textbf{(33)}$$

where:

$N_2O_{direct-N_{fertilizer}}$ = the direct $N_2O$ emission as a result of nitrogen application within the project boundary up to time $t^*$; t $CO_2$-e.

$FSN_t$ = amount of synthetic fertilizer nitrogen applied at time $t$ adjusted for volatilization as $NH_3$ and $NO_x$; t N

$FON_t$ = annual amount of organic fertilizer nitrogen applied at time $t$ adjusted for volatilization as $NH_3$ and $NO_x$; t N

$N_{SN-Fert,t}$ = amount of synthetic fertilizer nitrogen applied at time $t$; t N

$N_{SN-Fert,t}$ = amount of organic fertilizer nitrogen applied at time $t$; t N

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

$Frac_{GASF}$ = fraction that volatilises as $NH_3$ and $NO_x$ for synthetic fertilizers; dimensionless

$Frac_{GASM}$ = fraction that volatilises as $NH_3$ and $NO_x$ for organic fertilizers; dimensionless

$GWP_{N2O}$ = Global Warming Potential for $N_2O$; t $CO_2$-e./t $N_2O$ (= 310 for the first commitment period)

As noted in IPCC GPG 2000, the default emission factor ($EF_1$) is 1.25 % of applied N, and this value should be used when country-specific factors are unavailable. The default values for the fractions of synthetic and organic fertilizer nitrogen that are emitted as $NO_x$ and $NH_3$ are 0.1 and 0.2 respectively in 1996 IPCC Guideline. Project developers 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 IPCC GPG 2000.

## 8 Leakage

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

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

There are three sources of the leakage covered by this methodology:

- GHGs emissions caused by vehicle fossil fuel combustion due to transportation of seedling, labours, staff and harvest products to and/or from project sites;
- Carbon stock decreases caused by displacement of pre-project agricultural crops, grazing and fuel-wood collection activities.
- Carbon stock decreases caused by the increased use of wood posts for fencing.

$$LK = LK_{Vehicle} + LK_{ActivityDisplacement} + LK_{fencing} \quad \textbf{(34)}$$

Note: In this methodology Eq. 32 is used to estimate leakage for the period of time elapsed between project start (*t=1*) and the year *t=t*, t** being the year for which actual net greenhouse gas removals by sinks are estimated.

### 8.1 Estimation of $LK_{Vehicle}$ (leakage due to fossil fuel consumption):

$$LK_{Vehicle} = LK_{Vehicle,CO_2} \quad \textbf{(35)}$$

$$LK_{Vehicle,CO_2} = \sum_{t=1}^{t^*}\sum_{x}\sum_{y}(EF_{xy} \cdot FuelConsumption_{xyt}) \quad \textbf{(36)}$$

$$FuelConsumption_{xyt} = n_{xyt} \cdot k_{xyt} \cdot e_{xyt} \quad \textbf{(37)}$$

where:

$LK_{Vehicle}$ = total GHG emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$

$LK_{Vehicle,CO2}$ = total $CO_2$ emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$

$x$ = vehicle type

$y$ = fuel type

$EF_{xy}$ = $CO_2$ emission factor for vehicle type *x* with fuel type *y;* dimensionless

$FuelConsumption_{xyt}$ = recorded consumption of fuel type *y* of vehicle type *x* at time *t*; liters

$n_{xyt}$ = number of vehicles

$k_{xyt}$ = kilometers traveled by each of vehicle type *x* with fuel type *y* at time *t*; km

$e_{xyt}$ = fuel efficiency of vehicle type *x* with fuel type *y* at time *t*; liters $km^{-1}$

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

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

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

### 8.2 Estimation of $LK_{ActivityDisplacement}$ (leakage due to activity displacement):

The land planned for AR CDM activities may be subjected to agricultural activities, grazing and fuel-wood collection. Thus, as the result of the project activity, these pre-project activities may be temporarily or permanently displaced from within the project boundary to areas outside the project boundary. The displacement may result in leakage if new agricultural or grazing areas are obtained by converting stocked areas, particularly forests, to new areas for agricultural or grazing activities or if the displaced fuel-wood collection results in degradation or deforestation of forests and devegetation of other lands.

For project activities involving grazing, if net livestock is not increased, $CO_2$ emissions resulting from fodder consumption and $CH_4$ emissions from enteric fermentation in displaced domestic livestock do not represent an overall net increase of GHG emissions attributable to the AR CDM project activity because they would occur in the without project scenario[17]. These sources can be excluded from the leakage calculations.

Taking into account the above, leakage due to activity displacement is estimated as follows:

$$LK_{Activitydisplacement} = LK_{conversion} + LK_{fuelwood} \quad \textbf{(38)}$$

where:

$LK_{ActivityDisplacement}$ = Leakage due to activity displacement; t $CO_2$-e.

$LK_{conversion}$ = Leakage due to conversion of forest to non-forest; t $CO_2$-e.

$LK_{fuel\text{-}wood}$ = Leakage due to the displacement of fuel-wood collection; t $CO_2$-e.

#### 8.2.1 Estimation of $LK_{conversion}$ (Leakage due to conversion of lands):

As a result of the A/R CDM project activity, agricultural activities may be displaced permanently or temporarily outside the project boundary. This 'activity shifting' or 'activity displacement' may result in leakage in the immediate years after the start of the project activity when activities are displaced to areas outside the project boundary. $LK_{conversion}$ occurs in two ways:

a) Conversion for grazing and

b) Conversion for cropland.

Therefore:

$$LK_{conversion} = LK_{conv-graz} + LK_{conv-crop} \quad \textbf{(39)}$$

where:

$LK_{conv\text{-}graz}$ = leakage resulting from the conversion for grazing and

$LK_{conv\text{-}crop}$ = leakage resulting from the conversion for cropland.

#### 8.2.2 Estimation of $LK_{conv\text{-}graz}$ (Leakage due to conversion of land to grazing land):

Depending on the specific project circumstances, the entire pre-project animal population, or a fraction of it, may have to be displaced permanently, or temporarily, outside the project boundary. This

[17] See Decision EB22, Annex 15 (http://cdm.unfccc.int/EB/Meetings/022/eb22_repan15.pdf)

displacement of animal populations may result in leakage. However, leakage due to conversion of land to grazing land is not attributable to the AR-CDM project activity if the conversion of land to grazing land occurs 5 or more years after the last measure taken to reduce animal populations in the project area[18]. The type and schedule of the measures to be taken to control animal grazing in the project areas should therefore be described in the AR-CDM-PDD and its implementation monitored.

Where pre-project grazing activities exist, it is necessary to estimate the pre-project animal population from different livestock groups in the project area. This can be done by interviewing the animal owners in the project area or, by interviewing a sample of them in case of multiple landowners or by conducting a Participatory Rural Appraisal (PRA). Other-sources of information, such as local animal census data, may also be used. As animal number may fluctuate over time, it is recommended to calculate the average animal population of the 5 to 10 years time period preceding the starting date of the AR-CDM project activity.

$$Na_{BL} = \frac{sNa_{BL}}{SFR_{PAga}} \tag{40}$$

where:

$Na_{BL}$ = average pre-project number of animals from the different livestock groups that are grazing in the project area; dimensionless

$sNa_{BL}$ = sampled pre-project number of animals from the different livestock groups that are grazing in the project area; dimensionless

$SFR_{PAga}$ = fraction of total project area sampled for animal grazing; dimensionless

Given the conditions under which this methodology is applicable (see section I.3), particularly the applicability of baseline approach 22(a), the methodology assumes that the estimated historical or current animal population size ($Na_{BL}$) will remain constant over the entire crediting period.

Based on the planned afforestation or reforestation establishment schedule and the prescribed management, the periods of time from which grazing should be excluded from different parcels to be planted can be specified. This planning should be used to estimate the animal population that will be displaced each year outside the project boundary.

$$Na_{outside,t} = Na_{BL} - Na_{AR,t} \tag{41}$$

where:

$Na_{outside,t}$ = number of animals displaced outside the project area at year $t$; dimensionless

$Na_{BL}$ = average number of animals from the different livestock groups that are grazing in the project area under the baseline scenario; dimensionless

$Na_{AR,t}$ = number of animals allowed in the project area under the proposed AR-CDM project activity at year $t$; dimensionless

**Case 1: $Na_{BL} < Na_{AR,t}$**

---

[18] A measure to reduce animal population in the project area is a measure taken to avoid grazing in the project area (e.g. fencing). Such measures can result in leakage. The methodology assumes that leakage occurs only once, immediately after the implementation of the measure. This is consistent with baseline approach 22(a), whereby the historical or current population of grazing animals is assumed to be the baseline situation. However, to be on the safe side, the methodology requires to monitor leakage the 5 years following the date of implementation of the measure taken to avoid grazing in the project area.

Leakage due to the displacement of animal grazing can be set as zero if the number of animals allowed in the project area under the proposed AR-CDM project is more than the average number of animals from the different livestock groups that are grazing in the project area under the baseline scenario.

$$L_{conv\text{-}graz} = 0, \text{ if } Na_{BL} < Na_{AR,t} \quad \textbf{(42)}$$

This situation can only occur if the planned AR-CDM project activity produces more fodder than the baseline activity.

**Case 2: $Na_{BL} > Na_{AR,t}$**

If the planned AR-CDM project activity produces less fodder than the baseline activity then, the animal populations will be displaced outside the project boundary due to the implementation of the AR-CDM project activity. These animals can be relocated in three different types of grazing areas:

- Existing grazing land areas under the control of the animal owners that are either sub-utilized or that have a potential to be managed for higher fodder production. These areas may be managed in a way that would provide sufficient fodder to feed the entire displaced animal population and prevent leakage. Any such measure have to be described in the PDD and subjected to monitoring. Such measures may not cause a significant increase of GHG emissions.
- New grazing land areas under the control of the animal owners, to be obtained from conversion of other land-uses to grazing land. This conversion is a source of leakage that should be estimated *ex ante* and monitored *ex post*.
- Unidentifiable grazing land areas, not under the control of the animal owners, which can either already exist or have to be established by converting other land-uses to new grazing land. This is typically the case when the animals are sold as a consequence or the implementation of the AR-CDM project activity.

The total area of grazing land in which the displaced animal population will be maintained can be estimated as follow:

$$GLA = EGL + NGL + XGL \quad \textbf{(43)}$$

where:

$GLA$ = total grazing land area outside the project boundary needed to feed the displaced animal populations; ha

$EGL$ = total existing grazing land area outside the project boundary that is under the control of the animal owners (or the project participants) and that will receive part of the displaced animal populations, up to time $t^*$; ha

$NGL$ = total new grazing land area outside the project boundary to be converted to grazing land that is under the control of the animal owners (or the project participants) and that will receive another part of the displaced animal populations, up to time $t^*$; ha

$XGL$ = total unidentifiable grazing land area outside the project boundary that will receive the remaining part of displaced animal populations, e.g. when the pre-project animal owners decide to sell the animals, up to time $t^*$; ha

The following steps are required:

***Step 1*:** Collect data on type of domestic species, their owners, population size, and number of months per annum during which animals from the different species are present in different discrete parcels of the area to be afforested or reforested. If several parcels of land are to be planted, collect these data from a sample. The sample size should not be less than 10% of the randomly selected parcels or 30 parcels. Estimate the annual biomass consumption of the animals over the project area to be planted as follows:

$$\Delta C_{L\,PAt} = \sum_{p=1}^{P}\sum_{an=1}^{An} DBI_{an} \cdot n_{pgt} \cdot a_{gp} \cdot 30 \cdot 0.001 \cdot \frac{1}{SFR_{PAga}} \qquad \textbf{(44)}$$

where:

| | | |
|---|---|---|
| $\Delta C_{L\,PA,t}$ | = | annual animal biomass consumption over the project area to be planted at time *t*; t d.m. $yr^{-1}$ |
| *p* | = | parcel index (P = total number of parcels); dimensionless |
| *an* | = | animal type index (An = total number of animal types); dimensionless |
| $DBI_j$ | = | daily biomass intake by animal type *j*; kg d.m. $head^{-1}$ $day^{-1}$ |
| $n_{pgt}$ | = | number of individual animals from the livestock group *g* at parcel *p* at time *t*; dimensionless |
| $a_{gp}$ | = | number of months per annum during which animals from the livestock group *g* are present at parcel *p*; dimensionless |
| 30 | = | average number of days in month; dimensionless |
| $SFR_{PAga}$ | = | fraction of total project area sampled for animal grazing; dimensionless. |

For data on daily biomass intake, preferably use local data or applicable data from the scientific literature. For default data on daily biomass intake by animal see Table 3.

***Step 2***: Interview the owners of the animal populations identified in step 1 to identify:

a) *Na*: the total number of animals from the different livestock groups that are grazing in the project area (or in the sampled discrete parcels); dimensionless

b) $Na_s$: the number of animals from the different livestock groups that the animal owners intend to sell as a consequence of the project implementation. Selling may be due to insufficient land under the control of the animal owners outside the project boundary; dimensionless

c) *EGL*: the existing grazing land areas outside the project boundary that are under the control of the animal owners and that will be used to maintain part of the displaced animal populations; ha. These areas shall be specified in the AR-CDM-PDD and subject to monitoring.

**Table 3: Approximate values of daily biomass intake (d.m. – dry mass) for different type of animals**

| **Animal Type** | | **Daily Feed Intake (MJ $head^{-1}$ $day^{-1}$)** | **Daily Biomass Intake (kg d.m. $head^{-1}$ $day^{-1}$)** |
|---|---|---|---|
| Sheep | Developed Countries | 20 | 2.0 |
| | Developing Countries | 13 | 1.3 |
| Goats | Developed Countries | 14 | 1.4 |

| | | | |
|---|---|---|---|
| | Developing Countries | 14 | 1.4 |
| Mules/Asses | Developed Countries | 60 | 6.0 |
| | Developing Countries | 60 | 6.0 |
| Sources: Feed intake from Crutzen *et al.* (1986). | | | |

d) *NGL*: the new grazing land areas outside the project boundary that are under the control of the animal owners and that will be converted to grass-land to maintain another part of the displaced animal populations; ha. These areas shall be specified in the AR-CDM-PDD and subject to monitoring.

***Step 3:*** Estimate the number of animals that can be displaced in *EGL*-areas:

a) Interview local experts and the owners of *EGL* areas about maximum population and number of months per annum during which animals of the type displaced can be present in these areas. Using Eq. 45, calculate the maximum annual biomass that these grazing areas can produce for animal feeding ($\Delta C_{Lmax}$).

b) Collect data on domestic species, their population, and number of months per annum during which animals from different species are already present in different discrete parcels of the areas identified in step 2. Using Eq. 45, calculate the annual biomass that these grazing areas are currently producing for animal feeding ($\Delta C_{Lcurrent}$). The average number of animals already present in the *EGL* areas selected for monitoring shall be specified in the AR-CDM-PDD ($Na_{EGl,t=1}$).

c) Determine if the *EGL* areas are sufficient for feeding the entire population of displaced animals.

- If: $(\Delta C_{Lmax} - \Delta C_{Lcurrent})_{EGL} \geq \Delta C_{L\,PA}$

  Then: Leakage due to activity displacement is set as zero (e.g. $LK_{conversion} = 0$) and no further-assessment of $LK_{conversion}$ will be necessary

- If: $(\Delta C_{Lmax} - \Delta C_{Lcurrent})_{EGL} < \Delta C_{L\,PA}$

  Then: Additional grazing areas will be required to feed the displaced animals.

a) Calculate the number of displaced animals that can be maintained in *EGL* areas as follows:

- Average annual biomass consumed by one average animal:

$$\Delta C_{av} = \Delta C_{LPAt} \cdot \frac{SFR}{NA} \qquad \textbf{(45)}$$

- Number of animals that can be displaced in *EGL*:

$$dNa_{EGL} = \frac{(\Delta C_{L\max} - \Delta C_{Lcurrent})_{EGL}}{\Delta C_{av}} \qquad \textbf{(46)}$$

***Step 4:*** Estimate the number of animals that can be displaced in *NGL*-areas:

a) Interview local experts and the owners of these areas about maximum population and number of months per annum during which animals can be present in these areas – after conversion to grazing land - for each type of animal species. Using Eq. 45 calculate the maximum annual biomass that these areas to be converted to grazing lands can produce for animal feeding ($\Delta C_{Lmax}$).

b) Do sub-step b) as in step 1, but for the *NGL* area. The average number of animals already present in the *NGL* areas selected for monitoring shall be specified in the AR-CDM-PDD ($Na_{NGL,t=1}$).

c) Determine if the *NGL* areas are sufficient for feeding the population of displaced animals that cannot be maintained in *EGL* areas:

- If: $(\Delta C_{Lmax} - \Delta C_{Lcurrent})_{EGL} + (\Delta C_{Lmax} - \Delta C_{Lcurrent})_{NGL} \geq \Delta C_{L\ PA}$ Then: *NGL* areas are sufficient and no animals will have to be displaced to unidentifiable areas, and *XGL* can be set as zero.
- If: $(\Delta C_{Lmax} - \Delta C_{Lcurrent})_{EGL} + (\Delta C_{Lmax} - \Delta C_{Lcurrent})_{NGL} < \Delta C_{L\ PA}$ Then: *NGL* areas are insufficient, and some animals will have to be displaced to unidentifiable areas.

d) Do sub-step d) as in step 1, but for *NGL* areas.

***Step 5:*** Estimate the number of animals that will have to be displaced to unidentifiable areas and estimate *XGL*:

a) Determine the number of animals to be displaced to unidentifiable areas using the following conservative decision rule:

- If: $Na_s \geq (Na - dNa_{EGL} + dNa_{NGL})$

  Then: $dNa_{XGL} = Na_s$
- If: $Na_s < (Na - dNa_{EGL} + dNa_{NGL})$

  Then: $dNa_{XGL} = (Na - dNa_{EGL} + dNa_{NGL})$

b) Calculate *XGL* using the following equation:

$$XGL = A \cdot \frac{dNa_{XGL}}{Na} \quad (47)$$

where:

*XGL* = total unidentified grazing land area outside the project boundary that will receive the remaining part of displaced animal populations, e.g. when the pre-project animal owners decide to sell the animals, up to time t*; ha

*A* = total project area; ha

*Na* = total number of animals from the different livestock groups that are grazing in the project area; dimensionless

$dNa_{XGL}$ = total number of animals to be displaced to unidentifiable areas; dimensionless

***Step 6:*** Estimate leakage due to displacement of grazing activities as follows:

$$LK_{conv\text{-}graz} = LK_{NGL} + LK_{XGL} \quad (48)$$

where:

$LK_{conv\text{-}graz}$ = leakage due to conversion of non-grassland to grassland; t $CO_2$-e.

$LK_{NGL}$ = leakage due to conversion of non-grassland to grassland in *NGL* areas under the control of the animal owners; t $CO_2$-e.

$LK_{XGL}$ = leakage due to conversion of non-grassland to grassland in unidentified *XGL* areas; t $CO_2$-e.

**a) Estimation of $LK_{NGL}$:**

- Stratify *NGL* areas in categories of land-use/land-cover that are significantly different in terms of carbon stock (e.g. crop-land, fallow land, mature forest).
- Estimate the mean carbon stocks in the five carbon pools (from IPCC GPG-LULUCF, literature or original measurements) of each *NGL* stratum. In the case of the soil organic carbon pool, always subtract from the estimate in the *NGL* strata the estimated mean carbon stock in the soil organic carbon pool of the project area (from IPCC GPG-LULUCF, literature or original measurements). This is not necessary for dead wood and litter, because in the project area, under the applicability conditions of this methodology, these pools have very small carbon stocks.
- If a significant proportion of the above-ground biomass in the *NGL* strata is merchantable timber volume, estimate the biomass of this volume (trough field measurements).
- Subtract from the total above-ground biomass in the *NGL* strata the biomass of the harvested timber and any woody biomass that is likely to be used as fuel-wood or for charcoal production.
- Assume that the remaining above-ground biomass will be 100% burned, which will result in emissions of non-$CO_2$ gases. If no estimates of harvested timber volume and/or fuel wood biomass are made, assume that all above-ground biomass will be burned. This assumption is conservative because the fraction of biomass that burns is always less than 100%.
- Estimate $LK_{NGL}$ as follows:

$$LK_{NGL} = \sum_{t=1}^{t^*} \left( ngl_t \cdot C_{NGL\,ac_t} + E_{ac_{BiomassBurn\,t}} \cdot (1 - WB_{ht}) \right) \qquad \textbf{(49)}$$

where:

$LK_{NGL}$ = leakage due to conversion of non-grassland to grassland; t $CO_2$-e.

$ngl_t$ = total area converted to grassland[19] at time *t*; ha

$C_{NGLac\,t}$ = mean carbon stock including above and below-ground biomass of the *NGL* area converted to grassland at time *t*; $CO_2$-e.

$WB_{ht}$ = fraction of total above-ground biomass harvested as timber and as fuel-wood at time *t* (not burned); dimensionless

[19] It is possible that not all *NGL* areas will be converted to grazing land in the first project year; $ngl_t$ shall be estimated as a proportion of the area annually afforested or reforested. The proportion shall be calculated as the ratio *NGL* relative to (*EGL+NGL+XGL*).

$E_{acBiomassBurnt}$ = total non-$CO_2$ emissions from biomass burning in land converted to grazing land at time *t* (calculated from 100% of the above-ground biomass); t $CO_2$-e. These can be calculated using Eq. 27.

- Calculate the average a$LK_{NGL}$ per displaced animal in *NGL* areas as follows.

$$aLK_{NGL} = \frac{LK_{NGL}}{dNa_{NGL}} \quad \textbf{(50)}$$

where:

$aLK_{NGL}$ = average leakage due to conversion of non-grassland to grassland per displaced animal in *NGL* areas; t $CO_2$-e. animal$^{-1}$

$LK_{NGL}$ = leakage due to conversion of non-grassland to grassland; t $CO_2$-e.

$dNa_{NGL}$ = total number of animals to be displaced to *NGL* areas; dimensionless

**b) Estimation of $LK_{XGL}$:**

- As it is not possible to identify land-use/land-cover in *XGL* areas, this methodology conservatively assumes that these areas are covered by mature forests and that these forests will be converted to grazing land.
- Estimate the mean carbon stocks in the five carbon pools (from IPCC GPG-LULUCF, literature or original measurements) of mature forests in the country or region where the grazing animals will most-likely be sold. In the case of the soil organic carbon pool, always subtract from the estimate in the *XGL* areas the estimated mean carbon stock in the soil organic carbon pool of the project area (from IPCC GPG-LULUCF, literature or original measurements). This is not necessary for dead wood and litter, because in the project area, under the applicability conditions of this methodology, these pools have very small carbon stocks.
- Estimate the likely percentage of above-ground biomass that is likely not to be burned (from literature or original studies). If no justifiable assumption can be made regarding this percentage, assume 100% of biomass burning.
- Estimate $LK_{XGL}$ as follows:

$$LK_{XGL} = \sum_{t=1}^{t^*}\left(xgl_t \cdot C_{XGLac_t} + E_{ac_{BiomassBurn\ t}} \cdot (1 - WB_{ht})\right) \quad \textbf{(51)}$$

where:

$LK_{XGLL}$ = leakage due to conversion of unidentifiable-land to grassland; t $CO_2$-e.

$xgl_t$ = total unidentifiable area converted to grassland[20] at time *t*; ha

$C_{XGLac\ t}$ = mean carbon stock including above and below-ground biomass of the *XGL* area converted to grassland at time *t*; $CO_2$-e.

[20] It is possible that not all *XGL* areas will be converted to grazing land in the first project year; $ngl_t$ shall be estimated as a proportion of the area annually afforested or reforested. The proportion shall be calculated as the ratio *XGL* relative to (*EGL*+*NGL*+*XGL*).

$WB_{ht}$ = fraction of total above-ground biomass not-burned at time $t$ (not burned); dimensionless

$E_{acBiomassBurnt}$ = total non-$CO_2$ emissions from biomass burning in unidentifiable land converted to grazing land at time $t$ (assuming 100% burning of above-ground biomass); t $CO_2$-e. These can be calculated using Eq. 27.

- Calculate the average $aLK_{XGL}$ per displaced animal in $XGL$ areas as follows.

$$aLK_{XGL} = \frac{LK_{XGL}}{dNa_{XGL}} \quad \textbf{(52)}$$

where:

$aLK_{XGL}$ = average leakage due to conversion of non-grassland to grassland per displaced animal in $XGL$ areas; t $CO_2$-e. animal$^{-1}$

$LK_{XGL}$ = leakage due to conversion of non-grassland to grassland; t $CO_2$-e.

$dNa_{XGL}$ = total number of animals to be displaced to $XGL$ areas; dimensionless

### 8.2.3 Estimation of $LK_{conv\text{-}crop}$ (Leakage due to conversion of land to crop land, based on area of conversion):

'Activity shifting' or 'activity displacement' may result in leakage immediately after the start of the project activity when activities are displaced to areas outside the project boundary. However, leakage due to conversion of land is not attributable to the AR-CDM project activity if the conversion of land occurs 5 or more years after the displacement of the activity to areas outside the project boundary. The type and schedule of measures to be taken to prevent the conversion of land outside the project boundary should therefore be described in the AR-CDM-PDD and its implementation monitored.

Alternative methodologies are presented for analyses at the household or at the community level (the household analysis is only appropriate where continued ownership or occupation of land parcels can be shown). For the household level analysis, over the five year period, 10 % of the randomly selected displaced households (or a minimum of randomly selected 30 households) will be tracked with respect to their land use. For the community level analysis, the land use of randomly selected 10 % of the communities (or a minimum of 10 communities) displaced or partially displaced by project activities will be tracked, with 10% of randomly selected households (or a minimum of 10 randomly selected households) in each community sampled to determine the area of unidentifiable conversion in the five years after the start of displacement from project area. The community level analysis allows for communities of differing sizes.

$$LK_{conv\text{-}crop} = CS_{AD} - CS_b \quad \textbf{(53)}$$

where:

$LK_{conv\text{-}crop}$ = leakage resulting from the conversion for cropland.

$CS_{AD}$ = locally derived carbon stock (including all five eligible carbon pools); t $CO_2$-e. ha$^{-1}$) of area of land on which activities shifted; t $CO_2$-e. ha-1.

$CS_b$ = carbon stock of baseline; t $CO_2$-e. ha$^{-1}$

**Case 1: $CS_{AD} < CS_b$**

Leakage due to displacement for cropland can be set as zero if the carbon stock on the land to which crops are displaced is less than the carbon stock from which they originated under the baseline scenario.

$$L_{conv\text{-}crop} = 0, \text{ if } CS_{AD} < CS_b \quad \textbf{(54)}$$

**Case 2:** $CS_{AD} > CS_b$

However, if activities are displaced to land with higher stocks, then a leakage debit should be taken by the project. Carbon stock decreases through biomass losses will be calculated by multiplying the area of land conversion by the carbon stock. Land holdings are broken down into two types:

a) Land holdings with areas of geographically identifiable land conversion outside the project boundary. The area of identifiable land converted by a sampled displaced household or community is multiplied by the mean carbon stock of the land strata type prior to conversion. If the previous land strata type is unknown, the strata with the highest carbon stock will be used.

b) Land holdings with areas of geographically unidentifiable land conversion outside the project boundary. This may be due to migration of households to unknown locations or any other circumstance that causes the location of the households' converted land to be unknown. Where the land households convert is unidentifiable, leakage GHG emissions is conservatively assumed equal to the area of land from which the household was displaced multiplied by a conservative value for regional forest biomass stock.

**a) Household level:**

***Step 1***: Randomly select households to be sampled (10% of all households or a minimum of 30 households), e.g by selecting them systematically from a list of all households listed in alphabetic order;

***Step 2***: Measure area of cropland within project boundaries each sampled household will be displaced from;

***Step 3:*** Interview sampled household to determine total area of cropland owned by each household that is planted ($TACP_h$), and the land cover class ($CS_i$) of the area ($IAC_{hi}$) and that each household intends to convert.

***Step 4:*** Estimate the carbon stock in each land cover stratum using methods detailed in IPCC GPG-LULUCF chapter 4.3, including all pools

***Step 5:*** Determine the mean conservative forest biomass stock for the project region ($\overline{CS}$) for application to unidentified areas;

***Step 6***: Calculate the leakage using the following equations:

$$LK_{conv-crop} = \sum_{hh=1}^{Hh}\left(\sum_{i=1}^{I} IAC_{hi} \cdot CS_i\right) \cdot SF + \sum_{hh=1}^{Hh}\left(TACP_h - \sum_{i=1}^{I} IAC_{hi}\right) \cdot \overline{CS} \cdot SF \quad \textbf{(55)}$$

and:

$$SF = \frac{TNHH}{SHH} \quad \textbf{(56)}$$

where:

$LK_{conv\text{-}crop}$= leakage due to conversion of land to cropland attributable to displacement (activity shifting); t $CO_2$-e.

| | | |
|---|---|---|
| $IAC_{hi}$ | = | identifiable areas converted by household *hh* in stratum *i*; hectares |
| $TACP_h$ | = | total area of cropland planted that is owned by household *h*; hectares |
| $hh$ | = | 1,2,3….*Hh* households; dimensionless |
| $i$ | = | 1,2,3….*I* strata; dimensionless |
| $CS_i$ | = | locally derived carbon stock of identified lands (including all the five eligible carbon pools) of stratum *i*; t $CO_2$-e. $ha^{-1}$ |
| $\overline{CS}$ | = | locally derived average carbon stock of unidentified lands (including all the five eligible carbon pools); t $CO_2$-e. $ha^{-1}$ |
| $SF$ | | sampling factor of household; dimensionless |
| $TNHH$ | = | total number of households using project lands in baseline; dimensionless |
| $SHH$ | = | sampled households, number of households sampled for $LK_{conv-crop}$; dimensionless |

**b) <u>Community level:</u>**

For the community based estimate, one calculates the leakage per community using an equation similar to Eq. 56 and then one sums over the communities based on area.

***Step 1***: Record the number of communities occupying land inside the project boundary. Randomly select 10% of the communities (or a minimum of 10 communities) to be sampled;

***Step 2***: Measure total area of cropland within project boundaries from which pre-project activities in each sampled community will be displaced ($TACP_c$);

***Step 3***: Calculate the number of households within each selected community ($TNHH_c$);

***Step 4***: Randomly select 10% of households (or a minimum of 10 households) to be sampled within selected communities, e.g by selecting them systematically from a list of all households listed in alphabetic order;

***Step 5***: Interview community members to estimate the area of identifiable land that each sampled community will convert due to displacement of pre-project activities ($IAC_{hc}$);

***Step 6*** Classify the estimated area of identifiable land that may be converted within the community into a pre-conversion land cover stratum;

***Step 7***: Estimate the carbon stock (including all 5 carbon pools) in each land cover stratum using methods detailed in IPCC GPG-LULUCF chapter 4.3 ($CS_i$);

***Step 8***: Determine the mean conservative forest biomass stock for the project region ($\overline{CS}$) for application to unidentified areas;

***Step 9***: Calculate the leakage using the following equations:

$$LK_{conv-crop,c} = \sum_{hh=1}^{Hh_c}\left(\sum_{i=1}^{I} IAC_{hci} \cdot CS_i\right) \cdot SF_c + \sum_{hh=1}^{Hh_c}\left(TACP_c - \sum_{i=1}^{I} IAC_{hci}\right) \cdot \overline{CS} \cdot SF_c \quad \textbf{(57)}$$

$$SF_c = \frac{TNHH_c}{SHH_c} \quad \textbf{(58)}$$

$$LK_{conv-crop} = TACP \cdot \frac{\sum_{c=1}^{C} LK_{conv-crop,c}}{\sum_{c=1}^{C} TACP_c} \quad \textbf{(59)}$$

where:

$LK_{conv-crop}$= leakage due to conversion of land to cropland attributable to displacement (activity shifting); t $CO_2$-e.

$LK_{conv-crop,c}$= leakage due to conversion of land to cropland attributable to displacement (activity shifting) in community *c*; t $CO_2$-e.

$TACP$ = total area of land on which pre-project activities were displaced due to project activities; hectares

$TACP_c$ = total area of land on which pre-project activities were displaced due to project activities in community *c*; hectares

$IAC_{hci}$ = identifiable areas converted of stratum *i* by household *hh* in community *c*; hectares

$CS_i$ = locally derived carbon stock (including all the five eligible carbon pools) of stratum *i*; t $CO_2$-e. $ha^{-1}$

$\overline{CS}$ = locally derived average carbon stock of unidentified lands (including all the five eligible carbon pools); t $CO_2$-e. $ha^{-1}$

$TNHH_c$ = total number of households using project lands in baseline in community *c*; dimensionless

$SHH_c$ = sampled households in community *c*, number of households sampled for leakage by activity shifting; dimensionless

$SF_c$ = sampling factor for community *c*; dimensionless

*c* = 1,2,3…*C*, communities; dimensionless

*i* = 1,2,3….*I,* strata; dimensionless

*hh* = 1,2,3, $Hh_c$, households in community *c;* dimensionless

### 8.2.4 Estimation of $LK_{fuel-wood}$ (Leakage due to displacement of fuel-wood collection):

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

$$FG_{BL} = \frac{sFG_{BL}}{SFR_{PAfw}} \quad \textbf{(60)}$$

where:

$FG_{BL}$ = average pre-project annual volume of fuel-wood gathering in the project area; $m^3\ yr^{-1}$

$sFG_{BL}$ = sampled average pre-project annual volume of fuel-wood gathering in the project area; $m^3\ yr^{-1}$

$SFR_{PAfw}$ = fraction of total area or households in the project area sampled; dimensionless

Given the conditions under which this methodology is applicable (see section I.3), particularly the applicability of baseline approach 22(a), the methodology assumes that the estimated historical or current fuel-wood consumption and/or charcoal production ($FG_{BL}$) will remain constant over the entire crediting period. Based on the planned afforestation or reforestation establishment schedule and the prescribed management, the periods of time from which fuel-wood collection and/or charcoal production should be excluded from the considered sample discrete areas as well as the amounts of fuel-wood produced in the different stands through thinning, coppicing and harvesting can be specified. This planning should be used to estimate the amount of fuel-wood and/or charcoal that may have to be obtained each year from sources outside the project boundary.

$$FG_{outside,t} = FG_{BL} - FG_{AR,t} \qquad \textbf{(61)}$$

where:

$FG_{outside,t}$ = volume of fuel-wood gathering displaced outside the project area at year $t$; $m^3\ yr^{-1}$

$FG_{BL}$ = average pre-project annual volume of fuel-wood gathering in the project area; $m^3\ yr^{-1}$

$FG_{AR,t}$ = volume of fuel-wood gathering allowed/planned in the project area under the proposed AR-CDM project activity; $m^3\ yr^{-1}$

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

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

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

$$LK_{fuel-wood} = \sum_{t=1}^{t^*} FG_t \cdot D \cdot BEF_2 \cdot CF \cdot \frac{44}{12} \qquad \textbf{(62)}$$

$$FG_t = FG_{outside,t} - FG_{NGL,t} \qquad \textbf{(63)}$$

where:

$LK_{fuel\text{-}wood}$ = leakage due to displacement of fuel-wood collection up to year $t^*$; t $CO_2$-e.

$FG_t$ = volume of fuel-wood gathering displaced in unidentified areas; $m^3\ yr^{-1}$

$FG_{outside,t}$ = volume of fuel-wood gathering displaced outside the project area at year $t$; $m^3\ yr^{-1}$

$FG_{NGL,t}$ = volume of fuel-wood gathering in $NGL$ areas and supplied to pre-project fuel-wood collectors and/or charcoal producers; $m^3\ yr^{-1}$

$D$ = average basic wood density; t d.m. $m^{-3}$ (See IPCC GPG-LULUCF, Table 3A.1.9)

$BEF_2$ = biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark); dimensionless Table 3A.1.10

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

### 8.2.5 Estimation of $LK_{fencing}$ (Leakage due to increased use of wood posts for fencing):

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

$$LK_{fencing} = \sum_{t=1}^{t^*} \frac{PAR_t}{DBP} \cdot FNRP \cdot DBP \cdot APV \cdot D \cdot BEF_2 \cdot CF \cdot \frac{44}{12} \qquad \textbf{(64)}$$

where:

$LK_{fencing}$ = leakage due to increased use of wood posts for fencing up to year $t^*$; t $CO_2$-e.

$PAR_t$ = perimeter of the areas to be fenced at year $t$; m

$DBP$ = average distance between wood posts; m

$FNRP$ = fraction of posts from off-site non-renewable sources; dimensionless

$APV$ = average volume of o wood posts (estimated from sampling); m$^3$

$D$ = average basic wood density; t d.m. m$^{-3}$ (See IPCC GPG-LULUCF, 2003 Table 3A.1.9)

$BEF_2$ = biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark); dimensionless Table 3A.1.10

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

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

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

## 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 AR CDM project activity ($C_{AR-CDM}$), in t $CO_2$-e.:

$$C_{AR-CDM} = C_{ACTUAL} - C_{BSL} - LK \qquad \textbf{(65)}$$

where:

$C_{AR-CDM}$ = net anthropogenic greenhouse gas removals by sinks; t $CO_2$-e.

$C_{ACTUAL}$ = actual net greenhouse gas removals by sinks (Eq. 13); t $CO_2$-e.

$C_{BSL}$ = baseline net greenhouse gas removals by sinks (Eq. 1 or 2); t $CO_2$-e.

*LK* = leakage (Eq. 34); t $CO_2$-e.

Note: In this methodology Eq. 66 is used to estimate net anthropogenic GHG removals by sinks for the period of time elapsed between project start ($t=1$) and the year $t=t^*$, $t^*$ being the year for which actual net greenhouse gas removals by sinks are estimated. This is done because project emissions and leakage are permanent, which requires to calculate their cumulative values since the starting date of the AR CDM project activity.

**Calculation of tCERs and lCERs**

To estimate the amount of CERs that can be issued at time $t^*= t_2$ (the date of verification) for the monitoring period $T = t_2 – t_1$, this methodology uses the EB approved equations[21] , which produce the same estimates as the following:

$$tCERs = C_{AR\text{-}CDM,t2} \quad \textbf{(66)}$$

$$lCERs = C_{AR\text{-}CDM,t2} - C_{AR\text{-}CDM,t1} \quad \textbf{(67)}$$

where:

*tCERs* = number of units of temporary Certified Emission Reductions

*lCERs* = number of units of long-term Certified Emission Reductions

$C_{AR\text{-}CDM,t2}$ = net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$; t $CO_2$-e.

$C_{AR\text{-}CDM,t1}$ = net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$; t $CO_2$-e.

## 10 Uncertainties and conservative approach

Assessment of uncertainties should follow guidance offered by IPCC 2000 and IPCC GPG-LULUCF. Particular examples of assessment of uncertainty related to expert judgment and method to combine uncertainties are provided below.

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

### 10.1 Uncertainty in expert judgment

Expert judgment usually will consist of a range, perhaps quoted together with a most likely value. Under these circumstances the following rules apply:

- Where experts only provide an upper and a lower limiting value, assume the probability density function is uniform and that the range corresponds to the 95% confidence interval.
- Where experts also provide a most likely value, assume a triangular probability density function using the most likely values as the mode and assuming that the upper and lower limiting values each exclude 2.5% of the population. The distribution need not be symmetrical.

### 10.2 Methods to Combine Uncertainties

Estimated carbon stock changes, emissions and removals arising from LULUCF activities have uncertainties associated with area or other activity data, biomass growth rates, expansion factors and other coefficients. It is assumed that the uncertainties of the various input data estimates are available, either as default values given in Chapters 2, 3 and 4 of IPCC GPG-LULUCF, expert judgment, or estimates based of sound statistical sampling.

Use of either Tier 1 (or Tier 2 see IPCC GPG-LULUCF) method will provide insight into how individual categories and greenhouse gases contribute to the uncertainty in total removals and emissions of the project. Being spreadsheet based, the Tier 1 is easy to apply, and it is good practice recommended by the IPCC GPG-LULUCF.

The Tier 1 method for combining uncertainties is based on the error propagation equation introduced in GPG 2000. Eq. 69 can be used to estimate the uncertainty of a product of several quantities, e.g., when an emission estimate is expressed as the product of an emission factor and activity data. It applies where there is no significant correlation among data and where uncertainties are relatively small (standard deviation less than about 30% of the mean). The equation can also be used to give approximate results where uncertainties are larger than this.

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2} \qquad \textbf{(68)}$$

where:

$U_{total}$ = percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage);

$U_n$ = percentage uncertainties associated with each of the quantities,

1,2,…,n = number of quantities

Where uncertain quantities are to be combined by addition or subtraction, as when deriving the overall uncertainty in the project estimates, Eq. 70 can be used.

$$U_E = \frac{\sqrt{(U_1 * E_1)^2 + (U_2 * E_2)^2 + \ldots + (U_n * E_n)^2}}{\left|E_1 + E_2 + \ldots + E_n\right|} \qquad \textbf{(69)}$$

where:

$U_E$ = percentage uncertainty of the sum

$U_n$ = percentage uncertainty associated with source/sink *n*

$E_n$ = emission/removal estimate for source/sink *n*

As with Eq. 69, Eq. 70 assumes that there is no significant correlation among emission and removal estimates and that uncertainties are relatively small. However, it still can be used to give approximate results where uncertainties are relatively large.

## 11 Data needed for *ex ante* estimations

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| Historical land use/cover data | Determining baseline approach, Demonstrating eligibility of land | Earliest possible up to now | Local | Publications, government, interview |
| Land use/cover map | Demonstrating eligibility of land, stratifying land area | Before 1990 and most recent date | Regional, local | Forestry inventory |
| Satellite image | Same as above cell | 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 | 1:10000 | Local government and institutional agencies |
| National and sectoral policies | Additionality consideration | Before 11 Nov. 2001 | National and sectoral | Local government |
| UNFCCC, EB and AR-WG decisions - reports | | 1997 up to now | International | UNFCCC website |
| IRR, NPV cost benefit ratio, or unit cost of service | Indicators of investment analysis | Most recent date | Local | Calculation (if any, depends on the way of additionality analysis) |
| 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 (if any, depends on the way of additionality analysis) |
| 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 (if any, depends on the way of additionality analysis) |
| Transaction costs | Including costs of project preparation, validation, registration, monitoring, etc. | Most recent date | National and international | DOE |
| Revenues | Those from timber, fuel-wood, non-wood products, with and without CER revenues, etc. | Most recent date, taking into account market risk | National and local | Local statistics, published data and/or survey (if any, depends on the way of additionality analysis) |
| 12/44 | Ration of molecular weights of carbon and $CO_2$; dimensionless | | Global default | IPCC |
| 16/12 | Ration of molecular weights of $CH_4$ and carbon; dimensionless | | Global default | IPCC |

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| 30 | Average number of days in month; dimensionless | | | |
| 44/12 | Ratio of molecular weights of $CO_2$ and carbon; dimensionless | | Global default | IPCC |
| 44/28 | Ratio of molecular weights of $N_2O$ and nitrogen; dimensionless | | Global default | IPCC |
| $an$ | Animal type index ($An$ = total number of animal types; dimensionless | | Project | Estimated *ex ante*, monitored *ex post* |
| $A$ | Total project area; ha | Most updated | Project | Estimated *ex ante*, monitored *ex post* |
| $A_{B,ikt\_sb}$ | Area of slash and burn in stratum *i*, stand model *k*, time t; ha | | Project | Estimated *ex ante*, monitored *ex post* |
| $Adist_{ikt}$ | Forest areas affected by disturbances in stratum *i,* stand model *k*, time *t*; ha $yr^{-1}$ | Most updated | Stratum and species | Estimated *ex ante*, monitored *ex post* |
| $Adist_{ikT}$ | Average annual area affected by disturbances for stratum *i,* stand model *k*, during the period *T*; ha $yr^{-1}$ | Most updated | Stratum and species | Estimated *ex ante*, monitored *ex post* |
| $a_{gpl}$ | Number of months per annum during which animals from the livestock group *g* are present at parcel *p*; dimensionless | Most updated | Project | Estimated *ex ante*, monitored *ex post* |
| $A_{ikt}$ | Area of stratum *i,* stand model *k*, at time *t*; hectare (ha) | Most updated | Stratum and species | Estimated *ex ante*, monitored *ex post* |
| $A_{ikt\_sb}$ | Area of slash and burn for stratum *i*, stand model *k*, time *t*; ha | Most updated | Stratum and species | Estimated *ex ante*, monitored *ex post* |
| $A_{ikT}$ | Average annual area for stratum *i,* stand model *k*, during the period *T*; ha $yr^{-1}$ | Most updated | Stratum and species | Estimated *ex ante*, monitored *ex post* |
| $aLK_{NGL}$ | Average leakage due to conversion of non-grassland to grassland per displaced animal in *NGL* areas; t $CO_2$-e. $animal^{-1}$ | Most updated | Project | Calculated |
| $aLK_{XGL}$ | Average leakage due to conversion of non-grassland to grassland per displaced animal in *XGL* areas; t $CO_2$-e. $animal^{-1}$ | Most updated | Project | Calculated |
| $APV$ | Average volume of wood posts (estimated from sampling); $m^3$ | Most updated | Project | Calculated |
| $BEF_{1,j}$ | Biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total above-ground biomass increment for species *j;* dimensionless | | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $BEF_2$ | Biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark); dimensionless Table 3A.1.10 | | Global default to local | GPG-LULUCF, national GHG inventory, local survey |

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| $BEF_{2,ijt}$ | Biomass expansion factor for converting merchantable volumes of extracted round wood to total above-ground biomass (including bark) for stratum *i,* species *j*, time *t*; dimensionless | | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $B_{ikt}$ | Average above-ground biomass stock before burning for stratum *i*, stand model *k*, time *t*; t d.m. $ha^{-1}$ | | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $B_{pre,ikt}$ | Average pre-existing stock on land to be planted before the start of a proposed A/R CDM project activity for baseline stratum i, stand model k, time t; t d.m. $ha^{-1}$ | Most updated | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $B_{w,ijt}$ | Average above-ground biomass stock for stratum *i,* species *j*, time *t*; t d.m. $ha^{-1}$ | Most updated | Local | National GHG inventory, local survey |
| c | Community index (C=total number of communities); dimensionless | | Project | Estimated *ex ante*, monitored *ex post* |
| $C_{AB,ijt}$ | Carbon stock in above-ground biomass for stratum *i,* species *j*, at time *t;* t C | | Local and species specific | Calculated |
| $C_{NGLac\ t}$ | Mean carbon stock including above and below-ground biomass of the NGL area converted to grassland at time *t*; $CO_2$-e. | | Regional, local default | Estimated *ex ante* |
| $C_{XGLac\ t}$ | Mean carbon stock including above and below-ground biomass of the XGL area converted to grassland at time *t*; $CO_2$-e. | | Regional, local default | Estimated *ex ante* |
| $C_{ACTUAL}$ | Actual net greenhouse gas removals by sinks; t $CO_2$-e. | | Project specific | Calculated |
| $C_{AR\text{-}CDM}$ | Net anthropogenic greenhouse gas removals by sinks; t $CO_2$-e. | | Project specific | Calculated |
| $C_{AR\text{-}CDM,t1}$ | Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$; t $CO_2$-e. | | Project specific | Calculated |
| $C_{AR\text{-}CDM,t2}$ | Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$; t $CO_2$-e. | | Project specific | Calculated |
| $C_{BB,ijt}$ | Carbon stock in below-ground biomass for stratum *i,* species *j*, at time *t;* t C | | Local and species specific | Calculated |
| $C_{BSL}$ | Baseline net greenhouse gas removals by sinks; t $CO_2$-e. | | Project specific | Calculated |
| *CE* | Average biomass combustion efficiency; dimensionless | | Global and national default | IPCC GPG-2000, national GHG inventory |
| $CF_j$ | Carbon fraction for species *j*; t C (t d.m.)$^{-1}$ | | Global default to local | GPG-LULUCF, national GHG inventory |
| $CF_{pre}$ | Carbon fraction of dry biomass in pre-existing vegetation, t C (t d.m.)$^{-1}$ | | Global default to local | GPG-LULUCF, national GHG inventory |
| $C_{ikt}$ | Total carbon stock in living biomass for stratum *i,* stand model *k*, calculated at time *t*; t C | | Stratum | Calculated |

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| $CS_i$ | Locally derived carbon stock (including all five eligible carbon pools) of stratum i; t $CO_2$-e. $ha^{-1}$ | Most updated | Project | Calculated |
| $\overline{CS}$ | Locally derived average carbon stock of unidentified lands (including all the five eligible carbon pools); t $CO_2$-e. $ha^{-1}$ | Most updated | Project | Calculated |
| $C_{TOTAL,ikt}$ | Average annual increment rate in total carbon stock in stratum *i,* stand model *k*, time *t*; t of $CO_2$ $ha^{-1}.yr^{-1}$ | | Stratum | Calculated |
| *D* | Average basic wood density; t d.m. $m^{-3}$ (See IPCC GPG-LULUCF, Table 3A.1.9) | | Global default to local | GPG-LULUCF, national GHG inventory |
| *DBH* | Tree diameter at breast height; cm | | Project specific | Measured |
| $DBI_j$ | Daily biomass intake by animal type *j*; kg d.m. $head^{-1}$ $day^{-1}$ | | Global default to local | Estimated *ex ante* |
| *DBP* | Average distance between wood posts; m | Most updated | Project | Estimated *ex ante*, measured *ex post* |
| $D_j$ | Basic wood density for species *j*; t d.m. $m^{-3}$ (See IPCC GPG-LULUCF, Table 3A.1.9) | | Global default to local | GPG-LULUCF, national GHG inventory, local survey |
| $dNa_{EGL}$ | Number of animals that can be displaced in *EGL* areas; dimensionless | Most updated | Project | Estimated *ex ante*, measured *ex post* |
| $dNa_{NGL}$ | Number of animals that can be displaced in *NGL* areas; dimensionless | Most updated | Project | Estimated *ex ante*, measured *ex post* |
| $dNa_{XGL}$ | Number of animals to be displaced in *XGL* areas; dimensionless | Most updated | Project | Estimated *ex ante*, measured *ex post* |
| $E_{acBiomassBurnt}$ | Total non-$CO_2$ emissions from biomass burning in land converted to grazing land at time *t* (calculated from 100% of the above-ground biomass); t $CO_2$-e. | Most updated | Project | Calculated |
| $E_{BiomassBurn}$ | Total increase in non-$CO_2$ emission as a result of biomass burning within the project boundary; t $CO_2$-e. | Most updated | Project | Calculated |
| $E_{BiomassBurn,\ CH4}$ | $CH_4$ emission from biomass burning in slash and burn; t $CO_2$-e. | Most updated | Project | Calculated |
| $E_{BiomassBurn,\ N2O}$ | $N_2O$ emission from biomass burning in slash and burn; t $CO_2$-e. | Most updated | Project | Calculated |
| $E_{BiomassBurn,CO2}$ | $CO_2$ emission from biomass burning in slash and burn; t $CO_2$-e. | Most updated | Project | Calculated |
| $E_{biomassloss}$ | Decrease in the carbon stock in the living biomass carbon pools of non-tree vegetation in the year of site preparation | Most updated | Project | Calculated |
| $EF_1$ | Emission factor for emissions from N inputs; t $N_2O$-N (t N input)-1 | Most updated | Global default | GPG 2001 |

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| $E_{FuelBurn}$ | Increase in GHG emission as a result of burning of fossil fuels within the project boundary; t $CO_2$-e. | Most updated | Project | Calculated |
| $EF_{xy}$ | $CO_2$ emission factor for vehicle type *x* with fuel type *y;* dimensionless | Most updated | Global to national | IPCC Guideline, GPG 2000, national inventory |
| *EGL* | Total existing grazing land area outside the project boundary that is under the control of the animal owners (or the project participants) and that will receive part of the displaced animal populations, up to time *t*;* ha | | Project | Estimated *ex ante* |
| *Ei* | Emission/removal estimate for source/sink *i* | | | |
| $ER_{CH4}$ | Emission ratio for $CH_4$ (IPCC default value = 0.012) | | Global default | IPCC default value = 0.012 |
| $ER_{N2O}$ | Emission ratio for $N_2O$ (IPCC default value = 0.007) | | Global default | IPCC default value = 0.007 |
| $e_{xyt}$ | Fuel efficiency of vehicle type *x* with fuel type *y* at time *t*; liters $km^{-1}$ | | Global to national | GPG-2000, IPCC 1996 Guidelines, national GHG inventory |
| $FG_{AR,t}$ | Volume of fuel-wood gathering allowed/planned in the project area under the proposed AR-CDM project activity; $m^3$ $yr^{-1}$ | | Project | Estimated *ex ante*, measured *ex post* |
| $FG_{BL}$ | Average pre-project annual volume of fuel-wood gathering in the project area; $m^3$ $yr^{-1}$ | | Project | Estimated *ex ante* |
| $FG_{ijt}$ | Annual volume of fuel wood harvesting for stratum *i,* species *j*, time *t*; $m^3$ $ha^{-1}$ $yr^{-1}$ | | Stratum | Estimated *ex ante*, monitored *ex post* |
| $FG_{ijT}$ | Average annual volume of fuel wood harvested for stratum *i,* species *j*, during the period *T*; $m^3$ $ha^{-1}$ $yr^{-1}$ | | Stratum | Estimated *ex ante*, monitored *ex post* |
| $FG_{NGL,t}$ | Volume of fuel-wood gathering in *NGL* areas and supplied to pre-project fuel-wood collectors and/or charcoal producers; $m^3$ $yr^{-1}$ | | Project | Estimated *ex ante* and *ex post* |
| $FG_{outside,t}$ | Volume of fuel-wood gathering displaced outside the project area at year *t*; $m^3$ $yr^{-1}$ | | Project | Estimated *ex ante* and *ex post* |
| $FG_t$ | Volume of fuel-wood gathering displaced in unidentified areas; $m^3$ $yr^{-1}$ | | Project | Estimated *ex ante* and *ex post* |
| $f_i(DBH_t,H_t)$ | An allometric equation linking above-ground biomass of living trees (d.m $ha^{-1}$) to mean diameter at breast height (DBH) and possibly mean tree height (H) for species *j*; dimensionless | | National, local, species specific | Forestry inventory, published data, local survey |
| *FNRP* | Fraction of posts from off-site non-renewable sources; dimensionless | | Project | Estimated *ex ante* and measured *ex post* |
| $FON_t$ | Annual amount of organic fertilizer nitrogen applied at time *t* adjusted for volatilization as $NH_3$ and $NO_x$; t N | | Project | Estimated *ex ante* and measured *ex post* |

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| $Frac_{GASF}$ | Fraction that volatilizes as $NH_3$ and $NO_x$ for synthetic fertilizers; dimensionless | | Global default | IPCC Guideline |
| $Frac_{GASM}$ | Fraction that volatilizes as $NH_3$ and $NO_x$ for organic fertilizers; dimensionless | | Global default | IPCC Guideline |
| $FSN_t$ | Amount of synthetic fertilizer nitrogen applied at time *t* adjusted for volatilization as $NH_3$ and $NO_x$; t N | | Project | Estimated to measured *ex ante*, measured *ex post* |
| $FuelConsumption_{xyt}$ | Consumption of fuel type *y* of vehicle type *x* at time *t*; liters | | Project | Estimated to measured *ex ante*, measured *ex post* |
| $GHG_E$ | Sum of the increases in non-$CO_2$ GHG emissions by sources within the project boundary as a result of the implementation of an AR CDM project activity; t $CO_2$-e. | | Project specific | Calculated |
| *GLA* | Total grazing land area outside the project boundary needed to feed the displaced animal populations; ha | | Project | Estimated *ex ante* |
| $G_{TOTAL,ijt}$ | Annual average increment rate in total biomass in units of dry matter for stratum *i,* species *j,* time *t*; t d.m $ha^{-1}$ $yr^{-1}$ | Most recent | Global default to local | GPG-LULUCF, national and local forestry inventory |
| $G_{w,ijt}$ | Average annual above-ground biomass increment for stratum *i,* species *j*, time *t*; t d.m $ha^{-1}$ $yr^{-1}$ | | Global default to local | GPG-LULUCF, national GHG inventory |
| $GWP_{CH4}$ | Global Warming Potential for $CH_4$ | | Global | IPCC default = 21 |
| $GWP_{N2O}$ | Global Warming Potential for $N_2O$ | | Global default | IPCC default = 310 |
| *hh* | Household index (*Hh* = total number of households); dimensionless | | Project | Estimated *ex ante*, monitored *ex post* |
| $HH_c$ | total number of households in community *c*; dimensionless | | Project | Estimated *ex ante*, monitored *ex post* |
| *H* | Tree height; m | | Project | Estimated to measured *ex ante*, measured *ex post* |
| $H_{ijt}$ | Annually extracted merchantable volume for stratum *i,* species *j*, time *t*; $m^3$ $ha^{-1}$ $yr^{-1}$ | | Local/stand | Estimated *ex ante*, monitored *ex post* |
| $H_{ijT}$ | Average annually harvested merchantable volume for stratum *i,* species *j*, during the period *T*; $m^3$ $ha^{-1}$ $yr^{-1}$ | | Local/stand | Estimated *ex ante*, monitored *ex post* |
| *i* | Stratum index for both baseline strata and the strata of the project scenario | | Project | Estimated *ex ante*, monitored *ex post* |
| $IAC_{hi}$ | Identifiable areas converted in stratum *i* by household *hh*; hectares | Most updated | Project | Calculated |
| $IAC_{hic}$ | Identifiable Areas Converted in stratum *i* by household *hh* in community *c*; hectares | Most updated | Project | Calculated |

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| $I_{v,ijt}$ | Average annual increment in merchantable volume for stratum *i*, species *j*, time *t*; $m^3$ $ha^{-1}$ $yr^{-1}$ | | Local/stand | Estimated *ex ante* |
| $I_{v,ijT}$ | Average annual net increment in merchantable volume for stratum *i*, species *j* during the period *T*; $m^3$ $ha^{-1}$ $yr^{-1}$ | | Local/stand | Estimated *ex ante* |
| *j* | Species representing a specific stand model (*J* = total species) | | Project | Estimated *ex ante* |
| *k* | Stand model consisting of one or several species (*K* = total stand models) | | | |
| $k_{xyt}$ | Kilometers traveled by each of vehicle type *x* with fuel type *y* at time *t*; km | | Project | Estimated *ex ante*, monitored *ex post* |
| *lCERs* | Number of units of long-term Certified Emission Reductions | | Project | Calculated |
| $L_{fw,ijt}$ | Annual carbon loss due to fuel wood gathering for stratum *i*, species *j*, time *t*; $CO_2$-e. $yr^{-1}$ | | Local/stand | Estimated *ex ante*, monitored *ex post* |
| $L_{hr,ijt}$ | Annual carbon loss due to commercial harvesting for stratum *i*, species *j*, time *t*; t $CO_2$-e. $yr^{-1}$ | | Local/stand | Estimated *ex ante*, monitored *ex post* |
| *LK* | Total project leakage (as per Eq. 32); t $CO_2$-e. | | Project | Calculated |
| $LK_{fuel\text{-}wood}$ | Leakage due to the displacement of fuel-wood collection; t $CO_2$-e. | | Project | Calculated |
| $LK_{ActivityDisplacement}$ | Leakage due to activity displacement; t $CO_2$-e. | | Project | Calculated |
| $LK_{conversion}$ | Leakage due to conversion of land for grazing or cropland; t $CO_2$-e. | | Project | Calculated |
| $LK_{conv\text{-}graz}$ | Leakage resulting from conversion of land for grazing; t $CO_2$-e. | | Project | Calculated |
| $LK_{conv\text{-}crop}$ | Leakage resulting from conversion of land for cropland; t $CO_2$-e. | | Project | Calculated |
| $LK_{conv\text{-}crop,c}$ | Leakage resulting from conversion of land for cropland in community *c*; t $CO_2$-e. | | Project | Calculated |
| $LK_{fencing}$ | Leakage due to increased use of wood posts for fencing; t $CO_2$-e. | | Project | Calculated |
| $LK_{NGL}$ | Leakage due to conversion of non-grassland to grassland in *NGL* areas under the control of the animal owners; t $CO_2$-e. | | Project | Calculated |
| $LK_{Vehicle}$ | Total GHG emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$ | | Project | Calculated |
| $LK_{Vehicle,CH4}$ | Total $CH_4$ emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$ | | Project | Calculated |
| $LK_{Vehicle,CO2}$ | Total $CO_2$ emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$ | | Project | Calculated |
| $LK_{Vehicle,N2O}$ | Total $N_2O$ emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$ | | Project | Calculated |

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| $LK_{XGL}$ | Leakage due to conversion of non-grassland to grassland in unidentified *XGL* areas; t $CO_2$-e. | | Project | Calculated |
| $L_{ot,ijt}$ | Annual natural losses (mortality) of carbon for stratum *i*, species *j*, time *t*; $CO_2$-e. $yr^{-1}$ | | Local/stand | Calculated |
| $Mf_{ijT}$ | Mortality factor = *percentage* of $V_{ijtl}$ died during the period *T*; dimensionless | | Local/stand | Estimated |
| $m_{BL}$ | Total baseline strata | | | |
| $m_{PS}$ | Total strata in project scenario | | | |
| $N_2O_{direct-N_{fertilizer}}$ | $N_2O$ emission as a result of direct nitrogen application within the project boundary; t $CO_2$-e. | | Project | Calculated |
| *Na* | Total number of animals from the different livestock groups that are grazing in the project area (or in the sampled discrete areas); dimensionless | | Project | Estimated-measured |
| $Na_{AR,t}$ | Number of animals allowed in the project area under the proposed AR-CDM project activity at year *t*; dimensionless | | Project | Estimated *ex ante*, monitored *ex post* |
| $Na_{BL}$ | Average pre-project number of animals from the different livestock groups that are grazing in the project area; dimensionless | | Project | Estimated *ex ante* |
| $Na_{EGL,t=1}$ | Average number of animals present in the *EGL* areas selected for monitoring at project start; dimensionless | | Project | Estimated *ex ante*, monitored *ex post* |
| $Na_{NGL,t=1}$ | Average number of animals present in the *NGL* areas selected for monitoring at project start; dimensionless | | Project | Estimated *ex ante*, monitored *ex post* |
| $Na_{outside,t}$ | Number of animals displaced outside the project area at year *t*; dimensionless | | Project | Estimated *ex ante*, monitored *ex post* |
| $Na_s$ | Number of animals from the different livestock groups that the animal owners intend to sell as a consequence of the project implementation; dimensionless | | Project | Estimated *ex ante*, monitored *ex post* |
| *N/C ratio* | Nitrogen-carbon ratio; dimensionless | | Global | IPCC |
| *NGL* | Total new grazing land area outside the project boundary to be converted to grazing land that is under the control of the animal owners (or the project participants) and that will receive another part of the displaced animal populations, up to time *t*;* ha | | Project | Estimated *ex ante* |
| $ngl_t$ | Total area converted to grassland at time *t*; ha | | Project | Estimated *ex ante* |
| $n_{pgt}$ | Number of individual animals from the livestock group *g* at parcel *p* at time *t*; dimensionless | | Project | Estimated *ex ante* |

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| $N_{SN\text{-}Fert,t}$ | Amount of synthetic fertilizer nitrogen applied at time *t*; t N | | Project | Estimated *ex ante*, monitored *ex post* |
| $nTR_{ijt}$ | Number of trees in stratum *i*, species *j*, at time *t*; dimensionless $ha^{-1}$ | | Project | Estimated *ex ante*, monitored *ex post* |
| $n_{xyt}$ | Number of vehicles | | Project | Estimated *ex ante*, monitored *ex post* |
| *p* | Parcel index (*P* = total number of parcels); dimensionless | | Index | |
| $PAR_t$ | Perimeter of the areas to be fenced at year *t*; m | | Project | Estimated *ex ante*, monitored *ex post* |
| $PBB_{ikt}$ | Average proportion of biomass burnt for stratum *i*, stand model *k*, time *t*; dimensionless | | Global and national default | IPCC GPG-2000, national GHG inventory |
| $R_j$ | Root-shoot ratio appropriate to increments for species *j*; dimensionless | | Global default to local | GPG-LULUCF, national GHG inven-tory, local survey |
| *SF* | Sampling factor; dimensionless | | Project | Calculated *ex ante* |
| $SF_c$ | Sampling factor of community *c*; dimensionless | | Project | Calculated *ex ante* |
| $sFG_{BL}$ | Sampled average pre-project annual volume of fuel-wood gathering in the project area; $m^3$ $yr^{-1}$ | | Project | Estimated *ex ante* and *ex post* |
| $SFR_{PAfw}$ | Fraction of total area or households in the project area sampled for fuel-wood; dimensionless | | Project | Defined *ex ante* |
| $SFR_{PAga}$ | Fraction of total area or households in the project area sampled for grazing animals; dimensionless | | Project | Defined *ex ante* |
| $SFR_{EGL}$ | Fraction of total *EGL* areas sampled; dimensionless | | Project | Defined *ex ante* |
| $SFR_{NGL}$ | Fraction of total *NGL* areas sampled; dimensionless | | Project | Defined *ex ante* |
| *SHH* | Sampled households, number of households sampled for $LK_{conv\text{-}crop}$; dimensionless | | Project | Defined *ex ante* |
| $SHH_c$ | Sampled households in community *c*, number of households sampled for $LK_{conv\text{-}crop}$; dimensionless | | Project | Defined *ex ante* |
| $sNa_{BL}$ | Sampled pre-project number of animals from the different livestock groups that are grazing in the project area; dimensionless | | Project | Estimated *ex ante* |
| *t* | 1, 2, 3, …*t** years elapsed since the start of the AR CDM project activity | | Project | Estimated *ex ante*, monitored *ex post* |
| *T* | Number of years between times $t_2$ and $t_1$ $(T = t_2 - t_1)$ | | Project | Estimated *ex ante*, monitored *ex post* |

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| $t^*$ | Number of years elapsed since the start of the AR project activity; yr | | | |
| *TACP* | Total Area of Cropland Planted by the project; hectares | Most updated | Project | Calculated |
| $TACP_c$ | Total area of cropland planted that is owned by community *c*; hectares | Most updated | Project | Calculated |
| $TACP_h$ | Total area of cropland planted that is owned by household *hh*; hectares | Most updated | Project | Calculated |
| *tCERs* | Number of units of temporary Certified Emission Reductions | | Project | Calculated |
| $t_{cp}$ | Year at which the first crediting period ends; yr | | | |
| *TNHH* | Total number of households using project lands in baseline; dimensionless | Most updated | Project | Calculated |
| $TNHH_c$ | Total number of households using project lands in baseline in community *c*; dimensionless | Most updated | Project | Calculated |
| $U_E$ | Percentage uncertainty of the sum | | | |
| $U_n$ | Percentage uncertainty associated with source/sink *n* | | | |
| $U_{total}$ | Percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage); | | | |
| $V_{ijt}$ | Average merchantable volume of stratum *i*, species *j*, at time *t;* $m^3$ $ha^{-1}$ | | Local and species specific | Forestry inventory, yield table, local survey |
| $V_{ijt1}$ | Average merchantable volume of stratum *i*, species *j*, at time $t = t_1$; $m^3$ $ha^{-1}$ | | Local and species specific | Forestry inventory, yield table, local survey |
| $V_{ijt2}$ | Average merchantable volume of stratum *i*, species *j*, at time $t = t_2$; $m^3$ $ha^{-1}$ | | Local and species specific | Forestry inventory, yield table, local survey |
| $WB_{ht}$ | Fraction of total above-ground biomass harvested as timber and as fuel-wood at time *t* (not burned); dimensionless | | Defined *ex ante* | Estimated *ex ante* and *ex post* |
| *x* | Vehicle type | | Project | Estimated *ex ante*, monitored *ex post* |
| *XGL* | Total unidentifiable grazing land area outside the project boundary that will receive the remaining part of displaced animal populations, e.g. when the pre-project animal owners decide to sell the animals, up to time $t^*$; ha | | Project | Estimated *ex ante* and *ex post* |
| $xgl_t$ | Total unidentifiable area converted to grassland at time *t*; ha | | Project | Estimated *ex ante*, monitored *ex post* |
| *y* | Fuel type | | Project | Estimated *ex ante*, monitored *ex post* |

| Data/Parameters | Descriptions | Vintage | Data sources and geographical scale | |
|---|---|---|---|---|
| $\Delta C_{av}$ | Average annual biomass consumed by one average animal; t d.m.$yr^{-1}$ | | Project | Estimated *ex ante* |
| $\Delta C_{G,ikt}$ | Annual increase in carbon *stock* due to biomass growth for stratum *i,* stand model *k,* time *t*; t $CO_2$-e. $yr^{-1}$ | | Project | Estimated *ex ante*, monitored *ex post* |
| $\Delta C_{ikt}$ | Annual carbon stock change in living biomass for stratum *i,* stand model *k*, time *t;* t $CO_2$-e. $yr^{-1}$. | | Project | Estimated *ex ante*, monitored *ex post* |
| $\Delta C_{L,ikt}$ | Annual decrease in carbon *stock* due to biomass loss for stratum *i,* stand model *k*, time *t;* t $CO_2$-e. $yr^{-1}$ | | Project | Estimated *ex ante* |
| $\Delta C_{L\ PA,t}$ | Annual animal biomass consumption over the project area to be planted at time *t*; t d.m.$yr^{-1}$ | | Project | Estimated *ex ante* |
| $\Delta C_{Lcurrent}$ | Current annual biomass that the grazing areas can produce for animal feeding; t d.m.$yr^{-1}$ | | Project | Estimated *ex ante* |
| $\Delta C_{Lmax}$ | Maximum annual biomass that the grazing areas can produce for animal feeding; t d.m.$yr^{-1}$ | | Project | Estimated *ex ante* |

## 12 Other information

None

## Section III: Monitoring methodology description

The proposed new methodology proposes methods for monitoring the following elements:

- The proposed CDM AR project activity including the project boundary, forest establishment, and forest management activities;
- Actual net GHG removals by sinks including changes in carbon stock in above-ground biomass and below-ground biomass, increase in GHG emissions within the project boundary due to site preparation, transportation, thinning and logging and nitrogen fertilization;
- Leakage due to displacement of agricultural crops, grazing and fuel-wood collection activities, vehicle use for transportation of staff, products and services, and increased use of wood posts for fencing;
- 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 AR CDM project activity, to ensure the integrity of data collected.

The baseline net GHG removals by sinks are assumed to be constant due to acceptance of the baseline approach 22 (a) in the related baseline methodology. The proposed monitoring methodology stratifies the project area based on local climate, existing vegetation, site class and tree species to be planted with the aid of land use/cover maps, satellite images, soil map, GPS and/or field survey. The proposed 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 located plots ensure the measuring and monitoring consistently over time.

### 1 Monitoring project boundary and project implementation

Monitoring of project implementation includes:

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

The corresponding methodology procedures are outlined below.

### 1.1 Monitoring of the boundary of the proposed AR CDM project activity

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

- Field surveys concerning the project boundary within which the AR activity has occurred, site by site;
- Measuring geographical positions (latitude and longitude of each corner polygon sites) using GPS;
- Checking whether the afforested/reforested areas are consistent with the eligible areas as defined in the CDM-AR-PDD;
- If afforestation/reforestation activities fall outside of the project boundary as defined in the CDM-AR-PDD, these lands shall not be accounted as a part of the AR CDM project activity.
- Input the measured geographical positions into the GIS system and calculate the implemented area of each stratum and stand;

- The development of the tree cover shall be monitored periodically all through the crediting period, including through remote sensing as applicable. If tree cover is affected by natural hazards (forest fires, plagues, etc.) or human interventions (harvesting, deforestation) beyond average regional damage levels, location; area of the deforested land and carbon losses shall be identified. These areas shall be treated as separate strata. Similarly, if the planting on certain lands within the project boundary fails these lands will be documented.

### 1.2 Monitoring of forest establishment

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

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

### 1.3 Monitoring of forest management

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

- Cleaning and site preparation measures: date, location, area, biomass removed and other measures undertaken
- Planting: date, location, area, tree species (establishment of the stand models)
- Fertilization: date, location, area, tree species, amount and type of fertilizer applied, etc.
- Thinning: date, location, area, tree species, thinning intensity, volumes or biomass removed
- Harvesting: date, location, area, tree species, volumes or biomass removed
- Coppicing: date, location, area, tree species, volumes or biomass removed
- Fuel wood collection: date, location, area, tree species, volumes or biomass removed
- Checking and confirming that harvested lands are re-planted, re-sowed or coppiced as planned and/or as required by forest law
- Checking and ensuring that good conditions exist for natural regeneration if harvested lands are allowed to regenerate naturally

- Monitoring of disturbances: date, location, area (GPS coordinates and remote sensing, as applicable), tree species, type of disturbance, biomass lost, implemented corrective measures, change in the boundary of strata and stands.

## 2 Stratification and sampling for *ex post* calculations

The number and boundaries of the strata defined *ex ante* using the methodology procedure outlined in Section II.2 may change during the crediting period (*ex post*). For this reason, strata should be monitored periodically. If a change in the number and area of the project strata occurs, the sampling framework should be adjusted accordingly. The methodology procedures for monitoring strata and defining the sampling framework are outlined below.

### 2.1 Monitoring of strata:

Stratification of the project area into relatively homogeneous units can either increase the measuring precision without increasing the cost unduly, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit.

Project participants should present in the AR-CDM-PDD an *ex ante* stratification of the project area using the methods outlined in section II.2 and build a geo-referenced spatial data base in a GIS platform for each parameter used for stratification of the project area under the baseline and the project scenario. This geo-referenced spatial data base shall be updated periodically due to the following reasons:

- Unexpected disturbances occurring during the crediting period (e.g. due to fire, pests or disease outbreaks), affecting differently different parts of an originally homogeneous stratum or stand;
- Forest management (cleaning, planting, thinning, harvesting, coppicing, re-replanting) may be implemented at different intensities, dates and spatial locations than originally planned in the PDD;
- Eligible land areas as defined in the AR-CDM-PDD not yet under the control of the project participant at the start of the project activity have become under the control of the project participants (see Section II.1, point c);
- Two different strata may be similar enough to allow their merging into one stratum.

If one of the above occurs, *ex post* stratification may be required. The possible need for *ex post* stratification shall be evaluated at each monitoring event and changes in the strata should be reported to the DOE for verification.

Monitoring of strata and stand boundaries shall be done using a Geographical Information System (GIS), which allows for integrating data from different sources (including GPS coordinates and remote sensing data). The monitoring of strata and stand boundaries is critical for a transparent and verifiable monitoring of the variable $A_{ikt}$ (area of stratum *i,* stand model *k*, at time *t*), which is of outmost importance for an accurate and precise calculation of net anthropogenic GHG removals by sinks.

## 2.2 Sampling framework

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

### 2.2.1 Definition of the sample size and allocation among strata

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

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

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

$A$ = total size of all strata (A), e.g. the total project area; ha

$A_i$ = size of each stratum (= $\sum_{t=1}^{tcr}\sum_{k}^{K_P} A_{ikt}$ where *tcr* is the end of the crediting period); ha

$k$ = 1, 2, 3, … $K_P$ stand models in the project scenario

$A_{ikt}$ = area of stratum *i*, stand model *k*, time *t*; ha

$AP$ = sample plot size; ha

$st_i$ = standard deviation for each stratum *i*; dimensionless

$C_i$ = cost of establishment of a sample plot for each stratum *i;* e.g. US$

$Q$ = approximate average value of the estimated quantity *Q,* (e.g. wood volume); e.g. $m^3\ ha^{-1}$

$DLP$ = desired level of precision (e.g. 10%); dimensionless

Then:

$$N = \frac{A}{AP} \quad ; \quad N_i = \frac{A_i}{AP} \quad ; \quad E = Q \cdot DLP \qquad \textbf{(70)}$$

where:

$N$ = maximum possible number of sample plots in the project area

$N_i$ = maximum possible number of sample plots in stratum *i*

$E$ = allowable error

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

$$n = \frac{\left[\sum_{i=1}^{m_{PS}} N_i \cdot st_i \cdot \sqrt{Ci}\right] \cdot \left[\sum_{i=1}^{m_{PS}} N_i \cdot st_i \cdot \frac{1}{\sqrt{C_i}}\right]}{\left(N \cdot \frac{E}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{m_{PS}} N_i \cdot (st_i)^2} \quad \textbf{(71)}$$

$$n_i = \frac{\sum_{i=1}^{m_{PS}} N_i \cdot st_i \cdot \sqrt{C_i}}{\left(N \cdot \frac{E}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{m_{SP}} N_i \cdot (st_i)^2} \cdot \frac{N_i \cdot st_i}{\sqrt{C_i}} \quad \textbf{(72)}$$

where:

| | | |
|---|---|---|
| $n$ | = | sample size (total number of sample plots required) in the project area |
| $n_i$ | = | sample size for stratum $i$ |
| $i$ | = | 1, 2, 3, ... $m_{SP}$ project scenario (*ex post*) strata |
| $z_{\alpha/2}$ | = | value of the statistic $z$ (normal probability density function), for $\alpha = 0.05$ (implying a 95% confidence level) |

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

$$n = \frac{\left[\sum_{i=1}^{m_{PS}} N_i \cdot st_i\right]^2}{\left(N \cdot \frac{E}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{m_{PS}} N_i \cdot (st_i)^2} \quad \textbf{(73)}$$

$$n_i = \frac{\sum_{h=1}^{m_{PS}} N_i \cdot st_i}{\left(N \cdot \frac{E}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{m_{PS}} N_i \cdot (st_i)^2} \cdot N_i \cdot st_i \quad \textbf{(74)}$$

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

### 2.2.2 Sample plot size

The plot area *a* has major influence on the sampling intensity and time and resources spent in the field measurements. The area of a plot depends on the stand density. Therefore, increasing the plot area decreases the variability between two samples. According to Freese (1962)[22], the relationship between coefficient of variation and plot area can be denoted as follows:

$$CV_2^{\,2} = \quad CV_1^{\,2} \cdot \sqrt{\frac{a_1}{a_2}} \qquad (75)$$

where $a_1$ and $a_2$ represent different sample plot areas and their corresponding coefficient of variation (*CV*).

Thus, by increasing the sample plot area, variation among plots can be reduced permitting the use of small sample size at the same precision level. Usually, the size of plots is between 100 $m^2$ for dense stands and 1000 $m^2$ for open stands.

### 2.2.3 Plot location

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

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

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

### 2.2.4 Monitoring frequency

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

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

- The growth rate of trees and the financial needs of the project activity: the later the date of the first verification, the higher will be the amount of net anthropogenic GHG removals by sinks but the lower the financial net present value of a CER.

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

- Harvesting events and rotation length: The time of monitoring and subsequent verification and certification shall not coincide with peaks in carbon stocks based on paragraph 12 of appendix B in decision 19/CP.9.

### 2.2.5 Measuring and estimating carbon stock changes over time

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

### 2.2.6 Monitoring GHG emissions by sources increased as results of the AR CDM project activity

An AR CDM project activity may increase GHG emissions, in particular $CO_2$, $CH_4$ and $N_2O$. The list below contains factors that may result in an increase of GHG emissions[23]:

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

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

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

The baseline carbon stock changes do not need to be monitored after the project is established, because the accepted baseline approach 22(a) assumes continuation of existing changes in carbon pools within the project boundary from the time of project validation.

However, if the project participants choose a renewable crediting period, relevant data necessary for determining the renewed baseline, including net greenhouse gas removals by sinks during the crediting period, shall be collected and archived to determine whether the baseline approach and baseline scenario are still valid or have to be updated. Reasons for a possible need for updating may include:

- National, local and sectoral policies that may influence land use in the absence of the proposed AR CDM project activity;
- Technical progresses that may change the baseline approach and baseline scenario;
- Climate conditions and other environmental factors that may change to such a degree as to significantly change the successional and disturbance processes or species composition, resulting in, e.g., improved climate conditions and/or available seed source would make the natural regeneration possible that is not expected to occur for the current baseline scenario;

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

- Significant changes of political, social and economic situation, making baseline approach and the projection of baseline scenario unreasonable;
- Existing barriers that may be removed, for instance:
  - ✔ Removal of existing investment barriers: Local farmers (communities) can afford the high establishment investment in the early stage or have chance to get commercial loans from banks for the reforestation activity;
  - ✔ Removal of existing technological barriers: Local farmers (communities) get knowledge and skills for producing high quality seedling, successful tree planting, controlling forest fire, pest and disease, and etc.;
  - ✔ Removal of existing institutional barriers (e.g., well-organized institutional instruments to integrate separate households and address technological and financial barriers);
- Market that may change the alternative land use, e.g., significant price rising of wood and non-woody products would make the degraded land economically attractive in the absence of the proposed AR CDM project activity;
- Check that the baseline net GHG removals by sinks are not under-estimated before the crediting period can be renewed using control plots.

The carbon stock changes in the baseline scenario can be estimated by measuring carbon stock in the above-ground biomass on control plots respectively at the initial stage and at the end of the crediting period. The control plots shall be established outside the project boundary and serve as proxy and accurately reflect the development of the degraded lands in the absence of the project activity. Measuring the carbon stock change in above-ground biomass is sufficient for the purpose of baseline scenario checking.

## 4 Data to be collected and archived for the estimation of baseline net GHG removals by sinks

**Table 4: Data to be collected and archived for the estimation of baseline net GHG removals by sinks**

| ID number | Data Variable | Source of data | Data Unit | Measured (m), calculated (c), estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|
| | National, local and sectoral policies that may influence land use in the absence of the proposed AR CDM project activity | Various | n.a. | collected | Start and end of the crediting period | As complete as possible | |
| | Natural and anthropogenic factors influencing land use, land cover and natural regeneration | Various | n.a. | collected | Start and end of the crediting period | As complete as possible | |
| 2.3.01 | Stratum ID | Stratification map | Alpha numeric | | 20 years | 100% | Stratum identification for baseline scenario checking |
| 2.3.02 | Carbon stock in above-ground biomass at the end of the crediting period | Calculated based on baseline plot measure-ment | t $CO_2$-e. $yr^{-1}$ | c | End of the crediting period | 100% of baseline plots | Calculated based on baseline plot measurement for different strata/sub-strata |
| 2.3.03 | Carbon stock in above-ground biomass at the start of the crediting period | Calculated based on baseline plot measure-ment | t $CO_2$-e. $yr^{-1}$ | c | Start of the crediting period | 100% of baseline plots | Calculated based on baseline plot measurement for different strata/sub-strata |
| 2.3.06 | Baseline carbon stock change in above-ground biomass | Calculated | t $CO_2$-e. $yr^{-1}$ | c | 20 years | 100% | Calculated |

## 5 Calculation of *ex post* actual net GHG removal by sinks

The actual net greenhouse gas removals by sinks represent the sum of the verifiable changes in carbon stocks in the carbon pools within the project boundary, minus the increase in GHG emissions measured in $CO_2$ equivalents by the sources that are increased as a result of the implementation of an AR CDM project activity, while avoiding double counting, within the project boundary, attributable to the AR CDM project activity. The calculations can be performed annually or periodically according to the monitoring plan. Therefore[24]:

$$C_{ACTUAL} = \Delta C_{LB} - GHG_E \qquad \textbf{(76)}$$

where:

$C_{ACTUAL}$ = actual net greenhouse gas removals by sinks; t $CO_2$-e.

$\Delta C_{LB}$ = sum of the changes in living biomass carbon stocks (above- and below-ground); t $CO_2$-e.

$GHG_E$ = sum of the increases in non-$CO_2$ GHG emissions by sources within the project boundary as a result of the implementation of an AR CDM project activity; t $CO_2$-e.

Note: In this methodology Eq. 77 is used to estimate actual net greenhouse gas removal by sinks for the period of time elapsed between project start (*t=1*) and the year *t=t*, t** being the year for which actual net greenhouse gas removals by sinks are estimated. The 'stock change' method should be used to determine annual or periodical values.

$$\Delta C_{P,LB} = \Delta C_{P,LB_T} - E_{biomassloss} \qquad \textbf{(77)}$$

where:

$\Delta C_{P,LB}$ = sum of the changes in living biomass carbon stocks (above- and below-ground); t $CO_2$-e.

$\Delta C_{P,LB\,T}$ = sum of the changes in living tree biomass carbon stocks (above- and below-ground); t $CO_2$-e.

$E_{biomassloss}$ = decrease in the carbon stock in the living biomass carbon pools of non-tree vegetation in the year of site preparation, up to time $t^*$; t $CO_2$-e. (as per Eq. 15)

### 5.1 Estimation of changes in the carbon stocks

The carbon stock changes in pools of soil organic carbon, litter and dead wood are ignored in this methodology, thus, the verifiable changes in carbon stock equal to the carbon stock changes in above-ground biomass and below-ground biomass within the project boundary, estimated using the following methods and equations[25]:

$$\Delta C_{P,LB_T} = \sum_{t=1}^{t^*} \sum_{i=1}^{S_{ps}} \sum_{k=1}^{K} \Delta C_{P,ikt} \qquad \textbf{(78)}$$

where:

[24] IPCC GPG-LULUCF Equation 3.2.1

[25] IPCC GPG-LULUCF Equation 3.2.3

$\Delta C_{P,LB}$ = sum of the changes in living biomass carbon stocks (above- and below-ground); t $CO_2$-e.

$\Delta C_{P,ikt}$ = annual carbon stock change in living biomass for stratum *i,* stand model *k*, time *t;* t $CO_2$-e. $yr^{-1}$

*i* = 1, 2, 3*,* ... $S_{ps}$ strata of the project activity

*k* = 1, 2, 3, … *K* stand models

*t* = 1, 2, 3, ...*t** years elapsed since the start of the AR project activity

and

$$\Delta C_{P,ikt} = (\Delta C_{AB,ikt} + \Delta C_{BB,ikt}) \cdot \frac{44}{12} \qquad \textbf{(79)}$$

where:

$\Delta C_{P,ikt}$ = annual carbon stock change in living biomass for stratum *i,* stand model *k*, time *t;* t $CO_2$-e. $yr^{-1}$

$\Delta C_{AB,ikt}$ = annual carbon stock change in above-ground biomass for stratum *i,* stand model *k*, time *t;* t C $yr^{-1}$

$\Delta C_{BB,ikt}$ = annual carbon stock change in below-ground biomass for stratum *i,* stand model *k*, time *t;* t C $yr^{-1}$

The mean change in carbon stocks in above-ground biomass and below-ground biomass per unit area are estimated based on field measurements on permanent plots. Two methods are available: Biomass Expansion Factors (BEF) method and Allometric Equations method.

**BEF Method**

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

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

***Step 3***: Choose 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 IPCC GPG LULUCF, or from published sources. If a significant amount of effort is required to develop local BEFs and root-shoot ratios, 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 IPCC 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. Stem-wood 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 above-ground biomass and below-ground biomass via basic wood density, BEF root-shoot ratio and carbon fraction, given by[26]:

$$MC_{AB,ijt} = MV_{ijt} \cdot D_j \cdot BEF_j \cdot CF_j \qquad \textbf{(80)}$$

$$MC_{BB,ijt} = MC_{AB,ijt} \cdot R_j \qquad \textbf{(81)}$$

where:

$MC_{AB,ijt}$ = mean carbon stock in above-ground biomass per unit area for stratum *i,* species *j*, time *t;* t C $ha^{-1}$

$MC_{BB,ijt}$ = mean carbon stock in below-ground biomass per unit area for stratum *i,* species *j*, time *t;* t C $ha^{-1}$

$MV_{ijt}$ = mean merchantable volume per unit area for stratum *i,* species *j*, time *t;* $m^3$ $ha^{-1}$

$D_j$ = volume-weighted average wood density; t d.m. $m^{-3}$ merchantable volume

$BEF_j$ = biomass expansion factor for conversion of biomass of merchantable volume to above-ground biomass; dimensionless

$CF_j$ = carbon fraction; IPCC default value = 0.5; t C (t d.m.)$^{-1}$;

$R_j$ = root-shoot ratio; dimensionless

***Step 5:*** The total carbon stock in living biomass for stratum *i,* species *j*, time *t* is calculated from the area for stratum *i,* species *j*, time *t* and the mean carbon stocks in above-ground biomass and below-ground biomass per unit area, as follows:

$$C_{AB,ikt} = A_{ikt} \cdot MC_{AB,ikt} \qquad \textbf{(82)}$$

$$C_{BB,ikt} = A_{ikt} \cdot MC_{BB,ikt} \qquad \textbf{(83)}$$

where:

$\Delta C_{AB,ijt}$ = annual carbon stock change in above-ground biomass for stratum *i,* species *j*, time *t;* t C $yr^{-1}$

$\Delta C_{BB,ijt}$ = annual carbon stock change in below-ground biomass for stratum *i,* species *j*, time *t;* t C $yr^{-1}$

$A_{ijt}$ = area of stratum *i,* species *j*, at time *t*; hectare (ha)

Note: The area of a stratum *i* planted with species *j* in stand model *k* has a time notation because stands with species *j* will be established (planted) at different dates.

[26] IPCC GPG-LULUCF Equation 4.3.1

$MC_{AB,ijt}$ = mean carbon stock in above-ground biomass per unit area for stratum *i,* species *j*, time *t;* t C ha$^{-1}$

$MC_{BB,ijt}$ = mean carbon stock in below-ground biomass per unit area for stratum *i,* species *j*, time *t;* t C ha$^{-1}$

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

$$\Delta C_{AB,ikt} = \frac{\sum_{j=1}^{J}(C_{AB,ikt_2} - C_{AB,ikt_1})}{T} \quad \textbf{(84)}$$

$$\Delta C_{BB,ikt} = \frac{\sum_{j=1}^{J}(C_{BB,ikt_2} - C_{BB,ikt_1})}{T} \quad \textbf{(85)}$$

where:

$\Delta C_{AB,ikt}$ = annual carbon stock change in above-ground biomass for stratum *i,* stand model *k*, time *t;* t C yr$^{-1}$

$\Delta C_{BB,ikt}$ = annual carbon stock change in below-ground biomass for stratum *i,* stand model *k*, time *t;* t C yr$^{-1}$

$C_{AB,ijt2}$ = carbon stock in above-ground biomass for stratum *i,* species *j*, calculated at time $t = t_2$; t C

$C_{AB,ijt1}$ = carbon stock in above-ground biomass for stratum *i,* species *j*, calculated at time $t = t_1$; t C

$C_{BB,ijt2}$ = carbon stock in below-ground biomass for stratum *i,* species *j*, calculated at time $t = t_2$; t C

$C_{BB,ijt1}$ = carbon stock in below-ground biomass for stratum *i,* species *j*, calculated at time $t = t_1$; t C

$T$ = number of years between monitoring time $t_2$ and $t_1$ ($T = t_2 - t_1$); years.

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

**Allometric method**

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

When first measured all trees should be tagged to permit the tracking of individual trees in plots through time.

Where a tree has died, been harvested or can not be found then the biomass at time $t_2$ should be made equal to zero to give the requisite deduction.

***Step 2*****:** Choose or establish appropriate allometric equations.

$$TB_{ABj} = f_j(DBH, H) \qquad \textbf{(86)}$$

where:

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

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 IPCC GPG LULUCF, conservative estimates shall be ensured. The respective procedures and assumptions have to be described in the monitoring plan of the PDD.
Also generic allometric equations can be used, as long as it can be proven that they underestimate carbon sequestration.

***Step 3*****:** Estimate carbon stock in above-ground biomass per tree using selected allometric equations applied to the tree measurements in Step 1

$$TC_{ABj} = TB_{ABj} \cdot CF_j \qquad \textbf{(87)}$$

where:

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

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

$$\Delta TC_{ABjT} = TC_{ABj,t2} - TC_{ABj,t1} \qquad \textbf{(88)}$$

where:

- $\Delta TC_{ABjT}$ = carbon stock change in above-ground biomass per tree of species *j* between two monitoring events; kg C tree$^{-1}$
- $\Delta TC_{ABj,t2}$ = carbon stock change in above-ground biomass per tree of species *j* at monitoring event $t_2$; kg C tree$^{-1}$
- $\Delta TC_{ABj,t1}$ = carbon stock change in above-ground biomass per tree of species *j* at monitoring event $t_1$; kg C tree$^{-1}$

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

$$\Delta PC_{ABikT} = \frac{XF \cdot \sum_{tr=1}^{TR} \Delta TC_{ABjT,tr}}{1000} \qquad \textbf{(89)}$$

$$XF = \frac{10,000}{AP} \qquad \textbf{(90)}$$

where:

| | | |
|---|---|---|
| $\Delta PC_{AB,ijT}$ | = | plot level carbon stock change in above ground biomass in stratum *i*, species *j*, between two monitoring events; t C $ha^{-1}$ |
| $\Delta TC_{ABjT}$ | = | carbon stock change in above-ground biomass per tree of species *j* between two monitoring events; kg C $tree^{-1}$ |
| $XF$ | = | plot expansion factor from per plot values to per hectare values |
| $AP$ | = | plot area; $m^2$ |
| $tr$ | = | tree (*TR* = total number of trees in the plot) |

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

$$\Delta MC_{ABikT} = \frac{\sum_{pl=1}^{PL_{ik}} \sum_{j}^{J} \Delta PC_{ABikT,pl}}{PL_{ik}} \quad \textbf{(91)}$$

where:

| | | |
|---|---|---|
| $\Delta MC_{ABikT}$ | = | mean carbon stock change in above-ground biomass in stratum *i*, stand model *k*, between two monitoring events; t C $ha^{-1}$. |
| $\Delta PC_{ABijT}$ | = | plot level mean carbon stock change in above-ground biomass in stratum *i*, species *j*, between two monitoring events; t C $ha^{-1}$. |
| $pl$ | = | plot number in stratum *i*, species *j*; dimensionless |
| $PL_{ik}$ | = | total number of plots in stratum *i*, stand model *k*; dimensionless |
| $j$ | = | species *j* (*J* = total number of species) |

***Step 7:*** Estimate carbon stock in below-ground biomass using root-shoot ratios and above-ground carbon stock and apply steps 4 and 5 to below-ground biomass.

$$TC_{BBj} = TC_{ABj} \cdot R_j \quad \textbf{(92)}$$

$$\Delta TC_{BBjT} = TC_{BBj,t2} - TC_{BBj,t1} \quad \textbf{(93)}$$

$$\Delta PC_{BB,ikT} = \frac{XF \cdot \sum_{tr=1}^{TR} \Delta TC_{BBjT}}{1000} \quad \textbf{(94)}$$

$$\Delta MC_{BB,ikT} = \frac{\sum_{pl=1}^{PL_{ik}} \Delta PC_{BBikT,pl}}{PL_{ik}} \quad \textbf{(95)}$$

where:

| | | |
|---|---|---|
| $TC_{BBj}$ | = | carbon stock in below-ground biomass per tree of species *j*; kg C $tree^{-1}$ |

$TC_{ABj}$ = carbon stock in above-ground biomass per tree of species *j* as calculated in step 1; kg C $tree^{-1}$

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

$\Delta TC_{BBjT}$ = carbon stock change in below-ground biomass per tree of species *j* between two monitoring events; kg C $tree^{-1}$

$\Delta PC_{BB,\,ijT}$ = plot level carbon stock change in below-ground biomass of species *j* between two monitoring events; t C $ha^{-1}$

$XF$ = plot expansion factor from per plot values to per hectare values (see Eq. 91); dimensionless

$tr$ = tree (*TR* = total number of trees in the plot)

$\Delta MC_{BBikT}$ = mean carbon stock change in below-ground biomass for stratum *i*, stand model *k*, between two monitoring events; t C $ha^{-1}$

$\Delta PC_{BBikT}$ = plot level carbon stock change in below-ground biomass for stratum *i*, stand model *k*, between two monitoring events; t C $ha^{-1}$ *pl* = plot number in stratum *i*, stand model *k*; dimensionless

$PL_{ik}$ = total number of plots in stratum *i*, stand model *k*; dimensionless

***Step 8****:* Calculate the annual carbon stock change by dividing the carbon changes between two monitoring events by the number of years between monitoring events.

$$\Delta MC_{ABikt} = \frac{\Delta MC_{ABikT}}{T} \qquad \textbf{(96)}$$

$$\Delta MC_{BBikt} = \frac{\Delta MC_{BBikT}}{T} \qquad \textbf{(97)}$$

where:

$\Delta MC_{AB,ikt}$ = annual mean carbon stock change in above-ground biomass for stratum *i*, stand model *k,* at year *t*; t C $ha^{-1}$ $yr^{-1}$

$\Delta MC_{BB,ikt}$ = annual mean carbon stock change in below-ground biomass for stratum *i*, stand model *k,* at year *t*; t C $ha^{-1}$ $yr^{-1}$

$\Delta MC_{ABikT}$ = mean carbon stock change in above-ground biomass for stratum *i*, stand model *k,* between two monitoring events; t C $ha^{-1}$ $yr^{-1}$

$\Delta MC_{BBikT}$ = mean carbon stock change in below-ground biomass for stratum *i*, stand model *k,* between two monitoring events; t C $ha^{-1}$ $yr^{-1}$

$T$ = number of years between two monitoring events which in this methodology is 5 years

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

$$\Delta C_{AB,ikt} = A_{ikt} \cdot \Delta MC_{AB,ikt} \qquad \textbf{(98)}$$

$$\Delta C_{BB,ikt} = A_{ikt} \cdot \Delta MC_{BB,ikt} \qquad \textbf{(99)}$$

where:

$A_{ikt}$ = area of stratum *i*, stand model *k,* at time *t*; hectare (ha)

$\Delta C_{AB,ikt}$ = changes in carbon stock in above-ground biomass for stratum *i*, stand model *k,* at time *t*; t C $yr^{-1}$

$\Delta C_{BB,ikt}$ = changes in carbon stock in below-ground biomass for stratum *i*, stand model *k,* at time *t*; t C $yr^{-1}$

$\Delta MC_{AB,ikt}$ = annual mean carbon stock change in above-ground biomass for stratum *i*, stand model *k,* at year *t*; t C $ha^{-1}$ $yr^{-1}$

$\Delta MC_{BB,ikt}$ = annual mean carbon stock change in below-ground biomass for stratum *i*, stand model *k,* at year *t*; t C $ha^{-1}$ $yr^{-1}$

Note that stand models will most often be one of the strata, and therefore will be included as such rather than as a separate consideration.

## 5.2 Estimation of the increase in emissions

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

$$GHG_E = E_{FuelBurn} + E_{BiomassBurn} + N_2O_{direct-N_{fertilizer}} \quad \textbf{(100)}$$

where:

$GHG_E$ = increase in GHG emission as a result of the implementation of the proposed AR CDM project activity within the project boundary; t $CO_2$-e.

$E_{FuelBurn}$ = increase in GHG emission as a result of burning of fossil fuels within the project boundary; t $CO_2$-e.

$E_{BiomassBurn}$ = increase in GHG emission as a result of biomass burning within the project boundary; t $CO_2$-e.

$N_2O_{direct-N_{fertilizer}}$ = increase in $N_2O$ emission as a result of direct nitrogen application within the project boundary; t $CO_2$-e.

Note: In this methodology Eq. 101 is used to estimate the increase in GHG emission for the period of time elapsed between project start ($t = 1$) and the year $t = t^*$, $t^*$ being the year for which actual net greenhouse gas removals by sinks are estimated.

### 5.2.1 Estimation of $E_{FuelBurn}$ (GHG emissions from burning of fossil fuels):

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

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

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

- National emission factors: These emission factors may be developed by national programmes such as national GHGs inventory;
- Regional emission factors;

- IPCC default emission factors, provided that a careful review of the consistency of these factors with the country conditions has been made. IPCC default factors may be used when no other information is available.

***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:

$$E_{FuelBurn} = \sum_{t=1}^{t^*} (CSP_{diesel\,t} \cdot EF_{diesel} + CSP_{gasoline\,t} \cdot EF_{gasoline}) \cdot 0.001 \qquad \mathbf{(101)}$$

where:

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

### 5.2.2 Estimation of $E_{BiomassBurn}$ (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, this would result in $CO_2$ and non-$CO_2$ emissions.

***Step 1*****:** Estimating the above-ground biomass stock per unit area before slash and burn or removal. To be conservative this methodology requires that the highest biomass over slash and burn cycles be applied as the baseline and for calculation of emissions from biomass burning. The degraded land or logged land is usually dominated by young trees/seedling, herbaceous plants and shrubs. The above-ground biomass of herbaceous plants such vegetation 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. 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 and young trees left, destructive harvesting techniques can also be used to measure the above-ground biomass. An alternative approach is to use allometric equations for the trees and shrubs. As long as the trees are larger than the defined minimum diameter for the equation, equations used elsewhere in the project can be applied. For smaller trees it is advised to harvest them with the herbaceous vegetation. If the shrubs are large, it is possible 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 IPCC GPG LULUCF).

***Step 2*****:** Estimating mean proportion of biomass burnt (or harvested) and emission factors. The proportion of biomass burnt can be estimated by sampling after burning. The combustion efficiencies may be chosen from Table 3.A.14 of IPCC 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 IPCC GPG-LULUCF.

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

$$E_{BiomassBurn} = E_{BiomassBurn,CO_2} + E_{BiomassBurn,N_2O} + E_{BiomassBurn,CH_4} \qquad \textbf{(102)}$$

where:

$E_{BiomassBurn}$ = total GHG emission from biomass burning in slash and burn; t $CO_2$-e.

$E_{BiomassBurn,CO2}$ = $CO_2$ emission from biomass burning in slash and burn; t $CO_2$-e.

$E_{BiomassBurn, N2O}$ = $N_2O$ emission from biomass burning in slash and burn; t $CO_2$-e.

$E_{BiomassBurn, CH4}$ = $CH_4$ emission from biomass burning in slash and burn; t $CO_2$-e.

and:

$$E_{BiomassBurn,CO_2} = \sum_{t=1}^{t*}\sum_{i=1}^{m_{PS}}\sum_{k=1}^{K_P}(A_{ikt\_sb} \cdot B_{ikt} \cdot PBB_{ikt} \cdot CE \cdot CF) \cdot \frac{44}{12} \qquad \textbf{(103)}$$

where:

$A_{ikt\_sb}$ = area of slash and burn for stratum *i*, stand model *k*, time *t*; ha

$B_{ikt}$ = average above-ground biomass stock before burning for stratum *i*, stand model *k*, time *t*; t d.m. $ha^{-1}$

$PBB_{ikt}$ = average proportion of biomass burnt for stratum *i*, stand model *k*, time *t*; dimensionless

*CE* = average biomass combustion efficiency (IPCC default = 0.1); dimensionless

*CF* = carbon fraction (IPCC default = 0.5); t C (t d.m.)$^{-1}$

$$E_{BiomassBurn,N_2O} = E_{BiomassBurn,CO_2} \cdot \frac{12}{44} \cdot (N/C\,ratio) \cdot ER_{N_20} \cdot \frac{44}{28} \cdot GWP_{N_2O} \qquad \textbf{(104)}$$

$$E_{BiomassBurn,CH_4} = E_{BiomassBurn,CO_2} \cdot \frac{12}{44} \cdot ER_{CH_4} \cdot \frac{16}{12} \cdot GWP_{CH_4} \qquad \textbf{(105)}$$

where:[27]

*N/C ratio* = nitrogen-carbon ratio (IPCC default = 0.01); dimensionless

12/44 = ration of molecular weights of carbon and $CO_2$; 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

$ER_{N20}$ = emission ratio for $N_2O$ (IPCC default = 0.007); t $CO_2$-e./t C

$ER_{CH4}$ = emission ratio for $CH_4$ (IPCC default = 0.012); t $CO_2$-e./t C

27 Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF and Equation 3.2.19 in IPCC GPG-LULUCF

$GWP_{N2O}$ = Global Warming Potential for $N_2O$ (IPCC default = 310 for the first commitment period); t $CO_2$-e./t $N_2O$

$GWP_{CH4}$ = Global Warming Potential for $CH_4$ (IPCC default = 21 for the first commitment period); t $CO_2$-e./t $CH_4$

### 5.2.3 Estimation of $N_2O_{direct-N_{fertilizer}}$ (nitrous oxide emissions from nitrogen fertilization):

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 (IPCC GPG-LULUCF). The method of 1996 IPCC Guideline, GPG-2000 and IPCC 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[28]:

$$N_{SN-Fert} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{PS}}\sum_{k=1}^{K_P} A_{ikt} \cdot N_{SN-Fert,ikt} \cdot 0.001 \quad \textbf{(106)}$$

$$N_{ON-Fert} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{PS}}\sum_{j=1}^{K_P} A_{ikt} \cdot N_{ON-Fert,ikt} \cdot 0.001 \quad \textbf{(107)}$$

where:

$N_{SN\text{-}Fert}$ = total amount of synthetic fertilizer used within the project boundary; t N

Note: This quantity could also be estimated by monitoring and recording annual purchases and use of synthetic fertilizers at the project level (instead of the actual consumption at the stand level, $A_{ikt}$)

$N_{ON\text{-}Fert}$ = total amount of organic fertilizer used within the project boundary; t N

Note: This quantity could also be estimated by monitoring and recording annual purchases and use of synthetic fertilizers at the project level (instead of the actual consumption at the stand level, $A_{ikt}$)

$A_{ikt}$ = area with N applied in stratum *i,* stand model *k*, at time *t*; hectare (ha)

$N_{SN\text{-}Fert,ijt}$ = use of synthetic fertilizer per unit area for stratum *i,* stand model *k*, at time *t*; kg N $ha^{-1}$ $yr^{-1}$

$N_{ON\text{-}Fert,ijt}$ = use of organic fertilizer per unit area for stratum *i,* stand model *k*, at time *t*; kg N $ha^{-1}$ $yr^{-1}$

***Step 2*****:** Choosing the fractions of synthetic and organic fertilizer nitrogen that is emitted as $NO_x$ and $NH_3$, and emission factors. As noted in GPG 2000 and 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 fertilizer nitrogen that are emitted as $NO_x$ and $NH_3$ are 0.1 and 0.2 respectively in

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

1996 IPCC Guideline[29].

***Step 3*:** Calculating direct $N_2O$ emissions from nitrogen fertilization[30]:

$$N_2O_{direct-N_{fertilizer}} = (F_{SN} + F_{ON}) \cdot EF_1 \cdot \frac{44}{28} \cdot GWP_{N_2O} \quad \textbf{(108)}$$

$$F_{SN} = N_{SN-Fert} \cdot (1 - Frac_{GASF}) \quad \textbf{(109)}$$

$$F_{ON} = N_{ON-Fert} \cdot (1 - Frac_{GASM}) \quad \textbf{(110)}$$

where:

$N_2O_{direct-N_{fertilizer}}$ = total direct $N_2O$ emission as a result of nitrogen application within the project boundary at time *t**, t $CO_2$-e.

| | | |
|---|---|---|
| $F_{SN}$ | = | total amount of synthetic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_x$; t N |
| $F_{ON}$ | = | total amount of organic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_x$; t N |
| $N_{SN\text{-}Fert}$ | = | total amount of synthetic fertilizer used within the project boundary; t N |
| $N_{SN\text{-}Fert}$ | = | total amount of organic fertilizer used within the project boundary; t N |
| $EF_1$ | = | emission Factor for emissions from N inputs; t $N_2O$-N (t N input)$^{-1}$ |
| $Frac_{GASF}$ | = | fraction that volatilizes as $NH_3$ and $NO_x$ for synthetic fertilizers; dimensionless |
| $Frac_{GASF}$ | = | fraction that volatilizes 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 $N_2O$ (IPCC default value = 310 for the first commitment period) ; t $CO_2$-e. (t $N_2O$)$^{-1}$ |

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

30 Refers to Equation 3.2.18 in IPCC GPG-LULUCF, Equation 4.22 and Equation 4.23 in GPG-2000

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

**Table 5: Data to be collected and archived for actual net GHG removals by sinks**

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| 2.1.1.04 | *DLP* | Desired level of precision (e.g. 10%) | | % | defined | Before the start of the project | 100% | For the purpose of QA/QC and measuring and monitoring precision control |
| 2.1.2.08 | $PBB_{ikt}$ | Average proportion of bio-mass burnt for stratum *i*, stand model *k*, time *t* | Measured after slash and burn | dimensionless | m | Annually | 100% | Sampling survey after slash and burn |
| 2.1.1.07 | $PL_{ID}$ | Sample plot ID (1, 2, 3, … pl, …) | Project and plot map, GIS | alpha numeric | defined | Before the start of the project | 100% | Numeric series ID will be assigned to each permanent sample plot |
| | $PL_{ik}$ | Total number of plots in stra-tum *i*, stand model *k* | Field measurement | dimensionless | m | 5-year | 100% | |
| 2.1.1.20 | $R_j$ | Root-shoot ratio | Local-derived, national inventory, | dimensionless | e | 5 year | 100% of sampling plots | Local-derived and species-specific value have the priority |
| | *16/12* | Ratio of molecular weights of $CH_4$ and carbon; | Universal constant | dimensionless | universal constant | | | |
| | *44/12* | Ratio of molecular weights of carbon and $CO_2$; dimen-sionless | Universal constant | dimensionless | universal constant | | | |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | *44/28* | Ratio of molecular weights of $N_2O$ and nitrogen; dimensionless | Universal constant | dimensionless | universal constant | | | |
| 2.1.1.03 | | Confidence level (e.g. 95%) | AR-CDM-PDD | % | defined | Before the start of the project | 100% | For the purpose of QA/QC and measuring and monitoring precision control |
| | $A$ | Total size of all strata (A), e.g. the total project area | GIS or/and GPS | hectares | m | Before the start of the project and adjusted thereafter every 5-year | 100% | |
| | $A_i$ | Area of each stratum | GIS or/and GPS | hectares | m | Before the start of the project and adjusted thereafter every 5-year | 100% | |
| 2.1.2.18 | $A_{N,ikt}$ | Area of with N applied in stratum *i*, stand model *k*, at time *t*; | Monitoring activity | hectares | m | Yearly | 100% | For different tree species and/or management intensity |
| 2.1.1.25 | $A_{ikt}$ | Area of stratum *i*, stand model *k*, at time *t*; | GIS or/and GPS | hectares | m | Yearly | 100% | Measured for different strata and stands |
| 2.1.2.06 | $A_{B,ikt\_sb}$ | Area of slash and burn in stratum *i*, stand model *k*, at time *t* | Measurement | hectares | m | Yearly | 100% | Measured for different strata and stands |
| | *AP* | Sample plot area | Field measurement | $m^2$ | m | 5-year | 100% | |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| 2.1.1.18 | *BEF* | Biomass expansion factor (BEF) | Local-derived, national inventory, IPCC GPG LULUCF | dimensionless | e | 5 year | 100% of sampling plots | Local-derived and species-specific value have the priority (IPCC default in LULUCF GPG 2003, Table 3A.1.10) |
| 2.1.2.07 | $B_{ijt}$ | Average above-ground bio-mass stock before burning for stratum *i*, species *j*, time *t*; | Field measurement | t d.m. $ha^{-1}$ | m | Before burning | sample plots | |
| 2.1.2.12 | *N/C ratio* | Nitrogen/carbon ratio; | Literature | dimensionless | e | Once per spe-cies or group of species | | IPCC default value (0.01) is used if no appropriate value |
| 2.1.1.21 | $C_{AB,ijt}$ | Carbon stock in above-ground biomass for stratum *i*, species *j*, time *t*; | Calculations | t C | c | 5-year | 100% | (Eq. 83) |
| | $C_{ACTUAL}$ | Actual net greenhouse gas removals by sinks; | Calculations | t $CO_2$-e. | c | 5-year | 100% | (Eq. 77) |
| 2.1.1.22 | $C_{BB,ijt}$ | Carbon stock in below-ground biomass for stratum *i*, species *j*, time *t*; | Calculations | t C | c | 5-year | 100% | (Eq. 84) |
| 2.1.2.09 | *CE* | Average 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 |
| 2.1.2.10 | *CF* | Carbon fraction | Local, national, IPCC | t C (t d.m.)$^{-1}$ | e | Once per crediting period | | Local-derived and species-specific value have the priority (IPCC default = 0.5) |
| 2.1.1.19 | $CF_j$ | Carbon fraction of species *j* | Local, national, GPG for LULUCF IPCC | t C (t d.m.)$^{-2}$ | e | Once per species | 100% of species or species group | Local-derived and species-specific value have the priority (IPCC default = 0.5) |
| | $C_i$ | Cost of establishment of a sample plot for each stratum *i* | Measurement | US$ or local currency | m | 5-years | 100% | |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| 2.1.2.01 | $CSP_{diesel\ t}$ | Amount of diesel consumption for year *t* | Measurement | liter (l) | m | Yearly | 100% | Measuring either diesel consumption per unit area for site preparation, or per unit volume logged or thinned |
| 2.1.2.02 | $CSP_{gasoline\ t}$ | Amount of gasoline consumption for year *t* | Measurement | liter (l) | m | Yearly | 100% | Measuring either diesel consumption per unit area for site preparation, or per unit volume logged or thinned |
| 2.1.1.12 | *DBH* | Diameter at breast height of living and standing dead trees | Plot measurement | cm (living/dead) | m | 5 year | 100% trees in plots | Measuring at each monitoring time per sampling method |
| 2.1.1.17a | $D_j$ | Wood density of species *j* | Local-derived, national inventory, IPCC GPG LULUCF | t d.m. $m^{-3}$ | e | 5 year | 100% of sampling plots | Local-derived and species-specific value have the priority |
| 2.1.1.17b | *D* | Average wood density | Local-derived, national inventory, IPCC GPG LULUCF | t d.m. $m^{-3}$ | e | 5 year | 100% of sampling plots | Local-derived and species-specific value have the priority |
| | *E* | Allowable error | Calculations | depends on the variable calculated | c | 5-year | 100% of the variables | (Eq. 71) |
| 2.1.2.15 | $E_{BiomassBurn}$ | Increase in GHG emission as a result of biomass burning within the project boundary | Calculations | t $CO_2$-e. | c | 5-year | 100% | (Eq. 103) |
| 2.1.2.14 | $E_{BiomassBurn,\ CH4}$ | $CH_4$ emission from biomass burning in slash and burn | Calculations | t $CO_2$-e. | c | 5-year | 100% | (Eq.106) |
| 2.1.2.13 | $E_{BiomassBurn,\ N2O}$ | $N_2O$ emission from biomass burning in slash and burn | Calculations | t $CO_2$-e. | c | 5-year | 100% | (Eq. 105) |
| 2.1.2.11 | $E_{BiomassBurn,CO2}$ | $CO_2$ emission from biomass burning in slash and burn | Calculations | t $CO_2$-e. | c | 5-year | 100% | (Eq. 104) |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| 2.1.2.23 | $EF_1$ | Emission factor for emission from N input | GPG 2000, GPG LULUCF, IPCC Guidelines, National inventory | t $N_2O$-N (t N input)$^{-1}$ | e | Before start of monitoring, once per crediting period | 100% | IPCC default value (1.25%) is used if no more appropriate data |
| 2.1.2.03 | $EF_{diesel}$ | Emission factor for diesel | GPG 2000, IPPCC Guidelines, national inventory | kg $CO_2$ $l^{-1}$ | e | At beginning of the project | | National inventory value should has priority |
| 2.1.2.04 | $EF_{gasoline}$ | Emission factor for gasoline | GPG 2000, IPPCC Guidelines, national inventory | kg $CO_2$ $l^{-1}$ | e | At beginning of the project | | National inventory value should has priority |
| 2.1.2.05 | $E_{FuelBurn}$ | Increase in GHG emission as a result of burning of fossil fuels within the project boundary | Calculations | t $CO_2$-e. | c | 5-year | 100% | (Eq. 102) |
| | $ER_{N20}$ | Emission ratio for $N_2O$ | Literature | dimensionless | e | Yearly | | (IPCC default = 0.007) |
| | $ER_{CH4}$ | Emission ratio for $CH_4$ | Literature | dimensionless | e | Yearly | | (IPCC default = 0.012) |
| | $f_j(DBH,H)$ | Allometric equation for species *j* linking above-ground tree biomass (kg tree$^{-1}$ ) to diameter at breast height (DBH) and possibly tree height (H) measured in plots for stratum *i*, species *j*, time *t*. | Literature and/or field measurements | kg tree$^{-1}$ | m-e-c | Once per species | for all major species or group of species | Use local/global equations validated for local conditions |
| | $F_{ON}$ | Total amount of organic fer-tilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_x$ | Calculations | t N | c | 5-year | 100% | (Eq. 111) |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| 2.1.2.21-22 | $Frac_{GASF}$ | Fraction that volatilizes as $NH_3$ and $NO_x$ for synthetic fertilizers | GPG 2000, GPG LULUCF, IPCC Guideline, National inventory | dimensionless | e | Once per fertilizer type used | | IPCC default value (0.1) is used if no more appropriate data |
| | $F_{SN}$ | Total amount of synthetic fertilizer nitrogen applied adjusted for volatilization as $NH_3$ and $NO_x$ | Calculations | t N | c | 5-year | 100% | (Eq. 110) |
| 2.1.2.25 | $GHG_E$ | Increase in GHG emission as a result of the implementation of the proposed AR CDM project activity within the project boundary | Calculations | t $CO_2$-e. | c | 5-year | 100% | (Eq. 101) |
| | $GWP_{CH4}$ | Global Warming Potential for $CH_4$ | IPCC literature - EB decisions | | e | Once per commitment period | | (IPCC default = 21) |
| | $GWP_{N2O}$ | Global Warming Potential for $N_2O$ | IPCC literature - EB decisions | | e | Once per commitment period | | (IPCC default = 310) |
| 2.1.1.38 | $H_{ijt}$ | Annually harvested volume and fuel wood for stratum *i*, species *j*, at time *t* | Harvesting statistics | $m^3$ | c | Annually | 100% stands | Annually recorded |
| 2.1.1.01 | $i_{ID}$ | Stratum *i*D (1, 2, 3, … $m_{SP}$ project scenario (*ex post*) strata) | Stand map, GIS | alpha numeric | defined | At stand establishment | 100% | Each stand has a particular year *to* be planted under each stratum |
| 2.1.1.02 | $ID_{ikt}$ | Stand ID | Stand map, GIS | alpha numeric | defined | At stand establishment | 100% | Each stand has a particular year *to* be planted under each stratum |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| 2.1.1.08 | *lat/long* | Plot location | Project and plot map and GPS locating, GIS | | m | 5 years | 100% | Using GPS to locate before start of the project and at time of each field measurement |
| 2.1.1.23 | $MC_{AB,ijt}$ | Mean carbon stock in above-ground biomass per unit area for stratum *i*, species *j*, time *t* | Calculations | t C $ha^{-1}$ | c | 5-year | 100% | (Eq. 81) |
| 2.1.1.24 | $MC_{BB,ijt}$ | Mean carbon stock in below-ground biomass per unit area for stratum *i*, species *j*, time *t* | Calculations | t C $ha^{-1}$ | c | 5-year | 100% | (Eq. 82) |
| 2.1.1.16 | $MV_{ijt}$ | Mean merchantable volume per unit area for stratum *i*, species *j*, time *t* | | $m^3$ $ha^{-1}$ | $m^3$ | 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 |
| | *N* | Maximum possible number of sample plots in the project area | Calculations | dimensionless | c | 5-years | 100% | (Eq. 71) |
| | *n* | Sample size (total number of sample plots required) in the project area | Calculations | dimensionless | c | 5-years | 100% | (Eq. 72 or Eq. 74) |
| | $N_i$ | Maximum possible number of sample plots in stratum *i* | Calculations | dimensionless | c | Before the start of the project and adjusted thereafter every 5-year | 100% | (Eq. 71) |
| 2.1.1.06 | $n_i$ | Sample size for stratum *i* | Calculations | dimensionless | c | Before the start of the project and adjusted thereafter every 5-year | 100% | (Eq. 73 or Eq. 75) Calculated for each stratum |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| 2.1.2.20 | $N_{ON\text{-}Fert}$ | Total amount of organic fertilizer used within the project boundary | Calculations | t N | c | 5-year | 100% | (Eq.108) |
| 2.1.2.17 | $N_{ON\text{-}Fert,ikt}$ | use of organic fertilizer per unit area for stratum *i*, stand model *k*, at time *t* | Field measurement | kg N $ha^{-1}$ $yr^{-1}$ | m | yearly | 100% | For the purpose of QA/QC and measuring and monitoring precision control |
| 2.1.2.19 | $N_{SN\text{-}Fert}$ | Total amount of synthetic fertilizer used within the project boundary | Calculations | t N | c | 5-year | 100% | (Eq. 107) |
| 2.1.2.16 | $N_{SN\text{-}Fert,ikt}$ | Use of synthetic fertilizer per unit area for stratum *i*, stand model *k*, at time *t* | Field measurement | kg N $ha^{-1}$ $yr^{-1}$ | m | yearly | 100% | |
| 2.1.1.11 | $nTR_{PLikt}$ | Number of trees in the sample plot | Plot measurement | number | m | 5 years | 100% trees in plots | Counted in plot measurement |
| 2.1.2.24 | $N_2O_{direct-N_{fertilizer}}$ | Increase in $N_2O$ emission as a result of direct nitrogen application within the project boundary | Calculations | t $CO_2$-e. | c | 5-year | 100% | (Eq.109) |
| 2.1.1.04 | *DLP* | Desired level of precision (e.g. 10%) | | % | defined | Before the start of the project | 100% | For the purpose of QA/QC and measuring and monitoring precision control |
| 2.1.2.08 | $PBB_{ikt}$ | Proportion of biomass burnt | Measured after slash and burn | dimensionless | m | Annually | 100% | Sampling survey after slash and burn |
| | $PBB_{ikt}$ | Average proportion of biomass burnt for stratum *i*, stand model *k*, time *t* | Field estimates or literature | dimensionless | e | before burning | sample plots | Used for estimating numbers of sample plots of each stratum and stand, as necessary |
| 2.1.1.07 | $PL_{ID}$ | Sample plot ID (1, 2, 3, … pl, …) | Project and plot map, GIS | alpha numeric | defined | Before the start of the project | 100% | Numeric series ID will be assigned to each permanent sample plot |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | $PL_{ik}$ | Total number of plots in stratum *i*, stand model *k* | Field measurement | dimensionless | m | 5-year | 100% | |
| 2.1.1.20 | $R_j$ | Root-shoot ratio | Local-derived, national inventory, | Dimensionless | e | 5 year | 100% of sampling plots | Local-derived and species-specific value have the priority |
| 2.1.1.05 | $st_i$ | Standard deviation for each stratum *i*; dimensionless | | | e | At each monitoring event | 100% | Used for estimating numbers of sample plots of each stratum and stand, as necessary |
| | $TB_{ABj}$ | Above-ground biomass of a tree | Calculations | kg dry matter $tree^{-1}$ | c | 5-year | 100% | (Eq. 87) |
| | $TC_{ABj}$ | Carbon stock in above-ground biomass per tree of species *j* | Calculations | kg C $tree^{-1}$ | c | 5-year | 100% | (Eq. 88) |
| 2.1.1.10 | *tID* | Age of plantation (1, 2, 3, … years) | GIS | year | m | At stand establishment | 100% | Counted since the planted year |
| | $tr_{ID}$ | Tree ID (1, 2, 3, … tr … TR = total number of trees in the plot) | Field measurement | dimensionless | m | 5-year | 100% | |
| | *XF* | Plot expansion factor from per plot values to per hectare values (Eq. 76) | Calculations | dimensionless | c | 5-year | 100% | (Eq. 91) |
| | $z_{\alpha/2}$ | Value of the statistic z (normal probability density function), for α = 0.05 (implying a 95% confidence level) | Statistic book | dimensionless | m | 5-years | 0% | |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| 2.1.1.28 | $\Delta C_{AB,ijt}$ | annual carbon stock change in above-ground biomass for stratum *i*, species *j*, time *t*; | Calculations | $t\ C\ yr^{-1}$ | c | 5-year | 100% | (Eq. 85 or Eq. 99) |
| 2.1.1.28 | $\Delta C_{AB,ikt}$ | Annual carbon stock change in above-ground biomass for stratum *i*, stand model *k*, time *t*; | Calculations | $t\ C\ yr^{-1}$ | c | 5-year | 100% | (Eq. 85 or Eq. 99) |
| 2.1.1.29 | $\Delta C_{BB,ijt}$ | Annual carbon stock change in below-ground biomass for stratum *i*, species *j*, time *t*; | Calculations | $t\ C\ yr^{-1}$ | c | 5-year | 100% | (Eq. 86 or Eq. 100) |
| 2.1.1.29 | $\Delta C_{BB,ikt}$ | Annual carbon stock change in below-ground biomass for stratum *i*, stand model *k*, time *t*; | Calculations | $t\ C\ yr^{-1}$ | c | 5-year | 100% | (Eq. 86 or Eq. 100) |
| | $\Delta C_{LB,ikt}$ | Annual carbon stock change in living biomass for stratum *i*, stand model *k*, time *t* | Calculations | $t\ CO_2$-e. $yr^{-1}$ | c | 5-year | 100% | (Eq. 80) |
| | $\Delta C_{P,LB}$ | Sum of the changes in living biomass carbon stocks (above- and below-ground) | Calculations | $t\ CO_2$-e. | c | 5-year | 100% | (Eq. 79) |
| | $\Delta MC_{ABikT}$ | Mean carbons stock change in above-ground biomass stratum *i*, stand model *k*, between two monitoring events | Calculations | $t\ C\ ha^{-1}$ | c | 5-year | 100% | (Eq. 92) |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | $\Delta MC_{ABikt}$ | Mean carbons stock change in above-ground biomass stratum *i*, stand model *k*, between two monitoring events | Calculations | t C $ha^{-1}$ | c | 5-year | 100% | (Eq. 97) |
| | $\Delta MC_{BB,ikt}$ | Mean carbons stock change in below-ground biomass stratum *i*, stand model *k* | Calculations | t C $ha^{-1}$ | c | 5-year | 100% | (Eq. 98) |
| | $\Delta MC_{BBikT}$ | Mean carbons stock change in below-ground biomass stratum *i*, stand model *k*, between two monitoring events | Calculations | t C $ha^{-1}$ | c | 5-year | 100% | (Eq. 96) |
| | $\Delta PC_{AB,ijT}$ | Plot level mean carbon stock change in above-ground bio-mass ins stratum *i*, species *j* between two monitoring events | Calculations | t C $ha^{-1}$ | c | 5-year | 100% | (Eq. 90) |
| | $\Delta PC_{BB,ijT}$ | Plot level mean carbon stock change in above-ground bio-mass in stratum *i*, species *j* between two monitoring events | Calculations | t C $ha^{-1}$ | c | 5-year | 100% | (Eq. 95) |
| | $\Delta TC_{ABjt}$ | Carbon stock change in above-ground biomass per tree of species *j* in year *t* | Calculations | kg C $tree^{-1}$ | c | 5-year | 100% | (Eq. 89) |
| | $\Delta TC_{ABjT}$ | Carbon stock change in above-ground biomass per tree of species *j* between two monitoring events | Calculations | kg C $tree^{-1}$ | c | 5-year | 100% | (Eq. 89) |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | $\Delta TC_{BBjt}$ | Carbon stock change in below-ground biomass per tree of species *j* in year *t* | Calculations | kg C $tree^{-1}$ | c | 5-year | 100% | (Eq.94) |
| | $\Delta TC_{BBjT}$ | Carbon stock change in below-ground biomass per tree of species *j* between two monitoring events | Calculations | kg C $tree^{-1}$ | c | 5-year | 100% | (Eq. 94) |

## 7 Leakage

For the type of AR CDM project activity to which this methodology applies, leakage shall be estimated as follows:

$$LK = LK_{Vehicle} + LK_{ActivityDisplacement} + LK_{fencing} \quad \textbf{(111)}$$

Note: In this methodology Eq. 112 is used to estimate leakage for the period of time elapsed between project start (*t=1*) and the year *t=t*, t** being the year for which actual net greenhouse gas removals by sinks are estimated.

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

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

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

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

***Step 3***: Estimating the GHG emissions using bottom-up approach described in GPG 2000 for energy sector[31].

$$LK_{Vehicle} = LK_{Vehicle,CO_2} \quad \textbf{(112)}$$

$$LK_{Vehicle,CO_2} = \sum_{t=1}^{t*} \sum_{x} \sum_{y} (EF_{xy} \cdot FuelConsumption_{xyt}) \quad \textbf{(113)}$$

$$FuelConsumption_{xyt} = n_{xyt} \cdot k_{xyt} \cdot e_{xyt} \quad \textbf{(114)}$$

where:

$LK_{Vehicle}$ = total GHG emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$

$LK_{Vehicle,CO2}$ = total $CO_2$ emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$

$LK_{Vehicle,CH4}$ = total $CH_4$ emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$

$LK_{Vehicle,N2O}$ = total $N_2O$ emissions due to fossil fuel combustion from vehicles; t $CO_2$-e. $yr^{-1}$

$x$ = vehicle type

$y$ = fuel type

$EF_{xy}$ = $CO_2$ emission factor for vehicle type *x* with fuel type *y;* dimensionless

$FuelConsumption_{xyt}$ = consumption of fuel type *y* of vehicle type *x* at time *t*; liters

$n_{xyt}$ = number of vehicles

$k_{xyt}$ = kilometers traveled by each of vehicle type *x* with fuel type *y* at time *t*; km

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

$e_{xyt}$ = fuel efficiency of vehicle type *x* with fuel type *y* at time *t*; liters $km^{-1}$

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

### 7.2 Estimation of $LK_{ActivityDisplacement}$ (leakage due to activity displacement):

Leakage due to activity displacement is estimated as follows:

$$LK_{Activitydisplacement} = LK_{conversion} + LK_{fuelwood} \quad \textbf{(115)}$$

where:

$LK_{ActivityDisplacement}$ = leakage due to activity displacement; t $CO_2$-e.

$LK_{conversion}$ = leakage due to conversion of forest to non-forest; t $CO_2$-e.

$LK_{fuel\text{-}wood}$ = leakage due to the displacement of fuel-wood collection; t $CO_2$-e.

As a result of the A/R CDM project activity, agricultural activities may be displaced permanently or temporarily outside the project boundary. This 'activity shifting' or 'activity displacement' may result in leakage in the immediate years after the start of the project activity when activities are displaced to areas outside the project boundary. $LK_{conversion}$ occurs in two ways:

a) Conversion for grazing and
b) Conversion for cropland.

Therefore:

$$LK_{conversion} = LK_{conv-graz} + LK_{conv-crop} \quad \textbf{(116)}$$

where:

$LK_{conv\text{-}graz}$ = leakage resulting from the conversion for grazing and

$LK_{conv\text{-}crop}$ = leakage resulting from the conversion for cropland

#### 7.2.1 Estimation of $LK_{conv\text{-}graz}$ (Leakage due to conversion of land to grazing land):

Leakage due to conversion of land to grazing land is not attributable to the AR-CDM project activity if the conversion of land to grazing land occurs 5 years after the last measure taken to reduce animal populations in the project area. Monitoring of leakage due to the conversion of land to grazing land is therefore necessary only up to the fifth year after the last measure taken to reduce animal populations in the project area.

***Step 1:*** Monitor the grazing control measures specified in the AR-CDM-PDD. This is necessary to establish the actual date of the last measure taken to control animal grazing. Monitoring of leakage due to conversion of land to grazing land will not be necessary 5 years after this date because any conversion of land to grazing land would not be reasonably attributable to the AR CDM project activity.

***Step 2:*** For each verification period, estimate the average animal population size present in the project area to estimate the number of animals displaced outside the project boundary. Monitoring can be done by periodically surveying the project area or a randomly selected sample of discrete areas as part of the project area and by interviewing the animal owners.

$$Na_{outside,t} = Na_{BL} - Na_{AR,t} \quad \textbf{(117)}$$

where:

$Na_{outside,t}$ = number of animals displaced outside the project area at year $t$; dimensionless

$Na_{BL}$ = *ex ante* estimated pre-project number of animals from the different livestock groups that would be grazing in the project area under the baseline scenario; dimensionless. This estimate is fixed for the entire crediting period and is specified in the AR-CDM-PDD.

$Na_{AR,t}$ = monitored number of animals present in the project area at year $t$; dimensionless

If:

- $Na_{BL} < Na_{AR,t}$ then, it can be assumed that the AR-CDM project activity has not displaced grazing animal populations. Leakage due to conversion of land to grazing land can be set as zero ($LK_{conversion} = 0$) and no further monitoring step is needed.
- $Na_{BL} > Na_{AR,t}$ then it is necessary to monitor the animal populations in the *EGL* areas specified in the AR-CDM-PDD.

***Step3*:** For each verification period, estimate the average animal population size displaced in the *EGL* areas specified in the AR-CDM-PDD by periodically surveying these areas and interviewing their owners.

$$dNa_{EGL,t} = \frac{Na_{EGL,t} - Na_{EGL,t=1}}{SFR_{EGL}} \quad \textbf{(118)}$$

where:

$dNa_{EGLt}$ = number of animals displaced in *EGL* areas at time $t$; dimensionless

$Na_{EGL,t}$ = number of animals present in the sampled *EGL* areas at time $t$; dimensionless.

$Na_{EGL,t=1}$ = number of animals present in the sampled *EGL* areas at time $t=1$, as specified in the AR-CDM-PDD; dimensionless.

$SFR_{EGL}$ = fraction of sampled *EGL* areas sampled with respect to total, as specified in the AR-CDM-PDD; dimensionless

If:

- $Na_{BL} < (Na_{AR,t} + dNa_{EGL,t})$ then, it can be assumed that the animal populations displaced due to the AR-CDM project activity have not occasioned leakage due to conversion of land to grazing land ($LK_{conversion} = 0$) and no further monitoring step is needed.
- $Na_{BL} > (Na_{AR,t} + dNa_{EGL,t})$ then it is necessary to monitor the animal populations in the *NGL* areas specified in the AR-CDM-PDD.

***Step4*:** For each verification period, estimate the average animal population size displaced in the *NGL* areas specified in the AR-CDM-PDD by periodically surveying these areas and interviewing their owners.

$$dNa_{NGL,t} = \frac{Na_{NGL,t} - Na_{NGL,t=1}}{SFR_{NGL}} \quad \textbf{(119)}$$

where:

$dNa_{NGLt}$ = number of animals displaced in *NGL* areas at time $t$; dimensionless

$Na_{NGL,t}$ = number of animals present in the sampled *NGL* areas at time $t$; dimensionless.

$Na_{NGL,t=1}$ = number of animals present in the sampled *NGL* areas at time $t = 1$, as specified in the AR-CDM-PDD; dimensionless.

$SFR_{NGL}$ = fraction of sampled *NGL* areas sampled with respect to total, as specified in the AR-CDM-PDD; dimensionless

If:

- $Na_{BL} < (Na_{AR,t} + dNa_{EGL,t} + dNa_{NGL,t})$ then, it can be assumed that AR-CDM project activity has not displaced animal population to unidentified areas and leakage due to conversion of non-grassland to grassland in unidentified *XGL* areas can be set as zero ($LK_{XGL} = 0$).
- $Na_{BL} > (Na_{AR,t} + dNa_{EGL,t} + dNa_{NGL,t})$ then it is necessary to estimate the animal populations displaced in *XGL* areas as follows:

$$dNa_{XGL,t} = Na_{BL} - Na_{AR,t} - dNa_{EGL,t} - dNa_{NGL,t} \quad \textbf{(120)}$$

***Step 5:*** Estimate leakage due to displacement of grazing activities as follows:

$$LK_{conv\text{-}graz} = LK_{NGL} + LK_{XGL} \quad \textbf{(121)}$$

where:

$LK_{NGL}$ = leakage due to conversion of non-grassland to grassland in *NGL* areas under the control of the animal owners; t $CO_2$-e.

$LK_{XGL}$ = leakage due to conversion of non-grassland to grassland in unidentified *XGL* areas; t $CO_2$-e.

**a) Estimation of $LK_{NGL}$:**

$$LK_{NGL} = dNa_{NGL,t} \cdot aLK_{NGL} \quad \textbf{(122)}$$

where:

$LK_{NGL}$ = leakage due to conversion of non-grassland to grassland in *NGL* areas; t $CO_2$-e.

$dNa_{NGLt}$ = number of animals displaced in *NGL* areas at time *t* – as estimated in step 4; dimensionless

$aLK_{NGL}$ = average leakage due to conversion of non-grassland to grassland per displaced animal in *NGL* areas – as estimated *ex ante* in the AR-CDM-PDD; t $CO_2$-e. $animal^{-1}$

**b) Estimation of $LK_{XGL}$:**

$$LK_{XGL} = dNa_{XGL,t} \cdot aLK_{XGL} \quad \textbf{(123)}$$

where:

$LK_{XGL}$ = leakage due to conversion of non-grassland to grassland in *XGL* areas; t $CO_2$-e.

$dNa_{XGLt}$ = number of animals displaced in *XGL* areas at time *t* – as estimated in step 4; dimensionless

$aLK_{XGL}$ = average leakage due to conversion of non-grassland to grassland per displaced animal in *XGL* areas – as estimated *ex ante* in the AR-CDM-PDD; t $CO_2$-e. $animal^{-1}$

### 7.2.2 Estimation of $LK_{conv-crop}$ (Leakage due to conversion of land to crop land, based on area of conversion):

Leakage through land conversion due to activity displacement should be monitored through sampling the households and communities displaced from land by the project. However, leakage due to conversion of land is not attributable to the AR-CDM project activity if the conversion of land occurs 5 or more years after the displacement of the activity to areas outside the project boundary. Leakage estimation includes monitoring households with identifiable areas of land conversion and conservatively applying a deforestation area to households with unidentifiable areas of land conversion. The type and schedule of measures to be taken to prevent conversion of land outside the project boundary should be described in the AR-CDM-PDD and its implementation monitored.

$$LK_{conv-crop} = CS_{AD} - CS_b \quad \textbf{(124)}$$

where:

$CS_{AD}$ = locally derived carbon stock (including all the five eligible carbon pools; t $CO_2$-e. $ha^{-1}$) of area of land on which activities shifted; t $CO_2$-e. $ha^{-1}$

$CS_b$ = carbon stock of baseline; t $CO_2$-e. $ha^{-1}$

**Case 1: $CS_{AD} < CS_b$**

Leakage due to displacement for cropland can be set as zero if the carbon stock on the land to which crops are displaced is less than the carbon stock from which they originated under the baseline scenario.

$$L_{conv-crop} = 0, \text{ if } CS_{AD} < CS_b \quad \textbf{(125)}$$

**Case 2: $CS_{AD} > CS_b$**

**Step 0**: Determine if leakage analysis will take place at the household or community level. Household level analysis should only take place in project areas where households have clear land ownership or tenure.

**a) <u>Household level</u>:**

*$T_0$: Before start of project activities:*

**Step 1**: Record the number of households occupying land inside the project boundary (*TNHH*). Randomly select 10% of the households (or a minimum of 30) to be sampled;

**Step 2:** Measure area of land within project boundaries each sampled household will be displaced from due to project activities ($TACP_h$);

*$T_1$: Return one year after activity displacement and record land conversion outside project area:*

**Step 3**: Classify sampled households as either having identifiable or unidentifiable converted lands. Households which have moved from the area or which cannot be found should be placed in the 'unidentifiable households' category;

**Step 4**: Measure area of identifiable land each household has converted since displacement of pre-project activities ($IAC_{hi}$);

**Step 5**: Classify each area of identifiable converted land into a pre-conversion land cover stratum;

**Step 6**: Measure the carbon stock (including all 5 pools) in each land cover stratum using methods from IPCC GPG-LULUCF chapter 4.3;

**Step 7**: Determine the mean conservative forest biomass stock for the project region ($\overline{CS}$), if no mean regional stock data exists, use mean national stock reported in IPCC GPG-LULUCF (Table 3A.1.4);

**Step 8**: Calculate the leakage using the following equations:

$$LK_{conv-crop} = \sum_{hh=1}^{Hh}\left(\sum_{i=1}^{I} IAC_{hi} \cdot CS_i\right) \cdot SF + \sum_{hh=1}^{Hh}\left(TACP_h - \sum_{i=1}^{I} IAC_{hi}\right) \cdot \overline{CS} \cdot SF \qquad (126)$$

and:

$$SF = \frac{TNHH}{SHH} \qquad (127)$$

$LK_{conv-crop}$= leakage due to conversion of land to cropland attributable to displacement (activity shifting); t $CO_2$-e.

$IAC_{hi}$ = identifiable areas converted by household *hh* in stratum *i*; hectares

$TACP_h$ = total area of cropland planted that is owned by household *hh*; hectares

$hh$ = 1,2,3….*Hh* households; dimensionless

$i$ = 1,2,3….*I* strata; dimensionless

$CS_i$ = locally derived carbon stock of identified lands (including all the five eligible carbon pools) of stratum *i*; t $CO_2$-e. $ha^{-1}$

$\overline{CS}$ = locally derived average carbon stock of unidentified lands (including all five eligible carbon pools); t $CO_2$-e. $ha^{-1}$

$SF$ = sampling factor of household; dimensionless

$TNHH$ = total number of households using project lands in baseline; dimensionless

$SHH$ = sampled households, number of households sampled for $LK_{conv-crop}$; dimensionless

*$T_5$: Return after five years and record land conversion outside project area by repeating Steps 3-8.*

**b) <u>Community level:</u>**

*$T_0$: Before start of project activities:*

***Step 1***: Record the number of communities occupying land inside the project boundary. Randomly select 10 % of the communities (or a minimum of 10 communities) to be sampled;

***Step 2***: Measure total area of cropland within project boundaries from which pre-project activities in each sampled community will be displaced ($TACP_c$);

***Step 3***: Calculate the total number of households within each selected community ($TNHH_c$);

***Step 4***: Randomly select 10 % of households (or a minimum of 10 households) to be sampled within selected communities;

*$T_1$: Return one year after activity displacement and record land conversion outside project area:*

***Step 5***: Interview community members to estimate the area of identifiable land that each sampled community will convert due to displacement of pre-project activities ($IAC_{hc}$);

***Step 6***: Classify the estimated area of identifiable land that may be converted within the community into a pre-conversion land cover stratum;

***Step 7***: Estimate the carbon stock (including all 5 pools) in each land cover stratum using methods detailed in IPCC GPG-LULUCF chapter 4.3 ($CS_i$);

***Step 8***: Determine the mean conservative forest biomass stock for the project region ($\overline{CS}$) for application to unidentified areas;

***Step 10***: Calculate the leakage using the following equations:

$$LK_{conv-crop,c} = \sum_{hh=1}^{Hh_c}\left(\sum_{i=1}^{I} IAC_{hci}\cdot CS_i\right)\cdot SF_c + \sum_{hh=1}^{Hh_c}\left(TACP_c - \sum_{i=1}^{I} IAC_{hci}\right)\cdot \overline{CS}\cdot SF_c \qquad \textbf{(128)}$$

$$SF_c = \frac{TNHH_c}{SHH_c} \qquad \textbf{(129)}$$

$$LK_{conv-crop} = TACP \cdot \frac{\sum_{c=1}^{C} LK_{conv-crop,c}}{\sum_{c=1}^{C} TACP_c} \qquad \textbf{(130)}$$

where:

| | | |
|---|---|---|
| $LK_{conv\text{-}crop}$ | = | leakage due to conversion of land to cropland attributable to displacement (activity shifting); t $CO_2$-e. |
| $LK_{conv\text{-}crop,c}$ | = | leakage due to conversion of land to cropland attributable to displacement (activity shifting) in community *c*; t $CO_2$-e. |
| $TACP$ | = | total area of land on which pre-project activities were displaced due to project activities; hectares |
| $TACP_c$ | = | total area of land on which pre-project activities were displaced due to project activities in community *c*; hectares |
| $IAC_{hci}$ | = | identifiable areas converted of stratum *i* by household *hh* in community *c*; hectares |
| $CS_i$ | = | locally derived carbon stock (including all eligible carbon pools) of stratum *i*; t $CO_2$-e. $ha^{-1}$ |
| $\overline{CS}$ | = | locally derived average carbon stock of unidentified lands (including all five eligible carbon pools); t $CO_2$-e. $ha^{-1}$ |
| $TNHH_c$ | = | total number of households using project lands in baseline in community *c*; dimensionless |
| $SHH_c$ | = | sampled households in community *c*, number of households sampled for leakage by activity shifting; dimensionless |
| $SF_c$ | = | sampling factor for community *c*; dimensionless |
| *c* | = | 1,2,3…*C*, communities; dimensionless |

$i$ = 1,2,3….$I$, strata; dimensionless

$hh$ = 1,2,3, $Hh_c$, households in community $c$; dimensionless

### 7.2.3 Estimation of $LK_{fuel\text{-}wood}$ (Leakage due to displacement of fuel-wood collection):

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

$$FG_{outside,t} = FG_{BL} - FG_{AR,t} \quad (131)$$

where:

$FG_{outside,t}$ = volume of fuel-wood gathering displaced outside the project area at year $t$; $m^3\ yr^{-1}$

$FG_{BL}$ = average pre-project annual volume of fuel-wood gathering in the project area – estimated *ex ante* and specified in the AR-CDM-PDD; $m^3\ yr^{-1}$

$FG_{AR,t}$ = volume of fuel-wood gathered in the project area according to monitoring results; $m^3\ yr^{-1}$

***Step 2:*** In the *NGL* areas specified in the AR-CDM-PDD for monitoring of displaced animal grazing, monitor the volume of fuel-wood gathering that is supplied to pre-project fuel-wood collectors and/or charcoal producers ($FG_{NGL,t}$).

***Step 3:*** Leakage due to displacement of fuel-wood collection can be set as zero ($LK_{fuel\text{-}wood} = 0$) under the following circumstances:

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

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

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

$$LK_{fuel-wood} = \sum_{t=1}^{t*} FG_t \cdot D \cdot BEF_2 \cdot CF \cdot \frac{44}{12} \quad (132)$$

$$FG_t = FG_{outside,t} - FG_{NGL,t} \quad (133)$$

where:

$LK_{fuel\text{-}wood}$ = leakage due to displacement of fuel-wood collection up to year $t$*; t $CO_2$-e.

$FG_t$ = volume of fuel-wood gathering displaced in unidentified areas; $m^3\ yr^{-1}$

$FG_{outside,t}$ = volume of fuel-wood gathering displaced outside the project area at year $t$ – as per step 1; $m^3\ yr^{-1}$

$FG_{NGL,t}$ = monitored volume of fuel-wood gathering in *NGL* areas and supplied to pre-project fuel-wood collectors and/or charcoal producers – as per step 2; $m^3\ yr^{-1}$

$D$ = average basic wood density; t d.m. $m^{-3}$ (See IPCC GPG-LULUCF - Table 3A.1.9)

$BEF_2$ = biomass expansion factor for converting volumes of extracted round-wood to total above-ground biomass (including bark); dimensionless Table 3A.1.10

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

$44/12$ = ratio of molecular weights of carbon and $CO_2$; dimensionless

### 7.3 Estimation of $LK_{fencing}$ (Leakage due to increased use of wood posts for fencing):

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

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

$$LK_{fencing} = \sum_{t=1}^{t^*} \frac{PAR_t}{DBP} \cdot FNRP \cdot DBP \cdot APV \cdot D \cdot BEF_2 \cdot CF \cdot \frac{44}{12} \qquad \textbf{(134)}$$

where:

$LK_{fencing}$ = leakage due to increased use of wood posts for fencing up to year $t^*$; t $CO_2$

$PAR_t$ = perimeter of the areas to be fenced at year $t$; m

$DBP$ = average distance between wood posts; m

$FNRP$ = fraction of posts from off-site non-renewable sources; dimensionless

$APV$ = average volume of o wood posts (estimated from sampling); m$^3$

$D$ = average basic wood density of the posts; t d.m. m$^{-3}$ (See IPCC GPG-LULUCF - Table 3A.1.9)

$BEF_2$ = biomass expansion factor for converting volumes of extracted round-wood to total above-ground biomass (including bark); dimensionless Table 3A.1.10

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

$44/12$ = conversion factor to transform t of C to t of $CO_2$-e.

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

## 8 Data to be collected and archived for leakage

**Table 6: Data to be collected and archived for leakage**

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | *44/12* | Ration of molecular weights of carbon and $CO_2$; dimensionless | Universal constant | dimensionless | universal constant | | | |
| | $aLK_{NGL}$ | Average leakage due to conversion of non-grassland to grassland per displaced animal in *NGL* areas | AR-CDM-PDD | t $CO_2$ -e. animal$^{-1}$ | c - e | *Ex ante* in AR-CDM-PDD | $SFR_{NGL}$ | *Ex ante* estimate in the AR-CDM-PDD |
| | $aLK_{XGL}$ | Average leakage due to conversion of non-grassland to grassland per displaced animal in *XGL* areas | AR-CDM-PDD | t $CO_2$ -e. animal$^{-1}$ | c - e | *Ex ante* in AR-CDM-PDD | | *Ex ante* estimate in the AR-CDM-PDD |
| | *APV* | Average volume of wood posts | Estimated | m$^3$ | e | 5-year | $SFR_P$ | (Estimated from sampling) |
| | $BEF_2$ | Biomass expansion factor (BEF) | Local-derived, national inventory, IPCC GPG LULUCF | dimensionless | e | 5 year | 100% of sampling plots | Local-derived and species-specific value have the priority (IPCC default in LULUCF GPG 2003, Table 3A.1.10) |
| | *c* | Community index (*C*=total number of communities) | | dimensionless | defined | Years 0, 1 and 5 | | |
| | $CF_j$ | Carbon fraction of dry matter of species *j* | Literature, own studies | t C (t d.m.)$^{-1}$ | e | Once per species or group of species | 100% | Local/national data or IPCC default (= 0.5) |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | $CS_i$ | Locally derived carbon stock of identified lands (including all five eligible carbon pools) of stratum *i* | Field measurement | t $CO_2$-e. $ha^{-1}$ | m | Years 0, 1 and 5 | | (Eq. 129) |
| | $\overline{CS}$ | Locally derived average carbon stock of unidentified lands (including all five eligible carbon pools) | Field measurement | t $CO_2$-e. $ha^{-1}$ | m | Years 0, 1 and 5 | | (Eq. 127, 129) |
| | *DBP* | Average distance between wood posts | Field sampling | m | m | 5 years | $SFR_P$ | IPCC GPG-LULUCF - Table 3A.1.9) |
| | *Dj* | Wood density of species *j* | Local-derived, national inventory, IPCC GPG LULUCF | t d.m. $m^{-3}$ | e | 5 year | 100% of sampling plots | Locally derived and species-specific value have the priority |
| | $dNa_{EGLt}$ | Number of animals displaced in *EGL* areas at time *t* | Calculations | dimensionless | c | Yearly | 100% | (Eq. 119) |
| | $dNa_{NGLt}$ | Number of animals displaced in *NGL* areas at time *t* – as estimated in step 4 | Calculations | dimensionless | c | Yearly | 100% | (Eq. 120) |
| | $dNa_{XGLt}$ | number of animals displaced in *XGL* areas at time *t* – as estimated in step 4 | Calculations | dimensionless | c | Yearly | 100% | (Eq. 121) |
| *3.1.02* | $EF_{xy}$ | $CO_2$ emission factor for vehicle type *x* with fuel type *y* | GPG 2000, IPPC Guidelines, national inventory | kg $CO_2$ $l^{-1}$ | e | At beginning of the project | 100% | National inventory value should have priority |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| *3.1.04* | $e_{xyt}$ | Fuel efficiency of vehicle type *x* with fuel type *y* at time *t* | Local data, national data, IPCC | Liter km$^{-1}$ | e | 5 years | 100% | Estimated for each vehicle type and fuel type used |
| | $FG_{AR,t}$ | Volume of fuel-wood gathered in the project area according to monitoring results | Field sampling | m$^3$ yr$^{-1}$ | m | Yearly | $SFR_{PAfw}$ | (Eq. 132) |
| | $FG_{BL}$ | Average pre-project annual volume of fuel-wood gathering in the project area – estimated *ex ante* and specified in the AR-CDM-PDD | AR-CDM-PDD | m$^3$ yr$^{-1}$ | c - e | *Ex ante* in AR-CDM-PDD | | *Ex ante* estimate in the AR-CDM-PDD, (Eq. 132) |
| | $FG_{NGL,t}$ | Monitored volume of fuel-wood gathering in *NGL* areas and supplied to pre-project fuel-wood collectors and/or charcoal producers – as per step 2 | Field measurements | m$^3$ yr$^{-1}$ | m | Yearly | $SFR_{NGL}$ | |
| | $FG_{outside,t}$ | Volume of fuel-wood gathering displaced outside the project area at year *t* – as per step 1 | Calculations | m$^3$ yr$^{-1}$ | c | Yearly | 100% | (Eq. 132) |
| | $FG_t$ | Volume of fuel-wood gathering displaced in unidentified areas | Calculations | m$^3$ yr$^{-1}$ | c | Yearly | 100% | (Eq.134) |
| | *FNRP* | Fraction of posts from off-site non-renewable sources | Field measurements | dimensionless | m | 5 year | $SFR_P$ | |
| *3.1.05* | $FuelConsumption_{xyt}$ | Consumption of fuel type *y* of vehicle type *x* at time *t* | Calculations | liters | c | Yearly | 100% | (Eq. 115) |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | *hh* | Household index (*Hh*=total number of households) | | | defined | Years 0, 1 and 5 | | |
| | *i* | Strata index (*S*=total number of strata) | | dimensionless | defined | Years 0, 1 and 5 | | |
| | $IAC_{hi}$ | Identifiable areas converted by household *hh* in stratum *I* | Field measurement | ha | m | Years 0, 1 and 5 | 10% or at least 30 households | |
| | $IAC_{hci}$ | Identifiable areas converted of stratum *i*, by household *hh* in community *c* | Field measurement | ha | m | Years 0, 1 and 5 | 10% or at least 30 households | (Eq. 129) |
| *3.1.03* | $k_{xyt}$ | Kilometers traveled by each of vehicle type *x* with fuel type *y* at time *t* | Monitoring of project activity | Kilometers | m | Yearly | 100% | Monitoring kilometers for each vehicle type and fuel type used |
| *3.1.19* | *LK* | Total project leakage | Calculations | t $CO_2$-e. | c | Yearly | 100% | (Eq. 112) |
| | $LK_{fuel\text{-}wood}$ | Leakage due to the displace-ment of fuel-wood collection | Calculations | t $CO_2$-e. | c | Yearly | 100% | (Eq. 133) |
| | $LK_{ActivityDisplacement}$ | Leakage due to activity dis-placement | Calculations | t $CO_2$-e. | c | Yearly | 100% | (Eq. 116) |
| | $LK_{conversion}$ | Leakage due to conversion of forest to non-forest; t $CO_2$-e. | Calculations | t $CO_2$-e. | c | Yearly | 100% | (Eq 117) |
| | $LK_{conv\text{-}graz}$ | Leakage resulting from the conversion for grazing | Calculations | t $CO_2$-e. | c | Yearly | | (Eq. 117, 122) |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | $LK_{conv\text{-}crop}$ | Leakage resulting from the conversion for cropland. | Calculation | t $CO_2$-e. | c | Years 0, 1 and 5 | 10% or at least 30 households or 10% of communities (or at least 10), 10% of households per community or at least 10 | (Eq. 127, 131) |
| | $LK_{conv\text{-}crop,c}$ | Leakage due to conversion of land to cropland attributable to displacement (activity shifting) in community c | Calculation | t $CO_2$-e. | c | Years 0, 1 and 5 | 10% of communities (or at least 10), 10% of households per community or at least 10 | Eq. (129, 131) |
| | $LK_{fencing}$ | Leakage due to increased use of wood posts for fencing up to year t* | Calculations | t $CO_2$ -e. | c | Yearly | 100% | (Eq. 135) |
| | $LK_{NGL}$ | Leakage due to conversion of non-grassland to grassland in NGL areas | Calculations | t $CO_2$-e. | c | Yearly | 100% | (Eq. 123) |
| *3.1.06* | $LK_{Vehicle}$ | Total GHG emissions due to fossil fuel combustion from vehicles | Calculations | t $CO_2$-e. $yr^{-1}$ | c | Yearly | 100% | (Eq. 113) |
| | $LK_{Vehicle,CH4}$ | Total $CH_4$ emissions due to fossil fuel combustion from vehicles | Calculations | t $CO_2$-e. $yr^{-1}$ | c | Yearly | 100% | (Eq. 114) |
| | $LK_{Vehicle,CO2}$ | Total $CO_2$ emissions due to fossil fuel combustion from vehicles | Calculations | t $CO_2$-e. $yr^{-1}$ | c | Yearly | 100% | (Eq. 114) |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | $LK_{Vehicle,N2O}$ | Total $N_2O$ emissions due to fossil fuel combustion from vehicles | Calculations | t $CO_2$-e. $yr^{-1}$ | c | Yearly | 100% | (Eq. 114) |
| | $LK_{XGL}$ | Leakage due to conversion of non-grassland to grassland in *XGL* areas | Calculations | t $CO_2$-e. | c | Yearly | 100% | (Eq. 124) |
| | $Na_{AR,t}$ | Monitored number of animals present in the project area at year *t* | Field measurements | dimensionless | m | Yearly | $SFR_{PAga}$ | |
| | $Na_{BL}$ | Eex *ante* estimated pre-project number of animals from the different livestock groups that would be grazing in the project area under the baseline scenario | AR-CDM-PDD | dimensionless | e | *Ex ante* in AR-CDM-PDD | $SFR_{PAga}$ | This estimate is fixed for the entire crediting period and is specified in the AR-CDM-PDD. |
| | $Na_{EGL,t}$ | Number of animals present in the sampled *EGL* areas at time *t* | Field measurements | dimensionless | m | Yearly | $SFR_{EGL}$ | |
| | $Na_{EGL,t=1}$ | Number of animals present in the sampled *EGL* areas at time *t*=1, as specified in the AR-CDM-PDD | AR-CDM-PDD | dimensionless | c - e | *Ex ante* in AR-CDM-PDD | | *Ex ante* estimate in the AR-CDM-PDD |
| | $Na_{NGL,t}$ | Number of animals present in the sampled *NGL* areas at time *t* | Field measurements | dimensionless | m | Yearly | $SFR_{NGL}$ | |
| | $Na_{NGL,t=1}$ | Number of animals present in the sampled NGL areas at time *t*=1, as specified in the AR-CDM-PDD | AR-CDM-PDD | dimensionless | c - e | *Ex ante* in AR-CDM-PDD | | *Ex ante* estimate in the AR-CDM-PDD |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | $Na_{outside,t}$ | Number of animals displaced outside the project area at year *t* | Calculations | dimensionless | c | Yearly | 100% | (Eq. 118) |
| *3.1.01* | $n_{xyt}$ | Number of each vehicle type used | Monitoring of project activity | dimensionless | m | Yearly | 100% | Monitoring number of each vehicle type used |
| | $PAR_t$ | Perimeter of the areas to be fenced at year *t* | Field measure-ments, GPS, GIS | m | m | 5-years | 100% | (Eq. 135) |
| | $SF$ | Sampling factor of household *hh* | Calculations | dimensionless | c | Years 0, 1 and 5 | 10% or at least 30 households | Eq. (128) |
| | $SF_c$ | Sampling factor of household *c* | Calculations | dimensionless | c | Years 0, 1 and 5 | 10% or at least 30 households | Eq. (130) |
| | $SFR_{EGL}$ | Fraction of sampled *EGL* areas sampled with respect to total | CDM-AR-PDD | dimensionless | defined using statistical criteria | *Ex ante* in AR-CDM-PDD | | *Ex ante* estimate in the AR-CDM-PDD |
| | $SFR_{NGL}$ | Fraction of sampled *NGL* areas sampled with respect to total | CDM-AR-PDD | dimensionless | defined using statistical criteria | *Ex ante* in AR-CDM-PDD | | *Ex ante* estimate in the AR-CDM-PDD |
| | $SFR_P$ | Fraction of sampled project areas sampled fencing posts | CDM-AR-PDD | dimensionless | defined using statistical criteria | *Ex ante* in AR-CDM-PDD | | *Ex ante* estimate in the AR-CDM-PDD |
| | $SFR_{PAfw}$ | Fraction of sampled project areas sampled for fuel-wood collection | CDM-AR-PDD | dimensionless | defined using statistical criteria | *Ex ante* in AR-CDM-PDD | | *ex ante* estimate in the AR-CDM-PDD |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | $SFR_{PAga}$ | Fraction of sampled project areas sampled for grazing animals | CDM-AR-PDD | dimensionless | defined using statistical criteria | *Ex ante* in AR-CDM-PDD | | *Ex ante* estimate in the AR-CDM-PDD |
| | $SHH$ | Sampled households, number of households | Field measurement | dimensionless | defined | Year 0 | 10% or at least 30 households | |
| | $SHH_c$ | Sampled households in community *c* | Field measurement | dimensionless | defined | Year 0 | 10% of communities (or at least 10), 10% of households per community or at least 10 | Eq. 130 |
| | $TACP$ | Total area of land on which pre-project activities were displaced due to project activities | Field measurement | ha | m | Year 0 | 10% or at least 30 households | (Eq. 131) |
| | $TACP_c$ | Total area of cropland planted that is owned by community *c* | Field measurement | ha | m | Year 0 | 10% of communities (or at least 10), 10% of households per community or at least 10 | (Eq. 129) |
| | $TACP_h$ | Total area of cropland planted that is owned by household *hh* | Field measurement | ha | m | Year 0 | 10% or at least 30 households | (Eq. 127) |
| | $TNHH$ | Total number of households using project lands in baseline | Field measurement | dimensionless | defined | Year 0 | 10% or at least 30 households | (Eq. 128) |
| | $TNHH_c$ | Total number of households inc community *c* using project lands in baseline | Field measurement | dimensionless | defined | Year 0 | 10% of communities (or at least 10), 10% of households per community or at least 10 | (Eq. 130) |

| ID number | Data Variable | | Source of data | Data unit | Measured (m) calculated (c) estimated (e) | Recording frequency | Proportion of data monitored | Comment |
|---|---|---|---|---|---|---|---|---|
| | *x* | vehicle type | Monitoring of project activity | dimensionless | m | Yearly | 100% | |
| | *y* | fuel type | Monitoring of project activity | dimensionless | m | Yearly | 100% | |

## 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, the following general formula can be used to calculate the net anthropogenic GHG removals by sinks of an AR CDM project activity ($C_{AR-CDM}$), in t $CO_2$-e.:

$$C_{AR-CDM} = C_{ACTUAL} - C_{BSL} - LK \quad \textbf{(135)}$$

where:

$C_{AR-CDM}$ = net anthropogenic greenhouse gas removals by sinks; t $CO_2$-e.

$C_{ACTUAL}$ = actual net greenhouse gas removals by sinks; t $CO_2$-e.

$C_{BSL}$ = baseline net greenhouse gas removals by sinks (as pre-determined in the PDD); t $CO_2$-e.

$LK$ = leakage; t $CO_2$-e.

Note: In this methodology Eq. 136 is used to estimate net anthropogenic GHG removals by sinks for the period of time elapsed between project start ($t=1$) and the year $t=t^*$, $t^*$ being the year for which actual net greenhouse gas removals by sinks are estimated. This is done because project emissions and leakage are permanent, which requires to calculate their cumulative values since the starting date of the AR CDM project activity.

### Calculation of tCERs and lCERs

To estimate the amount of CERs that can be issued at time $t^*= t_2$ (the date of verification) for the monitoring period $T = t_2 – t_1$, this methodology uses the EB approved equations[32] , which produce the same estimates as the following:

$$tCERs = C_{AR\text{-}CDM,t2} \quad \textbf{(136)}$$

$$lCERs = C_{AR\text{-}CDM,t2} - C_{AR\text{-}CDM,t1} \quad \textbf{(137)}$$

where:

$tCERs$ = number of units of temporary Certified Emission Reductions

$lCERs$ = number of units of long-term Certified Emission Reductions

$C_{AR\text{-}CDM,t2}$ = net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$; t $CO_2$-e.

$C_{AR\text{-}CDM,t1}$ = net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$; t $CO_2$-e.

## 10 Uncertainties and conservative approach

See Chapter 11.2. 'Quality control (QC) and quality assurance (QA) procedures to be applied to the monitoring process.

## 11 Other information

### 11.1 Default values used in elaborating the new methodology

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

*CF* = carbon fraction of dry matter (IPCC default = 0.5); t C (t d.m.)$^{-1}$

$GWP_{N2O}$ = Global Warming Potential for $N_2O$ (IPCC default for the first commitment period = 310 kg); $CO_2$-e. (kg $N_2O$)$^{-1}$

$GWP_{CH4}$ = Global Warming Potential for $CH_4$ (IPCC default for the first commitment period = 21 kg); $CO_2$-e. (kg $CH_4$)$^{-1}$

$ER_{N2O}$ = emission ratio for $N_2O$ in biomass burning (IPCC default = 0.007); t $CO_2$-e. (t C)$^{-1}$

$ER_{CH4}$ = emission ratio for $CH_4$ in biomass burning(IPCC default = 0.012); t $CO_2$-e. (t C)$^{-1}$

*CE* = average combustion efficiency of biomass (IPCC default = 0.5); dimensionless

*N/C* = N/C ratio of biomass (IPCC default = 0.01); dimensionless

$EF_1$ = emission factor for emissions from N fertilization (IPCC default = 0.0125); kg $N_2O$-N (kg N input)$^{-1}$

$Frac_{GASF}$ = fraction that volatilizes as $NH_3$ and $NO_x$ for synthetic fertilizers (IPCC default = 0.1); dimensionless

$Frac_{GASM}$ = fraction that volatilizes as $NH_3$ and $NO_x$ for organic fertilizers (IPCC default: =0.2); dimensionless

*Sources of values:* IPCC, 1996 Guidelines, IPCC GPG-LULUCF, GPG-2000 for energy, GPG-2000 for agriculture.

Some of these values are not used in this methodology, however, they may be used by users in adaptation of the methodology to specific local conditions.

### 11.2 Quality control (QC) and quality assurance (QA) procedures to be applied to the monitoring process

Quality Control (QC) is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. The QC system is designed to:

- Provide routine and consistent checks to ensure data integrity, correctness, and completeness;
- Identify and address errors and omissions;
- Document and archive inventory material and record all QC activities.

QC activities include general methods such as accuracy checks on data acquisition and calculations and the use of approved standardized procedures for emission calculations, measurements, estimating uncertainties, archiving information and reporting. Higher tier QC activities include technical reviews of source or sink categories, activity and emission factor data, and methods.

Quality Assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, should be performed upon a finalized inventory following the implementation of QC procedures. Reviews verify that data quality objectives were met, ensure that the inventory represents the best possible estimates of emissions and sinks given the current state of scientific knowledge and data available, and support the effectiveness of the QC programme.

To ensure the net anthropogenic GHG removals by sinks to be measured and monitored precisely, credibly, verifiably and transparently, a quality assurance and quality control (QA/QC) procedure shall be implemented, including (1) collection of reliable field measurement; (2) verification of methods used to collect field data; (3) verification of data entry and analysis techniques; and (4) data maintenance and archiving. If after implementing the QA/QC plan it is found that the targeted precision level is not met, then additional field measurements need to be conducted until the targeted precision level is achieved.

### 11.2.1 Reliable field measurements

Collecting reliable field measurement data is an important step in the quality assurance plan. Persons involving in the field measurement work should be fully trained in the field data collection and data analyses. Standard Operating Procedures (SOPs) for each step of the field measurements shall be developed and adhered to at all times. These SOPs should detail all phases of the field measurements and contain provisions for documentation for verification purposes, so that measurements are comparable over time and can be checked and repeated in a consistent fashion. To ensure the collection of reliable field data,

- Field-team members shall be fully aware of all procedures and the importance of collecting data as accurately as possible;
- Field teams shall install test plots if needed in the field and measure all pertinent components using the SOPs;
- Field measurements shall be checked by a qualified person to correct any errors in techniques;
- A document that shows that these steps have been followed shall be presented as a part of the project documents. The document will list all names of the field team and the project leader will certify that the team is trained;
- Any new staff is adequately trained.

### 11.2.2 Verification of field data collection

To verify that plots have been installed and the measurements taken correctly, 10-20% of plots shall be randomly selected and re-measured independently. Key re-measurement elements include the location of plots, DBH and tree height. The re-measurement data shall be compared with the original measurement data. Any deviation between measurement and re-measurement below 5% will be considered tolerable and error above 5%. Any errors found shall be corrected and recorded. Any errors discovered should be expressed as a percentage of all plots that have been rechecked to provide an estimate of the measurement error.

### 11.2.3 Verification of data entry and analysis

Reliable estimation of carbon stock in pools requires proper entry of data into the data analyses spreadsheets. To minimize the possible errors in this process, the entry of both field data and laboratory data shall be reviewed using expert judgment and, where necessary, comparison with independent data to ensure that the data are realistic. Communication between all personnel involved in measuring and analyzing data should be used to resolve any apparent anomalies before the final analysis of the monitoring data is completed. If there are any problems with the monitoring plot data that cannot be resolved, the plot should not be used in the analysis.

### 11.2.4 Data maintenance and archiving

Because of the long-term nature of the AR CDM project activity, data shall be archived and maintained safely. Data archiving shall take both electronic and paper forms, and copies of all data shall be provided to each project participant. All electronic data and reports shall also be copied on durable media such as CDs and copies of the CDs are stored in multiple locations. The archives shall include:

- Copies of all original field measurement data, laboratory data, data analysis spreadsheet;

- Estimates of the carbon stock changes in all pools and non-$CO_2$ GHG and corresponding calculation spreadsheets;
- GIS products;
- Copies of the measuring and monitoring reports.

**Table 7: Quality control activities and procedures**

| QC activity | Procedures |
|---|---|
| Check that assumptions and criteria for the selection of activity data, emission factors and other estimation parameters are documented. | • Cross-check descriptions of activity data, emission factors and other estimation parameters with information on source and sink categories and ensure that these are properly recorded and archived. |
| Check for transcription errors in data input and reference. | • Confirm that bibliographical data references are properly cited in the internal documentation<br>• Cross-check a sample of input data from each source category (either measurements or parameters used in calculations) for transcription errors. |
| Check that emissions and removals are calculated correctly. | • Reproduce a representative sample of emission or removal calculations.<br>• Selectively mimic complex model calculations with abbreviated calculations to judge relative accuracy. |
| Check that parameter and units are correctly recorded and that appropriate conversion factors are used. | • Check that units are properly labeled in calculation sheets.<br>• Check that units are correctly carried through from beginning to end of calculations.<br>• Check that conversion factors are correct.<br>• Check that temporal and spatial adjustment factors are used correctly. |
| Check the integrity of database files. | • Confirm that the appropriate data processing steps are correctly represented in the database.<br>• Confirm that data relationships are correctly represented in the database.<br>• Ensure that data fields are properly labeled and have the correct design specifications.<br>• Ensure that adequate documentation of database and model structure and operation are archived.. |
| Check for consistency in data between categories. | • Identify parameters (e.g., activity data, and constants) that are common to multiple categories of sources and sinks, and confirm that there is consistency in the values used for these parameters in the emissions calculations. |
| Check that the movement of inventory data among processing steps is correct | • Check that emission and removal data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries.<br>• Check that emission and removal data are correctly transcribed between different intermediate products. |

| QC activity | Procedures |
|---|---|
| Check that uncertainties in emissions and removals are estimated or calculated correctly. | • Check that qualifications of individuals providing expert judgment for uncertainty estimates are appropriate.<br>• Check that qualifications, assumptions and expert judgments are recorded. Check that calculated uncertainties are complete and calculated correctly.<br>• If necessary, duplicate error calculations on a small sample of the probability distributions used by Monte Carlo analyses. |
| Undertake review of internal documentation | • Check that there is detailed internal documentation to support the estimates and enable reproduction of the emission and removal and uncertainty estimates.<br>• Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review.<br>• Check integrity of any data archiving arrangements of outside organizations involved in inventory preparation. |
| Check time series consistency. | • Check for temporal consistency in time series input data for each category of sources and sinks.<br>• Check for consistency in the algorithm/method used for calculations throughout the time series. |
| Undertake completeness checks. | • Confirm that estimates are reported for all categories of sources and sinks and for all years.<br>• Check that known data gaps that may result in incomplete emissions estimates are documented and treated in a conservative way. |
| Compare estimates to previous estimates. | • For each category, current inventory estimates should be compared to previous estimates, if available. If there are significant changes or departures from expected trends, re-check estimates and explain the difference. |

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

### 1 List of variables used in equations:

| Variable | SI Unit | Description |
|---|---|---|
| Historical land use/cover data | dimensionless | Determining baseline approach, Demonstrating eligibility of land |
| Land use/cover map | dimensionless | Demonstrating eligibility of land, stratifying land area |
| Satellite image | dimensionless | Same as above cell |
| Landform map | dimensionless | Stratifying land area |
| Soil map | dimensionless | Stratifying land area |
| National and sectoral policies | dimensionless | Additionality consideration |
| UNFCCC, EB and AR-WG decisions – reports | dimensionless | |

| Variable | SI Unit | Description |
|---|---|---|
| IRR, NPV cost benefit ratio, or unit cost of service | local currency, %, etc. | Indicators of investment analysis |
| Investment costs | local currency | 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 |
| Operations and maintenance costs | local currency | Including costs of thinning, pruning, harvesting, replanting, fuel, transportation, repairs, fire and disease control, patrolling, administration, etc. |
| Transaction costs | local currency | Including costs of project preparation, validation, registration, monitoring, etc. |
| Revenues | local currency | Those from timber, fuel-wood, non-wood products, with and without CER revenues, etc. |
| $A$ | ha | Total project area |
| $a$ | ha | Sample plot size |
| $A_{B,ikt\_sb}$ | ha | Area of slash and burn for stratum i, stand model k, time t |
| $A_i$ | ha | Size of each stratum |
| $Adist_{ikt}$ | ha year$^{-1}$ | Forest areas affected by disturbances in stratum *i,* stand model *k*, time *t* |
| $Adist_{ikT}$ | ha year$^{-1}$ | Average annual area affected by disturbances for stratum *i,* stand model *k*, during the period *T*; |
| $a_{gp}$ | dimensionless | Number of months per annum during which animals from the livestock group *g* are present at parcel *p*; dimensionless |
| $A_{ikt}$ | ha | Area of stratum *i,* stand model *k*, at time *t* |
| $A_{ikT}$ | ha | Area of stratum *i,* stand model *k*, during period *T* |
| $aLK_{NGL}$ | t $CO_2$-e. animal$^{-1}$ | Average leakage due to conversion of non-grassland per displaced animal in *NGL* areas |
| $aLK_{XGL}$ | t $CO_2$-e. animal$^{-1}$ | Average leakage due to conversion of non-grassland per displaced animal in *XGL* areas |
| $A_{N,ikt}$ | ha | Area with N applied in stratum *i,* stand model *k*, at time *t* |
| $AP$ | m$^2$ | Plot area |
| $APV$ | m$^3$ | Average volume of o wood posts (estimated from sampling) |
| $BEF_{1,j}$ | dimensionless | Biomass expansion factor for conversion of annual net increment (including bark) in merchantable volume to total above-ground biomass increment for species *j* |
| $BEF_2$ | dimensionless | Biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass (including bark) |
| $BEF_{2ijt}$ | dimensionless | Biomass expansion factor for converting merchantable volumes of extracted round wood to total above-ground biomass (including bark) for stratum *i,* species *j*, time *t* |
| $B_{ikt}$ | t d.m. ha$^{-1}$ | Average above-ground biomass stock before burning for stratum *i*, stand model *k*, time *t* |
| $B_{pre,ikt}$ | t d.m. ha$^{-1}$ | Average pre-existing stock on land to be planted before the start of a proposed A/R CDM project activity for baseline stratum *i*, stand model *k*, time *t*; t d.m. ha$^{-1}$ |
| $B_{w,ijt}$ | t d.m. ha$^{-1}$ | Average above-ground biomass stock for stratum *i,* species *j*, time *t* |
| *N/C ratio* | dimensionless | Nitrogen-carbon ratio |
| $c$ | dimensionless | Community index (C = total number of communities) |
| $C_{AB,ijt}$ | t d.m. | Carbon stock in above-ground biomass for stratum *i,* species *j*, at time *t* |
| $C_{NGLac\ t}$ | t $CO_2$-e. | Mean carbon stock of the *NGL* area converted to grassland at time *t* |
| $C_{XGLac\ t}$ | t $CO_2$-e. | Mean carbon stock of the *XGL* area converted to grassland at time *t* |
| $C_{ACTUAL}$ | t $CO_2$-e. | Actual net greenhouse gas removals by sinks (as per Eq. 1) |
| $C_{AR\text{-}CDM}$ | t $CO_2$-e. | Net anthropogenic greenhouse gas removals by sinks |
| $C_{AR\text{-}CDM,t1}$ | t $CO_2$-e. | Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$ |

| Variable | SI Unit | Description |
|---|---|---|
| $C_{AR\text{-}CDM,t2}$ | t $CO_2$-e. | Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$ |
| $C_{AR\text{-}CDM,t1}$ | t $CO_2$-e. | Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$ |
| $C_{AR\text{-}CDM,t2}$ | t $CO_2$-e. | Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$ |
| $C_{BB,ijt}$ | t C | Carbon stock in below-ground biomass for stratum *i,* species *j*, at time *t* |
| $C_{BSL}$ | t $CO_2$-e. | Baseline net greenhouse gas removals by sinks |
| $CE$ | dimensionless | Average biomass combustion efficiency |
| $CF_j$ | t C (t d.m.)$^{-1}$ | Carbon fraction for species *j* |
| $C_i$ | local currency | Cost of establishment of a sample plot for each stratum *i* |
| $C_{ikt}$ | t C | Total carbon stock in living biomass for stratum *i,* stand model *k*, calculated at time *t* |
| $CF_{pre}$ | t C (t d.m.)$^{-1}$ | Carbon fraction of dry biomass in pre-existing vegetation |
| $CS_i$ | t $CO_2$-e. ha$^{-1}$ | Locally derived carbon stock (including all five eligible carbon pools) of stratum i |
| $\overline{CS}$ | t $CO_2$-e. ha$^{-1}$ | Locally derived average carbon stock of unidentified lands (including all five eligible carbon pools); t $CO_2$-e. ha$^{-1}$ |
| $CSP_{diesel\ t}$ | l | Amount of diesel consumption for year *t* |
| $CSP_{gasoline\ t}$ | l | Amount of gasoline consumption for year *t* |
| $D_j$ | t d.m. (m$^3$)$^{-1}$ | Basic wood density of species *j* |
| $DBH$ | cm | Tree diameter at breast height |
| $DBI_j$ | kg (d.m.) (animal day)$^{-1}$ | Daily biomass intake by animal type *j* |
| $DBP$ | m | Average distance between wood posts |
| $DLP$ | dimensionless | Desired level of precision (e.g. 10%) |
| $dNa_{EGL}$ | dimensionless | Number of animals that can be displaced in *EGL* areas |
| $dNa_{NGL}$ | dimensionless | Number of animals that can be displaced in *NGL* areas |
| $dNa_{XGL}$ | dimensionless | Number of animals to be displaced in *XGL* areas |
| $E$ | dimensionless | Allowable error |
| $E_{acBiomassBurnt}$ | t $CO_2$-e. | Total non-$CO_2$ emissions from biomass burning in land converted to grazing land at time *t* (calculated from 100% of the above-ground biomass) |
| $E_{BiomassBurn}$ | t $CO_2$-e. | Total increase in non-$CO_2$ emission as a result of biomass burning within the project boundary |
| $E_{BiomassBurn,\ CH4}$ | t $CO_2$-e. | $CH_4$ emission from biomass burning in slash and burn |
| $E_{BiomassBurn,\ N2O}$ | t $CO_2$-e. | $N_2O$ emission from biomass burning in slash and burn |
| $E_{BiomassBurn,CO2}$ | t $CO_2$-e. | $CO_2$ emission from biomass burning in slash and burn |
| $E_{biomassloss}$ | t $CO_2$-e. | Decrease in the carbon stock in the living biomass carbon pools of non-tree vegetation in the year of site preparation |
| $EF_1$ | t $N_2O$ (N input)$^{-1}$ | Emission factor for emissions from N inputs |
| $EFdiesel$ | kg $CO_2$ l$^{-1}$ | Emission factor for diesel |
| $E_{FuelBurn}$ | t $CO_2$-e. | Increase in GHG emission as a result of burning of fossil fuels outside the project boundary |
| $EF_{xy}$ | dimensionless | $CO_2$ emission factor for vehicle type *x* with fuel type *y* |
| $EGL$ | ha | Total existing grazing land area outside the project boundary that is under the control of the animal owners (or the project participants) and that will receive part of the displaced animal populations, up to time *t*;* ha |
| $E_i$ | t $CO_2$-e. | Emission/removal estimate for source/sink *i* |
| $ER_{CH4}$ | t $CO_2$-e. (t C)$^{-1}$ | Emission ratio for $CH_4$ (IPCC default value = 0.012) |

| Variable | SI Unit | Description |
|---|---|---|
| $ER_{N2O}$ | t $CO_2$-e. (t C)$^{-1}$ | Emission ratio for $N_2O$ (IPCC default value = 0.007) |
| $e_{xyt}$ | l km$^{-1}$ | Fuel efficiency of vehicle type *x* with fuel type *y* at time *t* |
| $FG_{AR,t}$ | m$^3$ year$^{-1}$ | Volume of fuel-wood gathering allowed/planned in the project area under the proposed AR-CDM project activity |
| $FG_{BL}$ | m$^3$ year$^{-1}$ | Average pre-project annual volume of fuel-wood gathering in the project area |
| $FG_{ijt}$ | m$^3$ (ha year)$^{-1}$ | Annual volume of fuel wood harvesting for stratum *i,* species *j*, time *t* |
| $FG_{ijT}$ | m$^3$ (ha year)$^{-1}$ | Average annual volume of fuel wood harvested for stratum *i,* species *j*, during the period *T* |
| $FG_{NGL,t}$ | m$^3$ year$^{-1}$ | Volume of fuel-wood gathering in *NGL* areas and supplied to pre-project fuel-wood collectors and/or charcoal producers |
| $FG_{outside,t}$ | m$^3$ year$^{-1}$ | Volume of fuel-wood gathering displaced outside the project area at year *t* |
| $FG_t$ | m$^3$ year$^{-1}$ | Volume of fuel-wood gathering displaced in unidentified areas |
| $f_i(DBH_t,H_t)$ | dimensionless | An allometric equation linking above-ground biomass of living trees (d.m ha$^{-1}$) to mean diameter at breast height (*DBH*) and possibly mean tree height (*H*) for species *j*; dimensionless |
| *FNRP* | dimensionless | Fraction of posts from off-site non-renewable sources |
| $FON_t$ | t N | Annual amount of organic fertilizer nitrogen applied at time *t* adjusted for volatilization as $NH_3$ and NOx |
| $Frac_{GASF}$ | dimensionless | Fraction that volatilizes as $NH_3$ and $NO_x$ for synthetic fertilizers |
| $Frac_{GASM}$ | dimensionless | Fraction that volatilizes as $NH_3$ and $NO_x$ for organic fertilizers |
| $FSN_t$ | t N | Amount of synthetic fertilizer nitrogen applied at time *t* adjusted for volatilization as $NH_3$ and $NO_x$ |
| $FuelConsumption_{xyt}$ | l | Consumption of fuel type *y* of vehicle type *x* at time *t* |
| $GHG_E$ | t $CO_2$-e. | Sum of the increases in non-$CO_2$ GHG emissions by sources within the project boundary as a result of the implementation of an AR CDM project activity |
| *GLA* | ha | Total grazing land area outside the project boundary needed to feed the displaced animal populations |
| $G_{TOTAL,ijt}$ | t d.m. (ha year)$^{-1}$ | Annual average increment rate in total biomass in units of dry matter for stratum *i*, species *j*, time *t* |
| $G_{w,ijt}$ | t d.m. (ha year)$^{-1}$ | Average annual above-ground biomass increment for stratum *i,* species *j*, time *t* |
| $GWP_{CH4}$ | dimensionless | Global Warming Potential for $CH_4$ (21 for the first commitment period) |
| $GWP_{N2O}$ | dimensionless | Global Warming Potential for $N_2O$ (310 for the first commitment period) |
| *hh* | dimensionless | Household index (*Hh* = total number of households) |
| *H* | m | Tree height |
| $H_{it}$ | m$^3$ (ha year)$^{-1}$ | Annually extracted merchantable volume for stratum *i,* species *j*, time *t* |
| $H_{ijT}$ | m$^3$ (ha year)$^{-1}$ | Average annually harvested merchantable volume for stratum *i,* species *j*, during the period *T* |
| *i* | dimensionless | Stratum index (*I* = total number of strata) |
| $IAC_{hi}$ | ha | Identifiable areas converted in stratum *i* by household *hh* |
| $IAC_{hic}$ | ha | Identifiable areas converted in stratum *i* by household *hh* in community *c* |
| $I_{v,ijt}$ | m$^3$ (ha year)$^{-1}$ | Average annual increment in merchantable volume for stratum *i,* species *j*, time *t* |
| $I_{v,ijT}$ | m$^3$ (ha year)$^{-1}$ | Average annual net increment in merchantable volume for stratum *i,* species *j* during the period *T* |
| *j* | dimensionless | Tree species (*J* = total species) |
| *k* | dimensionless | Stand model consisting of one or several species (*K* = total stand models) |
| $k_{xyt}$ | km | Kilometers traveled by each of vehicle type *x* with fuel type *y* at time *t* |

| Variable | SI Unit | Description |
|---|---|---|
| $lCERs$ | dimensionless | Number of units of long-term Certified Emission Reductions |
| $L_{fw,ikt}$ | t $CO_2$-e. year$^{-1}$ | Annual carbon loss due to fuel wood gathering for stratum *i*, stand model *k*, time *t* |
| $L_{hr,ikt}$ | t $CO_2$-e. year$^{-1}$ | Annual carbon loss due to commercial harvesting for stratum *i*, stand model *k*, time *t* |
| $LK$ | t $CO_2$-e. | Total project leakage |
| $LK_{fuel\text{-}wood}$ | t $CO_2$-e. | Leakage due to the displacement of fuel-wood collection |
| $LK_{ActivityDisplacement}$ | t $CO_2$-e. | Leakage due to activity displacement |
| $LK_{conversion}$ | t $CO_2$-e. | Leakage due to conversion of land for grazing or cropland |
| $LK_{conv\text{-}graz}$ | t $CO_2$-e. | Leakage resulting from conversion of land for grazing |
| $LK_{conv\text{-}crop}$ | t $CO_2$-e. | Leakage resulting from conversion of land for cropland |
| $LK_{conv\text{-}crop,c}$ | t $CO_2$-e. | Leakage resulting from conversion of land for cropland in community *c* |
| $LK_{fencing}$ | t $CO_2$-e. | Leakage due to increased use of wood posts for fencing |
| $LK_{NGL}$ | t $CO_2$-e. | Leakage due to conversion of non-grassland to grassland in *NGL* areas under the control of the animal owners |
| $LK_{Vehicle}$ | t $CO_2$-e. year$^{-1}$ | Total GHG emissions due to fossil fuel combustion from vehicles |
| $LK_{Vehicle,CH4}$ | t $CO_2$-e. year$^{-1}$ | Total $CH_4$ emissions due to fossil fuel combustion from vehicles |
| $LK_{Vehicle,CO2}$ | t $CO_2$-e. year$^{-1}$ | Total $CO_2$ emissions due to fossil fuel combustion from vehicles |
| $LK_{Vehicle,N2O}$ | t $CO_2$-e. year$^{-1}$ | Total $N_2O$ emissions due to fossil fuel combustion from vehicles |
| $LK_{XGL}$ | t $CO_2$-e. | Leakage due to conversion of non-grassland to grassland in unidentified *XGL* areas |
| $MC_{AB,ijt}$ | t C ha$^{-1}$ | Mean carbon stock in above-ground biomass per unit area for stratum *i,* species *j*, time *t* |
| $MC_{BB,ijt}$ | t C ha$^{-1}$ | Mean carbon stock in below-ground biomass per unit area for stratum *i,* species *j*, time *t* |
| $MC_{AB,ijT}$ | t C ha$^{-1}$ | Mean carbon stock in above-ground biomass per unit area for stratum *i,* species *j*, between two monitoring events |
| $MC_{BB,ijT}$ | t C ha$^{-1}$ | Mean carbon stock in below-ground biomass per unit area for stratum *i,* species *j*, between two monitoring events |
| $MV_{ijt}$ | $m^3$ (ha year)$^{-1}$ | Mean merchantable volume per unit area for stratum *i,* species *j*, time *t* |
| $N$ | dimensionless | Maximum possible number of sample plots in the project area |
| $n$ | dimensionless | Sample size (total number of sample plots required) in the project area |
| $k$ | | Stand model (*K* = total stand models) |
| $L_{ot,ijt}$ | t $CO_2$-e..year$^{-1}$ | Annual natural losses (mortality) of carbon for stratum *i*, species *j* |
| $m_{BL}$ | | Total baseline strata |
| $Mf_{ijT}$ | dimensionless | Mortality factor = *percentage* of $V_{ijt1}$ died during the period *T* |
| $m_{PS}$ | | Total strata in the project scenario |
| $N_2O_{direct-N_{fertilizer}}$ | t $CO_2$-e. | Direct $N_2O$ emission as a result of nitrogen application within the project boundary up to time *t** |
| $Na$ | dimensionless | Total number of animals from the different livestock groups that are grazing in the project area (or in the sampled discrete areas) |
| $Na_{AR,t}$ | dimensionless | Number of animals allowed in the project area under the proposed AR-CDM project activity at year *t* |
| $Na_{BL}$ | dimensionless | Average pre-project number of animals from the different livestock groups that are grazing in the project area |
| $Na_{EGL,t}$ | dimensionless | Number of animals present in the sampled *EGL* areas at time *t* |
| $Na_{EGL,t=1}$ | dimensionless | Average number of animals present in the *EGL* areas selected for monitoring at project start |
| $Na_{NGL,t}$ | dimensionless | Number of animals present in the sampled *NGL* areas at time *t* |

| Variable | SI Unit | Description |
|---|---|---|
| $Na_{outside,t}$ | dimensionless | Number of animals displaced outside the project area at year *t* |
| $N_i$ | dimensionless | Maximum possible number of sample plots in stratum *i* |
| $n_i$ | dimensionless | Sample size for stratum *i* |
| $N_{ON\text{-}Fert}$ | t N | Total amount of organic fertilizer used within the project boundary |
| $N_{ON\text{-}Fert,ikt}$ | kg N (ha year)$^{-1}$ | Use of organic fertilizer per unit area for stratum *i,* stand model *k*, at time *t* |
| $Na_s$ | dimensionless | Number of animals from the different livestock groups that the animal owners intend to sell as a consequence of the project implementation |
| *NGL* | ha | Total new grazing land area outside the project boundary to be converted to grazing land that is under the control of the animal owners (or the project participants) and that will receive another part of the displaced animal populations, up to time *t** |
| $ngl_t$ | ha | Total area converted to grassland at time *t* |
| $n_{pgt}$ | dimensionless | Number of individual animals from the livestock group *g* at parcel *p* at time *t* |
| $N_{SN\text{-}Fert,t}$ | t N | Amount of synthetic fertilizer nitrogen applied at time *t* |
| $N_{SN\text{-}Fert,ikt}$ | kg N (ha year)$^{-1}$ | Use of synthetic fertilizer per unit area for stratum *i,* stand model *k*, at time *t* |
| $nTR_{ijt}$ | trees ha$^{-1}$ | Number of trees in stratum *i*, species *j*, at time *t* |
| $n_{xyt}$ | dimensionless | Number of vehicles |
| $PAR_t$ | m | Perimeter of the areas to be fenced at year *t* |
| $PBB_{ikt}$ | dimensionless | Average proportion of biomass burnt for stratum *i*, stand model *k*, time *t* |
| *pl* | dimensionless | Plot number in stratum *i*, species *j* |
| $PL_{ij}$ | dimensionless | Total number of plots in stratum *i*, species *j* |
| *Q* | variable | Approximate average value of the estimated quantity *Q,* (e.g. wood volume); e.g. m$^3$ ha$^{-1}$ |
| $R_j$ | dimensionless | Root-shoot ratio appropriate to increments for species *j* |
| $sFG_{BL}$ | m$^3$ ha$^{-1}$ | Sampled average pre-project annual volume of fuel-wood gathering in the project area |
| *SF* | dimensionless | Sampling factor |
| $SF_c$ | dimensionless | Sampling factor of community *c* |
| $SFR_{EGL}$ | dimensionless | Fraction of sampled *EGL* areas |
| $SFR_{NGL}$ | dimensionless | Fraction of sampled *NGL* areas |
| $SFR_P$ | dimensionless | Fraction of sampled fencing posts |
| $SFR_{PAfw}$ | dimensionless | Fraction of total project area sampled for fuel-wood collection |
| $SFR_{PAga}$ | dimensionless | Fraction of total project area sampled for grazing animals |
| *SHH* | dimensionless | Sampled households, number of households sampled for $LK_{conv\text{-}crop}$ |
| $SHH_c$ | dimensionless | Sampled households in community *c*, number of households sampled for $LK_{conv\text{-}crop}$ |
| $st_i$ | dimensionless | Standard deviation for each stratum *I* |
| $sNa_{BL}$ | dimensionless | Sampled pre-project number of animals from the different livestock groups that are grazing in the project area |
| *t* | years | 1, 2, 3, …*t** years elapsed since the start of the AR CDM project activity |
| *T* | years | Number of years between times $t_2$ and $t_1$ $(T = t_2 - t_1)$ |
| *t** | years | Number of years elapsed since the start of the AR project activity |
| *TACP* | ha | Total area of cropland planted by the project |
| $TACP_c$ | ha | Total area of cropland planted that is owned by community *c* |
| $TACP_h$ | ha | Total area of cropland planted that is owned by household *hh* |
| $TB_{ABj}$ | kg tree$^{-1}$ | Aboveground biomass per tree of species *j* |

| Variable | SI Unit | Description |
|---|---|---|
| $TC_{ABj}$ | kg C $tree^{-1}$ | Carbon stock in above-ground biomass per tree of species *j* |
| $TC_{BBj}$ | kg C $tree^{-1}$ | Carbon stock in below-ground biomass per tree of species *j* |
| *tCERs* | dimensionless | Number of units of temporary Certified Emission Reductions |
| *TNHH* | dimensionless | Total number of households using project lands in baseline |
| $TNHH_c$ | dimensionless | Total number of households using project lands in baseline in community *c* |
| *tr* | dimensionless | Tree (*TR* = total number of trees in the plot) |
| *x* | dimensionless | Vehicle type |
| *XF* | dimensionless | Plot expansion factor from per plot values to per hectare values |
| *y* | dimensionless | Fuel type |
| $z_{\alpha/2}$ | dimensionless | Value of the statistic *z* (normal probability density function), for $\alpha = 0.05$ (implying a 95% confidence level) |
| $\Delta C_{AB,ikt}$ | t C $year^{-1}$ | Changes in carbon stock in above-ground biomass for stratum *i*, stand model *k,* at time *t* |
| $\Delta C_{BB,ikt}$ | t C $year^{-1}$ | Changes in carbon stock in below-ground biomass for stratum *i*, stand model *k,* at time *t* |
| $t_{cp}$ | dimensionless | Year at which the first crediting period ends; yr |
| $U_E$ | % | Percentage uncertainty of the sum |
| $U_i$ | % | Percentage uncertainties associated with each of the quantities, |
| *Ui* | % | Percentage uncertainty associated with source/sink i |
| $U_{total}$ | % | Percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage); |
| $V_{ijt}$ | $m^3$ $ha^{-1}$ | Average merchantable volume of stratum *i,* species *j*, at time *t* |
| $V_{ijt1}$ | $m^3$ $ha^{-1}$ | Average merchantable volume of stratum *i,* species *j*, at time $t = t_1$ |
| $V_{ijt2}$ | $m^3$ $ha^{-1}$ | Average merchantable volume of stratum *i,* species *j*, at time $t = t_2$ |
| $WB_{ht}$ | % | Fraction of total above-ground biomass harvested as timber and as fuel-wood at time *t* (not burned) |
| *XGL* | ha | Total unidentifiable grazing land area outside the project boundary that will receive the remaining part of displaced animal populations, e.g. when the pre-project animal owners decide to sell the animals, up to time *t** |
| $xgl_t$ | ha | Total unidentifiable area converted to grassland at time *t* |
| $\Delta C_{av}$ | t d.m. $year^{-1}$ | Average annual biomass consumed by one average animal |
| $\Delta C_{G,ikt}$ | t $CO_2$-e. $year^{-1}$ | Annual increase in carbon stock due to biomass growth for stratum *i,* stand model *k,* time *t* |
| $\Delta CB_{B,ikt}$ | t $CO_2$-e. $year^{-1}$ | Annual carbon stock change in living biomass in the baseline for stratum *i,* stand model *k,* time *t* |
| $\Delta CB_{LB,ikt}$ | t $CO_2$-e. $year^{-1}$ | Annual carbon stock change in living biomass in the project scenario for stratum *i,* stand model *k,* time *t* |
| $\Delta C_{B,ikt}$ | t $CO_2$-e. $year^{-1}$ | Annual carbon stock change in living biomass in the baseline for stratum *i,* stand model *k,* time *t* |
| $\Delta C_{LB,ikt}$ | t $CO_2$-e. $year^{-1}$ | Annual carbon stock change in living biomass in the project scenario for stratum *i,* stand model *k,* time *t* |
| $\Delta C_{L,ikt}$ | t $CO_2$-e. $year^{-1}$ | Annual decrease in carbon stock due to biomass loss in the project scenario for stratum *i,* stand model *k,* time *t* |
| $\Delta C_{L\ PA,t}$ | t d.m. $year^{-1}$ | Annual animal biomass consumption over the project area to be planted at time *t* |
| $\Delta C_{P,LB}$ | t $CO_2$-e. | Sum of the changes in living biomass carbon stocks (above- and below-ground) |
| $\Delta C_{Lcurrent}$ | t d.m. $year^{-1}$ | Current annual biomass that the grazing areas can produce for animal feeding |

| Variable | SI Unit | Description |
|---|---|---|
| $\Delta C_{Lmax}$ | t d.m. $year^{-1}$ | Maximum annual biomass that the grazing areas can produce for animal feeding |
| $\Delta MC_{AB,ikt}$ | t C $year^{-1}$ | Annual mean carbon stock change in above-ground biomass for stratum *i*, stand model *k*, at year *t* |
| $\Delta MC_{ABikT}$ | t C $ha^{-1}$ | Mean carbon stock change in above-ground biomass for stratum *i*, stand model *k*, between two monitoring events |
| $\Delta MC_{BBikt}$ | t C $(ha\ year)^{-1}$ | Annual mean carbon stock change in below-ground biomass for stratum *i*, stand model *k*, at year *t* |
| $\Delta MC_{BBikT}$ | t C $ha^{-1}$ | Mean carbon stock change in below-ground biomass stock in stratum *i*, stand model *k*, between two monitoring events |
| $\Delta PC_{ABijT}$ | t C $ha^{-1}$ | Plot level carbon stock change in above-ground biomass for stratum *i*, species *j* between two monitoring events |
| $\Delta PC_{BBijT}$ | t C $ha^{-1}$ | Plot level carbon stock change in below-ground biomass for stratum *i*, species *j* between two monitoring events |
| $\Delta TC_{ABjT}$ | kg C $tree^{-1}$ | Carbon stock change in above-ground biomass per tree of species *j* between two monitoring events |
| $\Delta TC_{BBjT}$ | kg C $tree^{-1}$ | Carbon stock change in below-ground biomass per tree of species *j* between two monitoring events |
| $\Delta TC_{ABj,t}$ | kg C $tree^{-1}$ | Carbon stock change in above-ground biomass per tree of species *j* at the monitoring event in year t |
| $\Delta TC_{BBj,t}$ | kg C $tree^{-1}$ | Carbon stock change in below-ground biomass per tree of species *j* at the monitoring event in year t |

## 2 List of acronyms used in the methodologies:

| Acronym | Description |
|---|---|
| AR | Afforestation and Reforestation |
| CDM | Clean Development Mechanism |
| CER | Certified Emission Reduction |
| CF | Carbon Fraction |
| DBH | Diameter at Breast Height |
| DOE | Designated Operational Entity |
| EB | Executive Board |
| GHG | Greenhouse Gases |
| GPG | Good Practice Guidance |
| GWP | Global Warming Potential |
| H | Tree Height |
| IPCC | Intergovernmental Panel on Climate Change |
| lCER | long-term Certified Emission Reduction |
| LULUCF | Land Use Land-Use Change and Forestry |
| NFS | Nitrogen Fixing Species |
| PDD | Project Design Document |
| QA | Quality Assurance |
| QC | Quality Control |

| Acronym | Description |
|---|---|
| RS | Root to shoot ratio |
| tCER | temporary Certified Emission Reduction |

## 3 References:

All references are quoted in footnotes.