Approved afforestation and reforestation baseline and monitoring methodology AR-AM0003

"Afforestation and reforestation of degraded land through tree planting, assisted natural regeneration and control of animal grazing"

Source

This methodology is based on the draft CDM-AR-PDD "Assisted Natural Regeneration on Degraded Land in Albania", whose baseline study, monitoring and verification plan and project design document were prepared by the General Directorate for Forests and Pastures and the International Bank for Reconstruction and Development as Trustee of the BioCarbon Fund. For more information regarding the proposal and its consideration by the Executive Board, please refer to case ARNM0018 "Assisted Natural Regeneration on Degraded Land in Albania" on:
http://cdm.unfccc.int/methodologies/ARmethodologies/approved_ar.html.

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

1 Selected baseline approcha 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 fuelwood collection activities (including on-site charcoal production).

The conditions under which the methodology is applicable are:

- The project activity can lead to a shift of pre-project activities outside the project boundary, e.g. a displacement of grazing and fuelwood collection activities, including charcoal production;
- Lands to be afforested or reforested are severely degraded and the lands are still degrading or remain in a low carbon steady state;
- Environmental conditions or anthropogenic pressures do not permit the encroachment of natural tree vegetation that leads to the establishment of forests according to the threshold values of the national definition of forest for CDM purposes;
- Lands will be afforested or reforested through promotion of natural regeneration and or direct planting or seeding;
- 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 type 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.

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 conditions
Litter	No	Conservative approach under applicability conditions
Soil organic carbon	No	Conservative approach under applicability conditions

4 Summary description

The methodology is applicable to AR CDM project activities on degraded and degrading land which is either abandoned or subjected to grazing or fuelwood collection activities.

Baseline methodology steps:

i. The project boundary is defined for all discrete parcels of land to be afforested or reforested and that are under the control of the project participants at the starting date of the project activity. The methodology also provides rules for including in the project area discrete parcels of land not yet under the control of the project participants at the starting date of the proposed AR CDM project activity but expected to become under the control of the project participants 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. The selection of data sources shall be performed by the user.

iii. The baseline scenario is determined by the following steps:
The methodology is applicable only if the baseline land use is a continuation of the existing land use.
Step 1. Definition of the project boundary.
Step 2. Analysis of historical land use, local and sectoral land-use policies or regulations and land use alternatives.
Step 3. 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 4. Determination of the baseline land-use / land-cover for each stratum;

Step 5. 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 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. *Ex-ante* actual net GHG removal by sinks are 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 fuel consumption for transport of staff, products and services; displacement of pre-project grazing and fuel-food collection activities; increased consumption of wood posts for fencing.

Monitoring methodology steps:

i. The project implementation is monitored, including project boundary, 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 (grazing and fuelwood collection activities), increased fossil fuel and fencing posts consumption is monitored.

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

Section II. Baseline methodology description

1 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.

2 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 1 below.

***Table 1*: Gases considered from emissions by sources othern than resulting from changes in carbon pools**

Sources	Gas	Included/	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

An AR CDM project activity may contain more than one discrete parcel of land. Each discrete parcel of land shall have a unique geographical identification. The boundary shall be defined for each discrete parcel and shall not include the areas in between these discrete parcels of lands. The discrete parcels of lands are usually defined by polygons. To make the boundary geographically verifiable and transparent, the coordinates for all corners of the polygons shall be measured (using GPS, analysis of geo-referenced spatial data, or other appropriate techniques), recorded, archived and listed in the CDM-AR-PDD of the proposed AR CDM project activity.

b) 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 become under the control of the project participants during the crediting period may be included within the project boundary if all of the following conditions are met:

- The total area (hectares) of these parcels of land not yet under the control of the project participants is clearly defined in the CDM-AR-PDD;
- A justification of why these parcels of land are not yet but will become under the control of the project participants is provided in the CDM-AR-PDD;
- The candidate land areas among which the particular parcels of land will be chosen have been

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

identified and are unambiguously identified in the CDM-AR-PDD with coordinates and maps;

- All candidate land areas have been included in the baseline assessment and it can be shown that they are not different from the land areas already under the control of the project participants at the start of the proposed 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.

3 Ex-ante stratification

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

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

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

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) Do a preliminary stratification based on the collected information.

e) 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 stand model specific), respectively;
   - Events that have resulted in deforestation, and their timing;
   - 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.

f) Do the final stratification of the baseline scenario based on supplementary information collected from e) 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 deprived of trees or shrubs; with some trees or shrubs already present; subject to intensive collection of fuel wood or grazing. On the other hand, site and soil factors may not warrant a separate stratum as long as all lands have a baseline of continued degradation.

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

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

a) Define the "stand models" to be implemented in the project area by specifying:

- The species or species combination to be planted together in one single location and at the same date to create a "stand model";
- The growths assumptions for each species or 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 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 steps B.1 and B.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 data bases in a GIS platform for each parameter used for stratification of the project area under the baseline and the project scenario. This will facilitate consistency with the project boundary, precise overlay of baseline and project scenario strata, transparent monitoring and ex-post stratification.

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 B.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 B.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 Procedures for the selection of the most plausible baseline scenario

The baseline scenario is determined by the following steps:

Step 1: Define the project boundary as described in Section II.1 above[4].

Step 2: 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 attributable to 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 lead to progressive degradation of the land over time including a decrease or steady state 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, e.g.:

Vegetation degradation, e.g.:

- 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.

Soil degradation, e.g.:

- Lower soil erosion at time points in the past than in more recent time points;
- Higher soil organic carbon 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 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

[4] As outlined in Section II.2, 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.

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 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 that the land area within the boundary of the proposed AR CDM project activity is likely to change its current status (i.e. degraded or subject to further degradation), then this methodology is not applicable any further. 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 3: Stratify the AR CDM project area as explained in Section II.2 above.

Step 4: Determine the baseline land-use / land-cover scenario for each stratum.

Analyze the possibility of self-encroachment of trees[5] 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 step 6 below. Otherwise, the proposed AR CDM project activity is not different from the baseline scenario[6].

Step 5: Determine the baseline carbon stock changes:

a) For those strata without growing trees and/or shrubs, the sum of carbon stock changes is set as zero in all carbon pools. Sampling survey is preferred to confirm that the setting would not result in the underestimation of baseline net GHG removal by sinks.

b) For those strata with growing trees or shrubs, the sum of carbon stock changes is set zero in the soil organic carbon, dead wood and litter carbon pools, and a net positive change is estimated in the living biomass carbon pools based on the projection of number, growth rate of trees/shrubs, allometric equations, IPCC good practice guidance, and local or national or IPCC default parameters (details in Section II.4).

5 Estimation of the baseline net GHG removals by sinks

[5] 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).

[6] 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.

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 of conditions under which the proposed methodology is applicable (described in Section I.3) lands to be afforested or reforested are degraded lands, either abandoned or subjected to pre-project grazing 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 are expected to start to grow at any time during the crediting period,

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:

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

where:

C_{BSL} = baseline net greenhouse gas removals by sinks; tonnes 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 (a) and (b) 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; tonnes CO_2-e.
$\Delta C_{B,LB}$ = sum of the changes in living biomass carbon stocks in the baseline (above- and below-ground); tonnes CO_2-e.

Note: In this methodology Equation (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 baseline $\Delta C_{B,LB}$ (changes in living biomass carbon stocks in the baseline):

$$\Delta C_{B,LB} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{BL}} \Delta C_{B,ikt} \quad \textbf{(3)}$$

where:

$\Delta C_{B,LB}$ = sum of the changes in living biomass carbon stocks in the baseline (above- and below-ground); tonnes CO_2-e.
$\Delta C_{B,ikt}$ = annual carbon stock change in living biomass in the baseline for stratum i, stand model k, time t; tonnes CO_2-e. yr^{-1}

i = 1, 2, 3, ... m_{BL} baseline strata
k = 1, 2, 3, ... K stand model (see footnote 7)
t = 1, 2, 3, ...t^* years elapsed since the start of the AR CDM project activity

For those strata without growing trees, $\Delta C_{LB,ikt} = 0$. For those strata with a few growing trees, $\Delta C_{LB,ikt}$ is estimated using one of following two methods that can be chosen based on the availability of data. As the following equations will be used for both the baseline and the actual net GHG removals by sinks, the variable stand model k is included in all the equations. For the ex ante baseline estimation $k = 0$.[7]

A) Method 1 (Carbon gain-loss method)[8]

$$\Delta C_{ikt} = (\Delta C_{G,ikt} - \Delta C_{L,ikt}) \quad (4)$$

where:

ΔC_{ikt} = annual carbon stock change in living biomass for stratum *i,* for stand model *k,* time *t;* tonnes 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*; tonnes 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;* tonnes CO_2-e. yr^{-1}
Note: This methodology conservatively assumes that $\Delta C_{L,ikt} = 0$ for the baseline scenario[9].

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

where:

ΔC_{Gikt} = annual increase in carbon *stock* due to biomass growth for stratum *i,* for stand model *k,* time *t*; tonnes CO_2-e. yr^{-1}
A_{ikt} = area of stratum *i,* for stand model *k,* at time *t*; hectare (ha)
Note: The area of a stratum *i* has a time notation because depending on baseline land use/cover projections stand models *k* may appear at different dates within the same stratum.
$C_{TOTAL,ikt}$ = annual average increment rate in total carbon in stratum *i*, stand model *k,* time t; tonnes CO_2-e. ha^{-1} yr^{-1}
Note: $C_{TOTALikt}$ can be estimated as a constant annual average value

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

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

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[7] Within a baseline stratum, the vegetation type (= stand model) should be similar as a criterium for stratification
[8] GPG-LULUCF Equation 3.2.2, Equation 3.2.4 and Equation 3.2.5
[9] 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.

where:

$C_{TOTAL,ikt}$	=	annual average increment rate in total carbon in stratum *i*, stand model *k,* time t; tonnes CO_2-e. ha^{-1} yr^{-1} Note: $C_{TOTALikt}$ can be estimated as a constant annual average value.
$G_{w,ijt}$	=	average annual above-ground biomass increment for stratum *i,* species *j*, at time *t*; tonnes d.m. ha^{-1} yr^{-1}
R_j	=	root-shoot ratio appropriate to increments for species *j*; dimensionless Note: Care should be taken that the root-shoot ratio may change as a function of the above-ground biomass present at time (*t*) (see IPCC GPG, 2003, Annex 3.A1, Table 3A1.8)
CF_j	=	the carbon fraction for species *j*; tonnes C (tonne d.m.)$^{-1}$
$I_{v,ijt}$	=	average annual increment in merchantable volume for stratum *i,* species *j*; m^3 ha^{-1} yr^{-1} Note: I_{vijt} is estimated as "current annual increment – CAI". The "mean annual incremente" – MAI in the forestry jargon – can only be used if its use leads to conservative estimates.
D_j	=	basic wood density for species *j*; tonnes 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

B) Method 2 (stock change method)[10]

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

$$C_{ikt} = \sum_{j=1}^{J} C_{AB,ijt} + C_{BB,ijt} \qquad \textbf{(9)}$$

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

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

where:

ΔC_{ikt}	=	annual carbon stock change in living biomass for stratum *i,* stand model *k,* time *t;* tonnes CO_2-e. yr^{-1}.
C_{ikt}	=	carbon stock in living biomass for stratum *i,* stand model *k,* time *t;* tonnes CO_2-e.
C_{ikt2}	=	total carbon stock in living biomass for stratum *i,* stand model *k,* calculated at time $t = t_2$; tonnes C
C_{ikt1}	=	total carbon stock in living biomass for stratum *i,* stand model *k,* calculated at time $t = t_1$; tonnes 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;* tonnes C
$C_{BB,ijt}$	=	carbon stock in below-ground biomass for stratum *i,* species *j*, at time *t;* tonnes C
V_{ijt}	=	average merchantable volume of stratum *i,* species *j*, at time *t;* m^3 ha^{-1} Note: Stratification criteria shall include age classes so that V_{ijt} should have low variances within stratum *i,* species *j*, time *t.*

[10] GPG-LULUCF Equation 3.2.3

D_j = wood density for species *j*; tonnes d.m. m^{-3} merchantable volume
$BEF_{2,j}$ = biomass expansion factor for conversion of merchantable volume to above-ground tree biomass for species *j*; dimensionless
R_j = root-shoot ratio for species *j*; dimensionless

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

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

where:

$C_{AB,ijt}$ = carbon stock in above-ground biomass for stratum *i,* species *j*, at time *t;* tonnes 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}
CF_j = the carbon fraction for species *j*, tonnes C (tonnes d.m.)$^{-1}$
$f_j(DBH_t,H_t)$ = an allometric equation linking above-ground biomass of living trees (d.m. $tree^{-1}$) 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 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 Equation 3 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 $I_{v,ijt}$ 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);
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). Another alternative is for the project to carry out its own measurements.

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

Randomly select three plots for each age class of plantation of each species in the project area. The size of plots depends on the density of trees, in general between 100 m^2 for dense stands and 1000 m^2 for open stands. The sampling plots shall have similar density (number of trees per ha) to the project design in the PDD;

Measure diameter at breast height (DBH), tree height, crown diameter and living crown length; select a standard tree with mean DBH, tree height, crown diameter and the height of living crown; harvest the standard tree including all roots, measure the fresh weight of stem, branches, leaves, bark, stump, coarse roots and fine roots respectively, and sample for respective parts after oven drying at temperature around 50-60 ^oC, calculate moisture content of the samples and estimate above- and below-ground biomass of the standard tree; take a disk of stem at the middle of the stem, oven dry and calculate wood density (tonnes d.m. m^{-3}); establish allometric equation and calculating root-shoot ratio based on data measured above; calculate BEF and establish age-dependent or volume-dependent BEF equation.

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[11].

7 *Ex-ante* actual net GHG removals 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 non-CO_2 GHG emissions measured in CO_2 equivalents by 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[4]. Therefore:

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

where:

C_{ACTUAL} = actual net greenhouse gas removals by sinks; tonnes CO_2-e.
$\Delta C_{P,LB}$ = sum of the changes in living biomass carbon stocks under the project scenario (above- and below-ground); tonnes 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; tonnes CO_2-e.

Note: In this methodology Equation (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)

Treatment of pre-existing non-tree and tree vegetation

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

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:

- The carbon stocks in the living biomass of pre-existing non-tree and tree vegetation are not significant:
  a) 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;
  b) 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).
- 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 for land preparation before planting non-tree and tree vegetation is burned (and not harvested):
   - Non-CO_2 emissions are calculated from the carbon stock in the above-ground biomass of non-tree and tree vegetation (details in Section 2 below);
   - 100% carbon stock loss in the above-ground and below-ground biomass is assumed and estimated using the methods outlined in Section 1.2 below for the tree component and Equation 14 for the non-tree component.

b) If the tree biomass is partially or totally harvested before burning:
   - The carbon stock decrease in the harvested above-ground and below-ground tree biomass is estimated using the methods outlined in Section 1.2 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.

c) 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:

$$E_{biomassloss} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{PS}} \sum_{k=1}^{K} A_{ikt} \cdot B_{non-tree,ikt} \cdot CF_{non-tree} \cdot 44/12 \qquad \textbf{(14)}$$

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^*; tonnes CO_2-e.

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

$B_{non\text{-}tree,ikt}$	=	average non-tree biomass stock on land to be planted before the start of a proposed A/R CDM project activity for stratum *i*, stand model *k*, time *t*; tonnes d.m. ha^{-1}
$CF_{non\text{-}tree}$	=	carbon fraction of dry biomass in non-tree vegetation, tonnes C (tonnes d.m.)$^{-1}$
i	=	1, 2, 3, ...m_{ps} strata in the project scenario
k	=	1, 2, 3, …*K* stand model in the project scenario
t	=	1, 2, 3, ... *t** years elapsed since the start of the AR project activity

Treatment of trees

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 preexisting vegetation, among others) differ from the strata 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).

$$\Delta C_{P,LB} \quad \sum_{t=1}^{t^*}\sum_{i=1}^{m_{PS}}\sum_{k=1}^{K}\Delta C_{LB,ikt} \qquad \textbf{(15)}$$

where:

$\Delta C_{P,LB}$	=	sum of the changes in living biomass carbon stocks in the project scenario (above- and below-ground); tonnes CO_2-e.
$\Delta C_{LB,ikt}$	=	annual carbon stock change in living biomass in the project scenario for stratum *i,* stand model *k*, time *t;* tonnes CO_2-e. yr^{-1}
i	=	1, 2, 3, ... m_{ps} strata in the project scenario
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.4, i.e., Equation (3) to Equation (11). In addition:

When method 1 (carbon gain-loss method) is used:

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* ($\Delta C_{L,ikt}$)[12]

$$\Delta C_{L,ikt} = L_{hr,ikt} + L_{fw,ikt} + L_{ot,ikt} \qquad \textbf{(16)}$$

where:

$\Delta C_{L,ikt}$	=	average annual decrease in carbon stocks due to biomass loss for stand model *k,* species *j,* time *t*

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

$$L_{hr,ikt} = A_{ikt} \cdot \sum_{j=1}^{J} H_{ijt} \cdot D_j \cdot BEF_{2,j} \cdot CF_j \cdot 44/12 \quad \textbf{(17)}$$

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

$$L_{ot,ikt} = Adist_{ikt} \cdot \sum_{j=1}^{J} B_{w,ijt} \cdot M_{ijt} \cdot CF_j \cdot 44/12 \quad \textbf{(19)}$$

where:

$L_{hr,ikt}$ = annual carbon loss due to commercial harvesting for stratum *i*, stand model *k*, time *t*; tonnes CO_2-e. yr^{-1}
$L_{fw,ikt}$ = annual carbon loss due to fuel wood gathering for stratum *i*, stand model *k*, time *t*; CO_2-e. yr^{-1}
$L_{ot,ikt}$ = annual natural losses (mortality) of carbon for stratum *i*, stand model *k*, 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}
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.
D_j = wood density for species *j*; tonnes 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*; tonnes C (tonne d.m.)$^{-1}$
FG_{ijt} = annual volume of fuel wood harvesting for stratum *i,* species *j*, time *t*; m^3 ha^{-1} yr^{-1}
Note: See note made for H_{ijt}.
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*; tonnes d.m. ha^{-1}

This methodology allows assuming no disturbances in the ex-ante[13] 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

[13] *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.

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 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.

When method 2 (stock change method) is used:

The 'stand models' as defined in Section II.2, step 2 shall be developed and presented in the AR-CDM-PDD in a way that the values of V_{ijt} (average merchantable volume of stratum *i,* species *j*, at time *t*) used in Equation 10 represent the actual average merchantable volume of stratum *i,* species *j*, at time *t* after deduction of harvested volumes and mortality:

$$V_{ikt2} = V_{ikt1} \cdot (1 - Mf_{ikT}) + \sum_{j=1}^{J} (I_{v,ijT} - H_{ijT} - FG_{ijT}) \cdot T \qquad \textbf{(20)}$$

$$Mf_{ikT} = \left(\frac{Adist_{ikT}}{A_{ikT}} \right)^{T} \qquad \textbf{(21)}$$

where:

V_{ikt2}	=	average merchantable volume of stratum *i,* stand model *k*, at time $t = t_2$; $m^3\ ha^{-1}$
V_{ikt1}	=	average merchantable volume of stratum *i,* stand model *k*, at time $t = t_1$; $m^3\ ha^{-1}$
Mf_{ikT}	=	Mortality factor = fraction of V_{ikt1} died during the period *T*; dimensionless
$I_{v,ijT}$	=	average annual 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 $(T = t_2 - t_1)$
$Adist_{ikT}$	=	average annual area affected by disturbances for stratum *i,* stand model *k*, during the period *T*; $ha\ yr^{-1}$
A_{ikT}	=	average annual area for stratum *i,* stand model *k*, during the period *T*; $ha\ yr^{-1}$

The choices of methods and parameters shall be used in the same ways as described in Section II.4.

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)

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;

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

- 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:

$$GHG_E = E_{FuelBurn} + E_{BiomassBurn} + N_2O_{direct-N_{fertilizer}} \quad \textbf{(22)}$$

where:

GHG_E	=	increase in GHG emission as a result of the implementation of the proposed AR CDM project activity within the project boundary; tonnes CO_2-e.
$E_{FuelBurn}$	=	increase in GHG emission as a result of burning of fossil fuels within the project boundary; tonnes CO_2-e.
$E_{BiomassBurn}$	=	increase in GHG emission as a result of biomass burning within the project boundary; tonnes CO_2-e.
$N_2O_{direct-N_{fertilizer}}$	=	increase in N_2O emission as a result of direct nitrogen application within the project boundary; tonnes CO_2-e.

Note: In this methodology Equation (22) 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.
Accounting for increases in emissions by sources is only required if significant (≥ 2% of the actual net GHG removals by sinks); if insignificant, verifiable evidence should be provided that the assumptions for the exclusion are valid.

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

GHG emission from burning of fossil fuels is most likely resulted from the use of machinery during site preparation and logging. IPCC 1996 Guideline can be used to estimate this type of emissions:

$$E_{FuelBurn} = \sum_{t=1}^{t^*} (CSP_{diesel_t} \cdot EF_{diesel} + CSP_{gasoline_t} \cdot EF_{gasoline}) \cdot 0.001 \quad \textbf{(23)}$$

where:

$E_{FuelBurn}$	=	GHG emission from burning of fossil fuels for year *t*; kg CO_2
$CSP_{diesel\ t}$	=	amount of diesel consumption for year *t*; liter (l)
$CSP_{gasoline\ t}$	=	volume of gasoline consumption for year *t*, liter (l)
EF_{diesel}	=	emission factor for diesel, kg CO_2 l^{-1}
$EF_{gasoline}$	=	emission factor for gasoline, kg CO_2 l^{-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 as defined in step 2 (Section II.2). 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 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.

$$E_{BiomassBurn} = E_{BiomassBurn,CO_2} + E_{BiomassBurn,N_2O} + E_{BiomassBurn,CH_4} \quad \textbf{(24)}$$

where:

$E_{BiomassBurn}$	=	total GHG emission from biomass burning in slash and burn; tonnes CO_2-e.
$E_{BiomassBurn,CO2}$	=	CO_2 emission from biomass burning in slash and burn; tonnes CO_2-e.
$E_{BiomassBurn, N2O}$	=	N_2O emission from biomass burning in slash and burn; tonnes CO_2-e.
$E_{BiomassBurn, CH4}$	=	CH_4 emission from biomass burning in slash and burn; tonnes CO_2-e.

$$E_{BiomassBurn,CO_2} = \sum_{t=1}^{t^*}\sum_{i=1}^{s_{PS}}\sum_{k=1}^{k}(A_{B,ikt} \cdot B_{ikt} \cdot PBB_{ikt} \cdot CE \cdot CF) \cdot 44/12 \quad \textbf{(25)}$$

where:

$E_{BiomassBurn,CO2}$	=	CO_2 emission from biomass burning in slash and burn; tonnes CO_2-e.
$A_{B,ikt}$	=	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*; tonnes 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; dimensionless
CF	=	carbon fraction; tonnes C $(\text{tonne d.m.})^{-1}$
i	=	1, 2, 3, ...m_{ps} strata in the project scenario
k	=	1, 2, 3, …*K* stand model in the project scenario
t	=	1, 2, 3, ... *t** years elapsed since the start of the AR project activity

$$E_{BiomassBurn,N_2O} = E_{BiomassBurn,CO_2} \cdot 12/44 \cdot (N/C\,ratio) \cdot ER_{N_2O} \cdot 44/28 \cdot GWP_{N_2O} \quad \textbf{(26)}$$

$$E_{BiomassBurn,CH_4} = E_{BiomassBurn,CO_2} \cdot 12/44 \cdot ER_{CH_4} \cdot 16/12 \cdot GWP_{CH_4} \quad \textbf{(27)}$$

where[15]:

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

$E_{BiomassBurn,\ N2O}$	=	N_2O emission from biomass burning in slash and burn; tonnes CO_2-e.
$E_{BiomassBurn,\ CH4}$	=	CH_4 emission from biomass burning in slash and burn; tonnes CO_2-e.
$E_{BiomassBurn,CO2}$	=	CO_2 emission from biomass burning in slash and burn; tonnes CO_2-e.
N/C ratio	=	nitrogen-carbon ratio; dimensionless (IPCC default value = 0.01)
ER_{N2O}	=	emission ratio for N_2O (IPCC default value = 0.007)
ER_{CH4}	=	emission ratio for CH_4 (IPCC default value = 0.012)
GWP_{N2O}	=	Global Warming Potential for N_2O (310 for the first commitment period)
GWP_{CH4}	=	Global Warming Potential for CH_4 (21 for the first commitment period)

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.

7.2.3 Estimation of $N_2O_{direct-N_{fertilizer}}$ (nitrous oxide emissions from nitrogen fertilization practices)[16]

$$N_2O_{direct-N_{fertilizer}} = \sum_{t=1}^{t*} \left[(F_{SN_t} + F_{ON_t}) \cdot EF_1 \right] \cdot 44/28 \cdot GWP_{N_20} \quad \textbf{(28)}$$

$$F_{SN\,t} = N_{SN-Fert,\,t} \cdot (1 - Frac_{GASF}) \quad \textbf{(29)}$$

$$F_{ON\,t} = N_{ON-Fert,\,t} \cdot (1 - Frac_{GASM}) \quad \textbf{(30)}$$

where:

$N_2O_{direct-N_{fertilizer}}$	=	direct N_2O emission as a result of nitrogen application within the project boundary up to time *t**; tonnes CO_2-e.
FSN_t	=	amount of synthetic fertilizer nitrogen applied at time *t* adjusted for volatilization as NH_3 and NO_x; tonnes N
FON_t	=	annual amount of organic fertilizer nitrogen applied at time *t* adjusted for volatilization as NH_3 and NO_x; tonnes N
$N_{SN\text{-}Fert,t}$	=	amount of synthetic fertilizer nitrogen applied at time *t*; tonnes N
$N_{SN\text{-}Fert,t}$	=	amount of organic fertilizer nitrogen applied at time *t*; tonnes N
EF_1	=	emission Factor for emissions from N inputs; tonnes N_2O-N (tonnes N input)$^{-1}$
$Frac_{GASF}$	=	fraction that volatilises as NH_3 and NO_x for synthetic fertilizers; dimensionless
$Frac_{GASM}$	=	fraction that volatilises as NH_3 and NO_x for organic fertilizers; dimensionless
GWP_{N2O}	=	Global Warming Potential for 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 NOx and NH_3 are 0.1 and 0.2 respectively in 1996 IPCC Guideline. Project developers may develop specific emission factors that are more

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

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

8 Leakage

Leakage (LK) represents the increase in GHGs emissions by sources which occurs outside 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 decrease in carbon stocks which occurs outside the boundary of an AR CDM project activity which is measurable and attributable to the AR CDM project activity (see EB 22, Annex 15).

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 or from project sites;
- Carbon stock decreases caused by displacement of pre-project grazing and fuelwood collection activities;
- Carbon stock decreases caused by the increased use of wood posts for fencing.

$$LK = LK_{Vehicle} + LK_{ActivityDisplacement} + LK_{fencing} \quad \textbf{(31)}$$

where:

LK = total GHG emissions due to leakage; tonnes CO_2-e.
$LK_{Vehicle}$ = total GHG emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.
$LK_{ActivityDisplacement}$ = leakage due to activity displacement; tonnes CO_2-e.
$LK_{fencing}$ = leakage due to increased use of wood posts for fencing up to year t^*; tonnes CO_2-e.

Note: In this methodology Equation (31) 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):

$$LK_{Vehicle} = LK_{Vehicle,CO_2} + LK_{Vehicle,CH_4} + LK_{Vehicle,N_2O} \quad \textbf{(32)}$$

$$LK_{Vehicle,CO_2} = \sum_{t=1}^{t^*}\sum_{x}\sum_{y}(EF_{xy} \cdot FuelConsumption_{xyt}) \quad \textbf{(33)}$$

$$FuelConsumption_{xyt} = n_{zyt} \cdot k_{xyt} \cdot e_{xyt} \quad \textbf{(34)}$$

where:

$LK_{Vehicle}$ = total GHG emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.
$LK_{Vehicle,CO2}$ = total CO_2 emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.
$LK_{Vehicle,CH4}$ = total CH_4 emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.

$LK_{Vehicle,N2O}$ = total N_2O emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.
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 x of vehicle type y at time t; liters
n_{xyt} = number of vehicles
k_{xyt} = kilometers traveled by each of vehicle type y with fuel type x at time t; km
e_{xyt} = fuel efficiency of vehicle type x with fuel type y at time t; liters km^{-1}

Emissions of CH_4 and N_2O are estimated in the same way as CO_2 emission but with different emission factors and should be included in the overall calculation of leakages only if they represent more than 2% of actual net GHG removals by sinks. Country-specific emission factors shall be used if available. Default emission factors provided in the IPCC Guidelines and updated in the IPCC GPG 2000 may be used if there are no locally available data.

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

The land planned for AR CDM activities may be subjected to grazing and fuelwood collection. Thus, as the result of the project activity, grazing and fuelwood collection activities may be temporarily or permanently displaced from the project sites to other locations. The displacement may result in leakage if the new grazing areas are obtained by converting stocked areas, particularly forests, to grazing land, and if the displaced fuelwood collection results in degradation or deforestation of forests and devegetaion of other lands.

If net life stock 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:

$$LK_{ActivityDisplacement} = LK_{conversion} + LK_{fuelwood} \quad (35)$$

where:

$LK_{ActivityDisplacement}$ = leakage due to activity displacement; tonnes CO_2-e.
$LK_{conversion}$ = leakage due to conversion of non-grassland to grassland; tonnes CO_2-e.
$LK_{fuelwood}$ = leakage due to the displacement of fuelwood collection; tonnes CO_2-e.

8.2.1 Estimation of $LK_{conversion}$ (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 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

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

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 exists, 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, where several plots are present in the project area, by interviewing a sample of them or by conducting a Participatory Rural Appraisal (PRA). Others 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.

$$Na_{BL} = sNa_{BL} \cdot 1 / SFR_{PAga} \quad \textbf{(36)}$$

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; %

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 plots can be specified. This planning should be used to estimate the animal population that will be displaced each year outside the project boundary.

$$Na_{outside,t} = Na_{BL} - Na_{AR,t} \quad \textbf{(37)}$$

where:

$Na_{outside,t}$	=	number of animals displaced outside the project area at year *t*; dimensionless
Na_{BL}	=	average pre-project number of animals from the different livestock groups that are grazing in the project area; dimensionless
$Na_{AR,t}$	=	number of animals allowed in the project area under the proposed AR-CDM project activity at year *t*; dimensionless

Leakage due to displacement of animal grazing can be set as zero ($LK_{conversion} = 0$) under the following circumstance:

$$Na_{BL} < Na_{AR,t} \quad \textbf{(38)}$$

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 site, 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.

The above situation can only occur if the planned AR-CDM project activity produces more fodder than the baseline activity. In all other situations, the animal populations that will be displaced outside the project boundary due to the implementation of the AR-CDM project activity 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 should be described in the PDD and subjected to monitoring.
- 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:

$$GLA = EGL + NGL + XGL \quad \textbf{(39)}$$

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 geographically 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*:** Data collection on pasture practices

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 plots of the area to be afforested or reforested. If several plots are present, collect these data from a sample. The sample size should not be less than 10% of the plots or 30 plots. Estimate the annual biomass consumption of the animals over the project area to be planted as follows:

$$\Delta C_{L\,PAt} = \sum_{i=1}^{I} \sum_{an=1}^{An} (DBI_{an} \cdot n_{igt} \cdot a_{gpl}) \cdot 30 \cdot 0{,}001 \cdot \frac{1}{SFR_{PAga}} \quad \textbf{(40)}$$

where:

$\Delta C_{L\,PA,t}$	=	annual animal biomass consumption over the project area to be planted at time t; tonnes d.m. yr^{-1}
i	=	plot index (I = total number of plots); dimensionless
an	=	animal type index (An = total number of animal types); dimensionless
DBI_{an}	=	daily biomass intake by animal type an; kg d.m. $head^{-1}$ day^{-1}
n_{igt}	=	number of individual animals from the livestock group g at plot i at time t; dimensionless
a_{gpl}	=	number of months per annum during which animals from the livestock group g are present at plot pl; dimensionless
30	=	average number of days in month; dimensionless
SFR_{PAga}	=	fraction of total project area sampled; 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 2.

***Table 2*: 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).			

***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 plots); 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.
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 Equation 40, calculate the maximum annual biomass that these grazing areas can produce for animal feeding (ΔC_{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 plots of the areas identified in step 2. Using Equation 40, 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.

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

- Average annual biomass consumed by one average animal:

$$\Delta C_{av} = \Delta C_{LPAt} \cdot \frac{SFR}{Na} \quad \textbf{(41)}$$

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

$$dNa_{EGL} = \left(\Delta C_{L\max} - \Delta C_{Lcurrent}\right)_{EGL} \cdot \left(\Delta C_{av}\right)^{-1} \quad \textbf{(42)}$$

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 Equation 40 calculate the maximum annual biomass that these areas to be converted to grazing lands can produce for animal feeding (ΔC_{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. *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 geographically 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:

$$XGL = A \cdot \frac{1}{Na} \cdot dNa_{XGL} \qquad \textbf{(43)}$$

where:

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
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:

$$LK_{conversion} = LK_{NGL} + LK_{XGL} \qquad \textbf{(44)}$$

where:

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

$$LK_{NGL} = \sum_{t=1}^{t^*} \left(ngl_t \cdot C_{NGL\,ac_t} + E_{ac_{BiomassBurn\,t}} \cdot (1 - WB_{h\,t}) \right) \qquad \textbf{(45)}$$

where:

LK_{NGL} = leakage due to conversion of non-grassland to grassland; tonnes CO_2-e.
ngl_t = total area converted to grassland[19] at time t; ha
$C_{NGLac\,t}$ = mean carbon stock of NGL area converted to grassland at time t; CO_2-e.
WB_{ht} = fraction of total above-ground biomass harvested as timber and as fuelwood at time t (not burned); dimensionless
$E_{acBiomassBurnt}$ = 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); CO_2-e.

Non-CO_2 emissions from biomass burning ($E_{acBiomassBurnt}$) are estimated using Equation 23.

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

$$aLK_{NGL} = LK_{NGL} / dNa_{NGL} \qquad \textbf{(46)}$$

where:

aLK_{NGL} = average leakage due to conversion of non-grassland to grassland per displaced animal in NGL areas; tonnes CO_2-e. animal^{-1}
LK_{NGL} = leakage due to conversion of non-grassland to grassland; tonnes 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. If IPCC data or other literature data is used, conservative estimates shall be used. 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;

[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).

- 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:

$$LK_{XGL} = \sum_{t=1}^{t^*} \left(xgl_t \cdot C_{XGL\,ac_t} + E_{ac_{BiomassBurn\ t}} \cdot (1 - WB_{h\,t}) \right) \qquad \textbf{(47)}$$

where:

LK_{XGLL}	=	leakage due to conversion of unidentifiable-land to grassland; tonnes CO_2-e.
xgl_t	=	total unidentifiable area converted to grassland[20] at time t; ha
$C_{XGLac\ t}$	=	mean carbon stock of the XGL area converted to grassland at time t; CO_2-e.
$W\mathrm{B}_{\mathrm{ht}}$	=	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); tonnes CO_2-e.

Non-CO_2 emissions from biomass burning ($E_{acBiomassBurnt}$) shall be estimated using Equation 23.

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

$$aLK_{XGL} = LK_{XGL} / dNa_{XGL} \qquad \textbf{(48)}$$

where:

aLK_{XGL}	=	average leakage due to conversion of non-grassland to grassland per displaced animal in *XGL* areas; tonnes CO_2-e. animal^{-1}
LK_{XGL}	=	leakage due to conversion of non-grassland to grassland; tonnes CO_2-e.
dNa_{XGL}	=	total number of animals to be displaced to *XGL* areas; dimensionless

8.2.1 Estimation of LK$_{fuelwood}$ (Leakage due to displacement of fuelwood collection)

Depending on the specific project circumstance, all pre-project fuelwood collection activities (including on-site charcoal production), or a fraction of them, may have to be displaced permanently, or temporarily, outside the project boundary. Where pre-project fuelwood collection or charcoal production activities exist, it is necessary to estimate the pre-project consumption of fuelwood in different plots within the project area. This can be done by interviewing households or implementing a Participatory Rural Appraisal (PRA). Where several plots are present in the project area, sampling techniques can be used. Others sources of information, such as local studies on fuelwood consumption 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.

[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*).

$$FG_{BL} = sFG_{BL} \cdot \frac{1}{SFR_{PAfw}} \qquad \textbf{(49)}$$

where:

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

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 fuelwood consumption 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 fuelwood collection or charcoal production should be excluded from the different plots as well as the amounts of fuelwood produced in the different stands through thinning, coppicing and harvesting can be specified. This planning should be used to estimate the amount of fuelwood or charcoal that may have to be obtained each year from sources outside the project boundary.

$$FG_{outside,t} = FG_{BL} - FG_{AR,t} \qquad \textbf{(50)}$$

where:

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

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

- $FG_{BL} < FG_{AR,t}$
- $FG_{BL} < (FG_{AR,t} + FG_{NGL,t})$ where $FG_{NGL,t}$ = volume of fuelwood gathering in *NGL* areas that is supplied to pre-project fuelwood collectors or charcoal producers; $m^3\ yr^{-1}$
- $LK_{fuelwood} <$ 2% of actual net GHG removals by sinks (see EB22, Annex 15).

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

$$LK_{fuelwood} = \sum_{t=1}^{t*} FG_t \cdot D \cdot BEF_2 \cdot CF \cdot \frac{44}{12} \qquad \textbf{(51)}$$

$$FG_t = FG_{outside,t} - FG_{NGL,t} \qquad \textbf{(52)}$$

where:

$LK_{fuelwood}$	=	leakage due to displacement of fuelwood collection up to year $t*$; tonnes CO_2-e.
FG_t	=	volume of fuelwood gathering displaced in unidentified areas; $m^3\ yr^{-1}$
$FG_{outside,t}$	=	volume of fuelwood gathering displaced outside the project area at year t; $m^3\ yr^{-1}$

$FG_{NGL,t}$ = volume of fuelwood gathering in *NGL* areas and supplied to pre-project fuelwood collectors or charcoal producers; $m^3\ yr^{-1}$
D = basic wood density; tonnes 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); tonnes C (tonnes d.m.)$^{-1}$

8.3 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 fuelwood 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 follows:

$$LK_{fencing} = \sum_{t=1}^{t^*} \frac{PAR_t}{DBP} \cdot FNRP \cdot DBP \cdot APV \cdot D \cdot BEF_2 \cdot CF \cdot \frac{44}{12} \qquad \textbf{(53)}$$

where:

$LK_{fencing}$ = leakage due to increased use of wood posts for fencing up to year t^*; tonnes 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; %
APV = average volume of o wood posts (estimated from sampling); m^3
D = basic wood density of the posts; tonnes 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); tonnes C (tonnes 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 removals 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 tonnes CO_2-e.:

$$C_{AR-CDM} = C_{ACTUAL} - C_{BSL} - LK \qquad \textbf{(54)}$$

where:

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

C_{ACTUAL} = actual net greenhouse gas removals by sinks (as per Equation 13); tonnes CO_2-e.
C_{BSL} = baseline net greenhouse gas removals by sinks (as per Equation 1); tonnes CO_2-e.
LK = leakage (as per Equation 31); tonnes CO_2-e.

Note: In this methodology Equation (54) 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:

$$CERs = C_{AR\text{-}CDM,t2} \qquad \textbf{(55)}$$
$$lCERs = C_{AR\text{-}CDM,t2} - C_{AR\text{-}CDM,t1} \qquad \textbf{(56)}$$

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 $t^* = t_2$; tonnes CO_2-e.
$C_{AR\text{-}CDM,t1}$ = net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$; tonnes 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.

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.

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

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. Equation 57 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.

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2} \qquad \textbf{(57)}$$

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_i = 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, Equation 58 can be used.

$$U_E = \frac{\sqrt{(U_1 * E_1)^2 + (U_2 * E_2)^2 + \ldots + (U_n * E_n)^2}}{|E_1 + E_2 + \ldots + E_n|} \qquad \textbf{(58)}$$

where:

U_E = percentage uncertainty of the sum
Ui = percentage uncertainty associated with source/sink *i*
Ei = emission/removal estimate for source/sink *I*

As with Equation 57, Equation 58 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 estimation

***Table 2*: Data needed for ex-ante estimation**

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	Highest resolution available	Local government
Soil map	Stratifying land area	most recent date	Highest resolution available	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 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 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, fuelwood, non-wood products, with and without CER revenues, etc.	Most recent date, taking into account market risk	National and local	Local statistics, published data 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
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*
$A_{B,ikt}$	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 spe-	Estimated *ex-ante*, monitored *ex-post*

Data/Parameters	Descriptions	Vintage	Data sources and geographical scale	
			cies	
$Adist_{ikT}$	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 plot *pl*; 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}	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; tonnes 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; tonnes CO_2-e. $animal^{-1}$	Most updated	Project	Calculated
APV	Average volume of o 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
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
$BEF_{2,j}$	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		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*; tonnes d.m. ha^{-1}		Global default to local	GPG-LULUCF, national GHG inventory, local survey
$B_{non\text{-}tree,ikt}$	Average non-tree biomass stock on land to be planted before the start of a proposed A/R CDM project activity for stratum *i*, stand model *k*, time *t*	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*; tonnes d.m. ha^{-1}	Most updated	Local	National GHG inventory, local survey
$C_{AB,ijt}$	Carbon stock in above-ground biomass for stratum *i*, species *j*, at time *t;* tonnes C		Local and species specific	Calculated
$C_{NGLac\ t}$	Mean carbon stock of the NGL area converted to grassland at time *t*; tonnes CO_2-e.		Regional, local default	Estimated *ex-ante*
$C_{XGLac\ t}$	Mean carbon stock of the XGL area converted to grassland at time *t*; tonnes CO_2-e.		Regional, local default	Estimated *ex-ante*
C_{ACTUAL}	Actual net greenhouse gas removals by sinks (as per Equation 13); tonnes CO_2-e.		Project specific	Calculated
$C_{AR\text{-}CDM}$	Net anthropogenic greenhouse gas removals by sinks; tonnes CO_2-e.		Project specific	Calculated
$C_{AR\text{-}CDM,t1}$	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$; tonnes CO_2-e.		Project specific	Calculated
$C_{AR\text{-}CDM,t2}$	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$; tonnes CO_2-e.		Project specific	Calculated
$C_{BB,ijt}$	Carbon stock in below-ground biomass for stratum *i*, species *j*, at time *t*; tonnes C		Local and species specific	Calculated
C_{BSL}	Baseline net greenhouse gas removals by sinks (as per Equation 1); tonnes CO_2-e.		Project specific	Calculated

Data/Parameters	Descriptions	Vintage	Data sources and geographical scale	
CE	Average biomass combustion efficiency; dimensionless		Global and national default	IPCC GPG-2000, national GHG □ctivetory
CF	Carbon fraction of biomass burnt; tonnes C (tonne d.m.)$^{-1}$		Global default to local	GPG-LULUCF, national GHG inventory
CF_j	Carbon fraction for species *j*; tonnes C (tonne d.m.)$^{-1}$		Global default to local	GPG-LULUCF, national GHG inventory
$CF_{non\text{-}tree}$	Carbon fraction of dry biomass in non-tree vegetation; dimensionless		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*		Stratum	Calculated
C_{ikt1}	Total carbon stock in living biomass for stratum *i*, stand model *k*, calculated at time $t = t_1$; tonnes C		Stratum	Calculated
C_{ikt2}	Total carbon stock in living biomass for stratum *i*, stand model *k*, calculated at time $t = t_2$; tonnes C		Stratum	Calculated
$CSP_{diesel\ t}$	Amount of diesel consumption for year *t*; liter (l)		Project	Estimated *ex-ante*, monitored *ex-post*
$CSP_{gasoline\ t}$	Amount of gasoline consumption for year *t*, liter (l)		Project	Estimated *ex-ante*, monitored *ex-post*
$C_{TOTAL,ikt}$	Annual average increment rate in total carbon in stratum *i*, stand model *k*, time *t*; tonnes of CO_2-e. ha^{-1} yr^{-1}		Projec	Calculated
D	Basic wood density; tonnes 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_{an}	Daily biomass intake by animal type *an*; 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*; tonnes d.m. m^{-3}		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); tonnes 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; tonnes CO_2-e.	Most updated	Project	Calculated
$E_{BiomassBurn,\ CH4}$	CH_4 emission from biomass burning in slash and burn; tonnes CO_2-e.	Most updated	Project	Calculated
$E_{BiomassBurn,\ N2O}$	N_2O emission from biomass burning in slash and burn; tonnes CO_2-e.	Most updated	Project	Calculated
$E_{BiomassBurn,CO2}$	CO_2 emission from biomass burning in slash and burn; tonnes 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; tonnes N_2O-N (tonnes N input)$^{-1}$	Most updated	Global default	GPG 2001
EF_{diesel}	Emission factor for diesel, kg CO_2 l^{-1}	Most updated	Global to national	IPCC Guideline, GPG 2000, national inventory

Data/Parameters	Descriptions	Vintage	Data sources and geographical scale	
$EF_{gasoline}$	Emission factor for gasoline, kg CO_2 l^{-1}	Most updated	Global to national	IPCC Guideline, GPG 2000, national inventory
$E_{FuelBurn}$	Increase in GHG emission as a result of burning of fossil fuels within the project boundary; tonnes CO_2-e.	Most updated	Project	Calculated
$E_{FuelBurn}$	Increase in GHG emission as a result of burning of fossil fuels outside the project boundary; tonnes 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	Estimated
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 fuelwood 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 fuelwood 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 fuelwood gathering in *NGL* areas and supplied to pre-project fuelwood collectors or charcoal producers; m^3 yr^{-1}		Project	Estimated *ex-ante* and *ex-post*
$FG_{outside,t}$	Volume of fuelwood gathering displaced outside the project area at year *t*; m^3 yr^{-1}		Project	Estimated *ex-ante* and *ex-post*
FG_t	Volume of fuelwood gathering displaced in unidentified areas; m^3 yr^{-1}		Project	Estimated *ex-ante* and *ex-post*
$f_j(DBH_t,H_t)$	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; tonnes N		Project	Estimated *ex-ante* and measured *ex-post*
$Frac_{GASF}$	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; tonnes N		Project	Estimated to measured *ex-ante*, measured *ex-post*
$FuelConsumption_{xyt}$	Consumption of fuel type *x* of vehicle type *y* 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; tonnes 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*

Data/Parameters	Descriptions	Vintage	Data sources and geographical scale	
$G_{TOTAL,itj}$	Annual average increment rate in total biomass in units of dry matter for stratum *i*, species *j*, time *t*; tonnes 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*; tonnes 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
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*
$I_{v,ijt}$	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)		Project	
k_{xyt}	Kilometers traveled by each of vehicle type *y* with fuel type *x* at time *t*; km		Project	Estimated *ex-ante*, monitored *ex-post*
lCERs	Number of units of long-term Certified Emission Reductions		Project	Calculated
$L_{fw,ikt}$	Annual carbon loss due to fuel wood gathering for stratum *i*, stand model *k*, time *t*; CO_2-e. yr^{-1}		Local/stand	Estimated *ex-ante*, monitored *ex-post*
$L_{hr,ikt}$	Annual carbon loss due to commercial harvesting for stratum *i*, stand model *k*, time *t*; tonnes CO_2-e. yr^{-1}		Local/stand	Estimated *ex-ante*, monitored *ex-post*
LK	Total project leakage (as per Equation 31); tonnes CO_2-e.		Project	Calculated
$LK_{fuelwood}$	Leakage due to the displacement of fuelwood collection; tonnes CO_2-e.		Project	Calculated
$LK_{ActivityDisplacement}$	Leakage due to activity displacement; tonnes CO_2-e.		Project	Calculated
$LK_{conversion}$	Leakage due to conversion of non-grassland to grassland; tonnes CO_2-e.		Project	Calculated
$LK_{fencing}$	Leakage due to increased use of wood posts for fencing; tonnes 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; tonnes CO_2-e.		Project	Calculated
$LK_{Vehicle}$	Total GHG emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.		Project	Calculated
$LK_{Vehicle,CH4}$	Total CH_4 emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.		Project	Calculated
$LK_{Vehicle,CO2}$	Total CO_2 emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.		Project	Calculated
$LK_{Vehicle,N2O}$	Total N_2O emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.		Project	Calculated
LK_{XGL}	Leakage due to conversion of non-grassland to grassland in unidentified *XGL* areas; tonnes CO_2-e.		Project	Calculated
$L_{ot,ikt}$	Annual natural losses (mortality) of carbon for stratum *i*, stand model *k*, time *t*; CO_2-e. yr^{-1}		Local/stand	Calculated
Mf_{ijT}	Mortality factor = percentage of V_{ijt1} died during the period *T*; dimensionless		Local/stand	Estimated
m_{BL}	Total baseline strata			
m_{PS}	Total strata in the project scenario			

Data/Parameters	Descriptions	Vintage	Data sources and geographical scale	
$N_2O_{direct-N_{fertilizer}}$	Increase in N_2O emission as a result of direct nitrogen application within the project boundary; tonnes CO_2-e.		Project	Calculated
$N_2O_{direct-N_{fertilizer}}$	Direct N_2O emission as a result of nitrogen application within the project boundary up to time *t**; tonnes 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 plots); 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_{igt}	Number of individual animals from the livestock group *g* at plot *i* at time *t*; dimensionless		Project	Estimated *ex-ante*
$N_{SN\text{-}Fert,t}$	Amount of synthetic fertilizer nitrogen applied at time *t*; tonnes 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*
pl	Plot index (*PL* = total number of plots); 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 inventories
R_j	Root-shoot ratio appropriate to increments for species *j*; dimensionless		Global default to local	GPG-LULUCF, national GHG inventory, local survey
sFG_{BL}	Sampled average pre-project annual volume of fuelwood gathering in the project area; $m^3\ yr^{-1}$		Project	Estimated *ex-ante* and *ex-post*
SFR_{Pafw}	Fraction of total plots or households in the project area sampled for fuelwood; dimensionless		Project	Defined *ex-ante*
SFR_{Paga}	Fraction of total plots 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*
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*

Data/Parameters	Descriptions	Vintage	Data sources and geographical scale	
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*
t^*	Number of years elapsed since the start of the AR project activity; yr			
tCERs	Number of units of temporary Certified Emission Reductions		Project	Calculated
t_{cp}	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}	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 fuelwood 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*
ΔC_{av}	Average annual biomass consumed by one average animal; tonnes 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*; tonnes CO_2-e. yr^{-1}		Project	Estimated *ex-ante*, monitored *ex-post*
$\Delta CB_{B,ikt}$	Annual carbon stock change in living biomass in the baseline for stratum *i,* stand model *k*, time *t;* tonnes CO_2-e. yr^{-1}		Project	Estimated *ex-ante*, monitored *ex-post*
$\Delta CB_{B,ikt}$	Annual carbon stock change in living biomass in the baseline for stratum *i,* stand model *k*, time *t;* tonnes CO_2-e. yr^{-1}		Project	Estimated *ex-ante*, monitored *ex-post*
$\Delta C_{B,LB}$	Sum of the changes in living biomass carbon stocks in the baseline (above- and below-ground); tonnes CO_2-e.		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;* tonnes CO_2-e. yr^{-1}		Project	Estimated *ex-ante*
ΔC_{ikt}	Annual carbon stock change in living biomass in stratum *i*, stand model *k*, time *t;* tonnes 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*; tonnes d.m. yr^{-1}		Project	Estimated *ex-ante*
$\Delta C_{P,LB}$	Sum of the changes in living biomass carbon stocks in the project scenario (above- and below-		Project	Estimated *ex-ante*, monitored *ex-post*

Data/Parameters	Descriptions	Vintage	Data sources and geographical scale
	ground); tonnes CO_2-e.		
$\Delta C_{Lcurrent}$	Current annual biomass that the grazing areas can produce for animal feeding; tonnes d.m. yr^{-1}		Project Estimated *ex-ante*
ΔC_{Lmax}	Maximum annual biomass that the grazing areas can produce for animal feeding; tonnes d.m. yr^{-1}		Project Estimated *ex-ante*

12 Other information

Void

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 grazing and fuelwood 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 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 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 project plan. The following activities are foreseen:

- Field surveys concerning the actual project boundary within which AR activity has occurred, site by site;
- Measuring geographical positions (latitude and longitude of each corner polygon sites) using GPS;
- Checking whether the actual boundary is consistent with the description in the CDM-AR-PDD;
- If the actual boundary falls outside of the designed boundary in the CDM-AR-PDD, additional information for lands beyond the designed boundary in CDM-AR-PDD shall be provided; the eligibility of these lands as a part of the AR CDM project activity shall be justified; and the projected baseline scenario shall be demonstrated to be applicable to these lands. Otherwise, these lands shall not be accounted as a part of the AR CDM project activity. Such changes in boundary shall be communicated to the DOE and subject to validation during the project, e.g. during each verification event;

- Input the measured geographical positions into the GIS system and calculate the eligible area of each stratum and stand;
- The project boundary shall be monitored periodically all through the crediting period, including through remote sensing as applicable. If the forest area changes during the crediting period, for instance, because deforestation occurs on the project area, the specific location and area of the deforested land shall be identified. Similarly, if the planting on certain lands within the project boundary fails these lands will be documented.

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);
- Survival checking:
  - ✓ The initial survival rate of planted trees shall be counted three months after the planting, and re-planting shall be conducted if the survival rate is lower than 90 percent of the final planting density;
  - ✓ Final checking three years after the planting;
  - ✓ The checking of the survival rate may be conducted using permanent sample plots.
- Weeding checking: check and confirm that the weeding practice is implemented as described in the PDD;
- Survey and check that species and planting for each stratum are in line with the PDD;
- Document and justify any deviation from the planned forest establishment.

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 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 Sampling design and stratification

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 preferably in a GIS platform for each parameter used for stratification of the project area under the baseline and the project scenario.–This geo-referenced spatial data base should be completed at the earliest stages of the implementation of the AR CDM project activity. The DOE shall verify the achievement of this stratification and geo-referenced spatial data base at the first verification. The consistency of the actual boundary of the strata and stands as monitored in the field with the description in the AR-CDM-PDD shall be periodically monitored as the boundaries may change due to the following:

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

If one of the above occurs, *ex-post* stratification is required. The possible need for *ex-post* stratification shall be evaluated at each monitoring event and changes in the strata should be reported to the DOE for verification. Monitoring of strata and stand boundaries shall be done preferably 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_{it}	=	size of each stratum (= $\sum_{t=1}^{tcr}\sum_{k}^{K} A_{ikt}$ where *tcr* is the end of the crediting period); ha
AP	=	sample plot size; ha
st_i	=	standard deviation for each stratum *i*; dimensionless
C_i	=	cost of establishment of a sample plot for each stratum *I;* e.g. US $
Q	=	approximate average value of the estimated quantity *Q,* (e.g. wood volume); e.g. $m^3\ ha^{-1}$
p	=	desired level of precision (e.g. 10%); dimensionless

Then:

$$N = A / AP \ \ ; \ \ N_i = A_i \big/ AP \ \ ; \ E = Q * p \qquad \textbf{(59)}$$

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:

$$n = \frac{\left[\sum_{i=1}^{m_{PS}} N_i * st_i * \sqrt{Ci}\right] * \left[\sum_{i=1}^{m_{PS}} N_i * st_i \Big/ \sqrt{C_i}\right]}{\left(N * \frac{E}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{m_{PS}} N_i * (st_i)^2} \qquad \textbf{(60)}$$

$$n_i = \frac{\sum_{i=1}^{m_{PS}} N_i * st_i * \sqrt{C_i}}{\left(N * \frac{E}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{m_{SP}} N_i * (st_i)^2} * \frac{N_i * st_i}{\sqrt{C_i}} \qquad \textbf{(61)}$$

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 α = 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:

$$n = \frac{\left[\sum_{i=1}^{m_{PS}} N_i * st_i\right]^2}{\left(N * \frac{E}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{m_{PS}} N_i * (st_i)^2} \quad \textbf{(62)}$$

$$n_i = \frac{\sum_{h=1}^{m_{PS}} N_i * st_i}{\left(N * \frac{E}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{m_{PS}} N_i * (st_i)^2} * N_i * st_i \quad \textbf{(63)}$$

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:

$$CV_2^2 = CV_1^2 \sqrt{(a_1 / a_2)} \quad \textbf{(64)}$$

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

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

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

2.2.4 Monitoring frequency

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

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

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

2.2.5 Measuring and estimating carbon stock changes over time

The growth of individual trees on plots shall be measured at each monitoring event. Pre-existing (baseline) trees should conservatively and consistently with the baseline methodology not be measured and accounted for. Although non-tree vegetation such as herbaceous plants, grasses, and shrubs can occur, usually with biomass less than 10 percent, there is also non-tree vegetation on degraded lands and the baseline scenario has assumed the zero stock change for this non-tree biomass. Therefore, non-tree vegetation will not be measured and accounted. The omission of non-tree biomass 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 GHGs emissions, in particular CO_2, CH_4 and N_2O. The list below contains factors that may result in an increase of GHGs emissions[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 active-ity);
- 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.

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

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

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 or available seed source would make the natural regeneration possible that is not expected to occur for the current baseline scenario;
- 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 to 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.

For lands without growing trees, the above-ground biomass can be measured by simple harvesting techniques on up to four small subplots per sample plot.

For lands with growing trees, the sampling procedures and equations presented in Section II.2 shall be used.

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

***Table 1*: 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 measurement	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 measurement	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]:

$$C_{ACTUAL} = \Delta C_{P,LB} - GHG_E \quad \textbf{(65)}$$

where:

C_{ACTUAL} = actual net greenhouse gas removals by sinks; tonnes CO_2-e.
$\Delta C_{P,LB}$ = sum of the changes in living biomass carbon stocks in the project scenario (above- and below-ground); tonnes 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; tonnes CO_2-e.

Note: In this methodology Equation 65 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.

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]:

$$\Delta C_{P,LB} = \sum_{t=1}^{t^*} \sum_{i=1}^{m_{PS}} \sum_{k=1}^{K} \Delta C_{P,ikt} \quad \textbf{(66)}$$

where:

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

$$\Delta C_{P,ikt} = (\Delta C_{AB,ikt} + \Delta C_{BB,ikt}) \cdot 44/12 \quad \textbf{(67)}$$

24 IPCC GPG-LULUCF Equation 3.2.1
25 IPCC GPG-LULUCF Equation 3.2.3

where:

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

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

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

The mean change in carbon stocks in above-ground biomass and below-ground biomass per unit area is 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 ratio, involving, for instance, harvest of trees, then it is recommended not to use this method but rather to use the resources to develop local allometric equations as described in the allometric method below (refers to Chapter 4.3 in 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 st ands. 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]:

$$MC_{AB,ijt} = MV_{ijt} \cdot D_j \cdot BEF_j \cdot CF_j \qquad \textbf{(68)}$$

$$MC_{BB,ijt} = MC_{AB,ijt} \cdot R_j \qquad \textbf{(69)}$$

[26] IPCC GPG-LULUCF Equation 4.3.1

where:

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

$MC_{BB,ijt}$ = mean carbon stock in below-ground biomass per unit area for stratum *i,* species *j*, time *t;* tonnes 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; tonnes 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; tonnes C (tonnes d.m.)$^{-1}$; IPCC default value = 0.5.

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:

$$C_{AB,ijt} = A_{ikt} \cdot MC_{AB,ijt} \quad \textbf{(70)}$$

$$C_{BB,ijt} = A_{ikt} \cdot MC_{BB,ijt} \quad \textbf{(71)}$$

where:

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

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

A_{ikt} = area of stratum *i,* stand model *k*, 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

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

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

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

$$\Delta C_{AB,ikt} = \sum_{j=1}^{J} (C_{AB,ijt_2} - C_{AB,ijt_1}) \big/ T \quad \textbf{(72)}$$

$$\Delta C_{BB,ikt} = \sum_{j=1}^{J} (C_{BB,ijt_2} - C_{BB,ijt_1}) \big/ T \quad \textbf{(73)}$$

where:

$\Delta C_{AB,ikt}$	=	annual carbon stock change in above-ground biomass for stratum *i,* stand model *k*, time *t;* tonnes C yr^{-1}
$\Delta C_{BB,ikt}$	=	annual carbon stock change in below-ground biomass for stratum *i,* stand model *k*, time *t;* tonnes C yr^{-1}
$C_{AB,ijt2}$	=	carbon stock in above-ground biomass for stratum *i,* species *j*, calculated at time $t = t_2$; tonnes C
$C_{AB,ijt1}$	=	carbon stock in above-ground biomass for stratum *i,* species *j*, calculated at time $t = t_1$; tonnes C
$C_{BB,ijt2}$	=	carbon stock in below-ground biomass for stratum *i,* species *j*, calculated at time $t = t_2$; tonnes C
$C_{BB,ijt1}$	=	carbon stock in below-ground biomass for stratum *i,* species *j*, calculated at time $t = t_1$; tonnes C
T	=	number of years between monitoring time t_2 and t_1 ($T = t_2 - t_1$); years

Allometric method

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

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

Where a tree has died, been harvested or can not be found then the biomass at time 2 should be made equal to zero to give the requisite deduction.

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

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

$$TB_{ABj} = f_j(DBH, H) \quad \textbf{(74)}$$

where:

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

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

$$TC_{AB} = TB_{ABj} \cdot CF_j \quad \textbf{(75)}$$

where:

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

Step 4: Calculate the increment of above-ground biomass carbon accumulation at the tree level. Calculate by subtracting the biomass carbon at time t_2 from the biomass carbon at time t_1 for each tree.

$$\Delta TC_{ABjT} = TC_{ABj,t2} - TC_{ABj,t1} \quad \textbf{(76)}$$

where:

ΔTC_{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 of a tree species per plot on a per area basis. Calculate by summing the change in biomass carbon per tree species within each plot and multiplying by a plot expansion factor which is proportional to the area of the measurement plot. This is divided by 1,000 to convert from kg to tonnes.

$$\Delta PC_{AB,ijT} = \frac{\left(\sum_{tr=1}^{TR} \Delta TC_{ABjT} \cdot XF \right)}{1000} \quad \textbf{(77)}$$

$$XF = \frac{10{,}000}{AP} \quad \textbf{(78)}$$

where:

$\Delta PC_{AB,ijT}$	=	plot level mean carbon stock change in above-ground biomass in stratum *i*, species *j*, between two monitoring events; tonnes C ha^{-1}.

ΔTC_{ABT} = carbon stock change in above-ground biomass per tree 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 and stand model. Calculate by averaging across plots in a stratum and stand:

$$\Delta MC_{AB,ikT} = \frac{\sum_{pl=1}^{PL_{ik}} \sum_{j}^{J} \Delta PC_{AB,ijT}}{PL_{ik}} \quad \textbf{(79)}$$

where:

$\Delta MC_{AB,ikT}$ = mean carbon stock change in above-ground biomass in stratum i, stand model k, between two monitoring events; tonnes C ha^{-1}
$\Delta PC_{AB,ijT}$ = plot level mean carbon stock change in above-ground biomass in stratum i, species j, between two monitoring events; tonnes 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 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 for single trees of a species.

$$TC_{BBj} = TC_{ABj} \cdot R_j \quad \textbf{(80)}$$

$$\Delta TC_{BBjT} = TC_{BBj,t2} - TC_{BBj,t1} \quad \textbf{(81)}$$

$$\Delta PC_{BB,ijT} = \frac{\left(\sum_{tr=1}^{TR} \Delta TC_{BBjT} \cdot XF\right)}{1000} \quad \textbf{(82)}$$

$$\Delta MC_{BB,ikT} = \frac{\sum_{pl=1}^{PL_{ik}} \sum_{j}^{J} \Delta PC_{BB,ijT}}{PL_{ik}} \quad \textbf{(83)}$$

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
ΔTC_{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; tonnes C ha^{-1}

XF	=	plot expansion factor from per plot values to per hectare values; dimensionless
tr	=	tree (TR = total number of trees in the plot)
$\Delta MC_{BB,ikT}$	=	mean carbon stock change in below-ground biomass for stratum *i*, stand model *k*, between two monitoring events; tonnes C ha^{-1}
$\Delta PC_{BB,ijT}$	=	plot level carbon stock change in below-ground biomass for stratum *i*, species *j*, between two monitoring events; tonnes 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 by the number of years between monitoring events.

$$\Delta MC_{AB,ikt} = \Delta MC_{AB,ikT} / T \quad \textbf{(84)}$$

$$\Delta MC_{BB,ikt} = \Delta MC_{BB,ikT} / T \quad \textbf{(85)}$$

where:

$\Delta MC_{AB,ikt}$	=	annual mean carbon stock change in above-ground biomass for stratum *i*, stand model *k,* at year *t*; tonnes 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*; tonnes C ha^{-1} yr^{-1}
ΔMC_{ABikT}	=	mean carbon stock change in above-ground biomass for stratum *i*, stand models *k,* between two monitoring events; tonnes C ha^{-1}
ΔMC_{BBikT}	=	mean carbon stock change in below-ground biomass for stratum *i*, stand model *k,* between two monitoring events; tonnes C ha^{-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* at time *t* is calculated from the area of each stratum *i*, species *j* at time *t* and the annual mean carbon stock change in above-ground biomass and below-ground biomass per unit area, given by:

$$\Delta C_{AB,ikt} = A_{ikt} \cdot \Delta MC_{AB,ikt} \quad \textbf{(86)}$$

$$\Delta C_{BB,ikt} = A_{ikt} \cdot \Delta MC_{BB,ijt} \quad \textbf{(87)}$$

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

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:

$$GHG_E = E_{FuelBurn} + E_{BiomassBurn} + N_2O_{direct-N_{fertilizer}} \quad \textbf{(88)}$$

where:

GHG_E	=	increase in GHG emission as a result of the implementation of the proposed AR CDM project activity within the project boundary; tonnes CO_2-e.
$E_{FuelBurn}$	=	increase in GHG emission as a result of burning of fossil fuels within the project boundary; tonnes CO_2-e.
$E_{BiomassBurn}$	=	increase in GHG emission as a result of biomass burning within the project boundary; tonnes CO_2-e.
$N_2O_{direct-N_{fertilizer}}$	=	increase in N_2O emission as a result of direct nitrogen application within the project boundary; tonnes CO_2-e.

Note: In this methodology Equation (88) 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.

The monitoring of emissions by sources is only required if significant (≥ 2% of the actual net GHG removals by sinks); if insignificant, evidence should be provided (e.g. as part of the monitoring of the implementation) that the assumptions for the exclusion made in the *ex-ante* assessment still hold.

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 is most likely resulted from machinery use during site preparation, thinning and logging.

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

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

- National emission factors: These emission factors may be developed by national 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:

$$E_{FuelBurn} = \sum_{t=1}^{t^*} (CSP_{diesel_t} \cdot EF_{diesel} + CSP_{gasoline_t} \cdot EF_{gasoline}) \cdot 0.001 \quad (89)$$

where:

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

$CSP_{diesel\ t}$ = volume of diesel consumption for year *t*; liter (l)

$CSP_{gasoline\ t}$ = volume of gasoline consumption for year *t*, liter (l)

EF_{diesel} = emission factor for diesel, kg CO_2 l^{-1}

$EF_{gasoline}$ = emission factor for gasoline, kg CO_2 l^{-1}

Note the amount of fuel consumption can be calculated as the number of kilometers traveled times the average fuel efficiency of the vehicle (l/km)

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 or replanting, this would result in CO_2 and non-CO_2 emissions.

Step 1: Estimating the mean above-ground biomass stock per unit area before slash and burn or removal. The degraded land or logged land is usually dominated by herbaceous plants and shrubs. The above-ground biomass of herbaceous plants can be measured by simple harvesting techniques. A small frame (either circular or square), usually encompassing about 0.5-1.0 m^2 or less, is used to aid this task. The material inside the frame is cut to ground level and weighed. 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, if the shrubs are large, is to develop local shrub allometric equations based on variables such as crown area and height or diameter at base of plant or some other relevant variable (e.g., number of stems in multi-stemmed shrubs). The equations would then be based on regressions of biomass of the shrub versus some logical combination of the independent variables. The independent variable or variables would then be measured in the sampling plots (Refers to Chapter 4.3 in 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:

$$E_{BiomassBurn} = E_{BiomassBurn,CO_2} + E_{BiomassBurn,N_2O} + E_{BiomassBurn,CH_4} \quad \textbf{(90)}$$

where:

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

$E_{BiomassBurn,CO2}$ = CO_2 emission from biomass burning in slash and burn; tonnes CO_2-e.
$E_{BiomassBurn,N2O}$ = N_2O emission from biomass burning in slash and burn; tonnes CO_2-e.
$E_{BiomassBurn,CH4}$ = CH_4 emission from biomass burning in slash and burn; tonnes CO_2-e.

$$E_{BiomassBurn,CO_2} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{PS}}\sum_{k=1}^{K}(A_{ikt} \cdot B_{ikt} \cdot PBB_{ikt} \cdot CE \cdot CF) \cdot 44/12 \quad \textbf{(91)}$$

where:

$E_{BiomassBurn,CO2}$ = CO_2 emission from biomass burning in slash and burn; tonnes CO_2-e.
$A_{B,ikt}$ = 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; tonnes 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; dimensionless
CF = carbon fraction of biomass burnt; tonnes C (tonnes d.m.)$^{-1}$

$$E_{BiomassBurn,N_2O} = E_{BiomassBurn,CO_2} \cdot 12/44 \cdot (N/Cratio) \cdot ER_{N_2O} \cdot 44/28 \cdot GWP_{N_2O} \quad \textbf{(92)}$$

$$E_{BiomassBurn,CH_4} = E_{BiomassBurn,CO_2} \cdot 12/44 \cdot ER_{CH_4} \cdot 16/12 \cdot GWP_{CH_4} \quad \textbf{(93)}$$

where:[27]

$N/C\ ratio$ = nitrogen-carbon ratio; dimensionless (IPCC default value = 0.01)
ER_{N20} = emission ratio for N_2O (IPCC default = 0.007); dimensionless
ER_{CH4} = emission ratio for CH_4 (IPCC default = 0.012); dimensionless
GWP_{N2O} = Global Warming Potential for N_2O (IPCC default = 310 for the first commitment period); kg CO_2-e. (kg N_20)$^{-1}$
GWP_{CH4} = Global Warming Potential for CH_4 (IPCC default = 21 for the first commitment period); kg CO_2-e. (kg CH_4)$^{-1}$

5.2.3Estimation of $N_2O_{direct-N_{fertilizer}}$ (nitrous oxide emissions from nitrogen fertilization practices[28]):

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;

$$N_{SN-Fert} = \sum_{t=1}^{t^*}\sum_{i=1}^{m_{PS}}\sum_{j=1}^{s_{PS}} A_{N,ikt} \cdot N_{SN-Fert,ikt} \cdot 0.001 \quad \textbf{(94)}$$

27 Refers to Table 5.7 in 1996 Revised IPCC Guideline for LULUCF and Equation 3.2.19 in IPCC GPG-LULUCF
28 Refers to Equation 3.2.18 in IPCC GPG-LULUCF

$$N_{ON-Fert} = \sum_{t=1}^{t*} \sum_{i=1}^{m_{PS}} \sum_{j=1}^{s_{PS}} A_{N,ikt} \cdot N_{ON-Fert,ikt} \cdot 0.001 \qquad \textbf{(95)}$$

where:

$N_{SN-Fert}$ = total amount of synthetic fertilizer used within the project boundary; tonnes 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})

$N_{ON-Fert}$ = total amount of organic fertilizer used within the project boundary; tonnes 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})

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

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

$N_{ON-Fert,ikt}$ = 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 1996 IPCC Guideline[29].

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

$$N_2O_{direct-N_{fertilizer}} = \left[(F_{SN} + F_{ON}) \cdot EF_1\right] \cdot 44/28 \cdot GWP_{N_2O} \qquad \textbf{(96)}$$

$$F_{SN} = N_{SN-Fert} \cdot (1 - Frac_{GASF}) \qquad \textbf{(97)}$$

$$F_{ON} = N_{ON-Fert} \cdot (1 - Frac_{GASM}) \qquad \textbf{(98)}$$

where:

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

F_{SN} = total amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_x; tonnes N

F_{ON} = total amount of organic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_x; tonnes N

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

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

$N_{SN\text{-}Fert}$	=	total amount of organic fertilizer used within the project boundary; tonnes N
EF_1	=	emission Factor for emissions from N inputs; tonnes N_2O-N (tonnes 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
GWP_{N2O}	=	Global Warming Potential for N_2O (IPCC default value = 310)

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

Table 2: **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	Propor-tion of data moni-tored	Comment
2.1.1.04	*p*	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 biomass 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 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
	16/12	Ration of molecular weights of CH_4 and carbon	Universal constant	Dimensionless	Universal constant			
	44/12	Ration of molecular weights of carbon and CO_2	Universal constant	Dimensionless	Universal constant			
	44/28	Ration of molecular weights of N_2O and nitrogen	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

ID number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
	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 stratum *i*	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 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	$A_{B,ikt}$	Area of slash and burn in stratum *i*, species *j*, 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%	
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 biomass stock before burning for stratum *i*, species *j*, time *t*	Field measurement	tonnes d.m. ha^{-1}	m	Before burning	Sample plots	
2.1.2.12	*N/C ratio*	Nitrogen-carbon ratio	Literature	dimensionless	e	Once per species or group of species		IPCC default value (0.01) is used if no appropriate value

ID number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.21	$C_{AB,ijt}$	Carbon stock in above-ground biomass for stratum *i*, species *j*, time *t*	Calculations	tonnes C	c	5-year	100%	(Eq. 70)
	C_{ACTUAL}	Actual net greenhouse gas removals by sinks	Calculations	tonnes CO_2-e.	c	5-year	100%	(Eq. 65)
2.1.1.22	$C_{BB,ijt}$	Carbon stock in below-ground biomass for stratum *i*, species *j*, time *t*	Calculations	tonnes C	c	5-year	100%	(Eq. 71)
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 of biomass burnt	Local, national, IPCC	tonnes C (tonne 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	tonne C tonne^{-1}	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%	
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

ID number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
								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
2.1.1.17	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
	E	Allowable error	Calculations	Depends on the variable calculated	c	5-year	100% of the variables	(Eq. 59)
2.1.2.15	$E_{BiomassBurn}$	Increase in GHG emission as a result of biomass burning within the project boundary	Calculations	tonnes CO_2-e.	c	5-year	100%	(Eq. 90)
2.1.2.14	$E_{BiomassBurn, CH4}$	CH_4 emission from biomass burning in slash and burn	Calculations	tonnes CO_2-e.	c	5-year	100%	(Eq. 93)
2.1.2.13	$E_{BiomassBurn, N2O}$	N_2O emission from biomass burning in slash and burn	Calculations	tonnes CO_2-e.	c	5-year	100%	(Eq. 92)
2.1.2.11	$E_{BiomassBurn, CO2}$	CO_2 emission from biomass burning in slash and burn	Calculations	tonnes CO_2-e.	c	5-year	100%	(Eq. 91)
2.1.2.23	EF_1	Emission factor for emission from N input	GPG 2000, GPG LULUCF, IPCC Guidelines, National inventory	tonnes N_2O-N (tonnes 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

ID number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.2.04	$EF_{gasoline}$	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	tonnes CO_2-e.	c	5-year	100%	(Eq. 89)
	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 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 fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_x	Calculations	tonnes N	c	5-year	100%	(Eq. 98)
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

ID number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
	F_{SN}	Total amount of synthetic fertilizer nitrogen applied adjusted for volatilization as NH_3 and NO_x	Calculations	tonnes N	c	5-year	100%	(Eq. 97)
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	tonnes CO_2-e.	c	5-year	100%	(Eq. 88)
	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 ID (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
2.1.1.09	*j*	Tree species	Project list		m	5 years	100%	Arranged in PDD
	kID	Stand model ID (1, 2, 3, … *i* …S_{PS})	AR-CDM-PDD	Dimensionless		5 years	100%	May require *ex-post* adjustments

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	tonnes C ha^{-1}	c	5-year	100%	(Eq. 68)
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	tonnes C ha^{-1}	c	5-year	100%	(Eq. 69)
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. 59)
	n	Sample size (total number of sample plots required) in the project area	Calculations	Dimensionless	c	5-years	100%	(Eq. 60 or Eq. 62)
	N_i	Maximum possible number of sample plots in stratum *i*	Calculations	Dimensionless	c	Before the project start; thereafter adjusted tevery 5-year	100%	(Eq. 59)

ID number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.1.06	n_i	Sample size for stratum *i*	Calculations	Dimensionless	c	Before the project start; adjusted thereafter every 5-year	100%	(Eq. 61 or Eq. 63) Calculated for each stratum
2.1.2.20	$N_{ON\text{-}Fert}$	Total amount of organic fertilizer used within the project boundary	Calculations	tonnes N	c	5-year	100%	(Eq. 95)
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	tonnes N	c	5-year	100%	(Eq. 92)
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	tonnes CO_2-e.	c	5-year	100%	(Eq. 96)
2.1.1.04	p	Desired level of precision (e.g. 10%)		%	defined	Before the start of the project	100%	For QA/QC and measuring and monitoring precision control

ID number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
2.1.2.08	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
	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*			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 of species *j*	Calculations	kg dry matter tree^{-1}	c	5-year	100%	(Eq. 74)
	TC_{ABj}	Carbon stock in above-ground biomass per tree of species *j*	Calculations	kg C tree^{-1}	c	5-year	100%	(Eq. 75)
	TC_{BBj}	Carbon stock in below-ground biomass per tree of species *j*	Calculations	kg C tree^{-1}	c	5-year	100%	(Eq. 75)
2.1.1.10	*tID*	Age of plantation (1, 2… 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 plot)	Field measurement	Dimensionless	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
	XF	Plot expansion factor from per plot values to per hectare values (Eq. 76)	Calculations	Dimensionless	c	5-year	100%	(Eq. 78)
	$z_{\alpha/2}$	Value of the statistic z (normal probability density function), for $\alpha = 0.05$ (implying a 95% confidence level)	Statistic book	Dimensionless	m	5-years	0%	
2.1.1.28	$\Delta C_{AB,ijt}$	Annual carbon stock change in above-ground biomass for stratum i, species j, time t	Calculations	tonnes C yr^{-1}	c	5-year	100%	(Eq. 86)
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	tonnes C yr^{-1}	c	5-year	100%	(Eq. 72)
2.1.1.29	$\Delta C_{BB,ijt}$	Annual carbon stock change in below-ground biomass for stratum i, species j, time t	Calculations	tonnes C yr^{-1}	c	5-year	100%	(Eq. 87)
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	tonnes C yr^{-1}	c	5-year	100%	(Eq. 73)
	$\Delta C_{B,ikt}$	Annual carbon stock change in living biomass in the baseline for stratum i, stand model k, time t	Calculations	tonnes CO_2-e. yr^{-1}	c	5-year	100%	(Eq. 67)

ID number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Propor-tion of data moni-tored	Comment
	$\Delta C_{LB,ikt}$	Annual carbon stock change in living biomass in the project scenario for stratum *i*, stand model *k*, time *t*	Calculations	tonnes CO_2-e. yr^{-1}	c	5-year	100%	(Eq. 67)
	$\Delta C_{P,LB}$	Sum of the changes in living biomass carbon stocks in the project scenario (above- and below-ground)	Calculations	tonnes CO_2-e.	c	5-year	100%	(Eq. 66)
	$\Delta MC_{AB,ikt}$	Mean carbons stock change in above-ground biomass stratum *i*, stand model *k* at year *t*	Calculations	tonnes C ha^{-1} yr^{-1}	c	5-year	100%	(Eq. 79)
	$\Delta MC_{AB,ikT}$	Mean carbons stock change in above-ground biomass stratum *i*, stand model *k*, between two monitoring events	Calculations	tonnes C ha^{-1}	c	5-year	100%	(Eq. 84)
	$\Delta MC_{BB,ikt}$	Mean carbons stock change in below-ground biomass stratum *i*, species *j* at year *t*	Calculations	year t tonnes C ha^{-1} yr^{-1}	c	5-year	100%	(Eq. 85)
	$\Delta MC_{BB,ikT}$	Mean carbons stock change in below-ground biomass stratum *i*, species *j*, between two monitoring events	Calculations	tonnes C ha^{-1}	c	5-year	100%	(Eq. 83)
	$\Delta PC_{AB,ijT}$	Plot level mean carbon stock change in above-ground biomass in stratum *i*, species *j* between two monitoring events	Calculations	tonnes C ha^{-1}	c	5-year	100%	(Eq. 77)

ID number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
	$\Delta PC_{BB,ijT}$	Plot level mean carbon stock change below-ground biomass in stratum *i*, species *j* between between two monitoring events	Calculations	$t\ C\ ha^{-1}$	c	5-year	100%	(Eq. 82)
	ΔTC_{ABjt}	Carbon stock change in above-ground biomass per tree of species *j* in year *t*	Calculations	$kg\ C\ tree^{-1}\ yr^{-1}$	c	5-year	100%	(Eq. 76)
	ΔTC_{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. 76)
	$\Delta TC_{AB,jt}$	Carbon stock change in below-ground biomass per tree of species *j* in year *t*	Calculations	$kg\ C\ tree^{-1}\ yr^{-1}$	c	5-year	100%	(Eq. 76)
	ΔTC_{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. 81)

7 Leakage

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

$$LK = LK_{Vehicle} + LK_{ActivityDisplacement} + LK_{fencing} \quad \textbf{(99)}$$

where:

$LK_{Vehicle}$ = total GHG emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.
$LK_{ActivityDisplacement}$ = leakage due to activity displacement; tonnes CO_2-e.
$LK_{fencing}$ = leakage due to increased use of wood posts for fencing up to year t^*; tonnes CO_2-e.

Note: In this methodology Equation (99) 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].

$$LK_{Vehicle} = LK_{Vehicle,CO_2} + LK_{Vehicle,CH_4} + LK_{Vehicle,N_2O} \quad \textbf{(100)}$$

$$LK_{Vehicle,CO_2} = \sum_{t=1}^{t^*}\sum_{x}\sum_{y}(EF_{xy} \cdot FuelConsumption_{xyt}) \quad \textbf{(101)}$$

$$FuelConsumption_{xyt} = n_{zyt} \cdot k_{xyt} \cdot e_{xyt} \quad \textbf{(102)}$$

where:

$LK_{Vehicle}$ = total GHG emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.
$LK_{Vehicle,CO2}$ = total CO_2 emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.
$LK_{Vehicle,CH4}$ = total CH_4 emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.
$LK_{Vehicle,N2O}$ = total N_2O emissions due to fossil fuel combustion from vehicles; tonnes CO_2-e.

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

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 x of vehicle type y at time t; liters
n_{xyt}	=	number of vehicles
k_{xyt}	=	kilometers traveled by each of vehicle type y with fuel type x at time t; km
e_{xyt}	=	fuel efficiency of vehicle type x with fuel type y at time t; liters km^{-1}

Emissions of CH_4 and N_2O are estimated in the same way as CO_2 emission but with different emission factors and should be included in the overall calculation of leakages only if they represent more than 2% of actual net GHG removals by sinks. 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:

$$LK_{ActivityDisplacement} = LK_{conversion} + LK_{fuelwood} \tag{103}$$

where:

$LK_{ActivityDisplacement}$	=	leakage due to activity displacement; tonnes CO_2-e.
$LK_{conversion}$	=	leakage due to conversion of non-grassland to grassland; tonnes CO_2-e.
$LK_{fuelwood}$	=	leakage due to the displacement of fuelwood collection; tonnes CO_2-e.

7.2.1 Estimation of $LK_{conversion}$ (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[32]. Monitoring can be done by periodically surveying the project area or a sample of project plots and by interviewing the animal owners.

$$Na_{outside,t} = Na_{BL} - Na_{AR,t} \tag{104}$$

[32] As the methodology is based on baseline approach 22(a) it is assumed that the animal type mix does not change over time. This keeps the monitoring methodology simpler as during monitoring it is not necessary to account for different animal species. Only the number of animals has to be counted; aLK_{XGL} and aLK_{NGL} do already account for the animal type mix in the project area. They are per head averages calculated *ex ante* for all animal species, see Eq. 109 and Eq. 110.

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.

$$dNa_{EGL,t} = (Na_{EGL,t} - Na_{EGL(t=1)}) \cdot 1/SFR_{EGL} \qquad \textbf{(105)}$$

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.

$$dNa_{NGL,t} = (Na_{NGL,t} - Na_{NGL(t=1)}) \cdot 1/SFR_{NGL} \qquad \textbf{(106)}$$

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; %

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:

$$dNa_{XGL,t} = Na_{BL} - Na_{AR,t} - dNa_{EGL,t} - dNa_{NGL,t} \quad \textbf{(107)}$$

Step 5: Estimate leakage due to displacement of grazing activities as follows:

$$LK_{conversion} = LK_{NGL} + LK_{XGL} \quad \textbf{(108)}$$

where:

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

a) Estimation of LK_{NGL}:

$$LK_{NGL} = dNa_{NGL,t} \cdot aLK_{NGL} \quad \textbf{(109)}$$

where:

LK_{NGL} = leakage due to conversion of non-grassland to grassland in *NGL* areas; tonnes 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; tonnes CO_2-e. $animal^{-1}$

b) Estimation of LK_{XGL}:

$$LK_{XGL} = dNa_{XGL,t} \cdot aLK_{XGL} \quad \textbf{(110)}$$

where:

LK_{XGL} = leakage due to conversion of non-grassland to grassland in *XGL* areas; tonnes 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; tonnes CO_2-e. animal^{-1}

7.2.2 *Estimation of $LK_{fuelwood}$ (Leakage due to displacement of fuelwood collection)*

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

$$FG_{outside,t} = FG_{BL} - FG_{AR,t} \quad \textbf{(111)}$$

where:

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

FG_{BL} = average pre-project annual volume of fuelwood gathering in the project area – estimated *ex-ante* and specified in the AR-CDM-PDD; m^3 yr^{-1}

$FG_{AR,t}$ = volume of fuelwood 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 fuelwood gathering that is supplied to pre-project fuelwood collectors or charcoal producers ($FG_{NGL,t}$).

Step 3: Leakage due to displacement of fuelwood collection can be set as zero ($LK_{fuelwood} = 0$) under the following circumstances:

- $FG_{BL} < FG_{AR,t}$
- $FG_{BL} < (FG_{AR,t} + FG_{NGL,t})$

  Where: $FG_{NGL,t}$ = volume of fuelwood gathering in *NGL* areas that is supplied to pre-project fuelwood collectors or charcoal producers (as per step 2); m^3 yr^{-1}
- $LK_{fuelwood}$ < 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} or FG_{NGLt} to prove that the assumption is still valid.

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

$$LK_{fuelwood} = \sum_{t=1}^{t^*} FG_t \cdot D \cdot BEF_2 \cdot CF \cdot \frac{44}{12} \quad \textbf{(112)}$$

$$FG_t = FG_{outside,t} - FG_{NGL,\,t} \quad \textbf{(113)}$$

where:

$LK_{fuelwood}$ = leakage due to displacement of fuelwood collection up to year t^*; tonnes CO_2-e.
FG_t = volume of fuelwood gathering displaced in unidentified areas; $m^3\ yr^{-1}$
$FG_{outside,t}$ = volume of fuelwood gathering displaced outside the project area at year t – as per step 1; $m^3\ yr^{-1}$
$FG_{NGL,t}$ = monitored volume of fuelwood gathering in *NGL* areas and supplied to pre-project fuelwood collectors or charcoal producers – as per step 2; $m^3\ yr^{-1}$
D = basic wood density; tonnes 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); tonnes C (tonne d.m.)$^{-1}$

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:

$$LK_{fencing} = \sum_{t=1}^{t^*} \frac{PAR_t}{DBP} \cdot FNRP \cdot DBP \cdot APV \cdot D \cdot BEF_2 \cdot CF \cdot \frac{44}{12} \quad \textbf{(114)}$$

where:

$LK_{fencing}$ = leakage due to increased use of wood posts for fencing up to year t^*; tonnes 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; %
APV = average volume of o wood posts (estimated from sampling); m^3
D = basic wood density of the posts; tonnes 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); tonnes C (tonnes 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 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 3*: 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	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	tonnes 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	tonnes 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 o 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)
	CF_j	Carbon fraction of dry matter of species *j*	Literature, own studies	tonnes C (tonne d.m.)$^{-1}$	e	Once per species or group of species	100%	Local/national data or IPCC default (= 0.5)
	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	Local-derived and species-specific value have the priority

ID Number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
	dNa_{EGLt}	Number of animals displaced in *EGL* areas at time *t*	Calculations	dimensionless	c	Yearly	100%	(Eq. 105)
	dNa_{NGLt}	Number of animals displaced in *NGL* areas at time *t* – as estimated in step 4	Calculations	dimensionless	c	Yearly	100%	(Eq. 106)
	dNa_{XGLt}	Number of animals displaced in *XGL* areas at time *t* – as estimated in step 4	Calculations	dimensionless	c	Yearly	100%	(Eq. 107)
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
3.1.04	e_{xyt}	Fuel efficiency of Vehicle type *x* with fuel type *y* at time *t*	Local data, nation-nal data, IPCC	liter km^{-1}	e	5 years	100%	Estimated for each vehicle type and fuel type used
	$FG_{AR,t}$	Volume of fuelwood gathered in the project area according to monitoring results	Field sampling	m^3 yr^{-1}	m	Yearly	SFR_{PAfw}	
	FG_{BL}	Average pre-project annual volume of fuelwood 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
	$FG_{NGL,t}$	Monitored volume of fuelwood gathering in *NGL* areas and supplied to pre-project fuelwood collectors or charcoal producers – as per step 2	Field measurements	m^3 yr^{-1}	m	Yearly	SFR_{NGL}	

ID Number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
	$FG_{outside,t}$	Volume of fuelwood gathering displaced outside the project area at year t – as per step 1	Calculations	m^3 yr^{-1}	c	Yearly	100%	(Eq. 111)
	FG_t	Volume of fuelwood gathering displaced in unidentified areas	Calculations	m^3 yr^{-1}	c	Yearly	100%	(Eq. 113)
	FNR_P	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 *x* of vehicle type *y* at time *t*	Calculations	liters	c	Yearly	100%	(Eq. 102)
3.1.03	k_{xyt}	Kilometers traveled by each of vehicle type *y* with fuel type *x* 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	tonnes CO_2-e.	c	Yearly	100%	(Eq. 99)
	$LK_{fuelwood}$	Leakage due to the displacement of fuelwood collection	Calculations	tonnes CO_2-e.	c	Yearly	100%	(Eq. 112)
	$LK_{ActivityDisplacement}$	Leakage due to activity displacement	Calculations	tonnes CO_2-e.	c	Yearly	100%	(Eq. 103)
	$LK_{conversion}$	Leakage due to conversion of non-grassland to grassland	Calculations	tonnes CO_2-e.	c	Yearly	100%	(Eq. 108)
	$LK_{fencing}$	Leakage due to increased use of wood posts for fencing up to year *t**	Calculations	tonnes CO_2-e.	c	Yearly	100%	(Eq. 114)
	LK_{NGL}	Leakage due to conversion of non-grassland to grassland in *NGL* areas	Calculations	tonnes CO_2-e.	c	Yearly	100%	(Eq. 109)

ID Number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.1.06	$LK_{Vehicle}$	Total GHG emissions due to fossil fuel combustion from vehicles	Calculations	tonnes CO_2-e.	c	Yearly	100%	(Eq. 100)
	$LK_{Vehicle,CH4}$	Total CH_4 emissions due to fossil fuel combustion from vehicles	Calculations	tonnes CO_2-e.	c	Yearly	100%	(Eq. 101)
	$LK_{Vehicle,CO2}$	Total CO_2 emissions due to fossil fuel combustion from vehicles	Calculations	tonnes CO_2-e.	c	Yearly	100%	(Eq. 101)
	$LK_{Vehicle,N2O}$	Total N_2O emissions due to fossil fuel combustion from vehicles	Calculations	tonnes CO_2-e.	c	Yearly	100%	(Eq. 101)
	LK_{XGL}	Leakage due to conversion of non-grassland to grassland in *XGL* areas	Calculations	tonnes CO_2-e.	c	Yearly	100%	(Eq. 110)
	$Na_{AR,t}$	Monitored number of animals present in the project area at year *t*	Field measurements	dimensionless	m	Yearly	SFR_{PAga}	
	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	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}	

ID Number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
	$Na_{NGL,t=1}$	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
	$Na_{outside,t}$	Number of animals displaced outside the project area at year *t*	Calculations	dimensionless	c	Yearly	100%	(Eq. 104)
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 measurements, GPS, GIS	M	m	5-years	100%	
	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 fuelwood collection	CDM-AR-PDD	dimensionless	Defined using statistical criteria	*Ex-ante* in AR-CDM-PDD		*Ex-ante* estimate in the AR-CDM-PDD
	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
	x	Vehicle type	Monitoring of project activity	dimensionless	m	Yearly	100%	

ID Number	Data Variable		Source of data	Data unit	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
	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 tonnes CO_2-e.:

$$C_{AR-CDM} = C_{ACTUAL} - C_{BSL} - LK \quad \textbf{(115)}$$

where:

C_{AR-CDM} = net anthropogenic greenhouse gas removals by sinks; tonnes CO_2-e.
C_{ACTUAL} = actual net greenhouse gas removals by sinks; tonnes CO_2-e.
C_{BSL} = baseline net greenhouse gas removals by sinks (as pre-determined in the PDD); tonnes CO_2-e.
LK = leakage; tonnes CO_2-e.

Note: In this methodology Equation (115) 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[33], which produce the same estimates as the following:

$$tCERs = C_{AR-CDM,t2} \quad \textbf{(116)}$$

$$lCERs = C_{AR-CDM,t2} - C_{AR-CDM,t1} \quad \textbf{(117)}$$

where:

$tCERs$ = number of units of temporary Certified Emission Reductions
$lCERs$ = number of units of long-term Certified Emission Reductions
$C_{AR-CDM,t2}$ = net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$; tonnes CO_2-e.
$C_{AR-CDM,t1}$ = net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$; tonnes 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'.

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

11 Other information

11.1 Default values used in elaborating the new methodology

CF	=	carbon fraction of dry matter default = 0.5 tonnes C (tonnes d.m.)$^{-1}$
GWP_{N2O}	=	Global Warming Potential for N_2O = 310 kg CO_2-e. (kg N_20)$^{-1}$
GWP_{CH4}	=	Global Warming Potential for CH_4 = 21 kg CO_2-e. (kg CH_4)$^{-1}$
ER_{N20}	=	Emission ratio for N_2O in biomass burning = 0.007
ER_{CH4}	=	Emission ratio for CH_4 in biomass burning = 0.012
CF	=	Average combustion efficiency of biomass = 0.5
N/C	=	N/C ratio of biomass = 0.01 kg N (kg C)$^{-1}$
EF_1	=	Emission Factor for emissions from N fertilization = 0.0125 kg N_2O-N (kg N input)$^{-1}$
$Frac_{GASF}$	=	Fraction that volatilizes as NH_3 and NO_x for synthetic fertilizers = 0.1
$Frac_{GASM}$	=	Fraction that volatilizes as NH_3 and NO_x for organic fertilizers = 0.2

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 4*: Quality control activities and procedures**

QC activity	Procedures
Check that assumptions and criteria	• Cross-check descriptions of activity data, emission factors

QC activity	Procedures
for the selection of activity data, emission factors and other estimation parameters are documented.	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 • 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. • 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. • Check that units are correctly carried through from beginning to end of calculations. • Check that conversion factors are correct. • 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. • Confirm that data relationships are correctly represented in the database. • Ensure that data fields are properly labeled and have the correct design specifications. • 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. • Check that emission and removal data are correctly transcribed between different intermediate products.
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. • Check that qualifications, assumptions and expert judgments are recorded. Check that calculated uncertainties are complete and calculated correctly. • If necessary, duplicate error calculations on a small sample of the probability distributions used by Monte Carlo analyses.

QC activity	Procedures
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. • Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review. • 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. • 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. • 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.

The proposed new methodology has not been used for other purposes. However, since it is based on IPCC Guidelines, GPG-2000 and IPCC GPG LULUCF (both Chapters 3 and 4.3) it is highly likely that its components have been widely used.

Section IV: Lists of variables, acronyms and references

1 List of variables used in equations

***Table 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 sec-toral policies	dimensionless	Additionality consideration
UNFCCC, EB and AR-WG decisions - reports	dimensionless	
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, fuelwood, non-wood products, with and without CER revenues, etc.
A	hectares	Rotal project area
a	hectares	Sample plot size
$A_{B,ikt}$	hectares	Area of slash and burn for stratum *i*, stand model *k*, time *t*
A_i	hectares	Size of each stratum
$Adist_{ikt}$	hectares per year	Forest areas affected by disturbances in stratum *i,* stand model *k*, time *t*
$Adist_{ikT}$	hectares per year	Average annual area affected by disturbances for stratum *i,* stand model *k*, during the period *T*;
a_{gpl}	dimensionless	Number of months per annum during which animals from the livestock group *g* are present at plot *pl*; dimensionless
A_{ikt}	hectares	Area of stratum *i,* stand model *k*, at time *t*
A_{ikT}	hectares	Average annual area for stratum *i,* stand model *k*, during the period *T*
aLK_{NGL}	tonnes CO_2-e. per animal	Average leakage due to conversion of non-grassland to grassland per displaced animal in *NGL* areas
aLK_{XGL}	tonnes CO_2-e. per animal	Average leakage due to conversion of non-grassland to grassland per displaced animal in *XGL* areas
$A_{N,ikt}$	hectares	Area of with N applied in stratum *i*, stand model *k*, time *t*
AP	square meters	Plot area
APV	cubic meters	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 mer-chantable 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}	tonnes of dry matter per hectare	Average above-ground biomass stock before burning for stratum *i*, stand model *k*, time *t*
$B_{non\text{-}tree,ikt}$	tonnes of dry matter per hectare	Average non-tree biomass stock on land to be planted before the start of a proposed A/R CDM project activity for stratum *i*, stand model *k*, time *t*
$B_{w,ijt}$	tonnes of dry matter per hectare	Average above-ground biomass stock for stratum *i,* species *j*, time *t*
N/C ratio	dimensionless	Nitrogen-carbon ratio
$C_{AB,ijt}$	tonnes of dry matter	Carbon stock in above-ground biomass for stratum *i,* species *j*, at time *t*
$C_{NGLac\ t}$	tonnes CO_2-e.	Mean carbon stock of the *NGL* area converted to grassland at time *t*
$C_{XGLac\ t}$	tonnes CO_2-e.	Mean carbon stock of the *XGL* area converted to grassland at time *t*
C_{ACTUAL}	tonnes CO_2-e.	Actual net greenhouse gas removals by sinks (as per Equation 13)
$C_{AR\text{-}CDM}$	tonnes CO_2-e.	Net anthropogenic greenhouse gas removals by sinks
$C_{AR\text{-}CDM,t1}$	tonnes CO_2-e.	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$

Variable	SI Unit	Description
$C_{AR-CDM,t2}$	tonnes CO_2-e.	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$
$C_{BB,ijt1}$	tonnes of carbon	Carbon stock in below-ground biomass for stratum *i*, species *j*, calculated at time $t = t_1$
$C_{BB,ijt2}$	tonnes of carbon	Carbon stock in below-ground biomass for stratum *i*, species *j*, calculated at time $t = t_2$
$C_{AR-CDM,t1}$	tonnes CO_2-e.	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_1$
$C_{AR-CDM,t2}$	tonnes CO_2-e.	Net anthropogenic greenhouse gas removals by sinks, as estimated for $t^* = t_2$
$C_{BB,ijt}$	tonnes of carbon	Carbon stock in below-ground biomass for stratum *i*, species *j*, at time *t*
C_{BSL}	tonnes CO_2-e.	Baseline net greenhouse gas removals by sinks
CE	dimensionless	Average biomass combustion efficiency
CF_j	tonnes of carbon per tonne of dry matter	Carbon fraction for species *j*
C_i	local currency	Cost of establishment of a sample plot for each stratum *i*
C_{ikt}	tonnes of carbon	Total carbon stock in living biomass for stratum *i*, stand model *k*, calculated at time *t*
C_{ikt1}	tonnes of carbon	Total carbon stock in living biomass for stratum *i*, stand model *k*, calculated at time $t = t_1$
C_{ikt2}	tonnes of carbon	Total carbon stock in living biomass for stratum *i*, stand model *k*, calculated at time $t = t_2$
$CF_{non-tree}$	tonnes of carbon per tonne of dry matter	Carbon fraction of dry biomass in non-tree vegetation
$CSP_{diesel\ t}$	liters	Amount of diesel consumption for year *t*
$CSP_{gasoline\ t}$	liters	Amount of gasoline consumption for year *t*
D	tonnes of dry matter per cubic meter	Basic wood density
DBH	centimeters	Tree diameter at breast height
DBI_{an}	kilograms of dry matter per animal per day	Daily biomass intake by animal type *j*
DBP	meters	Average distance between wood posts
D_j	tonnes of dry matter per cubic meter	Basic wood density for species *j*
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
$E_{acBiomassBurnt}$	tonnes 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)
$E_{BiomassBurn}$	tonnes CO_2-e.	Total increase in non-CO_2 emission as a result of biomass burning within the project boundary
$E_{BiomassBurn,\ CH4}$	tonnes CO2-e.	CH_4 emission from biomass burning in slash and burn
$E_{BiomassBurn,\ N2O}$	tonnes $CO_{2-e.}$	N_2O emission from biomass burning in slash and burn
$E_{BiomassBurn,CO2}$	tonnes CO_2-e.	CO_2 emission from biomass burning in slash and burn
$E_{biomassloss}$	tonnes 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	tonnes of N_2O per tonne of N input	Emission Factor for emissions from N inputs
EF_{diesel}	kilograms of CO_2 per liter	Emission factor for diesel
$EF_{gasoline}$	kilograms of CO_2 per liter	Emission factor for gasoline
$E_{FuelBurn}$	tonnes CO_2-e.	Increase in GHG emission as a result of burning of fossil fuels within the project boundary
$E_{FuelBurn}$	tonnes 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	hectares	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
Ei	tonnes CO_2-e.	Emission/removal estimate for source/sink *i*
ER_{CH4}	tonnes CO_2-e. per tonne of C	Emission ratio for CH_4 (IPCC default value = 0.012)
ER_{N2O}	tonnes CO_2-e. per tonne of C	Emission ratio for N_2O (IPCC default value = 0.007)
e_{xyt}	liters per kilometer	Fuel efficiency of vehicle type *x* with fuel type *y* at time *t*
$FG_{AR,t}$	cubic meters per year	Volume of fuelwood gathering allowed/planned in the project area under the proposed AR-CDM project activity
FG_{BL}	cubic meters per year	Average pre-project annual volume of fuelwood gathering in the project area
FG_{ijt}	cubic meters per hectare per year	Annual volume of fuel wood harvesting for stratum *i*, species *j*, time *t*
FG_{ijT}	cubic meters per hectare per year	Average annual volume of fuel wood harvested for stratum *i*, species *j*, during the period *T*
$FG_{NGL,t}$	cubic meters per year	Volume of fuelwood gathering in *NGL* areas and supplied to pre-project fuelwood collectors or charcoal producers

Variable	SI Unit	Description
$FG_{outside,t}$	cubic meters per year	Volume of fuelwood gathering displaced outside the project area at year *t*
FG_t	cubic meters per year	Volume of fuelwood gathering displaced in unidentified areas
$f_j(DBH_t,H_t)$	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	tonnes of 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	tonnes of N	Amount of synthetic fertilizer nitrogen applied at time *t* adjusted for volatilization as NH_3 and NO_x
$FuelConsumption_{xyt}$	liters	Consumption of fuel type *x* of vehicle type *y* at time *t*
GHG_E	tonnes 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	hectares	Total grazing land area outside the project boundary needed to feed the displaced animal populations
$G_{TOTAL,ijt}$	tonnes of dry matter per hectare per year	Annual average increment rate in total biomass in units of dry matter for stratum *i*, species *j*, time *t*
$G_{w,ijt}$	tonnes of dry matter per hectare per year	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)
H	Meters	Rree height
H_{ijt}	cubic meters per hectare per year	Annually extracted merchantable volume for stratum *i*, species *j*, time *t*
H_{ijT}	cubic meters per hectare per year	Average annually harvested merchantable volume for stratum *i*, species *j*, during the period *T*
i	dimensionless	Stratum index (*I* = total number of strata)
$I_{v,ijt}$	cubic meters per hectare per year	Average annual increment in merchantable volume for stratum *i*, species *j*, time *t*
$I_{v,ijT}$	cubic meters per hectare per year	Average annual net increment in merchantable volume for stratum *i*, species *j* during the period *T*
j	dimensionless	Tree species (*J* = total species)
an	dimensionless	Animal type index (*An*= total number of animal types); dimensionless
k_{xyt}	kilometers	Kilometers traveled by each of vehicle type *y* with fuel type *x* at time *t*
lCERs	dimensionless	Number of units of long-term Certified Emission Reductions
$L_{fw,ikt}$	tonnes of CO_2-e. per year	Annual carbon loss due to fuel wood gathering for stratum *i*, stand model *k*, time *t*
$L_{hr,ikt}$	tonnes of CO_2-e. per year	Annual carbon loss due to commercial harvesting for stratum *i*, stand model *k*, time *t*
LK	tonnes of CO_2-e.	Total project leakage (as per Equation 31)
$LK_{fuelwood}$	tonnes of CO_2-e.	Leakage due to the displacement of fuelwood collection
$LK_{ActivityDisplacement}$	tonnes of CO_2-e.	Leakage due to activity displacement
$LK_{conversion}$	tonnes of CO_2-e.	Leakage due to conversion of non-grassland to grassland
$LK_{fencing}$	tonnes of CO_2-e.	Leakage due to increased use of wood posts for fencing
LK_{NGL}	tonnes of CO_2-e.	Leakage due to conversion of non-grassland to grassland in *NGL* areas under the control of the animal owners
$LK_{Vehicle}$	tonnes of CO_2-e.	Total GHG emissions due to fossil fuel combustion from vehicles
$LK_{Vehicle,CH4}$	tonnes of CO_2-e.	Total CH_4 emissions due to fossil fuel combustion from vehicles
$LK_{Vehicle,CO2}$	tonnes of CO_2-e.	Total CO_2 emissions due to fossil fuel combustion from vehicles
$LK_{Vehicle,N2O}$	tonnes of CO_2-e.	Total N_2O emissions due to fossil fuel combustion from vehicles
LK_{XGL}	tonnes of CO_2-e.	Leakage due to conversion of non-grassland to grassland in unidentified *XGL* areas
$MC_{AB,ijt}$	tonnes of carbon per hectare	Mean carbon stock in above-ground biomass per unit area for stratum *i*, species *j*, time *t*
$MC_{BB,ijt}$	tonnes of carbon per hectare	Mean carbon stock in below-ground biomass per unit area for stratum *i*, species *j*, time *t*
$MC_{AB,ikT}$	tonnes of carbon per hectare	Mean carbon stock in above-ground biomass per unit area for stratum *i*, stand model *k*, between two monitoring events
$MC_{BB,ikT}$	tonnes of carbon per hectare	Mean carbon stock in below-ground biomass per unit area for stratum *i*, stand model *k* between two monitoring events
MV_{ijt}	Cubic meters per hectare per year	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

Variable	SI Unit	Description
k		Stand model (K = total stand models)
$L_{ot,ikt}$	tonnes of CO_2-e. per year	annual natural losses (mortality) of carbon for stratum i, stand model k
m_{BL}	Index	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
$N_2O_{direct-N_{fertilizer}}$	tonnes of CO_2-e.	Increase in N_2O emission as a result of direct nitrogen application within the project boundary
$N_2O_{direct-N_{fertilizer}}$	tonnes of 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 plots)
$Na_{AR,t}$	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
$Na_{outside,t}$	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
$N_{ON\text{-}Fert}$	tonnes nitrogen	Total amount of organic fertilizer used within the project boundary
$N_{ON\text{-}Fert,ikt}$	kilograms of nitrogen per hectare per year	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	hectares	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	hectares	Total area converted to grassland at time t
n_{igt}	dimensionless	Number of individual animals from the livestock group g at plot i at time t
$N_{SN\text{-}Fert,t}$	tonnes nitrogen	Amount of synthetic fertilizer nitrogen applied at time t
$N_{SN\text{-}Fert,ikt}$	kilograms of nitrogen per hectare per year	Use of synthetic fertilizer per unit area for stratum i, stand model k, at time t
nTR_{ijt}	per hectare	Number of trees in stratum i, species j, at time t
n_{xyt}	dimensionless	Number of vehicles
PAR_t	meters	Perimeter of the areas to be fenced at year t
p	dimensionless	Desired level of precision (e.g. 10%)
PBB_{ikt}	dimensionless	Average proportion of biomass burnt for stratum i, stand model k, time t
pl	dimensionless	Plot number
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}	cubic meters per hectare	Sampled average pre-project annual volume of fuelwood gathering in the project area
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 fuelwood collection
SFR_{PAga}	dimensionless	Fraction of total project area sampled for grazing animals collection
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
TB_{ABj}	kilograms of biomass per tree	Above-ground biomass per tree of species j
TC_{ABj}	kilograms of carbon per tree	Carbon stock in above-ground biomass per tree of species j
TC_{BBj}	kilograms of carbon per tree	Carbon stock in below-ground biomass per tree of species j
$tCERs$	dimensionless	Number of units of temporary Certified Emission Reductions
tr	dimensionless	Tree (TR = total number of trees in the plot)
X	dimensionless	Vehicle type

Variable	SI Unit	Description
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)
$\Delta C_{AB,ikt}$	tonnes of carbon per year	Changes in carbon stock in above-ground biomass for stratum i, stand model k, at time t
$\Delta C_{BB,ikt}$	tonnes of carbon per year	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
U_E	percentage	Percentage uncertainty of the sum
U_i	percentage	Percentage uncertainties associated with each of the quantities
Ui	percentage	Percentage uncertainty associated with source/sink i
U_{total}	percentage	Percentage uncertainty in the product of the quantities (half the 95% confidence interval divided by the total and expressed as a percentage)
V_{ijt}	cubic meters per hectare	Average merchantable volume of stratum i, species j, at time t
V_{ijt1}	cubic meters per hectare	Average merchantable volume of stratum i, species j, at time $t = t_1$
V_{ijt2}	cubic meters per hectare	Average merchantable volume of stratum i, species j, at time $t = t_2$
$W\mathrm{B}_{\mathrm{ht}}$	dimensionless	Fraction of total above-ground biomass harvested as timber and as fuelwood at time t (not burned)
X	dimensionless	Vehicle type
XGL	hectares	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	hectares	Total unidentifiable area converted to grassland at time t
Y	dimensionless	Fuel type
ΔC_{av}	tonnes of dry matter per year	Average annual biomass consumed by one average animal
$\Delta C_{G,ikt}$	tonnes of CO_2-e. per year	Annual increase in carbon *stock* due to biomass growth for stratum i, stand model k, time t
$\Delta CB_{B,ikt}$	tonnes of CO_2-e. per year	Annual carbon stock change in living biomass in the baseline for stratum i, stand model k, time t
$\Delta CB_{LB,ikt}$	tonnes of CO_2-e. per year	Annual carbon stock change in living biomass in the project scenario for stratum i, stand model k, time t
$\Delta C_{B,ikt}$	tonnes of CO_2-e. per year	Annual carbon stock change in living biomass in the baseline for stratum i, stand model k, time t
$\Delta C_{LB,ikt}$	tonnes of CO_2-e. per year	Annual carbon stock change in living biomass in the project scenario for stratum i, stand model k, time t
$\Delta C_{L,ikt}$	tonnes of CO_2-e. per year	Annual decrease in carbon *stock* due to biomass loss for stratum i, stand model k, time t
$\Delta C_{L\,PA,t}$	tonnes of dry matter per year	Annual animal biomass consumption over the project area to be planted at time t
$\Delta C_{P,LB}$	tonnes of CO_2-e. per year	Sum of the changes in living biomass carbon stocks in the project scenario (above- and below-ground)
$\Delta C_{Lcurrent}$	tonnes of dry matter per year	Current annual biomass that the grazing areas can produce for animal feeding
ΔC_{Lmax}	tonnes of dry matter per year	Maximum annual biomass that the grazing areas can produce for animal feeding
$\Delta MC_{AB,ikt}$	tonnes of carbon per hectare per year	Annual mean carbon stock change in above-ground biomass for stratum i, species j, at year t
$\Delta MC_{AB,ikT}$	tonnes of carbon per hectare	Mean carbon stock change in above-ground biomass for stratum i, species j, between two monitoring events
$\Delta MC_{BB,ikt}$	tonnes of carbon per hectare per year	Annual mean carbon stock change in below-ground biomass for stratum i, species j, at year t
$\Delta MC_{BB,ikT}$	tonnes of carbon per hectare	Mean carbon stock change in below-ground biomass stock in stratum i, species j, between two monitoring events
$\Delta PC_{AB,ijT}$	tonnes of carbon per hectare	Plot level carbon stock change in above-ground of species j in stratum i, between two monitoring events
$\Delta PC_{BB,ijT}$	tonnes of carbon per hectare	Plot level carbon stock change in below-ground of species j in stratum i, between two monitoring events
ΔTC_{ABjT}	kilograms of carbon per tree	Carbon stock change in above-ground biomass per tree of species j between two monitoring events
ΔTC_{BBjT}	kilograms of carbon per tree	Carbon stock change in below-ground biomass per tree of species j between two monitoring events

Variable	SI Unit	Description
$\Delta TC_{ABj,t}$	kilograms of carbon per tree	Carbon stock change in above-ground biomass per tree of species *j* at the monitoring event in year *t*
$\Delta TC_{BBj,t}$	kilograms of carbon per tree	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

***Table 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
RS	Root to shoot ratio
tCER	temporary Certified Emission Reduction

3 References

All references are quoted in footnotes.

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