Approved afforestation and reforestation baseline and monitoring methodology AR-AM0006

“Afforestation/Reforestation with Trees Supported by Shrubs on Degraded Land”

(Version 03)

This methodology is based on the draft CDM-AR-PDD “Afforestation for Combating Desertification in Aohan County, Northern China” whose baseline study, monitoring and verification plan and project design document were prepared by the Institute of Forest Ecology and Environment, the Chinese Academy of Forestry, University of Tuscia, Italy, Department for Environmental Research and Development, Ministry for the Environment Land and Sea , Italy, Chifeng Institute of Forestry, Inner Mongolia Autonomous Region, China and Forestry Bureau of Aohan County, Inner Mongolia Autonomous Region, China, National Bureau to Combat Desertification, CCICCD, State Forestry Administration, China. For more information regarding the proposal and its consideration by the Executive Board please refer to case ARNM0020-rev: “Afforestation for Combating Desertification in Aohan County, Northern China” on <http://cdm.unfccc.int/goto/Arappmeth>.

Background

This methodology is an extension of the approved methodology AR-AM0001 (“Reforestation of Degraded Land”),[1] in the following aspects:

Including afforestation and allowing shrubs to be planted or seeded with the established plantation complying with the forest definition of DNA:

- Allowing agricultural intercropping between planted tree rows;
- Allowing nitrogen-fixing species to be planted or intercropped;
- Soil organic carbon pool that is subjected to decrease or low steady state in a long term;
- Allowing project to produce forage to feed livestock;
- Excluding burning of biomass during site preparation.

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

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

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

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[1] <http://cdm.unfccc.int/goto/Arappmeth>

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 tree planting. Nitrogen-fixing species and intercropping between tree rows may be used. Living biomass and soil organic carbon are the carbon pools to be considered.

The conditions under which the methodology is applicable are as follows:

(a) Lands to be afforested/reforested are severely degraded and the lands are still degrading or remain in a low carbon steady state;[2]

(b) The project activity does not lead to displacement of production of goods or delivery of utilities;

(c) Environmental conditions and human-caused degradation do not permit the encroachment of natural forest vegetation;

(d) Lands will be afforested/reforested by direct planting or seeding, with trees/shrubs complying with the minimum thresholds for the forest definition by the DNA;

(e) Inter-cropping between rows of trees/shrubs is allowed in the project activity and will then be included in the monitoring;

(f) Nitrogen-fixing species are allowed to be used;

(g) Plantation may be harvested with either short or long rotation and will be regenerated either by direct planting or natural sprouting;

(h) Carbon stocks in litter and deadwood can be expected to decrease more or increase less in the absence of the project activity, relative to the project scenario;

(i) Grazing will not occur within the project boundary in both the project case and baseline scenario;

(j) Site preparation and intercropping may cause a significant long-term net emission from soil carbon;

(k) If the proposed A/R CDM project activity produces forage to feed livestock, all forage shall have a similar nutritional value and digestibility, and will support only a single livestock group with a single manure management system;

(l) Biomass burning for site preparation is not practiced.

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[2] This includes checks on policies, e.g., “Demonstrate that national or sectoral land-use policies or regulations that create policy driven market distortions which give comparative advantages to afforestation/reforestation activities and that have been adopted before 11 November 2001 do not influence the areas of the proposed A/R CDM project activity (e.g., because the policy is not implemented, the policy does not target this area, or because there are prohibitive barriers to the policy in this area, etc). 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”.

3. Selected carbon pools

Table 1: Selection and justification of carbon pools

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

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[3] to demonstrate land eligibility within the project boundary.

2. Project boundary

Physical delineation

The "project boundary" geographically delineates the afforestation or reforestation project activity under the control of the project participants (PPs). The A/R CDM project activity may contain more than one discrete parcel of land. Each discrete parcel of land shall have a unique geographical identification.

It shall be demonstrated that each discrete area of land to be included in the boundary is eligible for an A/R CDM project activity. PPs shall apply the latest version of the tool "Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM project activities" as approved by the Executive Board.

The latest version of "Guidance on the application of the definition of project boundary to A/R CDM project activities" (available at: <http://cdm.unfccc.int/Reference/Guidclarif>) may be applied in identification of areas of land planned for an A/R CDM project activity.

Identification of all GHG emission sources in the project boundary

Furthermore, the project boundary includes the emission sources and gases listed in Table 2 below.

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[3] Hereinafter referred as "A/R eligibility tool" <http://cdm.unfccc.int/Reference/Procedures/index.html>.

Table 2: GHG emissions from sources other than those resulting from changes in carbon pools within the project boundary

Source	Gas	Included/ excluded	Justification / Explanation
N-fixing species	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
Livestock fed with forage produced by the project	CO_2	Excluded	Not applicable
	CH_4	Included	Potential significant emission source
	N_2O	Included	Potential significant emission source

3. *Ex ante* stratification

If the project activity area is not homogeneous, stratification should be carried out to improve the accuracy and the precision of biomass estimates. Different stratifications may be required for the baseline and project scenarios in order to achieve optimal accuracy of the estimates of net GHG removal by sinks.

For estimation of baseline net GHG removals by sinks, or estimation of actual net GHG removals by sinks, strata should be defined on the basis of parameters that are key entry variables in any method (e.g., growth models or yield curves/tables) used to estimate changes in biomass stocks:

- **For baseline net GHG removals by sinks.** It will usually be sufficient to stratify according to area of major vegetation types because baseline removals for degraded (or degrading) land are expected to be small in comparison to project removals;

- **For actual net GHG removals by sinks.** The *ex ante* estimations shall be based on the project planting/management plan. The *ex post* stratification shall be based on the actual implementation of the project planting/management plan. The *ex post* stratification may be affected by natural or anthropogenic impacts if they are able to add variability to growth pattern in the project area, e.g., local fires (see Section III.2).

Further subdivision of the project strata to represent spatial variation in the distribution of the baseline or the project biomass stocks/removals is not usually warranted. However, factors impacting growth (e.g., soil type) might be useful for *ex post* stratification if their variability in the project area is large.

For *ex ante* and ex *post* stratification, PPs may optionally make use of remote sensing data acquired close to the time the project commences and/or close to the time of occurrence of natural or anthropogenic impacts if such impacts add variability to growth pattern in the project area.

Note: In the equations used in this methodology, the letter “*i*” is used to represent a stratum, the letter “*j*” represent a species in baseline scenario and an age class (sub-stratum) in project scenario, and “*k*” represent species in project scenario. *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, storm, pests or disease outbreaks), affecting 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, or if monitoring finds similar carbon stock change in different strata or significant variation in carbon stock change within one stratum/substratum.

4. Procedure for selection of most plausible baseline scenario

PPs should determine the most plausible baseline scenario with the following steps:

Step 1: Define the project boundary as described in Section II.2 above.

Step 2: Analyze historical land use, local and sectoral land-use policies or regulations:

(a) Analyze the historical and existing land use/cover changes in a social-economic context and identify key factors that influence the land use/cover changes over time, using multiple sources of data including archives, maps 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) Demonstrate 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 and that it is likely that no natural encroachment of trees will occur. The demonstration should be based on verifiable 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 assessing one of the following indicators:

(i) Vegetation degradation, e.g.,

- The crown cover of non-tree vegetation has decreased in the recent past for reasons other than sustainable harvesting activities;

(ii) Soil degradation, e.g.,

- Soil erosion has increased between two time points in the recent past;
- Soil organic matter content has decreased between two time points in the recent past.

The fact that no natural encroachment of trees would occur can be demonstrated by:

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

(c) Demonstrate that national or sectoral land-use policies or regulations that create policy driven market distortions which give comparative advantages to afforestation/reforestation activities and that have been adopted before

11 November 2001 do not influence the areas of the proposed A/R CDM project activity (e.g., because the policy is not implemented, the policy does not target this area, or because there are prohibitive barriers to the policy in this area, etc[4]). If the policies (implemented before 11 November 2001) significantly impact the project area, then the baseline scenario cannot be "degraded land" and this methodology cannot be used.

Step 3: Stratify the project area as explained in Section II.3 above.

Step 4: Identify and list plausible alternative land uses including alternative future public or private activities on the degraded lands such as any similar A/R activity or any other feasible land development activities, considering relevant national or sectoral land-use policies that would impact the proposed project area, and land records, field surveys, data and feedback from stakeholders, and other appropriate sources.

Step 5: Demonstrate that under the plausible scenarios identified in Step 3, the most plausible scenario is that the project areas would remain degraded and degrading in absence of the project activity, by assessing the attractiveness of the plausible alternative land uses in terms of benefits to the PPs, consulting with stakeholders for existing and future land use, and identifying barriers for alternative land uses. This can be done in at least one of the following ways:

- **Generally:** By demonstrating that similar lands, in the vicinity, are also not, and are not planned to be used for these alternative land uses. Show that apparent financial or other barriers, which prevent alternative land uses can be identified;
- **Specifically** for **a forest as alternative land use:** Apply Step 2 (investment analysis) or Step 3 (barrier **analysis**) of the A/R "Tool for the demonstration and assessment of additionality", to demonstrate that this land use, in absence of the CDM, is unattractive;
- **Specifically for any agricultural alternative land uses:** Demonstrate that the project lands are **legally** restricted to forestry purposes only, and that these restrictions are generally complied with in the vicinity of the project area, and then use (ii) above to demonstrate that forestry land use, in absence of the CDM, is unattractive. Alternatively, use Step 2 of the A/R "Tool for the demonstration and assessment of additionality" to demonstrate that alternative agricultural land uses are financially non-viable.

This methodology is not applicable if project proponents can not clearly show in the application of Steps 1 to 5 that the baseline approach 22(a) (existing or historical changes in carbon stocks in the carbon pools within the project boundary) and the scenario "lands to be planted are degraded lands and will continue to degrade in absence of the project" is the most appropriate plausible baseline scenario.

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

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[4] To comply with ruling of the Executive Board of the CDM, see <http://cdm.unfccc.int/EB/Meetings/016/eb16repan3.pdf>

5. Estimation of baseline net GHG removals by sinks

The baseline net GHG removals by sinks is the sum of the baseline net GHG removals by sinks across all strata. For those strata without trees, the sum of carbon stock changes in above-ground and below-ground biomass is set as zero. For those strata with growing trees, the sum of carbon stock changes in above-ground and below-ground biomass is determined based on the projection of their number and growth, based on growth models (yield tables), allometric equations, and local or national or IPCC default parameters (see detail below in this section). The carbon stock changes in soil organic matter for all strata in baseline scenario are set as zero. The following formulae are used to calculate the baseline net GHG removals by sinks:

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

where:

i	Strata
j	Tree species
$C_{BSL,t}$	Sum of the changes in carbon stocks in trees for year *t*; tonnes CO_2 yr^{-1}
$\Delta C_{ij,BSL,t}$	Average annual carbon stock change for stratum *i*, species *j* in the absence of the project activity for year *t*; tonnes CO_2 yr^{-1}
t	Year 1 to length of crediting period

Carbon stock change in soil organic matter for all strata is set as zero in the baseline scenario. For those strata without growing trees, $\Delta C_{ij, BSL,t} = 0$. For those strata with a few growing trees, $\Delta C_{ij,BSL,t}$ is estimated using one of following two methods for biomass growth of living trees that can be chosen based on the availability of data.

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

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

where:

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

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

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

where:

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

$$G_{TOTAL,ij,t} = G_{w,ij,t} \cdot (1 + R_j) \qquad \textbf{(B.4)}$$

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

where:

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

Method 2 (stock change method)[6]

$$\Delta C_{ij,t} = (C_{2,ij} - C_{1,ij}) / T_i \cdot 44/12 \qquad \textbf{(B.6)}$$

$$C_{ij} = C_{AB,ij} + C_{BB,ij} \qquad \textbf{(B.7)}$$

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

$$C_{BB,ij} = C_{AB,ij} \cdot R_j \qquad \textbf{(B.9)}$$

where:

$\Delta C_{ij,t}$	Average annual carbon stock change due to biomass growth of living trees for stratum *i*; species *j*, tonnes CO_2 yr^{-1} for year *t*
$C_{2,ij}$	Total carbon stock in living biomass of trees for stratum *i*, species *j*, calculated at time 2; tonnes C
$C_{1,ij}$	Total carbon stock in living biomass of trees for stratum *i*, species *j*, calculated at time 1; tonnes C
T	Number of years between times 2 and 1

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[6] GPG-LULUCF Equation 3.2.3

$C_{AB,ij}$	Carbon stock in above-ground tree biomass for stratum *i*, species *j*; tonnes C
$C_{BB,ij}$	Carbon stock in below-ground tree biomass for stratum *i*, species *j*; tonnes C
A_{ij}	Area of stratum *i*, species *j*; hectare (ha)
V_{ij}	Merchantable volume of stratum *i*, species *j*; m^3 ha^{-1}
D_j	Basic wood density for species *j*; tonnes d.m. m^{-3} merchantable volume
$BEF_{2,j}$	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass for species *j*; dimensionless
CF_j	Carbon fraction for species *j*; tonnes C (tonne d.m.)$^{-1}$
R_j	Root-shoot ratio species *j*; dimensionless

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

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

$$C_{AB,ij} = \sum_{l=1}^{N_{ij}} f_j(DBH_{ijl}, H_{ijl}) \cdot CF_j \cdot 0.001 \qquad \textbf{(B.10)}$$

where:

$C_{AB,ij}$	Carbon stock in above-ground tree biomass for stratum *i*, species *j*; tonnes C
N_{ij}	Number of trees of species *j* in stratum *i*; dimensionless
$f_j\ (DBH_{ijl}, H_{ijl})$	Allometric equation linking above-ground biomass of living trees (kg d.m. tree^{-1}) to mean diameter at breast height (*DBH*) and possibly tree height (*H*) for species *j*
l	Sequence number of tree species *j* in stratum *i*; dimensionless
CF_j	Carbon fraction for species *j*; tonnes C (tonne d.m.)$^{-1}$
0.001	Conversion factor from kilograms to tonnes

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

(a) Existing local and species-specific;

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

(c) Species-specific from neighbouring countries with similar conditions. In the case of a large country that encompasses very different biome types, c) might be preferable to (b);

(d) Globally species-specific (e.g. GPG-LULUCF, IPCC 2006 Guideline for AFOLU).

If species-specific information is unavailable, information for similar species (e.g., shape of trees, broadleaved vs. deciduous etc) can be used, with data source priority as listed for species specific information.

When choosing from global or national databases because local data are limited, it shall be confirmed with any available local data that this choice of values does not lead to underestimating the baseline net GHG removals by sinks, as far as can be judged. Local data used for confirmation may be drawn from the literatures and local forestry inventory or measured directly by PPs especially for *BEF* and root-shoot ratios that are age- and species- dependent.

Attention should be given to the fact that trees under the baseline scenario are trees outside forest and the biomass expansion factors (BEF_2) for trees outside forest are generally higher than for forest trees. If BEF_2 from forests are used, the baseline net removals by sinks are subjected to be underestimated. Therefore, in case BEF_2 for trees outside forests are unavailable, to be conservative, the BEF_2 from forest trees shall be enlarged by 50%.

6. Additionality

This methodology uses the latest version of the "Tool for the demonstration and assessment of additionality for afforestation and reforestation CDM project activities" approved by the CDM Executive Board,[7] or alternatively the most recent version of the "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities" may be applied to demonstrate that a proposed A/R CDM project activity is additional and not the baseline scenario.

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

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

The average annual carbon stock change in above-ground woody biomass, below-ground woody biomass and soil organic matter between two monitoring events for stratum *i*, species *j*, species *k* can be estimated as described below.

$$\Delta C_{ijk,t} = (\Delta C_{AB,ijk,t} + \Delta C_{BB,ijk,t} + \Delta C_{SOC,ijk,t}) \cdot 44/12 \qquad \textbf{(B.11)}$$

where:

$\Delta C_{ijk,t}$	Changes in carbon stock in carbon pools for stratum *i*, substratum *j*, species *k*; tonnes CO_2 yr^{-1} for year *t*
$\Delta C_{AB,ijk,t}$	Changes in carbon stock in above-ground woody biomass for stratum *i*, substratum *j*, species *k*; tonnes C yr^{-1} for year *t*
$\Delta C_{BB,ijk,t}$	Changes in carbon stock in below-ground woody biomass for stratum *i*, substratum *j*, species *k*; tonnes C yr^{-1} for year *t*
$\Delta C_{SOC,ijk,t}$	Changes in carbon stock in soil organic matter for stratum *i*, substratum *j*, species *k*; tonnes C yr^{-1} for year *t*
44/12	Ratio of molecular weights of CO_2 and carbon, dimensionless

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[7] Throughout this document, "A/R additionality tool" refers to the document approved by the Executive Board of the CDM on the CDM website: <http://cdm.unfccc.int>.

(a).1 Calculation of average annual carbon stock change in living woody biomass[8]

$$\Delta C_{AB,ijk,t} = (C_{AB,t_2,ijk} - C_{AB,t_1,ijk}) \big/ T_1 \qquad \textbf{(B.12)}$$

$$\Delta C_{BB,ijk,t} = (C_{BB,t_2,ijk} - C_{BB,t_1,ijk}) \big/ T_1 \qquad \textbf{(B.13)}$$

$$C_{AB,ijk} = C_{AB\_tree,ijk} + C_{AB\_shrub,ijk} \qquad \textbf{(B.14)}$$

$$C_{BB,ijk} = C_{BB\_tree,ijk} + C_{BB\_shrub,ijk} \qquad \textbf{(B.15)}$$

where:

$\Delta C_{AB,ijk,t}$	Changes in carbon stock in above-ground woody biomass for stratum *i*, substratum *j*, species *k*; tonnes C yr^{-1} for year *t*
$\Delta C_{BB,ijk,t}$	Changes in carbon stock in below-ground woody biomass for stratum *i*, substratum *j*, species *k*; tonnes C yr^{-1} for year *t*
$C_{AB,t_2,ijk}$	Carbon stock in above-ground woody biomass for stratum *i*, substratum *j*, species *k*, calculated at time t_2; tonnes C
$C_{AB,t_1,ijk}$	Carbon stock in above-ground woody biomass for stratum *i*, substratum *j*, species *k*, calculated at time t_1; tonnes C
$C_{BB,t_2,ijk}$	Carbon stock in below-ground woody biomass for stratum *i*, substratum *j*, species *k*, calculated at time t_2; tonnes C
$C_{BB,t_1,ijk}$	Carbon stock in below-ground woody biomass for stratum *i*, substratum *j*, species *k*, calculated at time t_1; tonnes C
$C_{AB\_tree,ijk}$	Carbon stock in above-ground biomass of trees; tonnes C
$C_{AB\_shrub,ijk}$	Carbon stock in above-ground biomass of planted shrubs; tonnes C
$C_{BB\_tree,ijk}$	Carbon stock in below-ground biomass of trees; tonnes C
$C_{BB\_shrub,ijk}$	Carbon stock in below-ground biomass of planted shrubs; tonnes C
T_1	Number of years between time t_2 and t_1 for biomass, $T_1 = t_2 - t_1$; years

(a).1.1 Planted trees

The carbon stock in above- and below-ground biomass of pre-project existing trees shall not be included in the *ex ante* estimation. Biomass Expansion Factors (*BEF*) method can be used to estimate the carbon stock in above- and below-ground biomass of living trees[9] that were planted within the A/R CDM project:

$$C_{AB\_tree,ijk} = A_{tree\_ijk} \cdot V_{tree\_ijk} \cdot D_k \cdot BEF_k \cdot CF_k \qquad \textbf{(B.16)}$$

$$C_{BB\_tree,ijk} = C_{AB\_tree,ijk} \cdot R_k \qquad \textbf{(B.17)}$$

where:

$C_{AB\_tree,ijk}$	Carbon stock in above-ground biomass of trees; tonnes C
$C_{BB\_tree,ijk}$	Carbon stock in below-ground biomass of trees; tonnes C

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[8] Refers to equation 3.2.3 in GPG-LULUCF

[9] GPG-LULUCF Equation 3.2.3

A_{tree_ijk}	Area covered by trees for stratum *i*, substratum *j*, species *k*; ha
V_{tree_ijk}	Mean merchantable/standing volume for stratum *i*, substratum *j*, and species *k*; m^3 ha^{-1}
D_k	Volume-weighted average wood density for species *k*; tonnes d.m. m^{-3} merchantable/standing volume
BEF_k	Biomass expansion factor for conversion of tree biomass of merchantable or standing volume to above-ground biomass; dimensionless
CF_k	Carbon fraction, tonnes C (tonne d.m.)$^{-1}$; IPCC default value = 0.5
R_k	Root-shoot ratio, dimensionless

(a).1.2 Planted shrubs

$$C_{AB\_shrub,ijk} = A_{shrub,ijk} \cdot f(DB,H,C,N) \cdot CF_{s,k} \qquad \textbf{(B.18)}$$

$$C_{BB\_shrub,ijk} = C_{AB\_shrub,ijk} \cdot R_{s,k} \qquad \textbf{(B.19)}$$

where:

$C_{AB\_shrub,ijk}$	Carbon stock in above-ground biomass of shrubs; tonnes C
$C_{BB\_shrub,ijk}$	Carbon stock in below-ground biomass of shrubs; tonnes C
$A_{shrub,ijk}$	Area of stratum *i*, substratum *j*, covered by shrub species *k*; hectare (ha)
$CF_{s,k}$	Carbon fraction of shrub species *k*; dimensionless
$R_{s,k}$	Root-shoot ratio of shrub species *k*; dimensionless
$f(DB,H,C,N)$	An allometric equation linking above-ground biomass (d.m. ha^{-1}) of shrubs to one or more of the variables diameter at base (DB); shrub height (H), crown area/diameter (C) and possibly number of stems (N)

The choice of methods and parameters shall be made in the same way as described in Section II. 5. The changes of diameter at base (*DB*), shrub height (*H*), crown area/diameter (*C*) and number of stems (*N*) due to forage harvest and regrowth within each harvest cycle can be obtained from literature, local yield table for planted shrubs, or surveys on similar shrub plantations that are under different stages of the harvest cycle in the vicinity. If there are no allometric equations available, or it is impossible to estimate the biomass of planted shrubs, the carbon stock change in living biomass of planted shrubs can be conservatively assumed to be zero.

(a).2. Calculation of average annual carbon stock change in soil organic matter[10]

The estimates of stock change in soil organic matter are based on the difference between an initial and final quasi-equilibrium (stable) soil C stock. The initial value is obtained from estimates for project lands before activities commence. The final value comes from a long-established forest stand of the same species, management practice and growing under conditions similar to those in the project area. A linear stock change is assumed to occur between the initial and the final soil C stock values, over a period of *T* years typically taken to reach the final soil C stock (IPCC default: 20 years). The stock change between initial and final states is divided by *T* as an estimate of the mean annual increment in mineral soil C under project conditions (see also Section 3.2.2.3.1.1 in GPG LULUCF).

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[10] Refer to GPG-LULUCF Equation 3.2.31 and Equation 3.2.32

$$\Delta SOC_{ijk,t} = (SOC_{For,ijk} - SOC_{Non-For,ij}) \cdot A_{ijk} \big/ T_{For,ijk} \quad \textbf{(B.20)}$$

where:

$\Delta SOC_{ijk,t}$	Average annual carbon stock change in soil organic matter for stratum *i*, substratum *j*, species *k*; tonnes C yr^{-1}
$SOC_{For,ijk}$	Stable soil organic carbon stock per hectare of plantation for stratum *i*, substratum *j*, species *k*; tonnes C ha^{-1}
$SOC_{Non-For,ij}$	Stable soil organic carbon stock per hectare of lands before planting for stratum *i*, substratum *j*; tonnes C ha^{-1}
A_{ijk}	Area of stratum *i*, substratum *j*, species *k*; hectare (ha)
$T_{For,ijk}$	Duration of transition from $SOC_{Non-For,ij}$ to $SOC_{For,ijk}$; year

$SOC_{For,ijk}$ should be preferably locally species- and management-specific and obtained from peer-reviewed scientific or other authoritative literatures or survey on plantations in the vicinity that better relate to species, rotation and management practices of planted forests under the project conditions, whenever possible.

If verifiable evidence (survey on similar plantations in vicinity or publications) indicates that the afforestation/reforestation would either increase or leave the soil organic carbon stock unchanged, the carbon stock changes in the soil organic matter can be conservatively assumed to be zero.

(b). GHG emissions by sources

$$GHG_{E,t} = E_{Biomassloss,t} \quad \textbf{(B.21)}$$

where:

$GHG_{E,t}$	Increase in GHG emission as a result of the implementation of the proposed A/R CDM project activity within the project boundary; tonnes CO_2-e yr^{-1} for year *t*
$E_{Biomassloss,t}$	CO_2 emissions as a result of a decrease in carbon stock in living biomass of existing non-tree vegetation, tonnes CO_2. This is an initial loss, and therefore accounted once upfront as part of the first monitoring interval, not per year

(b).1 Calculation of the decrease in carbon stock in living biomass of existing non-tree vegetation

It is assumed that all existing non-tree vegetation will disappear due to site preparation or competition from planted trees. The carbon stock in existing non-tree vegetation can be estimated using local or national data available or by direct measurement during baseline survey using method described in Section III.5.b.2 below. This is a conservative assumption because there will be some non-tree vegetation in the project scenario. Some vegetation may re-grow even if all non-tree vegetation is removed during the site preparation (overall plough). The non-tree vegetation carbon loss will be accounted once during the crediting period, as part of the first monitoring interval.

$$E_{biomassloss,t} = \sum_i A_i \cdot B_{non-tree,i} \cdot CF_{non-tree} \cdot 44/12 \quad \textbf{(B.22)}$$

where:

$E_{biomassloss,t}$	CO_2 emissions as a result of a decrease in carbon stock in living biomass of existing non-tree vegetation, tonnes CO_2. This is an initial loss, and therefore accounted once upfront as part of the first monitoring interval, not per year
A_i	Area of stratum *i*; ha
$B_{non-tree,i}$	Average non-tree biomass stock on land to be planted before the start of a proposed A/R CDM project activity for stratum *i*; tonnes d.m. ha^{-1}
$CF_{non-tree}$	Carbon fraction of dry biomass in non-tree vegetation; tonnes C (tonne d.m.)$^{-1}$
44/12	Ratio of molecular weights of CO_2 and carbon, dimensionless

(c). Actual net GHG removals by sinks

The actual net greenhouse gas removals are calculated as follows:

$$C_{ACTUAL,t} = \sum_i \sum_j \sum_k \Delta C_{ijk,t} - GHG_{E,t} \qquad \textbf{(B.23)}$$

where:

$C_{ACTUAL,t}$	Actual net greenhouse gas removals by sinks, tonnes CO_2-e yr^{-1}
$\Delta C_{ijk,t}$	Average annual carbon stock change in living biomass of trees for stratum *i*, species *j*; tonnes CO_2 yr^{-1} for year *t*
$GHG_{E,t}$	GHG emissions by sources within the project boundary as a result of the implementation of an A/R CDM project activity; tonnes CO_2-e yr^{-1} for year *t*

8. Leakage

Leakage represents the increase in GHG emissions by sources, which occurs outside the boundary of an A/R CDM project activity, and which is measurable and attributable to the A/R CDM project activity. As per the applicability conditions, the proposed A/R CDM project activity will provide at least the same amount of goods and services for local communities as in the absence of the project activity, and there is no grazing in either the project scenario or baseline scenario. As a result, leakage due to shift of pre-project activities is nil. However, to increase the income of local communities or to improve the financial revenue stream of the project, some projects may intentionally plant forage species among tree rows. The production of forage will support the raising of livestock outside the project boundary, and as a result will increase leakage emissions due to enteric fermentation and manure management outside the project boundary.

Emission sources included in or excluded from leakage in the proposed methodology are listed in Table 3 below.

Table 3: Emissions sources included in or excluded from leakage

Source	Gas	Included/ excluded	Justification / Explanation of choice
Activity displacement (grazing, fuelwood collecting)	CO_2	Excluded	As per the applicability condition of the proposed methodology, there is no grazing either in the project case or the baseline scenario, and the project can provide the same amount of goods and services as in the absence of the A/R CDM project activity
	CH_4	Excluded	
	N_2O	Excluded	

Source	Gas	Included/ excluded	Justification / Explanation of choice
Livestock fed with forage produced by the project	CO_2	Excluded	Not applicable
	CH_4	Included	Potential significant emission source
	N_2O	Included	Potential significant emission source

There is one source of the leakage covered by this methodology:

- GHG emissions from livestock fed with forage produced by the project activities (forage-fed livestock).

$$LK_t = LK_{FFL,t} \quad \textbf{(B.24)}$$

where:

LK_t	Leakage due to the increase in GHG emissions by sources outside the project boundary and attributable to the A/R CDM project activity; tonnes CO_2-e yr^{-1} for year *t*
$LK_{FFL,t}$	GHG emissions from the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*

(a). Estimation of LK_{FFL} (leakage from forage-fed livestock)

The following types of leakage of GHG emissions from forage-fed livestock are accounted for:

(a) CH_4 emissions from enteric fermentation by the forage-fed livestock;

(b) CH_4 emissions from manure management for the forage-fed livestock;

(c) N_2O emissions from manure management for the forage-fed livestock.

$$LK_{FFL,t} = LK_{CH4_{FFL,Ferm,t}} + LK_{CH4_{FFL,manure,t}} + LK_{N_2O_{FFL,manure,t}} \quad \textbf{(B.25)}$$

where:

$LK_{FFL,t}$	GHG emissions from the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*
$LK_{CH4_{FFL,Ferm,t}}$	CH_4 emissions from enteric fermentation by the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*
$LK_{CH4_{FFL,manure,t}}$	CH_4 emissions from manure management for the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*
$LK_{N_2O_{FFL,manure,t}}$	N_2O emissions from manure management for the forage-fed livestock, tonnes CO_2-e yr^{-1} for year *t*

As specified as an applicability condition, all forage produced by the project shall have a similar nutritional value and digestibility, and will support only a single livestock group with a single manure management system. If these conditions are not met, this methodology can not be used.

For *ex ante* estimates of leakage emissions, a suitable livestock group and manure management system may be specified according to knowledge of intended project activities, forage types, and local farming practices.[11] Alternatively, the forage-fed livestock group may be selected *ex ante* as

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[11] In this case, only this livestock group and manure management system can be used by farmers that utilise forage provided by the project.

the pre-project livestock group that is fed the largest amount of forage most similar to that to be produced by the project, as determined from data obtained by a survey on livestock forage feeding from households likely to be involved in the project—at least 30 households or 10% of households, whichever is greater, should be sampled. The manure management system to be used in *ex ante* emissions estimation shall be selected as the most common manure management system for the identified forage-fed livestock group. Characteristics of the forage-fed livestock group that will help select appropriate enteric CH_4 emission factors should also be identified and determined - by household survey if necessary - including, for example, mean weight, growth rate, and milk production.

(b).CH_4 emissions from enteric fermentation of forage-fed livestock ($LK_{CH4_{FFL,Ferm,t}}$)

CH_4 emissions from enteric fermentation by the forage-fed livestock can be estimated based on forage production, daily biomass intake of the fed animals, and emission factors as per IPCC GPG 2000 and IPCC 2006 Guidelines for AFOLU, using the equation below.[12]

$$LK_{CH4_{FFL,Ferm,t}} = EF_1 \cdot Population_t \cdot 0.001 \cdot GWP_{CH4} \qquad \textbf{(B.26)}$$

$$Population_t = Produc_{Forage,t} / (DBI \cdot 365) \qquad \textbf{(B.27)}$$

where:

$LK_{CH4_{FFL,Ferm,t}}$	CH_4 emissions from enteric fermentation by the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*
EF_1	Enteric CH_4 emission factor for the forage-fed livestock; kg CH_4 $head^{-1}$ yr^{-1}
$Population_t$	Equivalent number of forage-fed livestock, head for year *t*
$Produc_{Forage,t}$	Production of forage by the project in year *t*; kg d.m. yr^{-1}
DBI	Daily biomass intake for the forage-fed livestock; kg d.m. $head^{-1}$ day^{-1}
GWP_{CH_4}	Global warming potential for CH_4 (with a value of 23 for the first commitment period)
0.001	Conversion of kilograms into tonnes; dimensionless
365	Number of days per year

The production of forage can be estimated by collecting production rates from literature that represents the shrub species, climate, soil conditions and other features of the area in which the forage will be grown. The production rate can also be estimated by sampling surveys of forage crops in the vicinity that produce the same type of forage in areas with similar soil conditions.

Country-specific emission factors for enteric CH_4 emissions, which have been fully documented in peer reviewed publications or are from national GHG inventory, are preferable. Otherwise, methane emission factors can be taken from Table 10.10 and Table 10.11 in the IPCC 2006 Guidelines for AFOLU. When selecting emission factors it is important to select those from a region similar to the project area. Also, scrutinise the tabulations in Annex 10A.1 of the IPCC 2006 Guideline for AFOLU to ensure that the underlying animal characteristics such as weight, growth rate and milk production used to develop the emission factors are similar to those attained for local conditions. In particular, data collected on average annual milk production by dairy cows

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[12] Refers to equation 10.19 and equation 10.20 in AFLOU volume of the IPCC 2006 Guidelines or equation 4.12 and equation 4.13 in GPG 2000 for agriculture.

should be used to help select a dairy cow emission factor. Data that have been fully documented in peer reviewed publications, or are from national GHG inventory, may also be used. If necessary, interpolate between dairy cow emission factors shown, for example, in IPCC Annex 10A.1, using the data collected on average annual milk production per head during the household survey.

For data on daily biomass intake, preferably use local data, or applicable data that have been fully documented in peer reviewed publications or are from national GHG inventory. When selecting the value of daily biomass intake, ensure that the chosen data are applicable to both the forage types to be produced by the project and the livestock group to be supported by the forage. For examples of default data on daily biomass intake by livestock group, see Table 4 below.

Table 4: Approximate values of daily biomass intake for different livestock groups[13]

Livestock groups	Country Group	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

(b).1 CH_4 emissions from manure management for forage-fed livestock ($LK_{CH_{4FFLmanure,t}}$)

The storage and treatment of manure under anaerobic conditions will produce CH_4. These conditions occur most readily when large numbers of animals are managed in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms), and where manure is disposed of in liquid-based systems. The main factors affecting CH_4 emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed. When manure is stored or treated as a liquid (e.g. in lagoons, ponds, tanks, or pits), it decomposes anaerobically and can produce a significant quantity of CH_4. The temperature and the retention time of storage greatly affect the amount of methane produced. When manure is handled as a solid (e.g. in stacks or piles), or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less CH_4 is produced.

CH_4 emissions from manure management for the forage-fed livestock can be estimated using IPCC methods:[14]

$$LK_{CH_{4FFL,manure,t}} = EF_2 \cdot Population_t \cdot 0.001 \cdot GWP_{CH4} \qquad \textbf{(B.28)}$$

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[13] Data from AR-AM0003/version 2.

[14] Refers to equation 10.22 in AFLOU volume of the IPCC 2006 Guidelines or equation 4.15 in GPG 2000 for agriculture.

where:

$LK_{CH_{4FFL,manure,t}}$	CH_4 emissions from manure management for the forage-fed livestock; tonnes CO_2-e yr^{-1} for *year t*
$Population_t$	Equivalent number of forage-fed livestock supported by the project, head for year *t*
EF_2	Manure management CH_4 emission factor for the forage-fed livestock; kg CH_4 head^{-1} yr^{-1}
GWP_{CH_4}	Global warming potential for CH_4 (with a value of 23 for the first commitment period)
0.001	Conversion of kilograms into tonnes, dimensionless

The best estimates of emissions will usually be obtained using country-specific emission factors that have been fully documented in peer-reviewed publications or are from national GHG inventory. It is recommended that country-specific emission factors be used that reflect the actual duration of storage and type of treatment of animal manure in the management system used. If appropriate country-specific emission factors are unavailable, default emission factors presented in Table 10.14–10.16 of the IPCC 2006 Guidelines for AFOLU may be used. These emission factors represent those for a range of livestock types and associated manure management systems, by regional management practice and temperature. When selecting a default factor, be sure to consult the supporting tables in Annex 10A.2 of IPCC 2006 Guidelines for AFOLU, for the distribution of manure management systems and animal waste characteristics used to estimate emissions. Select an emission factor for a region that most closely matches the circumstances of the livestock that are fed forage from the project.

(b).2 N_2O emissions from manure management for forage-fed livestock ($LK_{N_2O_{FFL,manure,t}}$)

Nitrous oxide emissions from manure management vary significantly between the type of management system used, and can also result in indirect emissions due to other forms of nitrogen loss from the system. As specified by an applicability condition, forage produced by the project must support only one livestock group and the group must have a single manure management system. The N_2O emissions from manure management for the forage-fed livestock supported by the project can be estimated using methods provided in the IPCC 2006 Guidelines for AFOLU, or in IPCC GPG 2000[15]:

$$LK_{N_2O_{FFL,manure,t}} = LK_{Direct\_N_2O,manure,t} + LK_{Indirect\_N_2O,manure,t} \quad \textbf{(B.29)}$$

$$LK_{Direct\_N_2O_{FFL,manure,t}} = Population_t \cdot Nex \cdot EF_3 \cdot 0.001 \cdot 44/28 \cdot GWP_{N_2O} \quad \textbf{(B.30)}$$

$$LK_{Direct\_N_2O_{FFL,manure,t}} = Population_t \cdot Nex \cdot Frac_{Gas} \cdot EF_4 \cdot 0.001 \cdot 44/28 \cdot GWP_{N_2O} \quad \textbf{(B.31)}$$

where:

$LK_{N_2O_{FFL,manure,t}}$	N_2O emissions from manure management for the forage-fed livestock, tonnes CO_2-e yr^{-1} for year *t*
$LK_{Direct\_N_2O_{FFL,manure,t}}$	Direct N_2O emissions from manure management for the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*

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[15] Refers to equations 10.25, 10.26 and 10.27 in AFLOU volume of the IPCC 2006 Guidelines and/or equation 4.18 in GPG 2000 for agriculture.

$LK_{Indirect\_N_2O_{FFL,manure,t}}$	Indirect N_2O emissions from manure management for the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*
$Population_t$	Equivalent number of forage-fed livestock, head, for *year t*
Nex	Annual average N excretion per head for the forage-fed livestock; kg N $head^{-1}$ yr^{-1}
EF_3	Emission factor for direct N_2O emission from manure management for the forage-fed livestock; kg N_2O-N $(kg\ N)^{-1}$
EF_4	Emission factor for N_2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces, kg N_2O-N (kg NH_3-N and NOx-N $emitted)^{-1}$. Use of the IPCC default factor of 0.01 is recommended
$Frac_{Gas}$	Fraction of managed livestock manure nitrogen that volatilises as NH_3 and NOx in the manure management phase for the forage-fed livestock; kg NH_3-N and NOx-N $(kg\ N)^{-1}$
GWP_{N_2O}	Global Warming Potential for N_2O (= 310 in the 1st C.P.)
44/28	Conversion of (N_2O-N) emissions to N_2O emissions, dimensionless
0.001	Conversion of kilograms to tonnes, dimensionless

Annual nitrogen excretion rates must be determined for the forage-fed livestock group supported by the project. The best estimates of excretion rates will usually be obtained using country-specific rates that have been fully documented in peer-reviewed publications or are from national GHG inventory. If country-specific data cannot be collected or derived, or appropriate data are not available from another country, default nitrogen excretion rates presented in Table 10.19 of IPCC 2006 Guidelines for AFOLU can be used.

The best estimates of emissions will usually be obtained using country-specific emission factors that have been fully documented in peer-reviewed publications or are from national GHG inventory. It is recommended to use country-specific emission factors that reflect the actual duration of storage and type of treatment of animal manure in the management system that is used. If appropriate country-specific emission factors are unavailable, the default emission factors presented in Table 10.21 and Table 11.3 of the IPCC 2006 Guidelines for AFOLU can be used. Default values for volatilization of NH_3 and NOx ($Frac_{Gas}$) in the manure management system are presented in the Table 10.22 of the IPCC 2006 Guidelines.

The default value for EF_4 in equation 10.27 of the IPCC 2006 Guidelines for AFOLU is 0.01 tonnes N_2O-N (tonnes NH_3-N and NOx-N $emitted)^{-1}$. Country-specific values for EF_4 should be used with great care because of the special complexity of transboundary atmospheric transport: instead, use of IPCC default values is recommended. This is because although specific countries may have specific measurements of N deposition and associated N_2O flux, in many cases the deposited N may not have originated in their country. Similarly, some of the N that volatilises in their country may be transported to and deposited in another country, where different conditions that affect the fraction emitted as N_2O may prevail.

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

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

$$C_{AR-CDM,t} = C_{ACTUAL,t} - C_{BSL,t} - LK_t \qquad \textbf{(B.32)}$$

where:

$C_{AR\text{-}CDM,t}$	Net anthropogenic GHG removal by sink for year *t*; tonnes CO_2-e yr^{-1}
$C_{ACTUAL,t}$	Actual net anthropogenic GHG removal by sink for year *t*; tonnes CO_2-e yr^{-1}
$C_{BSL,t}$	Baseline net greenhouse gas removals by sinks for year *t*; tonnes CO_2-e yr^{-1}
LK_t	Leakage; CO_2-e yr^{-1} for year *t*

Please see Section III.9 for the formulae to calculate net anthropogenic GHG removals by sinks for project activities using tCERs and for those using lCERs, which is based on EB 22 annex 15.

10. Uncertainties

(a). Uncertainties to be considered

To help reduce uncertainties in the accounting of emissions and removals**,** this methodology uses whenever possible the proven methods from the GPG-LULUCF, GPG-2000, and the IPCC's revised 2006 guidelines. As well, tools and guidance from the CDM Executive Board on conservative estimation of emissions and removals are also used. Despite this, potential uncertainties still arise from the choice of parameters to be used. Uncertainties arising from, for example, biomass expansion factors (*BEFs*) or wood density, would result in uncertainties in the estimation of both baseline net GHG removals by sinks and the actual net GHG removals by sinks - especially when global default values are used.

It is recommended that PPs identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances should then be obtained for these key parameters, whenever possible. These values should be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources;[16] or
- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or
- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value should be briefly noted in the CDM-AR-PDD. For any data provided by experts, the CDM-AR-PDD shall also record the experts name, affiliation, and principal qualification as an expert (e.g., that they are a member of a country's national forest inventory technical advisory group) as well as a 1-page summary CV for each expert consulted, included in an annex.

In choosing key parameters or making important assumptions based on information that is not specific to the project circumstances, such as in use of default data, PPs should select values that will lead to an accurate estimation of net GHG removals by sinks, taking into account uncertainties. If uncertainty is significant, PPs should choose data such that it tends to under-estimate, rather than over-estimate, net GHG removals by sinks.

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[16] Typically, citations for sources of data used should include: the report or paper title, publisher, page numbers, publication date etc (or a detailed web address). If web-based reports are cited, hardcopies should be included as Annexes in the CDM-AR-PDD if there is any likelihood such reports may not be permanently available.

11. Data needed for *ex ante* estimations

Table 5: Data/parameter, their vintage, geographical scale and possible data sources

Data / parameter	Description	Vintage	Data sources and geographical scale
Historical land use/cover data	Determining baseline approach Demonstrating eligibility of land	Earliest possible up to now	Publications, national or regional forestry inventory, local government, interview, PRA survey
Land use/cover map	Demonstrating eligibility of land, stratifying land area	Around 1990 and most recent date	National, regional or local forestry inventory
Satellite image	Demonstrating eligibility of land, stratifying land area	1989/1990 and most recent date	e.g. local Landsat
Landform map	Stratifying land area	Most recent date	1:100,000 or higher from local government and institutional agencies
Soil map	Stratifying land area	Most recent date	1:100,000 or higher from local government and institutional agencies
National and sectoral policies	Additionality consideration	since 1998	National and sectoral
UNFCCC decisions		1997 up to now	UNFCCC website
IRR, NPV cost benefit ratio, or unit cost of service	Indicators of investment analysis	Most recent date	Calculation based on local data
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 statistics, published data and/or survey
Operations and maintenance costs	Including costs of thinning, pruning, harvesting, replanting, fuel, transportation, repairs, fire and disease control, patrolling, administration, etc.	Most recent date, taking into account market risk	Local statistics, published data and/or survey
Transaction costs	Including costs of project preparation, validation, registration, monitoring, etc.	Most recent date	National and international
Revenues	Those from timber, fuelwood, non-wood products, with and without CER revenues, etc.	Most recent date, taking into account market risk	National or local statistics, published data and/or survey
$C_{BSL,t}$	Baseline net GHG removals by sinks for *year t*		Estimated per stratum per species
$\Delta C_{ij,BSL,t}$	Average annual carbon stock change in the absence of the project activity for year *t*		Estimated per stratum per species
T	1 to length of crediting period		Project

Data / parameter	Description	Vintage	Data sources and geographical scale
$\Delta C_{ij,t}$	Average annual carbon stock change for year *t*		Estimated per stratum per species
$\Delta C_{G,ij,t}$	Average annual increase in carbon due to biomass growth of living trees		Estimated per stratum per species
$\Delta C_{L,ij,t}$	Average annual decrease in carbon due to biomass loss of living trees		Estimated per stratum per species
A_{ij}	Area of baseline stratum *i*		Estimated per stratum per species
$G_{TOTAL,ij,t}$	Average annual increment of total dry biomass of living trees		Estimated per stratum per species
CF_j	The carbon fraction		IPCC default, national inventory, literature
44/12	Ratio of molecular weights of CO_2 and carbon		IPCC default
$G_{w,ij,t}$	Average annual above-ground dry biomass increment of living trees		Estimated per stratum per species
R_j	Root-shoot ratio		IPCC default, national inventory, literatures
$I_{v,ij,t}$	Average annual increment in merchantable volume		IPCC default, national inventory, literatures
D_j	Basic wood density		IPCC default, national inventory, literatures
$BEF_{1,j}$	Biomass expansion factor for conversion of annual net increment (including bark) in stem biomass to total above-ground tree biomass increment		IPCC default, national inventory, literatures
$C_{2,ij}$	Total carbon stock in living biomass of trees at time 2		Estimated per stratum per species
$C_{1,ij}$	Total carbon stock in living biomass of trees at time 1		Estimated per stratum per species
T	Number of years between times 2 and 1		
$C_{AB,ij}$	Carbon stock in above-ground tree biomass		Estimated per stratum per species
$C_{BB,ij}$	Carbon stock in below-ground tree biomass		Estimated per stratum per species
V_{ij}	Merchantable volume of trees		Estimated based on national or local yield table or growth curve
$BEF_{2,j}$	Biomass expansion factor for conversion of tree stem biomass to above-ground tree biomass		IPCC Guidelines, IPCC GPG-LULUCF, national inventory, local survey, literature
N_{ij}	Number of trees in baseline scenario		Sampling survey

Data / parameter	Description	Vintage	Data sources and geographical scale
$f_j(DBH,H)$	An allometric equation linking above-ground biomass of living trees (kg d.m tree^{-1}) to diameter at breast height (DBH) and possibly tree height (H)		Local survey, literature
$\Delta C_{ijk,t}$	Changes in carbon stock in carbon pools		Estimated on stratum/substratum and species basis
$\Delta C_{AB,ijk,t}$	Average annual carbon stock changes in above-ground woody biomass		Estimated on stratum/substratum and species basis
$\Delta C_{BB,ijk,t}$	Average annual carbon stock changes in below-ground woody biomass		Estimated on stratum/substratum and species basis
$\Delta C_{SOC,ijk,t}$	Average annual carbon stock changes in soil organic matter		Estimated on stratum/substratum and species basis
$C_{AB,t2,ijk}$	Carbon stock in above-ground woody biomass calculated at time t_2		Estimated on stratum/substratum and species basis
$C_{AB,\ t1,ijk}$	Carbon stock in above-ground woody biomass calculated at time t_1		Estimated on stratum/substratum and species basis
$C_{BB,t2,ijk}$	Carbon stock in below-ground woody biomass calculated at time t_2		Estimated on stratum/substratum and species basis
$C_{BB,\ t1,ijk}$	Carbon stock in below-ground biomass calculated at time t_1		Estimated on stratum/substratum and species basis
$C_{AB\_tree,ijk}$	Carbon stock in above-ground woody biomass of trees		Estimated on stratum/substratum and species basis
$C_{AB\_shrub,ijk}$	Carbon stock in above-ground biomass of planted shrubs		Estimated on stratum/substratum and species basis
$C_{BB,tree,ijk}$	Carbon stock in below-ground biomass of trees		Estimated on stratum/substratum and species basis
$C_{BB\_shrub,ijk}$	Carbon stock in below-ground biomass of planted shrubs		Estimated on stratum/substratum and species basis
T_1	Number of years between time t_2 and t_1 for biomass		
BEF_k	Species specific tree biomass expansion factor for conversion of merchantable or standing stem biomass to above-ground tree biomass	Most updated	GPG-LULUCF, IPCC 2006 Guidelines, national GHG inventory, local survey
$A_{tree,\ ijk}$	Area covered by trees in a stratum/substratum		Estimated per stratum/substratum per species

Data / parameter	Description	Vintage	Data sources and geographical scale
D_k	Biomass expansion factor for conversion of biomass of merchantable or standing volume to above-ground biomass	Most updated	GPG-LULUCF, IPCC 2006 Guidelines, national GHG inventory, local survey
V_{tree_ijk}	Mean merchantable/standing volume		Estimated per stratum per species based on local or national growth curve, yield table
CF_k	Carbon fraction	Most updated	GPG-LULUCF, IPCC 2006 Guidelines, national GHG inventory, local survey, ,per species
R_k	Root-shoot ratio of trees	Most updated	GPG-LULUCF, IPCC 2006 Guidelines, national GHG inventory, local survey, per species
$A_{shrub,ijk}$	Area covered by shrub in a stratum / substratum		Estimated per stratum/substratum per species
$CF_{s,k}$	Carbon fraction of shrub species	Most updated	National GHG inventory, literature, IPCC
$R_{s,k}$	Root-shoot ratio of shrub species	Most updated	National GHG inventory, literature, IPCC
$f(DB,H,C,N)$	Allometric equation linking above-ground biomass (d.m ha^{-1}) of shrubs to diameter at base (DB), shrub height (H), crown area/diameter (C) and possibly number of stems (N)	Most updated	National GHG inventory, literature, IPCC
$SOC_{For,ijk}$	Stable soil organic carbon stock per hectare of plantation	Most updated	IPCC Guidelines, GPG-LULUCF, national inventory, literature, species specific
$SOC_{Non\text{-}For,ij}$	Stable soil organic carbon stock per hectare of lands before planting	Most updated	IPCC Guidelines, GPG-LULUCF, national inventory, literature, species specific
$T_{For,i,j,k}$	Duration of transition from $SOC_{Non\text{-}For,ij}$ to $SOC_{For,ijk}$	Most updated	IPCC Guidelines, GPG-LULUCF, national inventory, literature, species specific
$C_{ACTUAL,t}$	Actual net greenhouse gas removals by sinks		Calculated
$GHG_{E,t}$	Increase in GHG emissions by the sources within the project boundary as a result of the implementation of an A/R CDM project activity		Calculated
$E_{biomassloss,t}$	Decrease in carbon stock in living biomass of existing non-tree vegetation		Estimated

Data / parameter	Description	Vintage	Data sources and geographical scale
$B_{non-tree,i}$	Average biomass stock on land to be planted, before the start of a proposed A/R CDM project activity		Local survey
$CF_{non-tree}$	Carbon fraction of dry biomass in non-tree vegetation	Most recent	IPCC Guidelines, GPG-LULUCF, national GHG inventory, local survey
44/28	Ratio of molecular weights of N_2O and nitrogen		Global default
GWP_{N_20}	Global warming potential for N_2O		with a value of 310 for the first commitment period (IPCC)
$\Delta B_{AB\_shrub_{ijk}}$	Annual stock change of above-ground biomass		Estimated, literatures
$LK_{FFL,t}$	GHG emissions from the forage-fed livestock		Estimated
$LK_{CH4_{FFL,Ferm,t}}$	CH_4 emissions from enteric fermentation of the forage-fed livestock to be supported by the project		Estimated
$LK_{CH_{4FFL,manure,t}}$	CH_4 emissions from manure management excreted by the forage-fed livestock		Estimated
$LK_{N_2O_{FFL,manure,t}}$	N_2O emissions from manure management excreted by the forage-fed livestock		Estimated
EF_1	CH_4 emission factor for the forage-fed livestock to be supported by the project	Most updated	GPG-2000, IPCC Guidelines, national GHG inventory
$Population_t$	Equivalent number of forage-fed livestock to be supported by the project	Most updated	Estimated
$Produc_{Forage,\ t}$	Production of forage by the project		Estimated
DBI	Daily biomass intake for the forage-fed livestock to be supported by the project, kg d.m.head^{-1}day^{-1}		National inventory, literature, IPCC default
GWP_{CH_4}	Global warming potential for CH_4		With a value of 23 for the first commitment period (IPCC default)
EF_2	Manure management CH_4 Emission factor for the forage-fed livestock supported by the project	Most updated	GPG-2000, IPCC Guidelines, national GHG inventory
$LK_{N_2O_{FFL,manure,t}}$	Direct N_2O emissions from manure management due to the forage-fed livestock		Estimated
$LK_{Inirect\_N_2O,manure}$	Indirect N_2O emissions from manure management due to the forage-fed livestock		Estimated

Data / parameter	Description	Vintage	Data sources and geographical scale
Nex	Annual average N excretion per head for the forage-fed livestock to be supported by the project	Most updated	GPG-2000, IPCC Guidelines, national GHG inventory
EF_3	Emission factor for direct N_2O emissions from manure management for the forage-fed livestock supported by the project	Most updated	GPG-2000, IPCC Guidelines, national GHG inventory
EF_4	Emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces	Most updated	GPG-2000, IPCC Guidelines, national GHG inventory
$Frac_{Gas}$	Fraction of forage-fed livestock manure nitrogen that volatilises as NH_3 and NOx under the selected manure management system for forage-fed livestock to be supported by the project	Most updated	GPG-2000, IPCC Guidelines, national GHG inventory

12. Other information

By applying the proposed methodology, the baseline will be developed in a transparent way:

- Widely available published data will be used whenever possible;
- Archives of land use/cover data from around 1990, or from the year 50 years before the start of the project, and from a most recent date before the start of a proposed A/R CDM project activity are set up and made available to the public. This will ensure that the lands to be planted are explicitly eligible for an A/R CDM project activity;
- Specific geographical positions including the coordinates of the polygons that define the boundary of each parcel of lands are recorded, archived and made available to validators and verifiers, allowing a DOE to validate and verify a proposed A/R CDM project activity;
- Land use/cover maps or satellite images / aerial photographs from around 1990, several time points in the last 50 years and most recent dates before the start of a proposed A/R CDM project activity are available, ensuring that the sites to be planted are visibly eligible to be an A/R CDM project activity;
- Supplementary surveys on historic changes of land use, land cover and land tenure will be conducted by means of field investigation, land-owner interviews, as well as collection of other data source, and made available to validators and verifiers;
- Comments of landowners/land users concerning their barriers of land use will be surveyed and made available;
- Stratification of a proposed project area will be conducted using broad, widely understood national or regional soil and ecosystem classifications, and made available.

Section III: Monitoring methodology description

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. Monitoring project boundary and project implementation

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

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

- Field survey concerning the actual boundary within which afforestation/reforestation activity has occurred, site by site;
- Measuring geographical positions (latitude and longitude of each corner of polygon sites) using GPS;
- Checking whether the actual boundary is consistent with the description in the PDD.

(b) Monitoring of forest establishment

To ensure that the planting quality conforms to the practice described in 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. For instance, no site burning during site preparation, record date, location, area, biomass removed and other measures undertaken;
- Planting: date, location, area, tree species, stand models.

(c) Monitoring of forest management

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

- Thinning: specific location, area, tree species, thinning intensity, biomass removed;
- Harvesting: harvest date, location, area, tree species, volume of biomass removed;
- Checking and confirming that harvested lands are re-planted or re-sowed in the year of harvesting or the following planting season if direct planting or seeding is used;
- Checking and ensuring that good conditions exist for natural regeneration if harvested lands are allowed to regenerate naturally;
- Survey the annual forage output;
- Monitoring of disturbances: date, location, area (GPS coordinates and remote sensing, as

applicable), tree species, type of disturbance, biomass lost, implemented corrective measures, change in the boundary of strata and stands.

2. Stratification and sampling for *ex post* calculations

(a) Stratification

See *ex ante* stratification.

(b) Sampling

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

(b).1 Determining sample size

The number of plots depends on species variation, accuracy and monitoring interval. Neyman's criterion of fixed levels of accuracy and costs in sampling, through establishing permanent monitoring plots of an A/R CDM project activity, is the most adequate statistical tool for determining the necessary number of permanent sampling plots for monitoring the project activity. The total sum of samples (n) is estimated as per a criterion of Neyman of fixed levels of accuracy and costs, according to Wenger (1984)L:[17]

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

$$n_h = n \cdot \frac{W_h \cdot s_h \Big/ \sqrt{C_h}}{\sum_{h=1}^{L} W_h \cdot s_h \Big/ \sqrt{C_h}} \qquad \textbf{(M.2)}$$

where:

L	Total number of strata
t_α	t value for a confidence level (90%)
E	Allowable error (±10% of the mean)
s_h	Standard deviation of stratum h
$n_{h\cdot}$	Number of samples per stratum that is allocated proportional to $W_h \cdot s_h \Big/ \sqrt{C_h}$.
W_h	N_h/N
N	Number of total sample units (all stratum), $N = \sum N_h$

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

N_h Number of sample units for stratum h, calculated by dividing the area of stratum *h* by area of each plot

C_h Cost to select a plot of the stratum *h*

The standard deviation of each stratum (s_h) can be determined through *ex ante* estimates of variance of carbon stock in both biomass and soil organic carbon from section II.7. The *t* value for 90% confidence is approximately equal to 1.7 when the number of sample plot is over 30. As the first step, use 1.7 as the *t* value and if the resulting n is less than 30, use the new n to get a new *t* value and conduct recalculation. This process can be repeated until the calculated *n* is stabilized. The allowable error is a value on a per-plot basis and can be estimated as ±10% of the expected mean carbon stock in biomass at the end of a rotation and in soil per plot , which can be estimated as part of the *ex ante* estimation of the actual net GHG removals by sinks described in the baseline methodology.

It is good practice to reasonably modify the sample size after the first monitoring event based on the actual variation of the carbon stock changes determined from taking the n samples.

(b).2 Locating sampling plots among strata/substrata

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

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

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

(b).3 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,[18] 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. PPs 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;

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[18] Paragraph 32 of decision 19/CP.9

- Harvesting events and rotation length: The time of monitoring and subsequent verification and certification shall not coincide with peaks in carbon stocks.[19]

(b).4 Measuring and estimating carbon stock changes over time

At each monitoring event, the growth of individual trees on plots shall be measured, and soil organic carbon shall be sampled and measured as well. Pre-existing 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 a 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, and soil carbon stock changes are estimated using Reliable Minimum Estimate (RME).

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 PPs 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 A/R 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, etc.;
    - Removal of existing institutional barriers (e.g., well-organized institutional instruments to integrate separate households and address technological and financial barriers);

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[19] Paragraph 12 of appendix B in decision 19/CP.9

- 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 usually sufficient for the purpose of baseline scenario checking. If the carbon stock in above-ground biomass at the end of the crediting period is statistically significantly higher than the carbon stock at the start of the crediting period, the baseline net GHG removals by sinks shall be re-set.

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

Table 1: Data to be collected in making decision on re-setting of baseline, in case of renewable crediting period

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	c	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	c	Start and end of the crediting period	As complete as possible	
3.4.01	Stratum ID	Stratification, map	Alpha numeric		20 years	100%	Stratum identification for baseline scenario checking
3.4.02	Carbon stock in above-ground biomass at the end of the crediting period	Calculated based on baseline plot measurement	t CO_2	c	The end of the crediting period	100% of baseline plots	Calculated based on baseline plot measurement for different strata/sub-strata
3.4.03	Carbon stock in above-ground biomass at the start of the crediting period	Calculated based on baseline plot measurement	t CO_2	c	The start of the crediting period	100% of baseline plots	Calculated based on baseline plot measurement for different strata/sub-strata
3.4.04	Baseline carbon stock change in above-ground biomass over the crediting period	Calculated	t CO_2-e yr^{-1}	c	20 years	100%	Calculated from 3.4.02 and 3.4.03

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

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

$$\Delta C_{ACTUAL,t} = \sum_i \sum_j \sum_k \Delta C_{ijk,t} - GHG_{E,t} \tag{M.3}$$

where:

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

Note: In the equations of this monitoring methodology, sub-strata represent age class (planting time). In case all trees are planted within a single year, sub-strata are not needed.

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

Since carbon stock changes in pools of litter and dead wood are ignored in this methodology, the verifiable changes in carbon stock equal to the carbon stock changes in above-ground and below-ground woody biomass and soil organic matter within the project boundary, estimated using the following equations.[20]

$$\Delta C_{ijk,t} = (\Delta C_{AB,ijk,t} + \Delta C_{BB,ijk,t} + \Delta C_{SOC,ijk,t}) \cdot 44/12 \tag{M.4}$$

$$\Delta C_{AB,ijk,t} = (C_{AB,m_2,ijk} - C_{AB,m_1,ijk})/T \tag{M.5}$$

$$\Delta C_{BB,ijk,t} = (C_{BB,m_2,ijk} - C_{BB,m_1,ijk})/T \tag{M.6}$$

$$\Delta C_{SOC,ijk,t} = (C_{SOC,m_2,ijk} - C_{SOC,m_1,ijk})/T \tag{M.7}$$

where:

$\Delta C_{ijk,t}$	Verifiable changes in carbon stock in living woody biomass for stratum *i*, sub-stratum *j* species *k*; tonnes CO_2 yr^{-1} in year *t*
$\Delta C_{AB,ijk,t}$	Changes in carbon stock in above-ground woody biomass for stratum *i*, sub-stratum *j* species *k*; tonnes C yr^{-1} in year *t*
$\Delta C_{BB,ijk,t}$	Changes in carbon stock in below-ground woody biomass for stratum *i*, sub-stratum *j* species *k*; tonnes C yr^{-1} in *year t*
$\Delta C_{SOC,ijk,t}$	Changes in carbon stock in soil organic matter for stratum *i*, substratum *j*, species *k*; tonnes C yr^{-1} in *year t*

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[20] Refers to GPG-LULUCF Equation 3.2.3

$C_{AB,m_2,ijk}$	Carbon stock in above-ground woody biomass for stratum *i*, sub-stratum *j* species *k*, calculated at monitoring point m$_2$; tonnes C
$C_{AB,m_1,ijk}$	Carbon stock in above-ground woody biomass for stratum *i*, sub-stratum *j* species *k*, calculated at monitoring point m$_1$; tonnes C
$C_{BB,m_2,ijk}$	Carbon stock in below-ground woody biomass for stratum *i*, sub-stratum j species *k*; calculated at monitoring point m$_2$, tonnes C
$C_{BB,m_1,ijk}$	Carbon stock in below-ground woody biomass for stratum *i*, sub-stratum j species *k*, calculated at monitoring point m$_1$; tonnes C
$C_{SOC,m_2,ijk}$	Carbon stock in soil organic matter for stratum *i*, substratum *j*, species *k*, calculated at time m$_2$; tonnes C
$C_{SOC,m_1,ijk}$	Carbon stock in soil organic matter for stratum *i*, substratum *j*, species *k*, calculated at time m$_1$; tonnes C
44/12	Ratio of molecular weights of carbon and CO$_2$; dimensionless
T	Number of years between monitoring point m$_2$ and m$_1$; which in this methodology is 5 years

(a).1 Measuring and estimating carbon stock changes in living woody biomass

The total carbon stock in living biomass in trees and planted shrubs for each stratum and sub-stratum in each monitoring point (m) is calculated from the area of each stratum and sub-stratum and mean carbon stock in above-ground woody biomass and below-ground woody biomass per unit area, given by:

$$C_{AB,m,ijk} = C_{AB\_tree,m,ijk} + C_{AB\_shrub,m,ijk} \qquad \textbf{(M.8)}$$

$$C_{BB,m,ijk} = C_{BB\_tree,m,ijk} + C_{BB\_shrub,m,ijk} \qquad \textbf{(M.9)}$$

where:

$C_{AB,m,ijk}$	Carbon stock in above-ground woody biomass at monitoring point m, tonnes C
$C_{AB\_tree,m,ijk}$	Carbon stock in above-ground biomass of trees at monitoring point m, tonnes C
$C_{AB\_shrub,m,ijk}$	Carbon stock in above-ground biomass of planted shrubs, tonnes C
$C_{BB,m,ijk}$	Carbon stock in below-ground woody biomass at monitoring point m, tonnes C
$C_{BB\_tree,m,ijk}$	Carbon stock in below-ground biomass of trees at monitoring point m, tonnes C
$C_{BB\_shrub,m,ijk}$	arbon stock in below-ground biomass of planted shrubs at monitoring point m, tonnes C

(a).1.1 Planted trees

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

$$C_{AB\_tree,m,ijk} = A_{ijk} \cdot MC_{AB\_tree,m,ijk} \qquad \textbf{(M.10)}$$

$$C_{BB\_tree,m,ijk} = A_{ijk} \cdot MC_{BB\_tree,m,ijk} \qquad \textbf{(M.11)}$$

where:

$C_{AB\_tree,m,ijk}$	Carbon stock in above-ground biomass of trees at monitoring point *m*; tonnes C
$C_{BB\_tree,m,ijk}$	Carbon stock in below-ground biomass of trees at monitoring point *m*; tonnes C
A_{ijk}	Area of stratum *i*, sub-stratum *j*, species *k*; hectare (ha)
$MC_{AB\_tree,m,ijk}$	Mean carbon stock in above-round tree biomass per unit area for stratum *i*, sub-stratum *j*, tree species *k*; tonnes C ha^{-1}
$MC_{BB\_tree,m,ijk}$	Mean carbon stock in below-round tree biomass per unit area for stratum *i*, sub-stratum *j,* tree species *k*; tonnes C ha^{-1}

The mean carbon stock in above-round biomass and below-round biomass of living trees per unit area is estimated based on field measurements on permanent plots. This can be estimated using two methods, i.e., Biomass Expansion Factors (*BEF*) method and Allometric Equations method. However, the measurement and *ex post* estimation shall not include pre-project trees. Since pre-project trees will not always be obviously distinguishable from those planted as part of the project, such trees shall be marked using permanent marker before or at the same time of planting.

BEF Method

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

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

Step 3: Choosing *BEF* and root-shoot ratio: The *BEF* and root-shoot ratio vary with local environmental conditions, species and age of trees, the volume of the commercial component of trees. These parameters can be determined by either developing a local regression equation or selecting from national inventory, Annex 3A.1 Table 3A.1.10 of GPG LULUCF, updated values in IPCC 2006 Guidelines for AFOLU, or from published sources. If a significant amount of effort is required to develop local *BEFs* and root-shoot ratio, involving, for instance, harvest of trees, then it is recommended not to use this method but rather to use the resources to develop local allometric equations as described in the allometric method below (refers to Chapter 4.3 in GPG LULUCF). If that is not possible either, national species specific defaults are for *BEF* and *R* can be used. Since both *BEF* and the root-shoot ratio are age dependent, it is desirable to use age-dependent equations. Stemwood volume can be very small in young stands and *BEF* can be very large, while for old stands *BEF* is usually significantly smaller. Therefore using average *BEF* value may result in significant errors for both young stands and old stands. It is preferable to use allometric equations, if the equations are available, and as a second best solution, to use age-dependent *BEFs* (but for very young trees, multiplying a small number for stemwood with a large number for the *BEF* can result in significant error).

Step 4: Converting the volume of the commercial component of trees into carbon stock in above-ground biomass and below-ground biomass via basic wood density, *BEF* root-shoot ratio and carbon fraction, given by[21]:

$$C_{AB\_tree} = V \cdot D \cdot BEF \cdot CF \qquad \textbf{(M.12)}$$

$$C_{BB\_tree} = MC_{AB\_tree} \cdot R \qquad \textbf{(M.13)}$$

where:

C_{AB_tree}	Carbon stock in above-ground biomass of each tree on plot; tonnes C tree^{-1}
C_{BB_tree}	Carbon stock in below-ground biomass of each tree on plot; tonnes C tree^{-1}
V	Merchantable volume of trees; m^3 tree^{-1}
D	Volume-weighted average wood density; tonnes d.m.m^{-3} merchantable volume
BEF	Tree biomass expansion factor for conversion of biomass of merchantable tree stem volume to above-ground tree biomass, dimensionless
CF	Carbon fraction, tonnes C (tonne d.m.)$^{-1}$; IPCC default value = 0.5.
R	Root-shoot ratio, dimensionless

Step 5: Calculating plot level carbon stock in above-ground and below-ground biomass of living trees:

$$C_{AB\_tree,m,ijk,p} = \sum_{l=1}^{N_{m,ijk,p}} C_{AB\_tree,m,ijk,p,l} \cdot \frac{10000}{A_p} \qquad \textbf{(M.14)}$$

$$C_{BB\_tree,m,ijk,p} = \sum_{l=1}^{N_{m,ijk,p}} C_{BB\_tree,m,ijk,p,l} \cdot \frac{10000}{A_p} \qquad \textbf{(M.15)}$$

where:

$C_{AB\_tree,m,ijk,p}$	Carbon stock in above-ground biomass of trees on plot *p* of stratum *i* sub-stratum *j* species *k* at monitoring point *m*; tonnes C ha^{-1}
$C_{BB\_tree,m,ijk,p}$	Carbon stock in below-ground biomass of trees on plot *p* of stratum *i* sub-stratum *j* species *k* at monitoring point *m*; tonnes C ha^{-1}
$C_{AB\_tree,m,ijk,p,l}$	Carbon stock in above-ground biomass of tree *l* on plot *p* of stratum *i* sub-stratum *j* species *k* at monitoring point *m*; tonnes C tree^{-1}
$C_{BB\_tree,m,ijk,p,l}$	Carbon stock in below-ground biomass of tree *l* on plot *p* of stratum *i* sub-stratum *j* species *k* at monitoring point *m*; tonnes C tree^{-1}
$N_{m,ijk,p}$	Number of trees on plot *p* of stratum *i* sub-stratum *j* species *k* at monitoring point *m*
A_p	Area of plot *p*; m^2
l	Sequence number of trees on plot *p*
10000	Conversion m^2 to hectare

Step 6: Calculating mean carbon stock in above- and below-ground biomass per unit area for each stratum/sub-stratum and tree species:

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[21] Refers to GPG LULUCF Equation 4.3.1

$$MC_{AB\_tree,m,\,ijk} = \frac{\sum_{p=1}^{P_{ijk}} C_{AB\_tree,m,\,ijk,p}}{P_{ijk}} \qquad \textbf{(M.16)}$$

$$MC_{BB\_tree,m,\,ijk} = \frac{\sum_{p=1}^{P_{ijk}} C_{BB\_tree,m,\,ijk,p}}{P_{ijk}} \qquad \textbf{(M.17)}$$

where**:**

$MC_{AB\_tree,m,ijk}$	Mean carbon stock in above-ground tree biomass per unit area for stratum *i* sub-stratum *j* tree species *k* at monitoring point *m*; tonnes C ha^{-1}
$MC_{BB\_tree,m,ijk}$	Mean carbon stock in below-ground tree biomass per unit area for stratum *i* sub-stratum *j* tree species *k* at monitoring point *m*; tonnes C ha^{-1}
$C_{AB\_tree,m,ijk,p}$	Carbon stock in above-ground biomass of trees on plot *p* of stratum *i* sub-stratum *j* species *k* at monitoring point *m*; tonnes C ha^{-1}
$C_{BB\_tree,m,ijk,p}$	Carbon stock in below-ground biomass of trees on plot *p* of stratum *i* sub-stratum *j* species *k* at monitoring point *m*; tonnes C ha^{-1}
P_{ijk}	Number of plots in stratum *i* sub-stratum *j* species *k*

Allometric method

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

Step 2: Choosing or establishing appropriate allometric equations.

$$B_{AB\_tree} = f(DBH, H) \qquad \textbf{(M.18)}$$

where:

B_{AB_tree}	Above-ground biomass of living trees; tonnes d.m. $tree^{-1}$
f(*DBH*,*H*)	Allometric equation linking above-ground tree biomass (tonnes d.m. $tree^{-1}$) to diameter at breast height (DBH) and possibly tree height (H)

The allometric equations are preferably local-derived and species-specific. When allometric equations developed from a biome-wide database, such as those in Annex 4A.2, Tables 4.A.1 and 4.A.2 of GPG LULUCF, or updated in IPCC 2006 Guidelines for AFOLU, are used, it is necessary to verify by destructively harvesting, within the project area but outside the sample plots, a few trees of different sizes and estimate their biomass and then compare against a selected equation. If the biomass estimated from the harvested trees is within about ±10% of that predicted by the equation, then it can be assumed that the selected equation is suitable for the project. If this is not the case, it is recommended to develop local allometric equations for the project use. For this, a sample of trees, representing different size classes, is destructively harvested, and its total biomass is determined. The number of trees to be destructively harvested and measured depends on the range of size classes and number of species—the greater the heterogeneity the more trees are required. If resources permit, the carbon content can be determined in the laboratory. Finally, allometric equations are constructed relating the biomass with values from easily measured variables, such as the *DBH* and total height (see Chapter 4.3 in GPG LULUCF). Also generic allometric equations can be used, as long as it can be proven that they retain a conservative approach, i.e., they underestimate carbon sequestration.

Step 3: Calculating carbon stock in living biomass of each tree on plots:

$$C_{AB\_tree} = B_{AB\_tree} \cdot CF \qquad \textbf{(M.19)}$$

$$C_{BB\_tree} = C_{AB\_tree} \cdot R \qquad \textbf{(M.20)}$$

where:

C_{AB_tree}	Carbon stock in above-ground biomass of each tree on plot; tonnes C tree^{-1}
C_{BB_tree}	Carbon stock in below-ground biomass of each tree on plot; tonnes C tree^{-1}
CF	Carbon fraction, tonnes C (tonne d.m.)$^{-1}$; IPCC default value = 0.5.
R	Root-shoot ratio, dimensionless

Step 4: Using equation (M.14) and (M.15) to estimate plot level carbon stock, followed by applying equation (M.16) and (M.17) to estimate mean carbon stock in above-ground and below-ground biomass of living trees per unit area for stratum *i* substratum *j* tree species *k* at monitoring point *m* in tonnes C ha^{-1}.

(a).1.2 Planted Shrubs

The limited precipitation usually cannot supply sufficient water for the normal growth of trees in semi-arid areas. In this case, shrubs may be planted in mixture with trees to reduce water consumption. The biomass of planted shrubs can be measured and estimated using allometric method.

Step 1: Measuring crown area (diameter), height, diameter at base of shrub and number of stems in the permanent sample plots.

Step 2: Choosing or establishing appropriate allometric equations for shrubs.

$$B_{AB\_shrub} = f(DB, H, C, N) \qquad \textbf{(M.21)}$$

where:

B_{AB_shrub}	Above-ground biomass of planted shrub, tonnes d.m. ha^{-1}
$f(DB, H, C, N)$	An allometric equation linking above-ground biomass (d.m. ha^{-1}) of shrubs (B_{AB_shrub}) to diameter at base (DB), shrub height (H), crown area/diameter (C) and number of stems (N)

Step 3: Estimating carbon stock in above-ground biomass of shrubs using selected allometric equations applied to the measurements in Step 1.

$$C_{AB\_shrub,m,ijk} = A_{shrub,ijk} \cdot B_{AB\_shrub,m,ijk} \cdot CF_{s,k} \qquad \textbf{(M.22)}$$

where:

$C_{AB\_shrub,m,ijk}$	Carbon stock in above-ground biomass of planted shrubs of stratum *i*, substratum *j*, and shrub species *k* at monitoring point m; tonnes C
$A_{shrub,ijk}$	Area of stratum *i*, substratum *j*, and shrub species *k*; hectare (ha)
$B_{AB\_shrub,m,ijk}$	Above-ground biomass of planted shrub of stratum *i*, substratum *j*, and shrub species *k* at monitoring point m; tonnes d.m. ha^{-1}
$CF_{s,k}$	Carbon fraction of shrub species *k*; dimensionless

Step 4: Estimating carbon stock in below-ground biomass and total carbon stock in biomass of planted shrubs.

$$C_{BB\_shrub,m,ijk} = C_{AB\_shrub,m,ijk} \cdot R_{s,k} \qquad \textbf{(M.23)}$$

where:

$C_{BB\_shrub,m,ijk}$	Carbon stock in below-ground biomass of planted shrubs of stratum *i*, substratum *j*, and shrub species *k* at monitoring point *m*; tonnes C
$C_{AB\_shrub,m,ijk}$	Carbon stock in above-ground biomass of planted shrubs of stratum *i*, substratum *j*, and shrub species *k* at monitoring point *m*; tonnes C
$R_{s,k}$	Root-shoot ratio of shrub species *k*, dimensionless

(a).2. Measuring and estimating carbon stock changes in soil organic matter

Step 1: Collecting the soil samples at 0-10 cm, 10-30 cm and optional 30-50 cm soil depth with a soil corer. Cores shall be taken at random located points for each species strip of trees, shrubs and intercrops in each sample plot. The number of cores for each species strip in each sample plot depends on variance of soil carbon and the volume of cores. For cores with 5 cm in diameter and 10 cm in length, five cores should be the minimum.

Step 2: The cores are then fully aggregated and mixed for respective strips of tree, shrub and intercrops to reduce the variability, and sub-samples shall be taken for respective depth and strips. If overall ploughing is applied or the disturbed area of soil surface is over 10% of the total surface area, at least five cores shall be randomly taken respectively for ploughed area and non-ploughed area for strips of tree and shrub, and mixed for ploughed and non-ploughed area, respectively.

Step 3: Sub-samples are then moved to laboratory, air dried, sieved through 2 mm sieve, and analyzed for soil organic carbon content.

Step 4: Separate cores shall be taken next to each of the carbon analysis cores. Precautions should be taken to avoid compression and disturbance. The samples are oven dried at 105^0C and weighed for bulk density determination. The bulk density equals the oven dry weight of soil in the core divided by the core volume after discounting the volume of coarse fraction of >2 mm..

Step 5: Calculating the soil organic carbon stock for each plot by multiplying the carbon concentration (percent mass), bulk density, 1 – (% volume of coarse fragments) and soil depth[22].

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[22] Refer to equation 4.3.3 in GPG-LULUCF

$$C_{SOC,m,ijk,p} = DR \cdot \sum_{l=1}^{3} (SOCC_{m,ijkl,d1} \cdot BD_{m,ijkl,d1} \cdot F_{m,ijkl,d1} \cdot Depth_l)$$
$$+ (1 - DR) \cdot \sum_{l=1}^{3} (SOCC_{m,ijkl,d2} \cdot BD_{m,ijkl,d2} \cdot F_{m,ijkl,d2} \cdot Depth_l) \qquad \textbf{(M.24)}$$

where:

$C_{SOC,m,ijk,p}$	Carbon stock in soil organic matter for stratum *i*, substratum *j*, species *k* plot *p* at monitoring point *m*; tonnes C.ha^{-1}
$SOCC_{m,ijkl,d1}$	Soil organic carbon content on disturbed area for stratum *i*, substratum *j*, species *k* and soil depth *l* at monitoring point *m*; g C (100g soil)$^{-1}$
$SOCC_{m,ijkl,d2}$	Soil organic carbon content on non-disturbed area for stratum *i*, substratum *j*, species *k* and soil depth *l* at monitoring point *m*; g C (100g soil)$^{-1}$
$BD_{m,ijkl,d1}$	Soil bulk density on disturbed area for stratum *i*, substratum *j*, species *k* and soil depth *l* at monitoring point *m*; g.cm^{-3}
$BD_{m,ijkl,d2}$	Soil bulk density on non-disturbed area for stratum *i*, substratum *j*, species *k* and soil depth *l* at monitoring point *m*; g.cm^{-3}
$Depth_l$	Sampling depth for stratum *i*, substratum *j*, species *k* and soil depth *l*; cm
$F_{m,ijkl,d1}$	1 – (% volume of coarse fragments) on disturbed area for stratum *i*, substratum *j*, species *k* and soil depth *l* at monitoring point m, to adjust the proportion of volumetric sample occupied by the coarse fragment of > 2mm; dimensionless
$F_{m,ijkl,d2}$	1 – (% volume of coarse fragments) on non-disturbed area for stratum *i*, substratum *j*, species *k* and soil depth *l* at monitoring point m, to adjust the proportion of volumetric sample occupied by the coarse fragment of > 2mm; dimensionless
DR	Disturbed ratio of surface land area during site preparation; dimensionless

Step 6: Calculating the mean soil organic carbon stock.

$$MC_{SOC,m,ijk} = \frac{\sum_{p=1}^{P_{ijk}} C_{SOC,m,ijk,p}}{P_{ijk}} \qquad \textbf{(M.25)}$$

where:

$MC_{SOC,m,ijk}$	Mean carbon stock in the soil organic matter carbon pool in stratum *i* substratum *j species k* at monitoring event *m*; tonnes C ha^{-1}.
$C_{SOC,m,ijk,p}$	Carbon stock in soil organic matter for stratum *i* substratum *j* species *k* plot *p* at monitoring point *m*; tonnes C.ha^{-1}
P_{ijk}	Number of plot in stratum *i* sub-stratum *j* species *k*

Step 7: Estimating the soil organic carbon stock change using equation (M.24) and Reliable Minimum Estimate (RME) approach.[23] Specifically, change in soil organic carbon can be estimated by comparing the mean soil organic carbon accumulation between two monitoring periods using the Reliable Minimum Estimate (RME) (Dawkins, 1957).[24] Under the RME

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[23] Refer to page 4.102-4.103 in GPG-LULUCF.

[24] Dawkins, H.C. (1957) Some results of stratified random sampling of tropical high forest. Seventh British Commonwealth Forestry Conference 7 (iii) 1-12.

approach, the monitoring results of the plots are pooled to assess the mean at monitoring interval m_2 and m_1. The change in soil carbon is calculated by subtracting the maximum estimate of the mean at monitoring time m_1 from the minimum mean estimate at monitoring *event* m_2. The resulting difference represents the minimum change in mean soil carbon with 90% confidence between the monitoring interval m_2 and m_1.

$$C_{SOC,m_2,ijk} = (MC_{SOC,m_2,ijk} - 90\% confidenceLevel) \cdot A_{ijk} \qquad \textbf{(M.26)}$$

$$C_{SOC,m_1,ijk} = (MC_{SOC,m_1,ijk} + 90\% confidenceLevel) \cdot A_{ijk} \qquad \textbf{(M.27)}$$

where:

$C_{SOC,m_2,ijk}$	Carbon stock in soil organic matter for stratum *i*, substratum *j*, species *k*, calculated at time m_2; tonnes C
$C_{SOC,m_1,ijk}$	Carbon stock in soil organic matter for stratum *i*, substratum *j*, species *k*, calculated at time m_1; tonnes C
$MC_{SOC,m_2,ijk}$	Mean carbon stock in soil organic matter per hectare for stratum *i*, substratum *j*, species *k*, calculated at time m_2; tonnes C ha^{-1}
$MC_{SOC,m_1,ijk}$	Mean carbon stock in soil organic matter per hectare for stratum *i*, substratum *j*, species *k*, calculated at time m_1; tonnes C ha^{-1}
A_{ijk}	Area of stratum *i* substratum *j* species *k*; ha

The initial soil organic carbon stock shall be sampled and estimated before the start of a proposed A/R CDM project activity, using the steps described above, respectively for each stratum.

(b). GHG emissions by sources

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

$$GHG_{E,t} = E_{Biomassloss,t} \qquad \textbf{(M.28)}$$

Where:

$GHG_{E,t}$	The increase in GHG emission as a result of the implementation of a proposed A/R CDM project activity within the project boundary; tonnes CO_2-e yr^{-1} in year *t*
$E_{Biomassloss,t}$	Decrease in carbon stock in living biomass of existing non-tree vegetation tonnes CO_2-e yr^{-1} in year *t*

(b).1 Decrease in carbon stock in living biomass of existing non-tree vegetation

It is assumed that all existing non-tree vegetation[25] will disappear due to site preparation or competition from planted trees.

Step 1: Measuring and estimating the above- and below-ground biomass of existing non-tree vegetation. This task shall be conducted before the start of project activity. For shrubs, destructive harvesting techniques can be used to measure the living biomass. A small frame (either circular or square), may be 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

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[25] Emissions due to loss of herbaceous vegetation are neglected. Please refer to guidance in paragraph 35 of EB 42 meeting report.

dry-to-wet matter ratios. These ratios are then used to convert the entire sample to oven-dry matter. An alternative approach, if the shrubs are large, is to develop local shrub allometric equations based on variables such as crown area and height or diameter at base of plant or some other relevant variable (e.g., number of stems in multi-stemmed shrubs). The equations would then be based on regressions of biomass of the shrub versus some logical combination of the independent variables. The independent variable or variables would then be measured in the sampling plots (Refers to Chapter 4.3 in GPG LULUCF).

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

$$E_{biomassloss,t} = \sum_{i} A_i \cdot B_{non-tree,i} \cdot CF_{non-tree} \cdot 44/12 \quad \forall t = 1 \qquad \textbf{(M.29)}$$

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

where:

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

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

Table 2: Data to be collected or used in order to monitor the verifiable changes in carbon stock in the carbon pools within the project boundary from the proposed A/R CDM project activity, and how this data will be archived

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.6.1.01	Stratum ID	Alpha numeric	Stratification map		Before the start of the project	100%	Each stratum has a particular combination of soil type, climate, and possibly tree species
3.6.1.02	Sub-stratum ID	Alpha numeric	Stratification map		Before the start of the project	100%	Each sub-stratum has a particular year to be planted under each stratum
3.6.1.03	Confidence level	%			Before the start of the project	100%	For the purpose of QA/QC and measuring and monitoring precision control
3.6.1.04	Precision level	%			Before the start of the project	100%	For the purpose of QA/QC and measuring and monitoring precision control
3.6.1.05	Standard deviation of each stratum			e	Before the start of the project	100%	Used for estimating numbers of sample plots of each stratum and sub-stratum
3.6.1.06	Number of sample plots			c	Before the start of the project	100%	For each stratum and sub-stratum, calculated from 3.6.1.03-3.6.1.05 using equation (1)-(2)
3.6.1.07	Sample plot ID	Alpha numeric	Project and plot map		Before the start of the project	100%	Numeric series ID will be assigned to each permanent sample plot
3.6.1.08	Plot location		Project and plot map and GPS locating	m	5 years	100%	Using GPS to locate before start of the project and at time of each field measurement
3.6.1.09	Tree species		Project design map		5 years	100%	Arranged in PDD

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.6.1.10	Age of plantation	year	Plot measurement	m	5 years	100% sampling plot	Counted since the planted year
3.6.1.12	Diameter at breast height (DBH)	cm	Plot measurement	m	5 year	100% trees in plots	Measuring at each monitoring time per sampling method
3.6.1.13	Tree height	m	Plot measurement	m	5 year	100% trees in plots	Measuring at each monitoring time per sampling method
3.6.1.14	Merchantable volume of each tree on plots	$m^3 \cdot tree^{-1}$	Calculated or plot measurement	c/m	5 year	100% of sampling plots	Calculated from 3.6.1.12 and possibly 3.6.1.13 using local-derived equations, or directly measured by field instrument
3.6.1.15	Wood density	t d.m. m^{-3}	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species-specific value have the priority
3.6.1.16	Tree biomass expansion factor (BEF)	Dimensionless	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species-specific value have the priority
3.6.1.17	Carbon fraction	t C.(t d.m.)$^{-1}$	Local, national, IPCC	e	5 year	100% of sampling plots	Local-derived and species-specific value have the priority

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.6.1.18	Root-shoot ratio	Dimensionless	Local-derived, national inventory, GPG for LULUCF	e	5 year	100% of sampling plots	Local-derived and species-specific value have the priority
3.6.1.19	Carbon stock in above-ground biomass of each tree on plots	t C tree^{-1}	Calculated from equation	c	5 year	100% of sampling plots	
3.6.1.20	Carbon stock in below-ground biomass of each tree on plots	t C tree^{-1}	Calculated from equation	c	5 year	100% of sampling plots	
3.6.1.21	Area of plot	m^2	Measurement	m	5 year	100% of sampling plots	Area of permanent sampling plot
3.6.1.22	Number of trees in each sampling plot	Alpha numeric	Measurement	m	5 year	100% of sampling plots	Area of permanent sampling plot
3.6.1.23	Carbon stock in above-ground biomass of trees on plot *p*	tonnes C ha^{-1}	Calculated	c	5 year	100% of sampling plots	
3.6.1.24	Carbon stock in below-ground biomass of trees on plot *p*	tonnes C ha^{-1}	Calculated	c	5 year	100% of sampling plots	
3.6.1.25	Mean Carbon stock in above-ground biomass per unit area per stratum per tree species	t C ha^{-1}	Calculated	c	5 year	100% of strata and sub-strata	

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.6.1.26	Mean Carbon stock in below-ground biomass per unit area per stratum per tree species	t C ha^{-1}	Calculated	c	5 year	100% of strata and sub-strata	
3.6.1.27	Area of stratum, sub-stratum and tree species	ha	Stratification map and data	m	5 year	100% of strata and sub-strata	Actual area of each stratum and sub-stratum
3.6.1.28	Carbon stock in above-ground biomass of stratum per tree species	t C	Calculated from equation (10)	c	5 year	100% of strata and sub-strata	
3.6.1.29	Carbon stock in below-ground biomass of stratum per tree species	t C	Calculated from equation (11)	c	5 year	100% of strata and sub-strata	
3.6.1.30	Crown diameter of planted shrub	m	Plot measurement	m	5 years	100% of strata and substrata plot	Measuring all shrubs at each monitoring event for all strata/substrata
3.6.1.31	Height of planted shrub	m	Plot measurement	m	5 years	100% of strata and substrata plot	Measuring all shrubs at each monitoring event for all strata/substrata
3.6.1.32	Diameter at base of planted shrub	cm	Plot measurement	m	5 years	100% of strata and substrata plot	Measuring all shrubs at each monitoring event for all strata/substrata
3.6.1.33	Number of stem for each planted shrub	numeric	Plot measurement	m	5 years	100% of strata and substrata plot	Measuring all shrubs at each monitoring event for all strata/substrata
3.6.1.34	Above-ground biomass of planted shrub per ha per stratum/substratum per species	t d.m.ha^{-1}	Calculation	c	5 years	100% of strata and substrata	

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.6.1.35	Area of planted shrubs per stratum/substratum per species	ha	Stratification map and data	m	5 years	100% of strata and substrata	Actual area for each shrub species of each stratum and substratum
3.6.1.36	Carbon fraction of each shrub species	t C.(t d.m.)$^{-1}$	Local, national, IPCC	e	Before the first monitoring	100% of shrub species	Local-derived and species-specific value have the priority
3.6.1.37	Carbon stock in above-ground biomass of planted shrub per stratum/substratum per species	t C	Calculation	c	5 years	100% of shrub species	
3.6.1.38	Root-shoot ratio of shrubs	Dimensionless	Local-derived, national inventory	e	Before the first monitoring	100% of species	Local-derived and species-specific value have the priority
3.6.1.39	Carbon stock in below-ground biomass of planted shrub per stratum/substratum per species	t C	calculation	c	5 years	100% of shrub species	
3.6.1.40	Carbon stock in above-ground biomass per stratum/substratum per species	t C	Calculated	c	5 years	100% of strata and substrata	
3.6.1.41	Carbon stock in below-ground biomass per stratum per species	t C	Calculated	c	5 years	100% of strata and substrata	

ID number	Data Variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.6.1.42	Carbon stock change in above-ground biomass of stratum per species	t C yr^{-1}	Calculated	c	5 year	100% of strata and sub-strata	
3.6.1.43	Carbon stock change in below-ground biomass of stratum per species	t C yr^{-1}	Calculated	c	5 year	100% of strata and sub-strata	
3.6.1.44	Soil organic carbon content	g C (100 g soil)$^{-1}$	Plot sampling and analyzing	m	10-20	100% of strata and substrata	Measured for under each species of each stratum and substratum
3.6.1.45	Soil bulk density	100 g soil. cm^{-3}	Plot sampling and measuring	m	10-20	100% of strata and substrata	Measured under each species of each stratum and substratum
3.6.1.46	Soil layer	cm	Plot measurement	m	10-20	100% of strata and substrata	Measured under each species of each stratum and substratum
3.6.1.47	Proportion of volumetric sample occupied by the coarse fragment of > 2mm	Dimensionless	Measurement	m	10-20	100% of strata and substrata	
3.6.1.48	Disturbed ratio of surface land area during site preparation	Dimensionless	Measurement	m	10-20	100% of strata and substrata	
3.6.1.49	Plot level soil organic carbon stock per ha, per species for each stratum and substratum	t C. ha^{-1}	Calculation	c	10-20	100% of strata and substrata	

ID number	**Data Variable**	**Data unit**	**Data source**	**Measured (m) calculated (c) estimated (e)**	**Recording frequency**	**Proportion of data monitored**	**Comment**
3.6.1.50	Mean soil organic carbon stock per ha, per species for each stratum and substratum	t C. ha^{-1}	Calculation	c	10-20	100% of strata and substrata	
3.6.1.51	Soil organic carbon stock, per species for each stratum and substratum	tC	Calculation	c	10-20	100% of strata and substrata	
3.6.1.52	Stock change in soil organic matter, per species per stratum/substratum	t C. yr^{-1}	Calculation	c	10-20	100% of strata and substrata	
3.6.1.53	Total carbon stock change	t CO_2-e yr^{-1}	Calculated	c	5 year	100% project area	

Table 3: Data to be collected or used in order to monitor the GHG emissions by the sources, measured in units of CO_2 equivalent, that are increased as a result of the implementation of the proposed A/R CDM project activity within the project boundary, and how this data will be archived

ID number	Data variable	Data unit	Data source	Measured (m) calculated (c) estimated (e)	Recording frequency	Proportion of data monitored	Comment
3.6.2.15	Area of stratum	ha	Stratification map and data	m	5 year	100% of strata and sub-strata	Actual area of each stratum and sub-stratum
3.6.2.16	Average biomass stock of non-tree vegetation on land to be planted	tonnes d.m.ha^{-1}	Site survey	m	Before planting activities	100% of strata and sub-strata	
3.6.2.17	Carbon fraction of dry biomass in non-tree vegetation	tonnes C (tonne d.m.)$^{-1}$	IPCC	e	Before planting activities	Global to local	IPCC default 0.5 can be used if local data unavailable
3.6.2.18	Decrease in carbon stock of existing non-tree vegetation due to A/R project implementation	tCO_2	Calculating	c	Before planting activities	All strata	
3.6.2.27	Total increase in GHG emission	t CO_2-e yr^{-1}		c	Annually	100%	

7. Leakage

Leakage represents the increase in GHG emissions by sources which occurs outside the boundary of an A/R CDM project activity and which is measurable and attributable to the A/R CDM project activity. The possible leakage under the applicability conditions of the proposed methodology that need to be monitored are:

GHG emissions associated with livestock fed with forage produced by project activities (forage-fed livestock). This includes CH_4 emissions due to enteric fermentation, and CH_4 and N_2O emissions due to management of manure excreted by the forage-fed livestock.

$$LK_t = LK_{FFL,t} \qquad \textbf{(M.30)}$$

where:

LK_t	Leakage due to the increase in GHG emissions by sources outside the project boundary and attributable to the A/R CDM project activity; tonnes CO_2-e yr^{-1} for year t
$LK_{FFL,t}$	GHG emissions from the forage-fed livestock; tonnes CO_2-e yr^{-1} for year t

a. Monitoring of leakage due to forage-fed livestock

To monitor and calculate the leakage of GHG emissions from forage-fed livestock, the following three GHG emissions by sources shall be monitored:

(a) CH_4 emissions from enteric fermentation by forage-fed livestock;

(b) CH_4 emissions from manure management for forage-fed livestock;

(c) N_2O emissions from manure management for forage-fed livestock.

$$LK_{FFL,t} = LK_{CH4_{FFL,Ferm,t}} + LK_{CH4_{FFL,manure,t}} + LK_{N_2O_{FFL,manure,t}} \qquad \textbf{(M.31)}$$

where:

$LK_{FFL,t}$	GHG emissions from forage-fed livestock; tonnes CO_2-e yr^{-1} for year t
$LK_{CH4_{FFL,Ferm,t}}$	CH_4 emissions from enteric fermentation by forage-fed livestock, tonnes CO_2-e yr^{-1} for year t
$LK_{CH_{4FFL,manure,t}}$	CH_4 emissions from manure management for forage-fed livestock, tonnes CO_2-e yr^{-1} for year t
$LK_{N_2O_{FFL,manure,t}}$	N_2O emissions from manure management for forage-fed livestock, tonnes CO_2-e yr^{-1} for year t

The leakage due to forage-fed livestock can be monitored and estimated as per IPCC GPG 2000 for agriculture, and the IPCC 2006 Guidelines for AFOLU.

Step 1: Establish the *ex post* forage-fed livestock group

As specified as an applicability condition, all forage produced by the project shall have a similar nutritional value and digestibility, and will support only a single livestock group with a single manure management system. If these conditions are not met, this methodology can not be used.

During *ex ante* estimates of leakage emissions, the livestock group and manure management system may have been identified according to knowledge of intended project activities, forage types, and local farming practices. Alternatively, the livestock group may have been selected *ex ante* by household survey, as the group that is fed the largest amount of forage most similar to that to be produced by the project, together with the associated manure management system for that livestock group. Regardless, no matter how the *ex ante* livestock group and manure management system were selected, an *ex post* survey of households using forage produced by the project shall be completed once every crediting period to confirm (or change as appropriate) the forage-fed livestock group and manure management system used for emissions estimates. Data shall be obtained by survey of a random sample of all households receiving forage from the project—at least 30 households or 10% of households, whichever is greater, should be sampled and data presented to substantiate selection of the forage fed livestock group and manure management system used. Characteristics of the forage-fed livestock group that will help select appropriate enteric CH_4 emission factors should also be determined/checked using data obtained during the *ex post* household survey—including, for example, mean weight, growth rate, and milk production.

Step 2: Collect data on forage production. As the forest management and other human intervention within each stratum is homogeneous (in case it is not, separate strata shall be made as per Section II.3.a), the forage production can be estimated as the forage output of each stratum per hectare, multiplied by the stratum area. As the forage production may fluctuate over the year, it is recommended to calculate the average output.

$$\text{Produc}_{Forage,t} = \sum_{i}\sum_{k} \text{Produc}_{Forage,ik,t} \cdot A_{ik} \qquad \textbf{(M.32)}$$

where:

$\text{Produc}_{Forage,t}$	Output of forage by the project, tonnes d.m. yr^{-1} in *year t*
$\text{Produc}_{Forage,ik,t}$	Output of forage by the project per hectare for stratum *i*, forage species *k*, tonnes d.m. ha^{-1} yr^{-1} in *year t*
A_{ik}	Area of stratum *i*, forage species *k*, ha

Step 3: Assuming all forage produced by the project will be consumed by the forage-fed livestock, which is a conservative approach, the equivalent population size of the livestock group fed with forage produced by the project can be calculated by:

$$Population_{t} = Produc_{Forage,t} \big/ (DBI \cdot 365) \qquad \textbf{(M.33)}$$

where:

$Population_{t}$	Equivalent number of forage-fed livestock supported by the project, head for year *t*
$Produc_{Forage,t}$	Production of forage by the project, tonnes d.m. yr^{-1} in yea*r t*
DBI	Daily biomass intake by forage-fed livestock supported by the project, kg d.m.$head^{-1}day^{-1}$
365	Number of days per year

It is preferable to determine *DBI* through household survey. At least 30 households using forage produced by the project to feed the livestock group should be randomly surveyed. The survey shall ensure that all data on daily biomass intake obtained from the survey is for livestock that are fed only on forage produced by the project. If it is not possible to complete a household survey, or forage-fed livestock also consume on a daily basis other types of forage than that produced by the project alone, *DBI* can also be chosen from Table 4 in Section II.8.b.1, or from default data provided by the GPG 2000 and the IPCC 2006 Guidelines for AFOLU.

Step 4: Determine the emission factors for each emission source for the forage-fed livestock group, including emission factors for CH_4 emissions from enteric fermentation (EF_1), emission factors for CH_4 emissions from manure management (EF_2), emission factors for direct N_2O emission from manure management (EF_3), the fraction of total annual N excretion for the livestock group for which manure is managed, and the fraction of managed livestock manure nitrogen that volatilises as NH_3 and NOx in the manure management phase. The best estimates of emissions will usually be obtained using country-specific emission factors that have been fully documented in peer-reviewed publications or are from national GHG inventory. If appropriate country-specific emission factors are unavailable, default emission factors presented in Tables 10.10, 10.11, 10.14, 10.15, 10.16, 10.21 and 11.3 of the IPCC 2006 Guidelines for AFOLU can be used. The IPCC default nitrogen excretion rates and default values for volatilization of NH_3 and NOx in manure management systems are presented in Tables 10.19 and 10.22, respectively, in the IPCC 2006 Guidelines for AFOLU.

To select default CH_4 emission factors for enteric fermentation it is important to identify the region most applicable to the project area. Scrutinise the tabulations in Annex 10A.1 of the IPCC 2006 Guidelines for AFOLU to ensure that the underlying animal characteristics such as weight, growth rate and milk production used to develop the emission factors are similar to local conditions.

When selecting a default CH_4 emission factor for manure management, be sure to consult the supporting tables in Annex 10A.2 of IPCC 2006 Guidelines for AFOLU, for the distribution of manure management systems and animal waste characteristics used to estimate emissions. Select an emission factor for a region that most closely matches that of the project circumstances.

The default value for EF_4 in equation 10.27 of the IPCC 2006 Guidelines for AFOLU is 0.01 tonnes N_2O-N (tonnes NH_3-N and NOx-N emitted)$^{-1}$. Country-specific values for EF_4 should be used with great care because of the special complexity of transboundary atmospheric transport: use of default values is recommended. This is because although specific countries may have specific measurements of N deposition and associated N_2O flux, in many cases the deposited N may not have originated in their country. Similarly, some of the N that volatilises in their country may be transported to and deposited in another country, where different conditions that affect the fraction emitted as N_2O may prevail.

Step 5: Calculate CH_4 emissions from enteric fermentation by, and CH_4 and N_2O emissions from manure management for, the forage-fed livestock using methods provided by the IPCC GPG 2000 and the IPCC 2006 Guidelines for AFOLU:

$$LK_{CH_{4\,FFL,Ferm,t}} = EF_1 \cdot Population_t \cdot 0.001 \cdot GWP_{CH_4} \quad \textbf{(M.34)}$$

$$LK_{CH_{4\,FFL,manure,t}} = EF_2 \cdot Population_t \cdot 0.001 \cdot GWP_{CH_4} \quad \textbf{(M.35)}$$

$$LK_{N_2O_{FFL,manure,t}} = LK_{Direct\_N_2O_{FFL,manure,t}} + LK_{Indirect\_N_2O_{FFL,manure,t}} \quad \textbf{(M.36)}$$

$$LK_{Direct\_N_2O_{FFL,manure,t}} = Population_t \cdot Nex \cdot EF_3 \cdot 0.001 \cdot \frac{44}{28} \cdot GWP_{N_2O} \qquad \textbf{(M.37)}$$

$$LK_{Indirect\_N_2O_{FFL,manure,t}} = Population_t \cdot Nex \cdot Frac_{Gas} \cdot EF_4 \cdot 0.001 \cdot \frac{44}{28} GWP_{N_2O} \qquad \textbf{(M.38)}$$

where:

$LK_{CH4_{FFL,Ferm,t}}$	CH_4 emissions from enteric fermentation by the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*
EF_1	Enteric CH_4 emission factor for the forage-fed livestock; kg CH_4 $head^{-1}$ yr^{-1}
$Population_t$·	Equivalent number of forage-fed livestock; head for year *t*
$LK_{CH_{4FFL,manure,t}}$	CH_4 emissions from manure management for the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*
EF_2	Manure management CH_4 emission factor for the forage-fed livestock, kg CH_4 $head^{-1}$ yr^{-1}
$LK_{Direct\_N_2O_{FFL,manure,t}}$	Direct N_2O emissions from manure management for the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*
$LK_{Indirect\_N_2O_{FFL,manure,t}}$	Indirect N_2O emissions from manure management for the forage-fed livestock; tonnes CO_2-e yr^{-1} for year *t*
Nex	Annual average N excretion per head by the forage-fed livestock; kg N $head^{-1}$ yr^{-1}
EF_3	Emission factor for direct N_2O emission from manure management for the forage-fed livestock; kg N_2O-N $(kg\ N)^{-1}$
EF_4	Emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O-N (kg NH_3-N and NOx-N $emitted)^{-1}$. Use of the IPCC default factor of 0.01 is recommended
$Frac_{Gas}$	Fraction of managed livestock manure nitrogen that volatilises as NH_3 and NOx in the manure management phase for the forage-fed livestock supported by the project, kg NH_3-N and NOx-N $(kg\ N)^{-1}$.
GWP_{CH_4}	Global Warming Potential for CH_4 (= 23 in the 1st C.P.)
GWP_{N_2O}	Global Warming Potential for N_2O (= 310 in the 1st C.P.)
$\frac{44}{28}$	Conversion of (N_2O-N) emissions to N_2O emissions, dimensionless
0.001	Conversion of kilograms into tonnes, dimensionless

Step 6: Calculate leakage emissions induced by the forage-fed livestock, using equation (M.31) above.

8. Data to be collected and archived for leakage

Table 4: Data and information that will be collected in order to monitor leakage of the proposed A/R CDM project activity

ID number	Data Variable	Data unit	Data sources	Measured (m) Calculated (c) estimated (e)	Recording Frequency	Pro-portion of data monitored	Comment
3.8.1.01	Area of each stratum and species	ha	Monitoring activity	m/c	5 years	100%	
3.8.1.02	Output of forage per hectare for different stratum and species	tonnes d.m. ha^{-1} yr^{-1}	Monitoring	c	Annually	100%	
3.8.1.03	Total output of forage	tonnes d.m. yr^{-1}	Calculation	c	Annually	100%	
3.8.1.04	Daily biomass intake for the forage-fed livestock group supported by the project	kg d.m.$head^{-1}day^{-1}$	Estimate or survey	e/m	Once	At least 30 household	If household survey is impossible, choosing value from table D
3.8.1.05	Equivalent number of forage-fed livestock supported by the project	head	Calculating	c	Annually	100%	
3.8.1.06	CH_4 emission factor for enteric fermentation the forage-fed livestock group	kg CH_4 $head^{-1}$ yr^{-1}	GPG 2000, IPCC Guidelines, national inventory	e	Before the start of project	100%	National or local value has the priority
3.8.1.07	CH_4 emissions from enteric fermentation by the forage-fed livestock	tonnes CO_2-e yr^{-1}	Calculating	c	Annually	100%	

ID number	Data Variable	Data unit	Data sources	Measured (m) Calculated (c) estimated (e)	Recording Frequency	Pro-portion of data monitored	Comment
3.8.1.08	Manure management CH_4 emission factor for the forage-fed livestock	kg CH_4 $head^{-1}$ yr^{-1}	GPG 2000, IPCC Guidelines, national inventory	e	Before the start of project	100%	National or local value has the priority
3.8.1.09	CH4 emissions from manure management for the forage-fed livestock	tonnes CO_2-e yr^{-1}	Calculating	c	Annually	100%	
3.8.1.10	Annual average N excretion per head for the forage-fed livestock	kg N $head^{-1}$ yr^{-1}	GPG 2000, IPCC Guidelines, national inventory	e	Before the start of project	100%	National or local value has the priority
3.8.1.11	Emission factor for direct N_2O emission from manure management for the forage-fed livestock	N_2O-N (kg N)$^{-1}$	GPG 2000, IPCC Guidelines, national inventory	e	Before the start of project	100%	National or local value has the priority
3.8.1.12	Fraction of managed livestock manure nitrogen that volatilises as NH_3 and NOx in the manure management phase for the forage-fed livestock	kg N_2O-N (kg NH_3-N and NOx-N emitted)$^{-1}$	GPG 2000, IPCC Guidelines, national inventory	e	Before the start of project	100%	National or local value has the priority

ID number	Data Variable	Data unit	Data sources	Measured (m) Calculated (c) estimated (e)	Recording Frequency	Pro-portion of data monitored	Comment
3.8.1.13	Emission factor for N_2O emissions from atmospheric deposition of nitrogen on soil and water surfaces	kg N_2O-N (kg NH_3-N and NOx-N emitted)$^{-1}$	GPG 2000, IPCC Guidelines	e	Before the start of project	100%	
3.8.1.14	Direct N_2O emissions from manure management for the forage-fed livestock	tonnes CO_2-e yr^{-1}	Calculating	c	Annually	100%	
3.8.1.15	Indirect N_2O emissions from manure management for the forage-fed livestock	tonnes CO_2-e yr^{-1}	Calculating	c	Annually	100%	
3.8.1.16	Direct N_2O emissions from manure management for the forage-fed livestock	tonnes CO_2-e yr^{-1}	Calculating	c	Annually	100%	
3.8.1.17	Leakage due to the forage-fed livestock	tonnes CO_2-e yr^{-1}	Calculating	c	Annually	100%	
3.8.1.18	Leakage due to the increase in GHG emissions by sources outside the project boundary	tonnes CO_2-e yr^{-1}	Calculating	c	Annually	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, following general formula can be used to calculate the net anthropogenic GHG removals by sinks of an A/R CDM project activity ($C_{AR\text{-}CDM}$), in tonnes CO_2-e yr^{-1}:

$$C_{AR-CDM,t} = \Delta C_{ACTUAL,t} - \Delta C_{BSL,t} - LK_t \qquad \textbf{(M.39)}$$

where:

$C_{AR\text{-}CDM,t}$	net anthropogenic GHG removals by sinks; tonnes CO_2-e yr^{-1} for year *t*
$\Delta C_{ACTUAL,t}$	actual net GHG removals by sinks; tonnes CO_2-e yr^{-1} for year *t*
$\Delta C_{BSL,t}$	baseline net GHG removals by sinks; tonnes CO_2-e yr^{-1} for year *t*
LK,t	leakage, tonnes CO_2-e yr^{-1} for year *t*

Ways of calculating t-CER and l-CER[26]

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

$$t - CER(t_v) = C_P(t_v) - C_B(t_v) - \sum_{0}^{t_v} E_t - \sum_{0}^{t_v} LK_t \qquad \textbf{(M.40)}$$

$$C_P(t_v) - \sum_{0}^{t_v} E_t = \sum_{1}^{t_v} \Delta C_{Actual,\,t} \qquad \textbf{(M.41)}$$

$$C_B(t_v) = \sum_{1}^{t_v} \Delta C_{BSL,\,t} \qquad \textbf{(M.42)}$$

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

$$l - CER(t_v) = \left[C_P(t_v) - C_P(t_v - \kappa)\right] - \left[C_B(t_v) - C_B(t_v - \kappa)\right] - \sum_{t_{v-\kappa}}^{t_v} E_t - \sum_{t_{v-\kappa}}^{t_v} LK_t \qquad \textbf{(M.43)}$$

$$C_P(t_v) - C_P(t_v - \kappa) - \sum_{t_{v-\kappa}}^{t_v} E_t = \sum_{t_{v-\kappa}}^{t_v} \Delta C_{Actual,\,t} \qquad \textbf{(M.44)}$$

$$C_B(t_v) - C_B(t_v - \kappa) = \sum_{t_{v-\kappa}}^{t_v} \Delta C_{BSL,\,t} \qquad \textbf{(M.45)}$$

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[26] EB 22 meeting report annex 15.

where:

$t-CER(t_v)$	t-CERs issued at year of verification t_v (t CO_2)
$l-CER(t_v)$	l-CERs issued at year of verification t_v (t CO_2)
$C_P(t_v)$	Existing carbon stocks at the year of verification t_v (t CO_2)
$C_B(t_v)$	Estimated carbon stocks of the baseline scenario at year of verification t_v (t CO_2)
E_t	Annual project emissions (t CO_2)
LK_t	Annual leakage (t CO_2)
t_v	Year of verification
κ	Time span between two verification occasions (year)

10. Uncertainties

Please see Section II. 10.

11. References

All references are quoted in footnotes.

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History of the document

Version	Date	Nature of revision(s)
03	EB 50, Annex 19 16 October 2009	Application of the guidance covered by paragraph 37 of the report of the EB 44 meeting with respect to insignificant GHG emissions from selected sources related to A/R CDM project activities.
02	EB 42, Para 35 26 September 2008	Revisions mainly in the following sections: *Section II. Baseline methodology* *7(b) GHG emissions by sources* *8 Leakage* *Section III. Monitoring* Methodology 5(b) *GHG emissions by sources* *7 Leakage* to apply the guidance provided in para 35, EB 42 meeting report regarding accounting of GHG emissions in A/R CDM project activities, from the following sources (i) fertilizer application, (ii) removal of herbaceous vegetation, and (iii) transportation. The Board agreed that emissions from these sources may be considered as insignificant.
01	EB 29, Annex 6 16 February 2007	Initial Adoption.
Decision Class: Regulatory **Document Type**: Standard **Business Function**: Methodology		