CLEAN DEVELOPMENT MECHANISM

AR-AM0014

A/R Large-scale Methodology

Afforestation and reforestation of degraded mangrove habitats

Version 03.0

Sectoral scope(s): 14

United Nations
Framework Convention on
Climate Change

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1. Introduction

1. This methodology allows afforestation and reforestation of wetland that constitutes degraded mangrove habitat. The methodology allows use of mangrove species and non-mangrove species but in case of more than 10 per cent area being covered by planting of non-mangrove species it prohibits changes in the hydrology of the project area. The methodology restricts the extent of soil disturbance in the project to be no more than 10 per cent. Project activities applying this methodology may choose to exclude or include accounting of any of the carbon pools of dead wood and soil organic carbon, but cannot include the litter carbon pool.

2. Scope, applicability, and entry into force

2.1. Scope

2. This methodology applies to afforestation and reforestation (A/R) project activities implemented in degraded mangrove habitats.

2.2. Applicability

3. This methodology is applicable under the following conditions:

   (a) The land subject to the project activity is degraded mangrove habitat;

   (b) More than 90 per cent of the project area is planted with mangrove species. If more than 10 per cent of the project area is planted with non-mangrove species then the project activity does not lead to alteration of hydrology of the project area and hydrology of connected up-gradient and down-gradient wetland area;

   (c) Soil disturbance attributable to the A/R clean development mechanism (CDM) project activity does not cover more than 10 per cent of area.[1]

4. A project activity applying this methodology shall also comply with the applicability conditions of the tools contained within the methodology and applied by the project activity.

2.3. Entry into force

5. The date of entry into force of the revision is the date of the publication of the EB 75 meeting report on 4 October 2013.

[1] For example, digging pits of size 0.50 m × 0.50 m (length × width) at a spacing of 3 m × 3 m is equal to a coverage of 2.78 per cent; continuous ploughing of land is equal to a coverage of 100 per cent.

3. Normative references

6. The following documents are indispensable for application of this methodology:[2]

   (a) Clean development mechanism project standard;

   (b) A/R methodological tools:

      (i) "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities";

      (ii) "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities";

      (iii) "Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities";

      (iv) "Estimation of non-CO_2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity";

      (v) "Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity".

4. Definitions

7. The definitions contained in the following documents shall apply:[3]

   (a) "Glossary of CDM terms";

   (b) "Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism (A/R CDM modalities and procedures) as contained in the annex to decision 5/CMP.1";

   (c) "IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry, 2003".

8. For the purpose of this methodology, the following specific definitions also apply:

   (a) **Degraded mangrove habitat -** refers to wetlands where, in their natural state, mangrove vegetation can grow and have soil or sediment that is usually water-logged with water that is saline or brackish, and that were subjected to impacts resulting in decrease of forest cover below that reported by the host Party to the Executive Board (hereinafter referred to as the Board) of the CDM according to paragraph 8 of annex to the decision 5/CMP.1 (A/R CDM modalities and procedures);

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[2] These documents are available online at: http://cdm.unfccc.int/Reference/index.html

[3] These documents are available online at the following URLs:

(a) <http://cdm.unfccc.int/Reference/index.html>;

(b) <http://cdm.unfccc.int/Reference/COPMOP/index.html>;

(c) <http://www.ipcc nggip.iges.or.jp/public/gpglulucf/gpglulucf.html>.

(b) **Soil disturbance -** refers to any activity that results in a decrease in soil organic carbon (SOC), for example ploughing, ripping, scarification, digging of pits and trenches, stump removal, etc.

5. Baseline and monitoring methodology

5.1. Selection of carbon pools and greenhouse gases accounted

9. The carbon pools selected for accounting of carbon stock changes are shown in table 1.

Table 1. Carbon pools selected for accounting of carbon stock changes

Carbon pool	Whether selected	Justification/Explanation
Above-ground biomass	Yes	This is the major carbon pool subjected to project activity
Below-ground biomass	Yes	Carbon stock in this pool is expected to increase due to the implementation of the project activity
Litter	No	Litter biomass is subjected to high turnover and displacement due to tidal currents. It is a conservative choice to exclude the pool from accounting because the project activity will not decrease the rate of accumulation of litter
Dead wood and Soil organic carbon	Optional	Carbon stock in these pools may increase due to implementation of the project activity

10. The emission sources and associated greenhouse gases (GHGs) selected for accounting are shown in table 2.

Table 2. Emission sources and GHGs selected for accounting

Sources	Gas	Whether Selected	Justification/Explanation
Burning of woody biomass	CO_2	No	CO_2 emissions due to burning of biomass are accounted as a change in carbon stock
	CH_4	Yes	Burning of woody biomass for the purpose of site preparation, or as part of forest management, is allowed under this methodology
	N_2O	Yes	Burning of woody biomass for the purpose of site preparation, or as part of forest management, is allowed under this methodology

5.2. Identification of the baseline scenario and demonstration of additionality

11. Project participants (PPs) shall identify the baseline and demonstrate that the project activity is additional by selecting one of the following options:

(a) Applying the "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities"; or

(b) Applying an approved standardized baseline appropriate to their project.

5.3. Stratification

12. If biomass distribution over the project area is not homogeneous, stratification should be carried out to improve the precision of biomass estimation. Different stratifications may be appropriate for the baseline and project scenarios in order to achieve optimal precision of estimation of net GHG removals by sinks. In particular:

(a) For baseline net GHG removals by sinks, it is usually sufficient to stratify the area according to major vegetation types and their crown cover and/or land use types;

(b) For actual net GHG removals by sinks the stratification for ex ante estimations is based on the project planting/management plan and the stratification for ex post estimations is based on the actual implementation of the project planting/management plan. If natural or anthropogenic impacts (e.g. local fires) or other factors (e.g. soil type) significantly alter the pattern of biomass distribution in the project area, then the ex post stratification is revised accordingly.

5.4. Baseline net GHG removals by sinks

13. The baseline net GHG removals by sinks shall be calculated as follows:

$$\Delta C_{BSL,t} = \Delta C_{TREE\_BSL,t} + \Delta C_{SHRUB\_BSL,t} + \Delta C_{DW\_BSL,t} \quad \text{Equation (1)}$$

Where:

$\Delta C_{BSL,t}$	=	Baseline net GHG removals by sinks in year *t*; t CO_2-e
$\Delta C_{TREE\_BSL,t}$	=	Change in carbon stock in baseline tree biomass within the project boundary in year *t*, as estimated in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO_2-e
$\Delta C_{SHRUB\_BSL,t}$	=	Change in carbon stock in baseline shrub biomass within the project boundary, in year *t*, as estimated in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO_2-e
$\Delta C_{DW\_BSL,t}$	=	Change in carbon stock in baseline dead wood biomass within the project boundary, in year *t*, as estimated in the tool "Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities"; t CO_2-e

5.5. Actual net GHG removals by sinks

14. GHG emissions resulting from removal of herbaceous vegetation, combustion of fossil fuel, fertilizer application, use of wood, decomposition of litter and fine roots of N-fixing trees, construction of access roads within the project boundary, and transportation

attributable to the project activity shall be considered insignificant and therefore accounted as zero.

15. The actual net GHG removals by sinks shall be calculated as follows:

$$\Delta C_{ACTUAL,t} = \Delta C_{P,t} - GHG_{E,t}$$ Equation (2)

Where:

$\Delta C_{ACTUAL,t}$	=	Actual net GHG removals by sinks, in year *t*; t CO_2-e
$\Delta C_{P,t}$	=	Change in the carbon stocks in project, occurring in the selected carbon pools, in year *t*; t CO_2-e
$GHG_{E,t}$	=	Increase in non-CO_2 GHG emissions within the project boundary as a result of the implementation of the A/R CDM project activity, in year *t*, as estimated in the tool “Estimation of non-CO_2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity”; t CO_2-e

16. Change in the carbon stocks in project, occurring in the selected carbon pools in year *t* shall be calculated as follows:

$$\Delta C_{P,t} = \Delta C_{TREE\_PROJ,t} + \Delta C_{SHRUB\_PROJ,t} + \Delta C_{DW\_PROJ,t} + \Delta SOC_{PROJ,t}$$ Equation (3)

Where:

$\Delta C_{P,t}$	=	Change in the carbon stocks in project, occurring in the selected carbon pools, in year *t*; t CO_2-e
$\Delta C_{TREE\_PROJ,t}$	=	Change in carbon stock in tree biomass in project in year *t*, as estimated in the tool “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities”; t CO_2-e
$\Delta C_{SHRUB\_PROJ,t}$	=	Change in carbon stock in shrub biomass in project in year *t*, as estimated in the tool “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities”; t CO_2-e
$\Delta C_{DW\_PROJ,t}$	=	Change in carbon stock in dead wood in project in year *t*, as estimated in the tool “Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities”; t CO_2-e
$\Delta SOC_{PROJ,t}$	=	Change in carbon stock in the soil organic carbon (SOC) pool within the project boundary, in year *t*; t CO_2-e

17. The change in carbon stock in the SOC pool within the project boundary, in year *t*, shall be estimated as follows:

$$\Delta SOC_{PROJ,t} = \frac{44}{12} \times \sum_{t=1}^{t} A_{PLANT,t} \times dSOC_t \times 1\ year$$ Equation (4)

Where:

$\Delta SOC_{PROJ,t}$	=	Change in SOC stock within the project boundary, in year *t*; t CO_2-e
$A_{PLANT,t}$	=	Area planted in year *t*; ha
$dSOC_t$	=	The rate of change in SOC stocks within the project boundary, in year *t*; t C ha^{-1} yr^{-}1. The following default value of is used, unless transparent and verifiable information can be provided to justify a different value: (i) $dSOC_t$= 0.50 t C ha^{-1} yr^{-1} for $t = t_{PLANT}$ to $t = t_{PLANT}$ + 20 years, where t_{PLANT} is the year in which planting takes place; (ii) $dSOC_t$ = 0 t C ha^{-1} yr^{-1} for $t > t_{PLANT}$ +20.

5.6. Leakage

18. Leakage shall be estimated as follows:

$$LK_t = LK_{AGRIC,t}$$ Equation (5)

Where:

LK_t	=	GHG emissions due to leakage, in year *t*; t CO_2-e
$LK_{AGRIC,t}$	=	Leakage due to the displacement of agricultural activities in year *t*, as estimated in the tool “Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity”; t CO_2-e

5.7. Net anthropogenic GHG removals by sinks

19. The net anthropogenic GHG removals by sinks shall be calculated as follows:

$$\Delta C_{AR-CDM,t} = \Delta C_{ACTUAL,t} - \Delta C_{BSL,t} - LK_t$$ Equation (6)

Where:

$\Delta C_{AR-CDM,t}$	=	Net anthropogenic GHG removals by sinks, in year *t*; t CO_2-e
$\Delta C_{ACTUAL,t}$	=	Actual net GHG removals by sinks, in year *t*; t CO_2-e
$\Delta C_{BSL,t}$	=	Baseline net GHG removals by sinks, in year *t*; t CO_2-e
LK_t	=	GHG emissions due to leakage, in year *t*; t CO_2-e

5.8. Calculation of tCERs and lCERs

20. The tCERs and lCERs for a verification period T = $t_2 - t_1$, (where t_1 and t_2 are the years of the start and the end, respectively, of the verification period) shall be calculated as follows:

$$tCER_{t_2} = \sum_{1}^{t_2} \Delta C_{AR-CDM,t} \qquad \text{Equation (7)}$$

$$lCER_{t_2} = \sum_{t_1+1}^{t_2} \Delta C_{AR-CDM,t} \qquad \text{Equation (8)}$$

Where:

$tCER_{t_2}$	=	Number of units of temporary Certified Emission Reductions issuable in year t_2
$lCER_{t_2}$	=	Number of units of long-term Certified Emission Reductions issuable in year t_2
$\Delta C_{AR-CDM,t}$	=	Net anthropogenic GHG removals by sinks, in year *t*; t CO_2-e
t_1, t_2	=	The years of the start and the end, respectively, of the verification period

21. If $lCER_{t_2} < 0$ then $lCER_{t_2}$ represents the number of *lCERs* that shall be replaced because of a reversal of net anthropogenic greenhouse gas removals by sinks since the previous certification.

6. Monitoring procedure

6.1. Monitoring plan

22. The monitoring plan shall provide for collection of all relevant data necessary for:

(a) Verification that the applicability conditions listed under paragraphs 3 and 4 have been met;

(b) Verification of changes in carbon stocks in the pools selected;

(c) Verification of project emissions and leakage emissions.

23. The data collected shall be archived for a period of at least two years after the end of the last crediting period of the project activity.

6.2. Monitoring of project implementation

24. Information shall be provided, and recorded in the project design document (PDD), to establish that the commonly accepted principles and practices of forest inventory and forest management in the host country are implemented. If such principles and practices

are not known or available, standard operating procedures (SOPs) and quality control/quality assurance (QA/QC) procedures for inventory operations, including field data collection and data management, shall be identified, recorded and applied. Use or adaptation of SOPs available from published handbooks, or from the “IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry 2003”, is recommended.

6.3. Precision requirements

25. For this methodology, the precision requirements are those listed in the tool “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities”.

6.4. Data requirements under the methodology

26. Description of data and parameters can be found in the tools used in this methodology.

27. Data and parameters obtained from measurement shall be monitored as required in the tools.

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Document information

Version	*Date*	*Description*
03.0	4 October 2013	EB 75, Annex 29 The revision: • Allows projects to use approved standardized baselines when applicable; • Corrects the variable relating to soil organic carbon in equation (3).
02.0.0	23 November 2012	EB 70, Annex 34 The revision: • Incorporates relevant decisions and clarifications issued by the Board up to the date of publication of the EB 69 report; • Simplifies the requirements for accounting for leakage by removing the reference to fuel wood collection, and by using the approved tool "Tool for calculation of GHG emissions due to leakage from increased use of non-renewable woody biomass attributable to an A/R CDM project activity". Due to overall modification of the document, no highlights of the changes are provided.
01.0.0	03 June 2011	EB 61, Annex 14 Initial adoption

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A/R Methodological tool

"Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities"

(Version 01)

I. SCOPE AND APPLICABILITY AND PARAMETERS

Scope

1. This tool provides a general framework and a step-wise approach to identify the baseline scenario and simultaneously demonstrates additionality in A/R CDM project activities.

2. Application of this tool allows for transparent identification of baseline scenario which further allows for conservative establishing of baseline net greenhouse gas removals by sinks for a proposed afforestation or reforestation project under the CDM.

3. Project participants proposing new baseline methodologies may incorporate this tool in their proposal. Project participants may also propose other approaches for identification of the baseline scenario and the demonstration of additionality to the Executive Board for its consideration.

4. In validating the application of this tool, Designated Operational Entities (DOEs) should assess credibility of all data, rationales, assumptions, justifications and documentation provided by project participants to support the selection of the baseline and demonstration of additionality.

Applicability conditions

The tool is applicable under the following conditions:

- Forestation of the land[1] within the proposed project boundary performed with or without being registered as the A/R CDM project activity shall not lead to violation of any applicable law even if the law is not enforced.
- This tool is not applicable to small - scale afforestation and reforestation project activities.

Parameters

5. This procedure does not use its own parameters.

II. PROCEDURE

6. Project participants shall apply the following five steps:

STEP 0. Preliminary screening based on the starting date of the A/R project activity

STEP 1. Identification of alternative scenarios

[1] In the context of this tool, forestation is used for the identification of possible land use scenarios that go beyond afforestation and reforestation as defined in the Marrakech Accords and includes the any establishment of forest through natural or artificial means.

STEP 2. Barrier analysis

STEP 3. Investment analysis (if needed)

STEP 4. Common practice analysis

The procedure is summarized in the indicative flowchart presented in Figure 1. For more specific detail regarding the individual steps, please refer to the text.

STEP 0. Preliminary screening based on the starting date of the A/R project activity

7. If project participants claim that the afforestation or reforestation CDM project activity has a starting date after 31 December 1999 but before the date of its registration, then the project participants shall:

- Provide evidence that the starting date of the A/R CDM project activity was after 31 December 1999, and
- Provide evidence that the incentive from the planned sale of CERs was seriously considered in the decision to proceed with the project activity. This evidence shall be based on (preferably official, legal and/or other corporate) documentation that was available to third parties at, or prior to, the start of the project activity.

STEP 1. Identification of alternative land use scenarios to the proposed A/R CDM project activity

8. This step serves to identify alternative land use scenarios to the proposed CDM project activity that could be the baseline scenario, through the following sub-steps:

Sub-step 1a. Identify credible alternative land use scenarios to the proposed CDM project activity

9. Identify realistic and credible land-use scenarios that would have occurred on the land within the proposed project boundary in the absence of the afforestation or reforestation project activity under the clean development mechanism (CDM)[2]. The scenarios should be feasible for the project participants or similar project developers taking into account relevant national and/or sectoral policies[3] and circumstances, such as historical land uses, practices and economic trends. The identified land use scenarios shall at least include:

- Continuation of the pre-project land use;
- Forestation of the land within the project boundary performed without being registered as the A/R CDM project activity;

[2] For example, continuation of the pre-project land-use or switch to land-use typical for region where the A/R CDM project is planned to be located, establishing agricultural plantation, tourist resort, hunting area/farm, utilizing regionally typical forms of funds investment or other economically attractive activities.

[3] The Annex 3 to the report of the EB at its twenty-second meeting and the Annex 19 to the report of the EB at its twenty-third meeting clarify how the relevant national and/or sectoral policies shall be taken into account during identification of a baseline scenario. See: http://cdm.unfccc.int/Reference/Guidclarif.

- If applicable, forestation of at least a part of the land within the project boundary of the proposed A/R CDM project at a rate resulting from[4]:
    - Legal requirements; or
    - Extrapolation of observed forestation activities in the geographical area with similar socio-economic and ecological conditions to the proposed A/R CDM project activity occurring in a period since 31 December 1989 as selected by the PPs.

10. For identifying the realistic and credible land-use scenarios; land use records, field surveys, data and feedback from stakeholders, and information from other appropriate sources, including Participatory rural appraisal (PRA)[5] may be used as appropriate. If the baseline approach selected is 22b or c, then the project shall perform a survey of local experts or land owners/users on their plans for land management/investments during the period to the project start.

11. All identified land use scenarios must be credible. All land uses within the boundary of the proposed A/R CDM project activity that are currently existing or that existed at some time since 31 December 1989 but no longer exist, may be deemed realistic and credible. For all other land use scenarios, credibility shall be justified[6]. The justification shall include elements of spatial planning information (if applicable) or legal requirements and may include assessment of economical feasibility of the proposed alternative land use scenario.

Outcome of Sub-step 1a: List of credible alternative land use scenarios that would have occurred on the land within the project boundary of the A/R CDM project activity.

Sub-step 1b. Consistency of credible alternative land use scenarios with enforced mandatory applicable laws and regulations

(This sub-step does not consider national and local policies that do not have legally-binding status and local policies that have been implemented since the adoption of the modalities and procedures for the CDM [decision 17/CP.7, 11 November 2001])

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[4] In this case, the project participants will assess the baseline rate of forestation and shall provide justification that the project will lead to an increased rate of afforestation/reforestation that would not occur in the absence of the project activity and that this results from direct intervention by the project participants. If the proposed A/R CDM project activity does not increase the rate of afforestation/reforestation, the proposed project activity is not additional.

[5] Participatory rural appraisal (PRA) is an approach to the analysis of local problems and the formulation of tentative solutions with local stakeholders. It makes use of a wide range of visualisation methods for group-based analysis to deal with spatial and temporal aspects of social and environmental problems. This methodology is, for example, described in:

- Chambers R (1992): Rural Appraisal: Rapid, Relaxed, and Participatory. Discussion Paper 311, Institute of Development Studies, Sussex.
- Theis J, Grady H (1991): Participatory rapid appraisal for community development. Save the Children Fund, London.

[6] e.g. construction of an airport is usually not a credible land use scenario in a rural region with low density population and weak road infrastructure.

12. Apply the following procedure:

- Demonstrate that all land use scenarios identified in the sub-step 1a: are in compliance with all mandatory applicable legal and regulatory requirements;
- If an alternative does not comply with all mandatory applicable legislation and regulations then show that, based on an examination of current practice in the region in which the mandatory law or regulation applies, those applicable mandatory legal or regulatory requirements are systematically not enforced and that non-compliance with those requirements is widespread, i.e. prevalent on at least 30% of area of the smallest administrative unit that encompasses the project area;
- Remove from the land use scenarios identified in the sub-step 1a, any land use scenarios which are not in compliance with applicable mandatory laws and regulations unless it can be shown these land use scenarios result from systematic lack of enforcement of applicable laws and regulations.

Outcome of Sub-step 1b: List of plausible alternative land use scenarios to the A/R CDM project activity that are in compliance with mandatory legislation and regulations taking into account the their enforcement in the region or country and EB decisions on national and/or sectoral policies and regulations.

<u>If the list resulting from the Sub-step 1b is empty or contains only one land use scenario, than the proposed A/R CDM project activity is not additional.</u>

→ ***Proceed to Step 2 (Barrier analysis)***

STEP 2. Barrier analysis

This step serves to identify barriers and to assess which of the land use scenarios identified in the sub-step 1b are not prevented by these barriers.

Sub-step 2a. Identification of barriers that would prevent the implementation of at least one alternative land use scenarios

13. Identify realistic and credible barriers that prevent realization of the land use scenarios identified in Sub-step 1b. The barriers should not be specific for the project participants, but should apply to the proposed A/R CDM project activity as such, even if similar project developers would have developed the project activity. Such barriers may include, among others:

- Investment barriers, other than insufficient financial returns as analyzed in Step 3, *inter alia*:
  - Similar activities have only been implemented with grants or other non-commercial finance terms. In this context similar activities are defined as activities of a similar scale that take place in a comparable environment with respect to regulatory framework and are undertaken in the relevant geographical area;
  - No private capital is available from domestic or international capital markets due to real or perceived risks associated with investments in the country where the A/R project activity is to be implemented, as demonstrated by the credit rating of the country or other country investment reports of reputed origin;
  - Debt funding is not available for the land-use scenarios;

- Lack of access to credit.

- Institutional barriers, *inter alia*:
  - Risk related to changes in government policies or laws;
  - Lack of enforcement of land-use-related legislation.
- Technological barriers, *inter alia*:
  - Lack of access to necessary materials, for example planting materials;
  - Lack of infrastructure for implementation of the technology.
- Barriers related to local tradition, inter alia:
  - Traditional knowledge or lack thereof, laws and customs, market conditions and practices;
  - Traditional equipment and technology.
- Barriers due to prevailing practice, *inter alia*:
  - The land use scenario is the "first of its kind": No activity of this type is currently operational in the host country or region.
- Barriers due to local ecological conditions, *inter alia*:
  - Degraded soil (e.g. water/wind erosion, salination, etc.);
  - Catastrophic natural and / or human-induced events (e.g. land slides, fire, etc);
  - Unfavourable meteorological conditions (e.g. early/late frost, drought);
  - Pervasive opportunistic species preventing land use (e.g. grasses, weeds);
  - Unfavourable course of ecological succession;
  - Biotic pressure in terms of grazing, fodder collection, etc.
- Barriers due to social conditions, *inter alia*:
  - Demographic pressure on the land (e.g. increased demand on land due to population growth);
  - Social conflict among interest groups in the region where the project takes place;
  - Widespread illegal practices (e.g. illegal grazing, non-timber product extraction and tree felling);
  - Lack of skilled and/or properly trained labour force;
  - Lack of organisation of local communities.
- Barriers relating to land tenure, ownership, inheritance, and property rights, *inter alia*:
  - Communal land ownership with a hierarchy of rights for different stakeholders limits the incentives to undertake the land-use scenarios;
  - Lack of suitable land tenure legislation and regulation to support the security of tenure;
  - Absence of clearly defined and regulated property rights in relation to natural resource products and services;

- Formal and informal tenure systems that increase the risks of fragmentation of land holdings;
- Possibilities of large price risk due to the fluctuations in the prices of products over the project period in the absence of efficient markets and insurance mechanisms;
- Barriers relating to markets, transport and storage;
- Unregulated and informal markets for products and services prevent the transmission of effective information to project participants;
- Remoteness of land area and undeveloped road and infrastructure incur large transportation expenditures, thus eroding the competitiveness and profitability of products from the land use;
- Possibilities of large price risk due to the fluctuations in the prices products over the project period in the absence of efficient markets and insurance mechanisms;
- Absence of facilities to convert, store and add value to products resulting from land use limits the possibilities to capture rents from the land use scenario.

Outcome of Step 2a: List of barriers that may prevent one or more land use scenarios identified in the Step 1b.

Sub-step 2b. Elimination of land use scenarios that are prevented by the identified barriers

14. Determine which land use scenarios identified in the Sub-step 1b are prevented by at least one of the barriers listed in sub-step 2a. Substantiate, that the barrier identified as preventing realization of a land use scenario is valid and conclusive in the context of the land use scenario in question. The assessment of a barrier may take into account the level of access to and availability of information, technologies and skilled labour in the region where the planned A/R CDM project activity is located. Eliminate these scenarios from further consideration.

15. If the land within the boundary of the proposed of the A/R CDM project activity was at least partially forested since 31 December 1989 and the land is not a forest at the project start, identify reasons/actions/incentives that allowed for the past forestation and demonstrate that the current legal/financial or other applicable regulations or socio-economical or ecological or other local conditions have changed to the extent that allows for conclusion that repetition of the forestation performed without being registered as the A/R CDM project activity is not possible.

16. Include all land use scenarios that were identified in the Sub-step 1b and were not eliminated in the Sub-step 2b into the list of land use scenarios that are not prevented by any barrier.

Outcome of Sub-step 2b: List of land use scenarios that are not prevented by any barrier.

17. In applying sub-steps 2a and 2b, provide transparent and documented evidence, and offer conservative interpretations of this documented evidence, as to how it demonstrates the existence and significance of the identified barriers. Anecdotal evidence can be included, but this alone is not sufficient proof of barriers. The type of evidence to be provided may include:

- Relevant legislation, regulatory information or environmental/natural resource-management norms, acts or rules;

- Relevant (sectoral) studies or surveys (e.g. market surveys, technology studies, etc) undertaken by universities, research institutions, associations, companies, bilateral/multilateral institutions, etc;
- Relevant statistical data from national or international statistics;
- Documentation of relevant market data (e.g. market prices, tariffs, rules);
- Written documentation from the company or institution developing or implementing the A/R CDM project activity or the A/R CDM project developer, such as minutes from Board meetings, correspondence, feasibility studies, financial or budgetary information, etc;
- Documents prepared by the project developer, contractors or project partners in the context of the proposed project activity or similar previous project implementations;
- Written documentation of independent expert judgements from agriculture, forestry and other land-use related Government / Non-Government bodies or individual experts, educational institutions (e.g. universities, technical schools, training centres), professional associations and others.

Sub-step 2c. Determination of baseline scenario (if allowed by the barrier analysis)

18. Apply the following decision tree to the outcome of sub-step 2b:

Is forestation without being registered as an A/R CDM project activity included in the list of land use scenarios that are not prevented by any barrier?

→ ***If yes, then:***

Does the list contain only one land use scenario?

→ ***If yes, then the proposed A/R CDM project activity is not additional.***

→ ***If no, then continue with Step 3: Investment analysis.***

→ ***If no, then:***

Does the list contain only one land use scenario?

→ ***If yes, then the remaining land use is the baseline scenario. Continue with Step 4: Common practice test***

→ ***If no, then through qualitative analysis, assess the removals by sinks for each scenario and select one of the following options:***

<u>Option 1</u>: Baseline scenario is the land use scenario that allows for the highest baseline GHG removals by sinks. Continue with Step 4: Common practice test, .

<u>Option 2</u>: Continue with Step 3: Investment analysis.

STEP 3. Investment analysis

19. This step serves to determine which of the remaining land use scenarios identified in the Sub-step 2b is the most economically or financially attractive. For this purpose, an investment comparison analysis is conducted.

Sub-step 3a. Determine appropriate analysis method

20. Determine whether to apply simple cost analysis, investment comparison analysis or benchmark analysis. If the planned A/R CDM project activity generates no financial or economic benefits other than CDM related income, then apply the simple cost analysis (Option I). Otherwise, use the investment comparison analysis (Option II) or the benchmark analysis (Option III). Note, that Options I, II and III are mutually exclusive hence, only one of them can be applied.

Sub-step 3b. – Option I. Apply simple cost analysis

21. Document the costs associated with the A/R CDM project activity and demonstrate that the activity generates no financial benefits other than CDM related income.

22. Document the incomes and costs associated with each of the land use scenarios that are not prevented by any barrier.

→ If at least one land use scenario that is not prevented by any barrier generates financial benefits then select as the baseline the land use scenario that allows for the highest difference between incomes and costs over the crediting period. Proceed to Sub-step 3d. Sensitivity analysis.

→ Otherwise, select as the baseline the land use scenario that allows for the highest baseline GHG removals by sinks. If the baseline is the proposed A/R CDM project activity then it is not additional. Otherwise, Proceed to Step 4. Common practice test.

Sub-step 3b. – Option II. Apply investment comparison analysis

23. Identify the financial indicator, such as IRR[7], NPV, payback period, cost benefit ratio most suitable for the project type and decision-making context.

Sub-step 3b. – Option III. Apply benchmark analysis

24. Identify a suitable financial indicator, such as IRR[8], NPV, payback period, cost benefit ratio, or other (e.g. required rate of return (RRR) related to investments in agriculture or forestry, bank deposit interest rate corrected for risk inherent to the project or the opportunity costs of land, such as any expected income from land speculation) most suitable for the project type and decision context. Identify the relevant benchmark value, such as the required rate of return (RRR) on equity. The benchmark is to represent standard returns in the market, considering the specific risk of the project type, but not linked to the subjective profitability expectation or risk profile of a particular project developer. Benchmarks can be derived from:

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[7] For the investment comparison analysis, IRRs can be calculated either as project IRRs or as equity IRRs. Project IRRs calculate a return based on project cash outflows and cash inflows only, irrespective the source of financing. Equity IRRs calculate a return to equity investors and therefore also consider amount and costs of available debt financing. The decision to proceed with an investment is based on returns to the investors, so equity IRR will be more appropriate in many cases. However, there will also be cases where a project IRR may be appropriate.

[8] For the benchmark analysis, the IRR shall be calculated as project IRR. If there is only one potential project developer (e.g. when the project activity upgrades an existing process), the IRR shall be calculated as equity IRR.

- Government bond rates, increased by a suitable risk premium to reflect private investment and/or the project type, as substantiated by an independent (financial) expert;
- Estimates of the cost of financing and required return on capital (e.g. commercial lending rates and guarantees required for the country and the type of project activity concerned), based on bankers views and private equity investors/funds' required return on comparable projects;
- A company internal benchmark (weighted average capital cost of the company) if there is only one potential project developer (e.g. when the proposed project land is owned or otherwise controlled by a single entity, physical person or a company, who is also the project developer). The project developers shall demonstrate that this benchmark has been consistently used in the past, i.e. that project activities under similar conditions developed by the same company used the same benchmark.

Sub-step 3c. Calculation and comparison of financial indicators (only applicable to options II and III):

25. Calculate the suitable financial indicator for the proposed A/R CDM project activity *without the financial benefits from the CDM* and for all the land use scenarios that are not prevented by any barrier. Include all relevant costs (including, for example, the investment cost, the operations and maintenance costs), and revenues (excluding tCER or lCERs revenues, but including subsidies/fiscal incentives where applicable), and, as appropriate, non-market cost and benefits in the case of public investors.

26. Present the investment analysis in a transparent manner and provide all the relevant assumptions in the CDM-AR-PDD, so that a reader can reproduce the analysis and obtain the same results. Clearly present critical economic parameters and assumptions (such as capital costs, lifetimes, and discount rate or cost of capital). Justify and/or cite assumptions in a manner that can be validated by the DOE. In calculating the financial indicator, the project's risks can be included through the cash flow pattern, subject to project-specific expectations and assumptions (e.g. insurance premiums can be used in the calculation to reflect specific risk equivalents).

27. Assumptions and input data for the investment analysis shall not differ across the project activity and its alternatives, unless differences can be well substantiated.

28. If **Option II** (investment comparison analysis) is used then apply the following decision tree:

Is forestation without being registered as an A/R CDM project activity included in the list of land use scenarios that are not prevented by any barrier?

→ ***If yes, then:***

> ***Has the proposed A/R CDM project activity a less favourable financial indicator (e.g. IRR), than at least one land use scenario that is not prevented by any barrier?***
>
> > → ***If yes, then select as the baseline scenario the land use scenario that allows for the highest value of the financial indicator (e.g. IRR). Proceed to Sub-step 3d. Sensitivity analysis.***
> >
> > → ***If no, then the proposed A/R CDM project activity is not additional.***

→ ***If no, then:***

> ***Select as the baseline scenario the land use scenario that allows for the highest financial indicator (e.g. IRR). Proceed to Sub-step 3d. Sensitivity analysis***

29. If **Option III** (benchmark analysis) is used then apply the following decision tree:

Is forestation without being registered as an A/R CDM project activity included in the list of land use scenarios that are not prevented by any barrier?

→ ***If yes, then:***

Has the proposed A/R CDM project activity a financial indicator (e.g. IRR) that does not meet the benchmark and at least one of the land use scenarios that are not prevented by any barrier has a financial indicator that meets the benchmark?

→ ***If yes, then select as the baseline scenario the land use scenario that meets the benchmark and allows for the most favourable financial indicator (such as IRR, NPV, cost benefit ratio). Proceed to Sub-step 3d. Sensitivity analysis.***

→ ***If no, then***

→ ***If the financial indicator of the A/R CDM project activity meets the benchmark, then the proposed A/R CDM project activity is not additional.***

→ ***If the financial indicators of neither the A /R CDM project activity nor any of the alternatives meets the benchmark then the baseline scenario is the continuation of the pre-project land use.***

→ ***If no, then:***

Has at least one of the land use scenarios that are not prevented by any barrier the financial indicator that meets the benchmark?

→ ***If yes, then select as the baseline scenario the land use scenario that has the most favourable financial indicator (such as IRR, NPV, cost benefit ratio). Proceed to Sub-step 3d. Sensitivity analysis.***

→ ***If no, then the baseline scenario is the continuation of the pre-project land use.***

Sub-step 3d. Sensitivity analysis (for Option II and III)

30. Include a sensitivity analysis to assess whether the initial conclusion regarding the financial attractiveness of the baseline scenario is robust to reasonable variations in the critical assumptions. The investment analysis only provides a valid argument in identifying the baseline scenario and demonstrating additionality if it consistently supports (for a realistic range of assumptions) the initial conclusion of the analysis.

31. Apply the following decision tree:

Is forestation without being registered as an A/R CDM project activity included in the list of land use scenarios that are not prevented by any barrier?

→ ***If yes, then:***

Is the sensitivity analysis conclusive?

→ If yes, then the selection of baseline scenario is valid. Proceed to Step 4. Common practice test.

→ If no, then the proposed A/R CDM project activity is not additional.

→ If no, then:

Is the sensitivity analysis conclusive?

→ If yes, then the selection of baseline scenario is valid. Proceed to Step 4. Common practice test.

→ If no, then select as the baseline scenario the land use, which allows for the highest baseline GHG removals by sinks. Proceed to Step 4. Common practice test.

Outcome of step 3: Identification of the most economically and/or financially attractive land use scenario within the boundary of the proposed A/R CDM project area according to the most suitable financial indicator, taking into account the results of the sensitivity analysis.

STEP 4. Common practice analysis

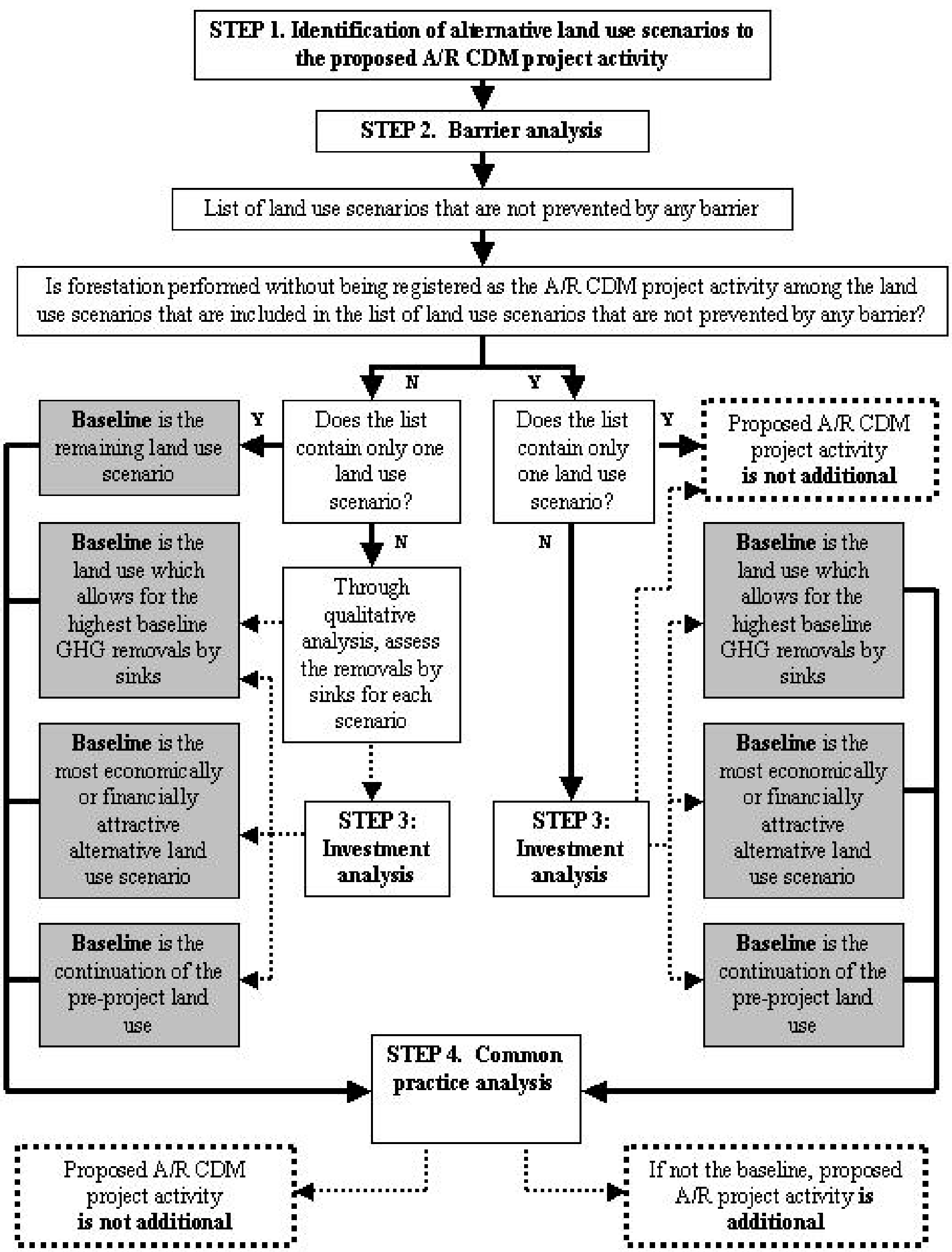
32. The previous steps shall be complemented with an analysis of the extent to which forestation activity has already diffused in the geographical area of the proposed A/R CDM project activity. This test is a credibility check to demonstrate additionality which complements the barrier analysis (Step 2) and, where applicable, the investment analysis (Step 3).

33. Provide an analysis to which extent similar forestation activities to the one proposed as the A/R CDM project activity have been implemented previously or are currently underway. Similar forestation activities are defined as that which are of similar scale, take place in a comparable environment, *inter alia*, with respect to the regulatory framework and are undertaken in the relevant geographical area, subject to further guidance by the underlying methodology. Other registered A/R CDM project activities shall not to be included in this analysis. Provide documented evidence and, where relevant, quantitative information. Limit your considerations to any period since 31 December 1989.

34. If forestation activities similar to the proposed A/R CDM project activity are identified, then compare the proposed project activity to the other similar forestation activities and assess whether there are essential distinctions between them. Essential distinctions may include a fundamental and verifiable change in circumstances under which the proposed A/R CDM project activity will be implemented when compared to circumstances under which similar forestations were carried out. For example, barriers may exist, or promotional policies may have ended. If certain benefits rendered the similar forestation activities financially attractive (e.g., subsidies or other financial flows) explain, why the proposed A/R CDM project activity cannot use the benefits. If applicable, explain why the similar forestation activities did not face barriers to which the proposed A/R CDM project activity is subject.

→ If Step 4 is satisfied, i.e. similar activities can be observed and essential distinctions between the proposed CDM project activity and similar activities cannot be made, then the proposed CDM project activity is <u>not additional</u>. Otherwise, the proposed A/R CDM project activity is not the baseline scenario and, hence, <u>it is additional</u>.

Figure 1: Indicative flowchart of the combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities.



Explanation:
Black arrow - continue;
Dotted arrow: possible outcome.

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History of the document

Version	Date	Nature of revision
01	EB35, Annex 19 19 October 2007	Initial adoption

A/R Methodological Tool

"Estimation of non-CO_2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity"

(Version 04.0.0)

I. SCOPE, APPLICABILITY AND ASSUMPTIONS

Scope

1. This tool can be used for estimation of non-CO_2 GHG emissions resulting from burning of biomass and forest fires.

Applicability

2. The tool is applicable to all occurrence of fire within the project boundary.

3. Non-CO_2 GHG emissions resulting from any occurrence of fire within the project boundary shall be accounted for each incidence of fire which affects an area greater than the minimum threshold area reported by the host Party for the purpose of defining forest, provided that the accumulated area affected by such fires in a given year is ≥5% of the project area.

Assumptions

4. This tool applies the following assumptions:

(a) Aboveground biomass of living trees shall be considered not to result in significant non-CO_2 GHG emission in case of fire, when

(i) A forest fire burns through the understory but does not climb into the tree canopy; or

(ii) A forest fire singes trees but does not cause mortality such that leaf regeneration can be observed within six months (this may be demonstrated in remote sensing imagery);

(b) 60% of the dead organic matter is entirely burnt in all fires.

Parameters

5. This tool provides steps to estimate the parameter(s) given in Table 1.

Table 1: Parameters determined by the tool

Parameter	Unit	Description
$GHG_{E,t}$	t CO_2-e	Emission of non-CO_2 GHGs resulting from burning of biomass and forest fires within the project boundary, in year *t*

II. ESTIMATION OF EMISSIONS OF GREENHOUSE GASES

6. Emission of non-CO_2 GHGs resulting from burning of biomass and forest fires within the project boundary in year *t* is estimated as follows:

$$GHG_{E,t} = GHG_{SPF,t} + GHG_{FMF,t} + GHG_{FF,t} \quad \textbf{(1)}$$

where:

$GHG_{E,t}$	Emission of non-CO_2 GHGs resulting from burning of biomass and forest fires within the project boundary in year *t*; t CO_2-e
$GHG_{SPF,t}$	Emission of non-CO_2 GHGs resulting from use of fire in site preparation in year *t*; t CO_2-e
$GHG_{FMF,t}$	Emission of non-CO_2 GHGs resulting from use of fire to clear the land of harvest residue prior to replanting of the land or other forest management, in year *t*; t CO_2-e
$GHG_{FF,t}$	Emission of non-CO_2 GHGs resulting from fire in year *t*; t CO_2-e
t	*1, 2, 3, …* years counted from the start of the A/R CDM project activity

Emission resulting from use of fire in site preparation

7. Emission of non-CO_2 GHGs resulting from use of fire in site preparation in year *t* is estimated as follows:

(a) For all areas of land where: (i) Slash-and-burn is a common practice in the baseline, and (ii) Fire has been used in the area at least once during the period of ten years preceding the start of the A/R CDM project activity:

$$GHG_{SPF,t} = 0 \quad \textbf{(2)}$$

(b) For all areas of land where the condition (a) above is not satisfied:

$$GHG_{SPF,t} = 0.07 * \sum_{i=1}^{M} \left(A_{SPF,i,t} * \frac{44}{12} * \left(CF_{TREE} * b_{TREE,i,t} + CF_{SHRUB} * BDR_{SF} * B_{FOREST} * CC_{SHRUB,i,t} \right) \right) \quad \textbf{(3)}$$

where:

$GHG_{SPF,t}$	Emission of non-CO_2 GHGs resulting from use of fire in site preparation in year *t*; t CO_2-e
0.07	Ratio of non-CO_2 GHG emissions to CO_2 emission resulting from burning of biomass; dimensionless The value of this ratio has been adapted from Table 2.5 of the *2006 IPCC Guidelines for National GHG Inventories*, taking into account methane (CH_4) and nitrous oxide (N_2O) emissions only
$b_{TREE,i,t}$	Mean tree biomass per hectare within stratum *i* in the project boundary <u>at the start of the project</u>; t d.m. ha^{-1} Estimated using the tool “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities”. Where pre-project living trees are not burned during site preparation, $b_{TREE,i}$ shall be set equal to zero
CF_{TREE}	Carbon fraction of biomass ; t C (t d.m)$^{-1}$. The IPCC default value of 0.50 is used

CF_{SHRUB}	Carbon fraction of shrub biomass; t C (t d.m.)$^{-1}$
	The IPCC default value of 0.50 is used
$A_{SPF,t}$	Area of land in which fire is used in site preparation in stratum *i* in year *t*; ha
BDR_{SF}	Ratio of shrub biomass per unit area in land having a shrub crown cover of 1.0 and the default above-ground biomass content in forest in the region/country where the A/R CDM project is located; dimensionless
	A default value of 0.10 is used unless transparent and verifiable information can be provided to justify a different value
B_{FOREST}	Default above-ground biomass content in forest in the region/country where the A/R CDM project is located; t d.m. ha^{-1}
	The value of this parameter is selected according to the guidance provided in the relevant entry in the tables at the end of this tool
$CC_{SHRUB,i,t}$	Crown cover of shrubs in area of land within the project boundary at the start of the project in which fire is used for site preparation in stratum *i* in year *t*; dimensionless
t	*1, 2, 3, …* years counted from the start of the A/R CDM project activity
i	Stratum within the baseline

Non-CO_2 emissions resulting from use of fire to clear the land of harvest residue prior to replanting of the land

8. Emissions of non-CO_2 GHGs resulting from use of fire to clear the land of harvest residue prior to replanting of the land is estimated on the basis of the ratio of the biomass left at site to the biomass harvested. In the case of fuelwood harvest this ratio is likely to be smaller than in the case of timber harvest. It is therefore conservative to apply the ratio in the case of timber harvest to the case of fuelwood and other harvests.

When the data on biomass of the harvest removed are available

9. If the data on biomass of the harvest removed are available, the emission of non-CO_2 GHGs resulting from use of fire to clear the land of harvest residue prior to replanting of the land is estimated as follows:

$$GHG_{FMF,t} = 0.07 * \frac{44}{12} * B_{HARVEST,t} * f_{BL} * CF_{TREE} \qquad \textbf{(4)}$$

where:

$GHG_{FMF,t}$	Emission of non-CO_2 GHGs resulting from use of fire to clear the land of harvest residue prior to replanting of the land, in year *t*; t CO_2-e
$B_{HARVEST,t}$	Biomass harvested from area subjected to use of fire to clear the land of harvest residue prior to replanting of the land in year *t*; t d.m.

f_{BL}	The fraction of aboveground tree biomass out of total harvest left on-site; dimensionless A value of 0.10 for temperate forest and 0.25 for tropical forest is used. These values of the parameter have been conservatively adapted from Table 3A.1.11 of the IPCC GPG LULUCF 2003
CF_{TREE}	Carbon fraction of biomass of trees harvested; t C (t d.m)$^{-1}$. IPCC default value of 0.50 t C (t d.m)$^{-1}$ is used
t	*1, 2, 3, …* years counted from the start of the A/R CDM project activity

When the data on biomass of the harvest removed are not available

10. If the data on biomass of the harvest removed are not available, the biomass of harvest removed is estimated as follows:

$$B_{HARVEST,t} = \frac{B_{FOREST}}{BEF_2} * A_{FMF,t} \quad \textbf{(5)}$$

where:

$B_{HARVEST,t}$	Biomass harvested from area subjected to use of fire to clear the land of harvest residue prior to replanting of the land in year *t*; t d.m.
B_{FOREST}	Default above-ground biomass content in forest in the region/country where the A/R CDM project is located; t d.m. ha^{-1} The value of this parameter is selected according to the guidance provided in the relevant entry in the tables at the end of this tool
BEF_2	The biomass expansion factor for trees harvested; dimensionless A value of 1.25 is used
$A_{FMF,t}$	Area of land subjected to use of fire to clear the land of harvest residue prior to replanting of the land in year *t*; ha
T	*1, 2, 3, …* years counted from the start of the A/R CDM project activity

Non-CO_2 emissions resulting from forest fires

11. Emission of GHGs resulting from the burning of aboveground project tree biomass in fire that is not site preparation or burning of harvest residue (defined from this point forward as forest fire) is calculated using the aboveground biomass in trees and dead wood of relevant strata in last verification.

$$GHG_{FF,t} = GHG_{FF\_TREE,t} + GHG_{FF\_DOM,t} \quad \textbf{(6)}$$

where:

$GHG_{FF,t}$	Emission of non-CO_2 GHGs resulting from forest fire, in year *t*; t CO_2-e
$GHG_{FF\_TREE,t}$	Emission of non-CO_2 GHGs resulting from the loss of aboveground biomass of trees due to forest fire, in year *t*; t CO_2-e
$GHG_{FF\_DOM,t}$	Emission of non-CO_2 GHGs resulting from the loss of dead organic matter due to forest fire, in year *t*; t CO_2-e

12. Emission of non-CO_2 GHGs resulting from the loss of aboveground tree biomass due fire is calculated using the above ground biomass in trees of relevant strata in last verification and a combustion factor. For the first verification, emission of non-CO_2 GHGs resulting from the loss of trees due to natural or anthropogenic forest fire is assumed to be zero.

$$GHG_{FF\_TREE,t} = 0.001 * \sum_{i=1}^{M} A_{BURN,i,t} * b_{TREE,i,t_L} * COMF_i * \left(EF_{CH4,i} * GWP_{CH4} + EF_{N2O,i} * GWP_{N2O}\right) \quad \textbf{(7)}$$

where:

$GHG_{FF\_TREE,t}$	Emission of non-CO_2 gases resulting from the loss of aboveground biomass of trees due to fire, in year *t*; t CO_2-e
$A_{BURN,i,t}$	Area burnt in stratum *i* in year *t*; ha
b_{TREE,i,t_L}	Mean aboveground tree biomass per hectare in stratum *i* in year t_L which is the year in which last verification was carried out before occurrence of the fire; t d.m. ha^{-1} Where aboveground biomass of living trees is not burnt by fire, b_{TREE,i,t_L} may be set equal to zero
$COMF_i$	Combustion factor for stratum *i*; dimensionless
$EF_{CH4,i}$	Emission factor for CH_4 in stratum *i*; g CH_4 (kg dry matter burnt)$^{-1}$
GWP_{CH4}	Global warming potential for CH_4; dimensionless Default value of 21 is used
$EF_{N2O,i}$	Emission factor for N_2O in stratum *i*; g N_2O (kg dry matter burnt)$^{-1}$
GWP_{N2O}	Global warming potential for N_2O; dimensionless Default value of 310 is used
I	1, 2, 3 … *M* strata
T	1, 2, 3, … years elapsed since the start of the project activity

13. Emission of non-CO_2 GHGs resulting from the loss of dead organic matter due to fire is calculated using the dead organic matter stock at the last verification. Where PPs elected at validation not to account for dead organic matter pool, the dead organic matter stock is considered zero and non-CO_2 GHG emissions from fire are not accounted. Where dead organic matter is accounted, for the first verification period emission of non-CO_2 GHGs resulting from the loss of dead organic matter due to fire is assumed to be zero, and for subsequent verification periods emission of non-CO_2 GHGs is estimated as follows:

$$GHG_{FF\_DOM,t} = 0.07 * \sum_{i=1}^{M} A_{BURN,i,t} * \left(C_{DW,i,t_L} + C_{LI,i,t_L}\right) \quad \textbf{(8)}$$

where:

$GHG_{FF\_DOM,t}$	Emission of GHGs resulting from the loss of dead organic matter due to fire, in year t; t CO_2-e
$A_{BURN,i,t}$	Area burnt in stratum i in year t; ha
C_{DW,i,t_L}	Carbon stock in dead wood in stratum i in year t_L which is the year in which last verification was carried out before occurrence of the fire, as estimated using the "Tool for estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities"; t CO_2-e
C_{LI,i,t_L}	Carbon stock in litter in stratum i in year t_L which is the year in which last verification was carried out before occurrence of the fire, as estimated using the "Tool for estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities"; t CO_2-e
I	1, 2, 3 … M strata
T	1, 2, 3, … years elapsed since the start of the project activity

III. DATA AND PARAMETERS USED IN THE TOOL

14. The following tables describe the data and parameters used in this tool. The guidelines contained in these tables regarding selection of data sources, and procedures to be followed in measurement, where applicable, should be treated as an integral part of this tool.

Data and parameters obtained from existing sources

Data / Parameter:	BDR_{SF}
Data unit:	Dimensionless
Used in equations:	3
Description	Ratio of shrub biomass per unit area in land having a shrub crown cover of 1.0 and the default above-ground biomass content in forest in the region/country where the A/R CDM project is located
Source of data:	A default value of 0.10 should be used unless transparent and verifiable information can be provided to justify a different value

Data / Parameter:	B_{FOREST}
Data unit:	t d.m. ha^{-1}
Used in equations:	3, 5
Description:	Default above-ground biomass content in forest in the region/country where the A/R CDM project is located

Source of data:	The source of data shall be selected, in order of preference, from the following: (a) Regional/national inventories e.g. national forest inventory, national GHG inventory; (b) Inventory from neighbouring countries with similar conditions; (c) Globally available data applicable to the project site or to the region/country where the site is located (e.g. latest data from FAO); (d) Default values from Table 3A.1.4 of IPCC GPG-LULUCF 2003

Data / Parameter:	$COMF_i$
Data unit:	dimensionless
Used in equations:	7
Description:	Combustion factor for stratum *i* (per vegetation type)
Source of data:	The source of data shall be selected, in order of preference, from the following: (a) Project-specific calculation, regional/national inventories e.g. national forest inventory, national GHG inventory; (b) Inventory from neighbouring countries with similar conditions; (c) Globally available data applicable to the project site or to the region/country where the site is located; (d) Default values as follows: **Forest type** / **Mean age (years)** / **Default value** Tropical forest: 3-5 – 0.46; 6-10 – 0.67; 11-17 – 0.50; 18 and above – 0.32 Boreal forest: All – 0.40 Temperate forest: All – 0.45

Data / Parameter:	EF_{CH4}
Data unit:	g kg^{-1} dry matter burnt
Used in equations:	7
Description:	Emission factor for CH_4 in stratum *i*
Source of data:	The source of data shall be selected, in order of preference, from the following: (a) Regional/national inventories e.g. national forest inventory, national GHG inventory; (b) Inventory from neighbouring countries with similar conditions; (c) Globally available data applicable to the project site or to the region/country where the site is located; (d) Default values as follows: (i) Tropical forest: 6.8 (ii) Other forest: 4.7

Data / Parameter:	EF_{N2O}
Data unit:	g kg^{-1} dry matter burnt
Used in equations:	7
Description:	Emission factor for N_2O in stratum *i*

Source of data:	The source of data shall be selected, in order of preference, from the following: (a) Regional/national inventories e.g. national forest inventory, national GHG inventory; (b) Inventory from neighbouring countries with similar conditions; (c) Globally available data applicable to the project site or to the region/country where the site is located; (d) Default values as follows: (i) Tropical forest: 0.20 (ii) Other forest: 0.26

Data and parameters obtained from measurements

Data / Parameter:	$A_{SPF,t}$
Data unit:	ha
Used in equations:	3
Description:	Area of land in which fire is used for site preparation in year *t*
Measurement procedures:	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In absence of these, SOPs from published handbooks, or from the *IPCC GPG LULUCF 2003*, may be applied
Monitoring frequency:	This area is measured whenever fire is used in site preparation
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In absence of these, QA/QC procedures from published handbooks, or from the *IPCC GPG LULUCF 2003*, may be applied

Data / Parameter:	$A_{FMF,t}$
Data unit:	ha
Used in equations:	5
Description:	Area of land subjected to use of fire to clear the land of harvest residue prior to replanting of the land in year *t*
Measurement procedures:	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the *IPCC GPG LULUCF 2003*, may be applied
Monitoring frequency:	This area is measured whenever fire is used to clear the land of harvest residue prior to replanting of the land
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the *IPCC GPG LULUCF 2003*, may be applied

Data / Parameter:	$A_{BURN,i,t}$
Data unit:	ha
Used in equations:	7

Description:	Area of land subjected to use of fire to clear the land of harvest residue prior to replanting of the land in year t
Source of data:	Field measurement or remote sensing measurement
Measurement procedures:	The area shall be delineated either on the ground using GPS or from georeferenced remote sensing data
Monitoring frequency:	This area is measured whenever forest fire has occurred
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied

Data / Parameter:	$CC_{SHRUB,t}$
Data unit:	Dimensionless
Used in equations:	3
Description:	Crown cover of shrubs in land where fire is used for site preparation in year *t*; dimensionless
Source of data:	Field measurement
Measurement procedures:	Ocular estimation of crown cover may be carried out or any other method such as the line transect method
Monitoring frequency:	This parameter is measured whenever fire is used in site preparation
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the *IPCC GPG LULUCF 2003*, may be applied

IV. References

IPCC, 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories,* prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.
URL: <http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html>

IPCC, 2003. *Good Practice Guidance for Land Use, Land-Use Change and Forestry*, Prepared by the National Greenhouse Gas Inventories Programme, Jim Penman, Michael Gytarsky, Taka Hiraishi, Thelma Krug, Dina Kruger, Riitta Pipatti, Leandro Buendia, Kyoko Miwa, Todd Ngara (eds). Published: IGES, Japan. URL:
<http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html>

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History of the document

Version	Date	Nature of revision
04.0.0	EB 65, Annex 31 25 November 2011	The revision expands the applicability of the tool by including an approach for estimation of non-CO_2 GHG emissions resulting from forest fires. Due to overall modification of the document, no highlights of the changes are provided.
03.1.0	EB 60, Annex 11 15 April 2011	The amendment: (i) Provides simplified approaches for estimation of emissions resulting from use of fire in initial site preparation and site preparation for replanting after a harvest; (ii) Aligns the tool with other recently approved A/R methodological tools; (iii) Limits estimation methods to non-CO_2 emissions only since CO_2 emissions are taken into account as stock change in the relevant pools; (iv)Changes the title from “Estimation of GHG emissions due to clearing, burning and decay of existing vegetation attributable to a CDM A/R project activity to “Estimation of non-CO_2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity”. Due to the overall modification of the document, no highlights of the changes are provided.
03	EB 50, Annex 22 16 October 2009	Following the classification of documents contained in the information note: Definitions of documents types issued by the Board (Annex 31 to EB 49 report) the guidance provided by the tool was updated and partitioned among several documents in order to allow their separate application.
02	EB 42, Para 35 26 September 2008	Following the guidance provided by the Executive Board at its forty second meeting, references to emissions from removals of herbaceous vegetation were removed (refer to paragraph 35 of the meeting report).
01	EB 36, Annex 20 30 November 2007	Initial adoption.
Decision Class: Regulatory **Document Type**: Tool **Business Function**: Methodology		

CLEAN DEVELOPMENT MECHANISM

AR-TOOL12

A/R Methodological tool

Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities

Version 03.1

United Nations
Framework Convention on
Climate Change

TABLE OF CONTENTS **Page**

1. Introduction

1. This tool provides a step-by-step method for estimating carbon stocks and change in carbon stocks in dead wood and/or litter in the baseline and project scenarios of an afforestation or reforestation (A/R) project activity under the clean development mechanism (CDM). The tool provides methods based on field measurements. Simplified methods based on conservative default factors are also available where certain conditions are met.

2. Scope, applicability, and entry into force

2.1. Scope

2. This tool can be used for estimation of carbon stocks and change in carbon stocks in dead wood and/or litter in the baseline and project scenarios of an A/R CDM project activity.

2.2. Applicability

3. This tool has no internal applicability conditions.

4. This tool makes the following assumptions:

   (a) Linearity of change of biomass in dead wood and litter over a period of time:

   Change of biomass in dead wood and litter may be assumed to proceed, on average, at an approximately constant rate between two points of time at which the biomass is estimated;

   (b) Appropriateness of root-shoot ratios:

   Root-shoot ratios appropriate for estimation of below-ground biomass from above-ground biomass of living trees are also appropriate for dead trees.

2.3. Entry into force

5. The date of entry into force is the date of the publication of the EB 85 meeting report on 24 July 2015.

3. Normative references

6. The following documents are indispensable for the application of this tool:

   (a) Glossary of CDM terms;

   (b) Tool “Demonstrating appropriateness of volume equations for estimation of aboveground tree biomass in A/R CDM project activities”;

   (c) Tool “Demonstrating appropriateness of allometric equations for estimation of aboveground tree biomass in A/R CDM project activities”;

(d) Tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities".

4. Definitions

7. The definitions contained in the Glossary of CDM terms shall apply. Where a term is not defined in the Glossary of CDM terms, project participants should consult the definitions provided in the *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC GPG-LULUCF 2003).

5. Parameters

8. This tool provides procedures to determine the following parameters:

Table 1. Parameters determined by the tool

Parameter	SI Unit	Description
$C_{DW,t}$	t CO_2e	Carbon stock in dead wood within the project boundary at a given point of time in year *t*
$\Delta C_{DW,t}$	t CO_2e	Change in carbon stock in dead wood within the project boundary in year *t*
$C_{LI,t}$	t CO_2e	Carbon stock in litter within the project boundary at a given point of time in year *t*
$\Delta C_{LI,t}$	t CO_2e	Change in carbon stock in litter within the project boundary in year *t*

9. While applying this tool in a methodology, the following notation should be used:

(a) In the baseline scenario:

$C_{DW\_BSL,t}$ for $C_{DW,t}$ and $C_{LI\_BSL,t}$ for $C_{LI,t}$;

$\Delta C_{DW\_BSL,t}$ for $\Delta C_{DW,t}$ and $\Delta C_{LI\_BSL,t}$ for $\Delta C_{LI,t}$

(b) In the project scenario:

$C_{DW\_PROJ,t}$ for $C_{DW,t}$ and $C_{LI\_PROJ,t}$ for $C_{LI,t}$;

$\Delta C_{DW\_PROJ,t}$ for $\Delta C_{DW,t}$ and $\Delta C_{LI\_PROJ,t}$ for $\Delta C_{LI,t}$

6. Estimation of carbon stock and change in carbon stock in dead wood

10. Carbon stock in dead wood is estimated on the basis of the same strata, and the same sample plots, which are used for the purpose of estimation of living tree biomass. However, project participants (PPs) applying this tool may use a different stratification for the purpose of estimation of carbon stock in dead wood if transparent and verifiable information can be given for justification of such a choice.

11. Two methods are offered for estimation of carbon stock in dead wood: a measurement-based method and a conservative default-factor based method.

6.1. Measurement-based methods for estimation of carbon stock in dead wood

12. For the purpose of this tool, the term "species" also implies a group of species when a biometric parameter (e.g. biomass expansion factor, root-shoot ratio, basic wood density) or a model (e.g. allometric equation, volume equation or table) is applicable to more than one species.

13. Biomass of dead wood of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t* is calculated separately for the following two types of dead wood:

(a) Standing dead wood;

(b) Lying dead wood.

Note: Uprooted trees lying on the ground, if not extracted, shall be treated as "standing dead wood" for estimation of deadwood biomass.

6.1.1. Standing dead wood

14. For the following two categories of standing dead wood, the biomass of standing dead wood is estimated by applying a biomass reduction factor to whole tree biomass:

(a) Dead trees which have lost only leaves and twigs.

Dead wood biomass is equal to whole tree biomass multiplied by a biomass reduction factor equal to 0.975;[1]

(b) Dead trees which have lost leaves, twigs and small branches (diameter < 10 cm).

Dead wood biomass is equal to whole tree biomass multiplied by a biomass reduction factor equal to 0.80.[2]

15. For dead trees and stumps which do not conform to the categories under paragraph 14, biomass is estimated using the method described in paragraphs 23–27.

16. For all dead trees falling in the categories mentioned under paragraph 14, measurement of tree dimensions (i.e. diameter and/or height) are carried out in sample plots laid down in each stratum. In exceptional situations, measurements may be carried out on all such dead trees in the stratum where trees are few and scattered out.

17. Tree dimensions (i.e. diameter and/or height as measured) are converted to dead wood biomass in standing dead trees by applying one of the following two methods:

(a) The biomass expansion factor (*BEF*) method; or

(b) The allometric method.

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[1] Adapted from the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC GPG-LULUCF 2003): p. 4.105, section 4.3.3.5.3 DEAD ORGANIC MATTER.

[2] Ibid.

6.1.1.1. Estimation of standing dead tree biomass using *BEF* method

18. Under this method volume tables (or volume functions/curves) are used to convert tree dimensions to stem volume of trees. Stem volume of trees is converted to above-ground tree biomass using basic wood density and biomass expansion factors and the above-ground tree biomass is expanded to total tree biomass using root-shoot ratios. Thus, dead wood biomass in standing dead trees of species *j* in sample plot *p* is calculated as:

$$B_{DWS\_TREE,j,p,i,t} = D_j \times BEF_{2,j} \times (1 + R_j) \times \sum_{k=1}^{K} V_{TREE,j}\,(DBH_{k,}H_k) \times \alpha_k \qquad \text{Equation (1)}$$

Where:

$B_{DWS\_TREE,j,p,i,t}$	=	Biomass of dead wood in dead trees of species *j* in sample plot *p* of stratum *i* at a point of time in year *t*; t d.m.
$V_{TREE,j}(DBH_{k,}H_k)$	=	Stem volume of the k^{th} dead tree of species *j* in plot *p* of stratum *i* as returned by the volume function for species *j* using the tree dimension(s) as entry data; m^3
DBH_k	=	Diameter of the k^{th} dead tree of species *j* in plot *p* of stratum *i* at a point of time in year *t*; metre or any other unit of length used by the volume function
H_k	=	Height of the k^{th} dead tree of species *j* in plot *p* of stratum *i* at a point of time in year *t*; metre or any other unit of length used by the volume function
α_k	=	Biomass reduction factor for the k^{th} dead tree, depending upon its category according to paragraph 14; dimensionless
D_j	=	Basic wood density of species *j*; t d.m. m^{-3}
$BEF_{2,j}$	=	Biomass expansion factor for conversion of stem biomass to above-ground tree biomass, for species *j*; dimensionless
R_j	=	Root-shoot ratio for tree species *j*; dimensionless
j	=	*1, 2, 3, …* tree species in plot *p*
k	=	*1, 2, 3, …* dead trees of species *j* in plot *p* in stratum *i*
p	=	*1, 2, 3, …* sample plots in stratum *i*
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

19. The volume table or volume function used must be demonstrated to be appropriate for the purpose of estimation of tree biomass by applying the tool “Demonstrating appropriateness of volume equations for estimation of aboveground tree biomass in A/R CDM project activities”.

6.1.1.2. Estimation of standing dead tree biomass using allometric method

20. Under this method allometric equations are used to convert tree dimensions to above-ground biomass of trees and the above-ground tree biomass is expanded to total tree biomass using root-shoot ratios. Thus, dead wood biomass in standing dead trees of species *j* in sample plot *p* is calculated as:

$$B_{DWS\_TREE,j,p,i,t} = (1 + R_j) \times \sum_{k=1}^{K} f_j\,(DBH_{k,}H_k) \times \alpha_k$$ Equation (2)

Where:

$B_{DWS\_TREE,j,p,i,t}$	=	Biomass of dead wood in standing dead trees of species *j* in sample plot *p* of stratum *i* at a point of time in year *t*; t d.m.
$f_j(DBH_{k,}H_k)$	=	Above-ground biomass of the k^{th} dead tree of species *j* in sample plot *p* of stratum *i* returned by the allometric function for species *j* using the tree dimension(s) as entry data; t d.m.
α_k	=	Biomass reduction factor for the k^{th} dead tree, depending upon its condition according to paragraph 14; dimensionless
R_j	=	Root-shoot ratio for tree species *j*; dimensionless
j	=	*1, 2, 3, …* tree species in plot *p*
k	=	*1, 2, 3, …* dead trees of species *j* in plot *p* in stratum *i*
p	=	*1, 2, 3, …* sample plots in stratum *i*
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

21. The allometric equation used must be demonstrated to be appropriate for the purpose of estimation of tree biomass by applying the tool "Demonstrating appropriateness of allometric equations for estimation of aboveground tree biomass in A/R CDM project activities".

6.1.1.3. Estimation of carbon stock in standing dead wood in dead trees

22. In both the *BEF* method and the allometric method, the carbon stock in dead wood biomass in standing dead trees of species *j* in sample plot *p* of stratum *i* is calculated as follows:

$$C_{DWS\_TREE,j,p,i,t} = \frac{44}{12} \times CF_{TREE} \times B_{DWS\_TREE,j,p,i,t}$$ Equation (3)

Where:

$C_{DWS\_TREE,j,p,i,t}$	=	Carbon stock in dead wood in standing dead trees of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t*; t CO_2e
CF_{TREE}	=	Carbon fraction of tree biomass; dimensionless

$B_{DWS\_TREE,j,p,i,t}$	=	Biomass of dead wood in standing dead trees of species *j* in sample plot *p* of stratum *i* at a point of time in year *t*; t d.m.
j	=	*1, 2, 3, …* tree species in plot *p*
p	=	*1, 2, 3*, … sample plots in stratum *i*
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

6.1.1.4. Estimation of carbon stock in standing dead wood in tree stumps

23. Each dead tree stump in a sample plot is categorized into a decay class as:

(a) Sound;

(b) Intermediate; or

(c) Rotten, on the basis of a machete test.[3]

24. A density reduction factor is assigned to each of the decay classes, which is to be multiplied by the basic wood density of the species of the stump to obtain its estimated wood density. The following default values[4] of the density reduction factors for the three decay classes are used, unless PPs have more specific data available with them: for the decay class: (a) Sound, the density reduction factor = 1.00; for the decay class; (b) Intermediate, the density reduction factor = 0.80; for the decay class; and (c) Rotten, the density reduction factor = 0.45.

25. For each dead tree stump of height less than 4 m the mid-height diameter is measured. For each dead tree stump of height 4 m and above, the diameter at breast height (*DBH*) is measured.

26. For stumps of height more than 4 m, the mid-height diameter of the stump is estimated[5] as:

$$D_{MID\_STUMP} = 0.57 \times DBH \times \left(\frac{H_{STUMP}}{H_{STUMP} - H_{DBH}}\right)^{0.80} \text{ for } H_{STUMP} > 4 \text{ m}$$ Equation (4)

Where:

D_{MID_STUMP}	=	Mid-height diameter of the dead tree stump; m
DBH	=	Diameter at breast height of the dead tree stump*;* m

3 The stump wood is struck with a machete - if the blade bounces off it is sound; if it enters slightly into the wood, is it intermediate; and if it causes the wood to fall apart, it is rotten. IPCC GPG LULUCF 2003, section 4.3.3.5.3 DEAD ORGANIC MATTER.

4 Adapted from Harmon, M. E. and J. Sexton. (1996) Guidelines for Measurements of Woody Detritus in Forest Ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

5 Adapted from Ormerod, D W, 1973. A simple bole model. *Forestry Chronicle*. 49:136-138.

H_{STUMP}	=	Height of the stump; m
H_{DBH}	=	Height above ground level at which DBH is measured; m

27. Carbon stock in dead wood in dead tree stumps of species *j* in plot *p* is calculated as:

$$C_{DWS\_STUMP,j,p,i,t} = \frac{44}{12} \times CF_{TREE} \times D_j \times (1 + R_j) \times \frac{\pi}{4} \sum_k D_{MID\_STUMP,k}{}^2 \times H_k * \beta_k \quad \text{Equation (5)}$$

Where:

$C_{DWS\_STUMP,j,p,i,t}$	=	Carbon stock in dead wood in dead tree stumps of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t*; t CO_2e
CF_{TREE}	=	Carbon fraction of tree biomass; dimensionless
D_j	=	Basic wood density of species *j*; t d.m. m^{-3}
R_j	=	Root-shoot ratio for tree species *j*; dimensionless
$D_{MID\_STUMP,k}$	=	Mid-height diameter of the k^{th} dead tree stump of species *j* in plot *p* in stratum *i* at a given point of time in year *t*; m
H_k	=	Height of the k^{th} dead tree stump of species *j* in plot *p* in stratum *i* at a given point of time in year *t*; m
β_k	=	Density reduction factor (per paragraph 24) applicable to the k^{th} dead tree stump of species *j* in plot *p* in stratum *i* at a given point of time in year *t*; dimensionless
j	=	*1, 2, 3, …* tree species in plot *p*
k	=	*1, 2, 3, …* dead trees of species *j* in plot *p* in stratum *i*
p	=	*1, 2, 3, …* sample plots in stratum *i*
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

6.1.2. Lying dead wood

28. Lying dead wood is estimated by using line transect method (Harmon and Sexton, 1996).[6] Two transect lines, of total length of at least 100 m,[7] approximately orthogonally bisecting each other at the centre of the plot are established and the diameter of each piece of lying dead wood (with diameter ≥10 cm) intersecting a transect line is measured.

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6 Harmon, M. E. and J. Sexton. (1996) Guidelines for Measurements of Woody Detritus in Forest Ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington, Seattle, WA, USA.

7 If the parcel area does not allow for the required length in two lines, then more than two lines are permissible. However, where lines are obliged to run in parallel they should be separated by at least 20 m.

29. Each piece of dead wood is assigned to one of three decay classes and each of the three decay classes are assigned a density reduction factor as explained in paragraphs 23 and 24.

30. Based on these measurements and categorization into decay classes, carbon stock in lying dead wood of species *j* in plot *p* is calculated as:

$$C_{DWL,j,p,i,t} = a_{PLOT} * \frac{44}{12} \times CF_{TREE} \times D_j * \frac{\pi^2}{8L} \times \sum_{n=1}^{N} D_{n^2} * \beta_n$$ Equation (6)

Where:

$C_{DWL,j,p,i,t}$	=	Carbon stock in lying dead wood of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t*; t CO_2e
a_{PLOT}	=	Area of the sample plot p; ha
CF_{TREE}	=	Carbon fraction of tree biomass; dimensionless
D_j	=	Basic wood density of species *j*; t d.m. m^{-3}
L	=	Sum of the lengths of the transect lines approximately orthogonally bisecting each other at the centre of the plot *p*; m
D_n	=	Diameter of the n^{th} piece of lying dead wood intersecting a transect line; cm
β_n	=	Density reduction factor applicable to the n^{th} piece of lying dead wood intersecting a transect line; dimensionless
j	=	*1, 2, 3,* … tree species in plot *p*
p	=	*1, 2, 3*, … sample plots in stratum *i*
i	=	*1, 2, 3,* … biomass estimation strata within the project boundary
t	=	*1, 2, 3,* … years elapsed since the start of the A/R CDM project activity

31. The carbon stock in dead wood in a stratum is then calculated as:

$$C_{DW,i,t} = \frac{A_i}{A_{PLOT,i}} \sum_p \sum_j (C_{DWS\_TREE,j,p,i,t} + C_{DWS\_STUMP,j,p,i,t} + C_{DWL,j,p,i,t})$$ Equation (7)

Where:

$C_{DW,i,t}$	=	Carbon stock in dead wood in stratum *i* at a given point of time in year *t*; t CO_2e
A_i	=	Total area of stratum *i*; ha
$A_{PLOT,i}$	=	Total area of sample plots in stratum *i*; ha

$C_{DWS\_TREE,j,p,i,t}$	=	Carbon stock in dead wood in standing dead trees of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t*; t CO_2e
$C_{DWS\_STUMP,j,p,i,t}$	=	Carbon stock in dead wood in dead tree stumps of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t*; t CO_2e
$C_{DWL,j,p,i,t}$	=	Carbon stock in lying dead wood of species *j* in sample plot *p* in stratum *i* at a given point of time in year *t*; t CO_2e
j	=	*1, 2, 3, …* tree species in plot *p*
p	=	*1, 2, 3, …* sample plots in stratum *i*
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

32. Finally, the carbon stock in dead tree biomass within the project boundary at a given point of time in year *t* is calculated by summing up $C_{DW,i,t}$ over all the strata, that is:

$$C_{DW,t} = \sum_{i} C_{DW,i,t} \quad \text{Equation (8)}$$

Where:

$C_{DW,t}$	=	Carbon stock in dead wood within the project boundary at a given point of time in year *t*; t CO_2e
$C_{DW,i,t}$	=	Carbon stock in dead wood in stratum *i* at a given point of time in year *t*; t CO_2e
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

6.2. Conservative default-factor based method for estimation of carbon stock in dead wood

33. If PPs do not wish to make sampling based measurements for estimation of *C* stock in dead wood, they may use the default-factor based method described in this section. The default-factor based method is applicable only if dead wood remains in situ and is not removed from the project boundary through any type of anthropogenic activities.

34. For all strata to which the default-factor based method is applied, the carbon stock in dead wood is estimated as:

$$C_{DW,i,t} = C_{TREE,i,t} \times DF_{DW} \quad \text{Equation (9)}$$

Where:

$C_{DW,i,t}$	=	Carbon stock in dead wood in stratum *i* at a given point of time in year *t*; t CO_2e

$C_{TREE,i,t}$	=	Carbon stock in trees biomass in stratum *i* at a point of time in year *t*, as calculated in the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO_2e
DF_{DW}	=	Conservative default factor expressing carbon stock in dead wood as a percentage of carbon stock in tree biomass; per cent
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

35. Value of the conservative default factor expressing carbon stock in dead wood as a percentage of carbon stock in tree biomass (DF_{DW}) is selected according to the guidance provided in the relevant table in Section 8 unless transparent and verifiable information can be provided to justify a different value.

6.3. Change in carbon stock in dead wood

36. The rate of change of dead wood biomass over a period of time is calculated assuming a linear change. Therefore, the rate of change in carbon stock in dead wood over a period of time is calculated as:

$$dC_{DW,(t_1,t_2)} = \frac{C_{DW,t_2} - C_{DW,t_1}}{T} \quad \text{Equation (10)}$$

Where:

$dC_{DW,(t_1,t_2)}$	=	Rate of change in carbon stock in dead wood within the project boundary during the period between a point of time in year t_1 and a point of time in year t_2; t CO_2e yr^{-1}
C_{DW,t_2}	=	Carbon stock in dead wood within the project boundary at a point of time in year t_2; t CO_2e
C_{DW,t_1}	=	Carbon stock in dead wood within the project boundary at a point of time in year t_1; t CO_2e
T	=	Time elapsed between two successive estimations ($T=t_2 - t_1$); yr

37. Change in carbon stock in dead wood within the project boundary in year t ($t_1 \leq t \leq t_2$) is given by:

$$\Delta C_{DW,t} = dC_{DW,(t_1 t_2)} \times 1 year \text{ for } t_1 \leq t \leq t_2 \quad \text{Equation (11)}$$

Where:

$\Delta C_{DW,t}$	=	Change in carbon stock in dead wood within the project boundary in year t; t CO_2e
$dC_{DW,(t_1 t_2)}$	=	Rate of change in carbon stock in dead wood within the project boundary during the period between a point of time in year t_1 and a point of time in year t_2; t CO_2e yr^{-1}

7. Estimation of carbon stock and change in carbon stock in litter

38. Carbon stock in litter is estimated on the basis of the same strata, and the same sample plots, which are used for the purpose of estimation of living tree biomass. However, PPs applying this tool may use a different stratification for the purpose of estimation of carbon stock in litter if transparent and verifiable information can be given for justification of such a choice.

39. Two methods are offered for estimation of carbon stock in litter: a measurement-based method and a conservative default-based approach.

7.1. Measurement-based method for estimation of carbon stock in litter

40. For estimating carbon stock in litter, four litter samples are collected from each sample plot, using a sampling frame which is placed in four randomly selected positions within the plot. The four samples are well mixed into one composite sample and its wet weight is taken. A sub-sample taken from the composite sample is weighed, oven dried, and weighed again to determine its dry weight. The dry-to-wet weight ratio of the sub-sample is calculated and used for estimating the dry weight of the composite litter sample.

41. Carbon stock in litter biomass in plot *p* is then calculated as:

$$C_{LI,p,i,t} = \frac{44}{12} \times CF_{LI} \times 2.5 * \frac{A_{p,i}}{a_{p,i}} \times B_{LI\_WET,p,i} \times DWR_{LI,p,i}$$ Equation (12)

Where:

$C_{LI,p,i,t}$	=	Carbon stock in litter in plot *p* in stratum *i*; t CO_2e
CF_{LI}	=	Carbon fraction of dry biomass in litter; dimensionless (IPCC default value[8] of 0.37 is used)
$B_{LI\_WET,p,i}$	=	Wet weight of the composite litter sample collected from plot *p* of stratum *i*; kg
$DWR_{LI,p,i}$	=	Dry-to-wet weight ratio of the litter sub-sample collected from plot *p* in stratum *i*; dimensionless <u>Note</u>: it is acceptable to determine this ratio for three randomly selected sample plots in a stratum and then apply the average ratio to all plots in that stratum
$A_{p,i}$	=	Area of sample plot *p* of stratum *i*; ha

[8] IPCC GPG for LULUCF, 2003, page 3.35, section 3.2.1.2.1.1 Choice of Method.

$a_{p,i}$	=	Area of sampling frame for plot *p* in stratum *i*; m^2 Note: The numerical factor 2.5 appears in this equation because of coversion of units from *kg* to *tonne* and from m^2 to *ha*, as well as because of the fact that $B_{LI\_WET,p,i}$ is the wet weight of litter collected from an area equal to four times the area of the sampling frame
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
p	=	*1, 2, 3, …* sample plots in stratum *i*
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

42. Carbon stock in litter in stratum *i* is then calculated as:

$$C_{LI,i,t} = \frac{A_i}{A_{PLOT,i}} \sum_p C_{LI,p,i,t} \qquad \text{Equation (13)}$$

Where:

$C_{LI,i,t}$	=	Carbon stock in litter in stratum *i* at a given point of time in year *t*; t CO_2e
A_i	=	Area of stratum *i*; ha
$A_{PLOT,i}$	=	Area of sample plots in stratum *i*; ha
$C_{LI,p,i,t}$	=	Carbon stock in litter in plot *p* in stratum *i*; t CO_2e
p	=	*1, 2, 3, …* sample plots in stratum *i*
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

43. Finally, the carbon stock in litter biomass within the project boundary at a given point of time in year *t* is calculated by summing up ($C_{LI,i,t}$) over all the strata, that is:

$$C_{LI,t} = \sum_i C_{LI,i,t} \qquad \text{Equation (14)}$$

Where:

$C_{LI,t}$	=	Carbon stock in litter within the project boundary at a given point of time in year *t*; t CO_2e
$C_{LI,i,t}$	=	Carbon stock in litter in stratum *i* at a given point of time in year *t*; t CO_2e
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

7.2. Conservative default-factor based method for estimation of carbon stock in litter

44. If PPs do not wish to make sampling based measurements for estimation of C stock in litter, they may use the default-factor based method described in this section. The default-factor based method is applicable only if litter remains in situ and is not removed from the project boundary through any type of anthropogenic activities.

45. For all strata to which this default method is applied, the carbon stock in litter is estimated as:

$$C_{LI,i,t} = C_{TREE,i,t} \times DF_{LI}$$ Equation (15)

Where:

$C_{LI,i,t}$	=	Carbon stock in litter in stratum *i* at a given point of time in year *t*; t CO_2e
$C_{TREE,i,t}$	=	Carbon stock in trees biomass in stratum *i* at a point of time in year *t*, as calculated in tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"; t CO_2e
DF_{LI}	=	Conservative default factor expressing carbon stock in litter as a percentage of carbon stock in tree biomass; percent
i	=	*1, 2, 3, …* biomass estimation strata within the project boundary
t	=	*1, 2, 3, …* years elapsed since the start of the A/R CDM project activity

46. Value of the conservative default factor expressing carbon stock in litter as a percentage of carbon stock in tree biomass (DF_{LI}) is selected according to the guidance provided in the relevant table in Section 8 unless transparent and verifiable information can be provided to justify a different value.

7.3. Change in carbon stock in litter

47. The rate of change of litter biomass over a period of time is calculated assuming a linear change. Therefore, the rate of change in carbon stock in litter over a period of time is calculated as:

$$dC_{LI,(t_1,t_2)} = \frac{C_{LI,t_2} - C_{LI,t_1}}{T}$$ Equation (16)

Where:

$dC_{LI,(t_1,t_2)}$	=	Rate of change in carbon stock in litter within the project boundary during the period between a point of time in year t_1 and a point of time in year t_2; t CO_2e yr^{-1}
C_{LI,t_2}	=	Carbon stock in litter within the project boundary at a point of time in year t_2; t CO_2e

C_{LI,t_1}	=	Carbon stock in litter within the project boundary at a point of time in year t_1; t CO_2e
T	=	Time elapsed between two successive estimations ($T=t_2 - t_1$); yr

48. Change in carbon stock in litter within the project boundary in year t ($t_1 \leq t \leq t_2$) is given by:

$$\Delta C_{LI,t} = dC_{LI,(t_1,t_2)} \times 1\ year \text{ for } t_1 \leq t \leq t_2$$ Equation (17)

Where:

$\Delta C_{LI,t}$	=	Change in carbon stock in litter within the project boundary in year t; t CO_2e
$dC_{LI,(t_1,t_2)}$	=	Rate of change in carbon stock in litter within the project boundary during the period between a point of time in year t_1 and a point of time in year t_2; t CO_2e yr^{-1}

8. Data and parameters used in the tool

49. The following tables describe the data and parameters used in this tool. The guidelines contained in these tables regarding selection of data sources, and procedures to be followed in measurement, where applicable, should be treated as an integral part of this tool.

8.1. Data and parameters not measured

Data / Parameter table 1.

Data / Parameter:	$\mathbf{BEF_{2,j}}$
Data unit:	Dimensionless
Used in equations:	1
Description:	Biomass expansion factor for conversion of stem biomass to above-ground biomass for tree species *j*
Source of data:	Values from Table 3A.1.10 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information can be provided to justify different values
Measurement procedures (if any):	-
Any comment:	*BEFs* in IPCC literature and national inventory are usually applicable to closed canopy forest. If applied to individual trees growing in an open field it is recommended that the selected *BEF* be increased by 30 per cent

Data / Parameter table 2.

Data / Parameter:	$\mathbf{CF_{TREE}}$
Data unit:	t C t^{-1} d.m.
Used in equations:	3, 5, 6

Description:	Carbon fraction of tree biomass
Source of data:	A value of 0.5 shall be used unless transparent and verifiable information can be provided to justify a different value
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 3.

Data / Parameter:	$\mathbf{CF_{LI}}$
Data unit:	t C t^{-1} d.m.
Used in equations:	12
Description:	Carbon fraction of litter biomass
Source of data:	IPCC default value of 0.37 t C t^{-1} d.m. may be used
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 4.

Data / Parameter:	$\mathbf{D_J}$
Data unit:	t d.m. m^{-3}
Used in equations:	1, 5, 6
Description:	Basic wood density for species *j*
Source of data:	Values from Table 3A.1.9 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information can be provided to justify different values
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 5.

Data / Parameter:	$\mathbf{DF_{DW}}$
Data unit:	Per cent
Used in equations:	9
Description:	Conservative default factor expressing carbon stock in dead wood as a percentage of carbon stock in tree biomass

<table>
<tr><td>Source of data:</td><td>Defaults conservatively derived from Delaney et al. 1997,[9] Smith et al. 2006,[10] Glenday 2008,[11] Keller et al. 2004,[12] Eaton and Lawrence 2006,[13] Krankina and Harmon 1995,[14] and Clark et al 2002:[15]
<table>
<tr><th>Biome</th><th>Elevation</th><th>Precipitation</th><th>DF_{DW}</th></tr>
<tr><td>Tropical</td><td><2000m</td><td><1000 mm yr^{-1}</td><td>2%</td></tr>
<tr><td>Tropical</td><td><2000m</td><td>1000-1600 mm yr^{-1}</td><td>1%</td></tr>
<tr><td>Tropical</td><td><2000m</td><td>>1600 mm yr^{-1}</td><td>6%</td></tr>
<tr><td>Tropical</td><td>>2000m</td><td>All</td><td>7%</td></tr>
<tr><td>Temperate/ boreal</td><td>All</td><td>All</td><td>8%</td></tr>
</table></td></tr>
<tr><td>Measurement procedures (if any):</td><td>-</td></tr>
<tr><td>Any comment:</td><td>-</td></tr>
</table>

Data / Parameter table 6.

Data / Parameter:	DF_{LI}
Data unit:	Per cent
Used in equations:	15
Description:	Default factor for the relationship between carbon stock in litter and carbon stock in living trees

9 Delaney, M., Brown, S., Lugo, A.E., Torres-Lezama, A. and Bello Quintero, N. 1997. The distribution of organic carbon in major components of forests located in five life zones of Venezuela. Journal of Tropical Ecology 13: 697-708.

10 Smith, James E.; Heath, Linda S.; Skog, Kenneth E.; Birdsey, Richard A. 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. Forest Service, Northeastern Research Station, General Technical Report NE-343. 216 p.

11 Glenday, J. 2008. Carbon storage and emissions offset potential in an African dry forest, the Arabuko-Sokoke Forest, Kenya. Envion. Monit. Assess 142: 85-95.

12 Keller, M., Palace, M., Asner, G., Pereira Jr, R. and Silva, JNM. 2004. Coarse woody debris in undisturbed and logged forests in eastern Brazilian Amazon. Global Change Biology 10: 784-795.

13 Eaton, J.M. and Lawrence, D. 2006. Woody debris stocks and fluxes during succession in a dry tropical forest. Forest Ecology and Management 232: 46-55.

14 Krankina, O.N., Harmon, M.E., 1995. Dynamics of the dead wood carbon pool in northwestern Russian boreal forests. Water Air Soil Pollut. 82,227–238.

15 Clark, D.B., Clark, D.A., Brown, S., Oberbauer, S.F., Veldkamp, E., 2002. Stocks and flows of coarse woody debris across a tropical rain forest nutrient and topography gradient. Forest Ecol. Manage. 5646, 1-112.

Source of data:	Defaults conservatively derived from sources cited above: <table><tr><th>Biome</th><th>Elevation</th><th>Precipitation</th><th>DF_{LI}</th></tr><tr><td>Tropical</td><td><2000m</td><td><1000 mm yr^{-1}</td><td>4%</td></tr><tr><td>Tropical</td><td><2000m</td><td>1000-1600 mm yr^{-1}</td><td>1%</td></tr><tr><td>Tropical</td><td><2000m</td><td>>1600 mm yr^{-1}</td><td>1%</td></tr><tr><td>Tropical</td><td>>2000m</td><td>All</td><td>1%</td></tr><tr><td>Temperate/ boreal</td><td>All</td><td>All</td><td>4%</td></tr></table>
Measurement procedures (if any):	-
Any comment:	-

Data / Parameter table 7.

Data / Parameter:	R_J
Data unit:	Dimensionless
Used in equations:	1, 2, 5
Description:	Root-shoot ratio for species *j*
Source of data:	The value of R_j shall be calculated as: $R = exp[-1.085+0.9256 \times ln(A)]/A$, where A is above-ground biomass (t d.m. ha^{-1}) [Source: Table 4.A.4 of IPCC GPG-LULUCF 2003] unless transparent and verifiable information can be provided to justify a different value
Measurement procedures (if any):	-
Any comment:	-

8.2. Data and parameters measured

Data / Parameter table 8.

Data / Parameter:	A_i
Data unit:	ha
Used in equations:	7, 13
Description:	Area of stratum *i*
Source of data:	Field measurement
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Monitoring frequency:	Every five years since the year of the initial verification

QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 9.

Data / Parameter:	$\mathbf{A_{PLOT,i}}$
Data unit:	ha
Used in equations:	7, 12, 13
Description:	Total area of sample plots in stratum *i*
Source of data:	Field measurement
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 10.

Data / Parameter:	$\mathbf{a_{p,i}}$
Data unit:	m^2
Used in equations:	12
Description:	Area of litter sampling frame used in plot *p* in stratum *i*
Source of data:	Measurement
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Any comment:	Often a litter sampling frame of 0.50 m^2 is used

Data / Parameter table 11.

Data / Parameter:	$\mathbf{B_{LI\_WET,p,i}}$
Data unit:	Kg
Used in equations:	12

Description:	Wet weight of the composite litter sample collected from plot *p* of stratum *i*; kg
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 12.

Data / Parameter:	$\mathbf{DBH}$
Data unit:	cm or any unit of length as specified
Used in equations:	1, 2, 4
Description:	Diameter at breast height of a tree. For the purpose of equations (1) and (2), *DBH* could be any other diameter or dimensional measurement (e.g. basal diameter, root-collar diameter, basal area, etc.) applicable for the model or data source used
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 13.

Data / Parameter:	$\mathbf{D}_{\boldsymbol{n}}$
Data unit:	cm
Used in equations:	6
Description:	Diameter of the n^{th} piece of lying dead wood intersecting a transect line
Source of data:	Field measurements along transect lines in sample plots
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In absence of these, SOPs from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Monitoring frequency:	Every five years since the year of the initial verification

QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 14.

Data / Parameter:	**H**
Data unit:	m or any other unit of length as specified
Used in equations:	1, 2, 4, 5
Description:	Height of tree
Source of data:	Field measurements in sample plots
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Monitoring frequency:	Every five years since the year of the initial verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, may be applied
Any comment:	-

Data / Parameter table 15.

Data / Parameter:	**T**
Data unit:	Year
Used in equations:	10, 16
Description:	Time period elapsed between two successive estimations of carbon stock
Source of data:	Recorded time
Measurement procedures (if any):	N/A
Monitoring frequency:	-
QA/QC procedures:	-
Any comment:	If the two successive estimations of carbon stock are carried out at different points of time in year t_2 and t_1, (e.g. in the month of April in year t_1 and in the month of September in year t_2), then a fractional value shall be assigned to T

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Document information

Version	Date	Description
03.1	24 July 2015	EB 85, Annex 23 Minor revision to correct paragraph 30, equation 6, the parameter a_{PLOT} has been included.
03.0	4 October 2013	EB 75, Annex 27 The revision introduces conditions under which the conservative default-factor based method for estimation of carbon stock in dead wood and litter can be used.
02.0.0	11 May 2012	EB 67, Annex 23 The revision: • Incorporates the use of the tools "Demonstrating appropriateness of allometric equations for estimation of aboveground tree biomass in A/R CDM project activities" and "Demonstrating appropriateness of volume equations for estimation of aboveground tree biomass in A/R CDM project activities"; • Uses a fixed value of carbon fraction for tree biomass across all tree species; • Allows use of more specific values of the parameters DF_{DW} and DF_{LI} instead of the default values provided in the tool; and • Enhances the clarity of the text in some paragraphs.
01.1.0	26 November 2010	EB 58, Annex 14 The revision: • Excludes estimation of emissions from the scope of the tool as this is dealt with in another approved tool; • Introduces simplified methods for estimation of carbon stock in some components of dead wood; • Provides for the option of default-factor based estimation of carbon stock in dead wood and litter; • Streamlines the general presentation of the tool with the recently approved tools; and • Changes the title to "Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities" from the previous title "Tool for estimation of Carbon Stocks, Removals and Emissions for the Dead Organic Matter Pools due to Implementation of a CDM A/R Project Activity". Due to overall modification of the document, no highlights of the changes are provided.
01	2 August 2008	EB 41, Annex 14 Initial adoption.

Decision Class: Regulatory
Document Type: Tool

Version	*Date*	*Description*

Business Function: Methodology
Keywords: afforestation reforestation, AR project activity, biomass, carbon pools

CLEAN DEVELOPMENT MECHANISM

AR-TOOL14

Methodological tool

Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities

Version 04.2

United Nations
Framework Convention on
Climate Change

TABLE OF CONTENTS **Page**

1. Introduction

1. This tool provides step-by-step methods for estimation of carbon stock in living biomass of trees and shrubs. For ex-ante (projected) estimation of tree biomass it applies tree growth and stand development models. For ex-post (actual) estimation of tree biomass it uses data from measurements conducted in sample plots. Remote sensing data may also be used in conjunction with data from measurements conducted in sample plots. Biomass of shrubs is estimated from shrub crown cover.

2. Scope, applicability, and entry into force

2.1. Scope

2. This tool can be used for estimation of carbon stock and change in carbon stock in living biomass of trees and shrubs in an afforestation and reforestation (A/R) clean development mechanism (CDM) project activity. The tool is applicable for:

(a) Estimation of carbon stock and change in carbon stock in living biomass of trees and shrubs in baseline;

(b) Ex-ante estimation (projection) of carbon stock and change in carbon stock in living biomass of trees and shrubs in project;

(c) Ex-post estimation of carbon stock and change in carbon stock in trees and shrubs for monitoring of project activities.

2.2. Applicability

3. This tool has no internal applicability conditions.

2.3. Entry into force

4. The date of entry into force is the date of the publication of the EB 85 meeting report on 24 July 2015.

3. Definitions and notation

5. The definitions contained in the Glossary of CDM terms shall apply.

6. For the purpose of this tool, the following definitions apply:

(a) **Uncertainty -** is in the mean value of an estimated parameter equal to the estimated standard error of the mean expanded at 90 per cent confidence level divided by the mean value, expressed as percentage;

Example: The mean value of above-ground tree biomass per hectare is estimated as 45.328 t d.m. ha-1 from a sample of size 34. Sample standard deviation was 12.776 t d.m. ha-1. The estimated standard error of the mean (SEM) is 12.776/$\sqrt{34}$ = 2.191 t d.m. ha-1. The SEM expanded at 90 per cent confidence level is therefore = 2.191 x t(0.1,33) = 2.191 x 1.692 = 3.707 t d.m. ha-1. This implies that the estimated mean has an uncertainty of (3.707/45.328)

×100 = 8.18 per cent.

Note. In this tool only sampling uncertainty is assessed and controlled. Uncertainty in values obtained from direct measurement (e.g. measured diameter of a tree) or values derived from models (e.g. biomass of a tree derived from its diameter using an allometric equation) is not quantified. This type of uncertainty should be managed through application of appropriate quality assurance and quality control (QA/QC) methods, as explained in the parameter description tables in section 12.

(b) **Species -** can also refer to a species group when a species-specific biometric parameter (e.g. biomass expansion factor), or a model (e.g. allometric equation), is demonstrated to be applicable to more than one species;

(c) **Tree biomass -** refers to above-ground and below-ground living biomass of trees;

(d) **Shrub biomass -** refers to above-ground and below-ground living biomass of shrubs;

(e) **Plot biomass -** refers to tree biomass per hectare in a plot;

(f) **Measurement of a sample plot -** refers to the measurement of one or more dimensions (e.g. diameter) of the trees in a sample plot, or measurement of a plot parameter (e.g. basal area per hectare), and conversion of the measured tree dimensions, or the measured plot parameter into plot biomass by using one of the methods provided in Appendix 1;

(g) **Conservative value of a parameter -** refers to the value which, when used in calculations, is more likely to result in underestimation rather than overestimation of the net anthropogenic GHG removals by sinks;

7. For reasons of consistency and readability, this tool uses the following conventions in naming of variables and parameters:

(a) Symbols for unit quantities (e.g. per hectare quantities) use lower case letters (e.g. b_{FOREST}), whereas symbols for total quantities use uppercase letters (e.g. B_{TREE});

(b) Subscripts used for qualifying a variable or a parameter appear in upper case letters (e.g. $C_{SHRUB\_PROJECT}$), whereas subscripts used for denoting indices appear in lower case letters (e.g. $C_{SHRUB\_PROJECT,i}$).

8. This tool uses the following units in their abbreviated form:

(a) Tonne dry matter is abbreviated as t d.m., and tonne dry matter per hectare is abbreviated as t d.m. ha^{-1};

(b) Tonne carbon dioxide equivalent is abbreviated as t CO_2e.

4. Parameters determined by the tool

9. This tool provides procedures to determine the parameters listed in Table 1.

Table 2. Parameters determined by the tool

Parameter	Unit	Description
$C_{TREE,t}$	t CO_2e	Carbon stock in tree biomass within the project boundary at a given point of time in year *t*
$\Delta C_{TREE,t}$	t CO_2e	Change in carbon stock in tree biomass within the project boundary in year *t*
$C_{SHRUB,t}$	t CO_2e	Carbon stock in shrub biomass within the project boundary at a given point of time in year *t*
$\Delta C_{SHRUB,t}$	t CO_2e	Change in carbon stock in shrub biomass within the project boundary in year *t*

10. While applying this tool in an approved A/R CDM methodology, the following corresponding notations should be used:

(a) In the baseline scenario:

$C_{TREE\_BSL,t}$ for $C_{TREE,t}$ and $C_{SHRUB\_BSL,t}$ for $C_{SHRUB,t}$

$\Delta C_{TREE\_BSL,t}$ for $\Delta C_{TREE,t}$ and $\Delta C_{SHRUB\_BSL,t}$ for $\Delta C_{SHRUB,t}$

(b) In the project scenario:

$C_{TREE\_PROJ,t}$ for $C_{TREE,t}$ and $C_{SHRUB\_PROJ,t}$ for $C_{SHRUB,t}$

$\Delta C_{TREE\_PROJ,t}$ for $\Delta C_{TREE,t}$ and $\Delta C_{SHRUB\_PROJ,t}$ for $\Delta C_{SHRUB,t}$

5. Conditions under which carbon stock and change in carbon stock may be estimated as zero

11. Carbon stock in trees in the baseline can be accounted as zero if all of the following conditions are met:

(a) The pre-project trees are neither harvested, nor cleared, nor removed throughout the crediting period of the project activity;

(b) The pre-project trees do not suffer mortality because of competition from trees planted in the project, or damage because of implementation of the project activity, at any time during the crediting period of the project activity;

(c) The pre-project trees are not inventoried along with the project trees in monitoring of carbon stocks but their continued existence, consistent with the baseline scenario, is monitored throughout the crediting period of the project activity.

12. Changes in carbon stocks in trees and shrubs in the baseline may be accounted as zero for those lands for which the project participants can demonstrate, through documentary evidence or through participatory rural appraisal (PRA), that one or more of the following indicators apply:

(a) Observed reduction in topsoil depth (e.g. as shown by root exposure, presence of pedestals, exposed sub-soil horizons);

(b) Presence of gully, sheet or rill erosion; or landslides, or other forms of mass-movement erosion;

(c) Presence of plant species locally known to be indicators of infertile land;

(d) Land comprises of bare sand dunes, or other bare lands;

(e) Land contains contaminated soils, mine spoils, or highly alkaline or saline soils;

(f) Land is subjected to periodic cycles (e.g. slash-and-burn, or clearing-regrowing cycles) so that the biomass oscillates between a minimum and a maximum value in the baseline;

(g) Conditions (a), (b) and (c) under paragraph 11 apply.

13. For the purpose of ex-ante estimation of carbon stock and change in carbon stock in the project scenario, change in carbon stock of shrubs may be estimated as zero.

6. Estimating change in carbon stock in trees between two points of time

14. Change in carbon stock in trees between two points of time is estimated by using one of the following methods or a combination thereof:

(a) Difference of two independent stock estimations;

(b) Direct estimation of change by re-measurement of sample plots;

(c) Estimation by proportionate crown cover;

(d) Demonstration of “no-decrease”.

6.1. Difference of two independent stock estimations

15. Under this method, change in carbon stock in trees is estimated as the difference between two successive and independent carbon stock estimations.

Note. This is method is efficient when the correlation between the plot biomass values on the two occasions is absent or weak (e.g. when there has been harvest or disturbance in a stratum after the first estimation, resulting in spatial re-distribution of tree biomass in the stratum).

16. Under this method, the change in carbon stock in trees and the associated uncertainty are estimated as follows:

$$\Delta C_{TREE} = C_{TREE,t_2} - C_{TREE,t_1}$$ Equation (1)

$$u_{\Delta C} = \frac{\sqrt{\left(u_1 \times C_{TREE,t_1}\right)^2 + \left(u_2 \times C_{TREE,t_2}\right)^2}}{|\Delta C_{TREE}|}$$ Equation (2)

Where:

ΔC_{TREE}	=	Change in carbon stock in trees during the period between two points of time t_1 and t_2; t CO_2e
C_{TREE,t_1}	=	Carbon stock in trees as estimated at time t_1; t CO_2e Note 1. At the first verification C_{TREE,t_1} is set equal to the carbon stock in the pre-project tree biomass ($i.e. C_{TREE,t_1} = C_{TREE\_BSL}$). However, this may be set equal to zero, if all of the conditions specified under paragraph 10 are met. Note 2. Even if C_{TREE,t_1} was made conservative at the time of previous verification, it is the estimated (undiscounted) value of C_{TREE,t_1} that is used here.
C_{TREE,t_2}	=	Carbon stock in trees as estimated at time t_2; t CO_2e
$u_{\Delta C}$	=	Uncertainty in ΔC_{TREE}
u_1, u_2	=	Uncertainties in C_{TREE,t_1} and C_{TREE,t_2} respectively

17. Carbon stock in trees at a point of time is estimated by using one of the applicable methods provided in section 8.

18. If $u_{\Delta C}$ estimated from Equation (2) is greater than 10 per cent, ΔC_{TREE} is made conservative by applying uncertainty discount according to the procedure provided in Appendix 2.

6.2. Direct estimation of change by re-measurement of sample plots

19. This method is applicable only in ex-post estimation of change in carbon stock in trees for monitoring of project activities. Under this method, the same sample plots are measured on two successive occasions and the plot-level change in biomass is obtained by subtracting the plot biomass on the first occasion from the plot biomass on the second occasion.

Note. This is method is efficient when there is a significant correlation between the plot biomass values on the two occasions (e.g. when there has been no harvest or disturbance in a stratum and therefore no significant spatial re-distribution of biomass has occurred in the stratum after the first estimation).

20. Under this method, the change in carbon stock and the associated uncertainty are estimated as follows:

$$\Delta C_{TREE} = \frac{44}{12} \times CF_{TREE} \times \Delta B_{TREE} \qquad \text{Equation (3)}$$

$$\Delta B_{TREE} = A \times \Delta b_{TREE} \qquad \text{Equation (4)}$$

$$\Delta b_{TREE} = \sum_{i=1}^{M} w_i \times \Delta b_{TREE,i}$$ Equation (5)

$$u_{\Delta C} = \frac{t_{VAL} \times \sqrt{\sum_{i=1}^{M} w_i^2 \times \frac{s_{\Delta,i}^2}{n_i}}}{|\Delta b_{TREE}|}$$ Equation (6)

Where:

ΔC_{TREE}	=	Change in carbon stock in trees between two successive measurements; t CO_2e
CF_{TREE}	=	Carbon fraction of tree biomass; t C (t d.m.)$^{-1}$ A default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value.
ΔB_{TREE}	=	Change in tree biomass within the biomass estimation strata; t d.m.
A	=	Sum of areas of the biomass estimation strata; ha
Δb_{TREE}	=	Mean change in tree biomass per hectare within the biomass estimation strata; t d.m. ha^{-1}
w_i	=	Ratio of the area of stratum *i* to the sum of areas of biomass estimation strata (i.e. $w_i = A_i/A$); dimensionless
$\Delta b_{TREE,i}$	=	Mean change in carbon stock per hectare in tree biomass in stratum *i*; t d.m. ha^{-1}
$u_{\Delta C}$	=	Uncertainty in ΔC_{TREE}
t_{VAL}	=	Two-sided Student's *t*-value for a confidence level of 90 per cent and degrees of freedom equal to *n* – *M*, where *n* is total number of sample plots within the tree biomass estimation strata, and *M* is the total number of tree biomass estimation strata
$s_{\Delta,i}^2$	=	Variance of mean change in tree biomass per hectare in stratum *i*; (t d.m. ha^{-1})^2
n_i	=	Number of sample plots, in stratum *i*, in which tree biomass was re-measured

21. Mean change in tree biomass per hectare in a stratum and the associated variance are estimated as follows:

$$\Delta b_{TREE,i} = \frac{\sum_{p=1}^{n_i} \Delta b_{TREE,p,i}}{n_i}$$ Equation (7)

$$s_{\Delta,i}^{2} = \frac{n_i \times \sum_{p=1}^{n_i} \Delta b_{TREE,p,i}^{2} - \left(\sum_{p=1}^{n_i} \Delta b_{TREE,p,i}\right)^2}{n_i \times (n_i - 1)}$$ Equation (8)

Where:

$\Delta b_{TREE,i}$	=	Mean change in tree biomass per hectare in stratum *i*; t d.m. ha^{-1}
$\Delta b_{TREE,p,i}$	=	Change in tree biomass per hectare in plot *p* in stratum *i*; t d.m. ha^{-1}
$s_{\Delta,i}^{2}$	=	Variance of mean change in tree biomass per hectare in stratum *i*; (t d.m. $ha^{-1})^2$
n_i	=	Number of sample plots, in stratum *i*, in which tree biomass was re-measured

22. If $u_{\Delta C}$ estimated from Equation (6) is greater than 10 per cent, ΔC_{TREE} is made conservative by applying uncertainty discount according to the procedure provided in Appendix 2.

23. Tree biomass per hectare in a sample plot is estimated by applying one of the plot measurement methods provided in Appendix 1.

6.3. Estimation by proportionate crown cover

24. This method is applicable only in ex-ante estimation of change in carbon stock in trees in the baseline where the mean pre-project tree crown cover is less than 20 per cent of the threshold tree crown cover reported by the host Party under paragraph 8 of the annex to decision 5/CMP.1

Example. The host Party has reported a threshold tree crown cover of 30 per cent to define ‘forest’ for the purposes of the CDM. The method of estimation by proportionate crown cover is applicable only if the mean pre-project tree crown cover is less than 20 per cent of 30 per cent (i.e. less than 6 per cent).

25. Under this method, the change in carbon stock in trees in the baseline is estimated as follows:

$$\Delta C_{TREE\_BSL} = \sum_{i=1}^{M} \Delta C_{TREE\_BSL,i}$$ Equation (9)

$$\Delta C_{TREE\_BSL,i} = \frac{44}{12} \times CF_{TREE} \times \Delta b_{FOREST} \times (1 + R_{TREE}) \times CC_{TREE\_BSL,i} \times A_i$$ Equation (10)

Where:

ΔC_{TREE_BSL}	=	Mean annual change in carbon stock in trees in the baseline; t CO_2e yr^{-1}
$\Delta C_{TREE\_BSL,i}$	=	Mean annual change in carbon stock in trees in the baseline, in baseline stratum *i*; t CO_2e yr^{-1}

CF_{TREE}	=	Carbon fraction of tree biomass; t C (t.d.m.)$^{-1}$. A default value of 0.47 t C (t.d.m.)$^{-1}$ is used unless transparent and verifiable information can be provided to justify a different value.
Δb_{FOREST}	=	Default mean annual increment of above-ground biomass in forest in the region or country where the A/R CDM project activity is located; t d.m. ha^{-1} yr^{-1}. Values of Δb_{FOREST} are taken from Table 3A.1.5 of the *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC GPG-LULUCF 2003) unless transparent and verifiable information can be provided to justify different values. <u>Note.</u> Tree biomass may reach a steady state in which biomass growth becomes zero or insignificant, either because of biological maturity of trees or because the rate of anthropogenic biomass extraction from the area is equal to the rate of biomass growth. Therefore, this parameter should be taken to be zero after the year in which tree biomass in the baseline reaches a steady state. The year in which tree biomass in the baseline reaches a steady-state is taken to be the 20th year from the start of the CDM project activity, unless transparent and verifiable information can be provided to justify a different year.
R_{TREE}	=	Root-shoot ratio for the trees in the baseline; dimensionless. A default value of 0.25 is used unless transparent and verifiable information can be provided to justify a different value.
$CC_{TREE\_BSL,i}$	=	Crown cover of trees in the baseline, in baseline stratum *i*, at the start of the A/R CDM project activity, expressed as a fraction (e.g. 10 per cent crown cover implies $CC_{TREE\_BSL,i}$ = 0.10); dimensionless
A_i	=	Area of baseline stratum *i*, delineated on the basis of tree crown cover at the start of the A/R CDM project activity; ha

6.4. Demonstration of "no-decrease"

26. This method is applicable only in ex-post estimation of change in carbon stock in trees for monitoring of project activities. Project participants may, at the time of a verification, demonstrate that tree biomass in one or more strata has not decreased relative to the tree biomass at the time of the previous verification, by proving that:

(a) No harvest has occurred in the stratum since the previous verification;

(b) The stratum was not affected by any disturbance (e.g. pest, fire) that would decrease the carbon stock in trees;

(c) Remote sensing data or inventory data, including participatory inventory or participatory photo-mapping data, demonstrate that tree crown cover in the stratum has not decreased since the previous verification.

27. Where all the three conditions above are demonstrated to have been met in a stratum, the change in carbon stock in trees in that stratum since the previous verification may be conservatively estimated as zero.

Note. This method is efficient when project participants are required to submit a verification and certification report at a point of time when the biomass increase in the project since the previous verification may not be large enough to justify the cost of conducting an inventory (e.g. when periodic verification and certification is required to re-validate lCERs already issued and significant number of new lCERs is not expected).

7. Estimating change in carbon stock in trees in a year

28. Change in carbon stock in trees in a year (annual change) between two successive verifications is estimated on the assumption of linear change.

29. Change in carbon stock in trees in a year is estimated as follows:

$$\Delta C_{TREE,t} = \frac{C_{TREE,t_2} - C_{TREE,t_1}}{T} \times 1\ year$$ Equation (11)

Where:

$\Delta C_{TREE,t}$	=	Change in carbon stock in trees within the project boundary in year *t*; t CO_2e
C_{TREE,t_2}	=	Carbon stock in trees within the project boundary at time t_2; t CO_2e. Note. Where estimation of carbon stock in tree biomass at time t_2 is carried out by applying different methods in different strata, C_{TREE,t_2} is set equal to the sum of carbon stocks in all the strata in which the project area is divided.
C_{TREE,t_1}	=	Carbon stock in trees within the project boundary at time t_1; t CO_2e. Note. Where estimation of carbon stock in tree biomass at time t_1 is carried out by applying different methods in different strata, C_{TREE,t_1} is set equal to the sum of carbon stocks in all the strata in which the project area is divided.
T	=	Time elapsed between two successive estimations ($T=t_2 – t_1$); yr. Note 1. Value of *T* does not have to be a whole number (e.g. an interval of 4 years and 5 months implies T = 4.417 yr). Note 2. Estimation of change in carbon stock in trees by proportionate crown cover (*see* section 6.3) results in an annual change estimate and hence Equation (11) does not apply under this method.

8. Estimating carbon stock in trees at a point of time

30. Carbon stock in trees at a point of time is estimated by using one of the following methods or a combination thereof:

    (a) Estimation by measurement of sample plots;

    (b) Estimation by modelling of tree growth and stand development;

    (c) Estimation by proportionate crown cover;

    (d) Updating the previous stock by independent measurement of change.

31. When estimation is carried out by methods (a), (c) or (d) above, the date of last measurement of sample plot, or estimation of crown cover, is considered to be the date of estimation of carbon stock, even if the full process of measurement extends over a period of time.

32. Where estimation of carbon stock in trees at a given point of time in year t is carried out by applying different methods in different strata, the value of $C_{TREE,t}$ is set equal to the sum of carbon stocks in all the strata in which the project area was divided.

8.1. Estimation by measurement of sample plots

33. Under this method, carbon stock in trees is estimated on the basis of measurements of sample plots. Sample plots are installed in one or more strata. Two sampling designs are available:

    (a) Stratified random sampling;

    (b) Double sampling.

8.1.1. Stratified random sampling

34. Under this method, random sample plots are installed in the strata (e.g. systematic sampling with a random start) and measured.

    Note. This method is more efficient when the sample plots are optimally allocated to the strata keeping in view the expected mean tree biomass per hectare and its variability in the strata. Number of sample plots and their allocation to strata may be estimated by using the A/R methodological tool "Calculation of the number of sample plots for measurements within A/R CDM project activities".

    Example 1. At the time of verification, it is known that out of eight parcels of plantation land, three have been harvested in the last two years. Hence the mean tree biomass per hectare in these parcels is low and is relatively homogeneous. Hence these three parcels are treated as one stratum. Of the remaining five parcels, two parcels had poor tree growth compared to the other three. Thus these five parcels are treated as two separate strata.

    Example 2. In a forest plantation raised through assisted natural regeneration, the tree biomass is seen to be distributed unevenly throughout the project area. Using satellite data it is seen that the distribution of the tree crown cover (which is expected to have a positive correlation with tree biomass) has clearly discernible patterns. Strata boundaries are therefore delineated on the basis tree crown cover estimated from the remote sensing data.

35. Mean carbon stock in trees within the tree biomass estimation strata and the associated uncertainty are estimated as follows (all time-dependent quantities relate to the time of measurement):

$$C_{TREE} = \frac{44}{12} \times CF_{TREE} \times B_{TREE}$$ Equation (12)

$$B_{TREE} = A \times b_{TREE}$$ Equation (13)

$$b_{TREE} = \sum_{i=1}^{M} w_i \times b_{TREE,i}$$ Equation (14)

$$u_C = \frac{t_{VAL} \times \sqrt{\sum_{i=1}^{M} w_i^2 \times \frac{s_i^2}{n_i}}}{b_{TREE}}$$ Equation (15)

Where:

C_{TREE}	=	Carbon stock in trees in the tree biomass estimation strata; t CO_2e
CF_{TREE}	=	Carbon fraction of tree biomass; t C (t d.m.)$^{-1}$. A default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value.
B_{TREE}	=	Tree biomass in the tree biomass estimation strata; t d.m.
A	=	Sum of areas of the tree biomass estimation strata; ha
b_{TREE}	=	Mean tree biomass per hectare in the tree biomass estimation strata; t d.m. ha^{-1}
w_i	=	Ratio of the area of stratum *i* to the sum of areas of tree biomass estimation strata (i.e. $w_i = A_i/A$); dimensionless
$b_{TREE,i}$	=	Mean tree biomass per hectare in stratum *i*; t d.m. ha^{-1}
u_C	=	Uncertainty in C_{TREE}
t_{VAL}	=	Two-sided Student's *t*-value for a confidence level of 90 per cent and degrees of freedom equal to *n* – *M*, where *n* is total number of sample plots within the tree biomass estimation strata and *M* is the total number of tree biomass estimation strata
s_i^2	=	Variance of tree biomass per hectare across all sample plots in stratum *i*; (t d.m. ha^{-1})^2
n_i	=	Number of sample plots in stratum *i*.

36. Mean tree biomass per hectare in a stratum and the associated variance are estimated as follows:

$$b_{TREE,i} = \frac{\sum_{p=1}^{n_i} b_{TREE,p,i}}{n_i}$$ Equation (16)

$$s_i^2 = \frac{n_i \times \sum_{p=1}^{n_i} b_{TREE,p,i}^2 - \left(\sum_{p=1}^{n_i} b_{TREE,p,i}\right)^2}{n_i \times (n_i - 1)}$$ Equation (17)

Where:

$b_{TREE,i}$	=	Mean tree biomass per hectare in stratum *i*; t d.m. ha^{-1}
$b_{TREE,p,i}$	=	Tree biomass per hectare in plot *p* of stratum *i*; t d.m. ha^{-1}
s_i^2	=	Variance of mean tree biomass per hectare in stratum *i*; (t d.m. $ha^{-1})^2$
n_i	=	Number of sample plots in stratum *i*.

37. If u_C estimated from Equation (15) is greater than 10 per cent, C_{TREE} is made conservative by applying uncertainty discount according to the procedure provided in Appendix 2.

38. Tree biomass per hectare in a plot is estimated by using one of the plot measurement methods provided in Appendix 1.

8.1.2. Double sampling

39. Under this method, a secondary variable is measured in all the sample plots in a stratum and tree biomass is measured in a sub-set of the same sample plots. The mean biomass and its variance are estimated from the measured plot biomass values in the sub-sample and are adjusted through regression of the plot biomass values against the observed plot values of the secondary variable in the sub-sample.

40. This method is applicable only if there is a linear relationship between the plot biomass values and the plot values of the secondary variable (i.e. the best-fit curve is a straight line) within the range of the values.

Note. This method is efficient when spatial distribution of tree biomass in the area is highly heterogeneous and does not show ‘block patterns’ at significant scale and thus does not allow delineation of strata. The method is more efficient when the cost of obtaining the values of the secondary variable is low compared to cost of measurement of plot biomass, and the correlation between the secondary variable and the measured plot biomass values is high.

Example 1. Spatial distribution of tree biomass in a stratum was highly heterogeneous and it was not efficient to delineate tree biomass sub-strata. The project participants measured basal area in 300 sample plots. In a sub-sample of 50 plots they also measured plot biomass. This double sampling design reduced the variance of the estimated mean by one half. To achieve the same precision without double sampling it would have been necessary to conduct plot biomass measurement in 200 plots which would have been costlier.

Example 2. In a large project area the spatial distribution of tree biomass was highly heterogeneous and it was not efficient to delineate tree biomass strata. However, remotely sensed satellite data covering the area was available at a very low cost. An index, namely, Normalized Difference Vegetation Index (NDVI), was constructed from this data which was found to have approximately linear relationship with the per-hectare tree biomass. A double sampling design was adopted with construction of NDVI in 2000 sample plots and measurement of diameter of all trees in 150 sample plots selected from the 2000 plots using systematic selection with a random start. This double sampling design reduced the variance of the estimated mean by one third. To achieve the same precision by measuring fixed-area plots alone would have required measurement of 300 fix-area sample plots which would have been costlier.

41. Equations (12) to (15) also apply in this method for aggregating the mean and its variance over the strata. However, for each stratum in which double sampling is applied, the following equations apply instead of Equations (16) and (17):

$$b_{TREE,i} = \frac{\sum_{p=1}^{n_i} b_{TREE,p,i}}{n_i} + \beta \times (\overline{x'} - \bar{x})$$ Equation (18)

$$s_i^2 = \frac{n_i \times \sum_{p=1}^{n_i} b_{TREE,p,i}^2 - \left(\sum_{p=1}^{n_i} b_{TREE,p,i}\right)^2}{n_i \times (n_i - 1)} \times (1 - (1 - \alpha) \times \rho^2)$$ Equation (19)

Where:

$b_{TREE,i}$	=	Mean tree biomass per hectare in stratum *i*; t d.m. ha^{-1}
$b_{TREE,p,i}$	=	Tree biomass per hectare in plot *p* of stratum *i*; t d.m. ha^{-1}
n_i	=	Number of sample plots in the sub-sample
β	=	Slope of the regression line of tree biomass per hectare in a sample plot against the secondary variable value of the plot
$\overline{x'}$	=	Mean value of the secondary variable across all the sample plots
$\bar{x}$	=	Mean value of the secondary variable across the sub-sample of sample plots in which tree biomass is also measured
s_i^2	=	Variance of mean tree biomass per hectare in stratum *i*; (t d.m. $ha^{-1})^2$
α	=	Ratio of number of sample plots in the sub-sample to the number of sample plots in the sample (α <1)
ρ	=	Coefficient of correlation between the secondary variable and the tree biomass per hectare in a sample plot, estimated across all the sample plots in the sub-sample

42. The slope of the regression β and the coefficient of correlation ρ are calculated as explained in Appendix 3.

43. Tree biomass per hectare in a sample plot is estimated by using one of the plot measurement methods provided in Appendix 1.

44. If u_C estimated from Equation (15) is greater than 10 per cent, C_{TREE} is made conservative by applying uncertainty discount according to the procedure provided in Appendix 2.

8.2. Estimation by modelling of tree growth and stand development

45. This method is used for ex-ante estimation (projection) of carbon stock in tree biomass. Under this method existing data are used in combination with tree growth models to predict the growth of trees and the development of the tree stand over time.

46. Stand parameters such as stocking (e.g. number of stems per hectare or basal area per hectare), age-class structure, and species composition at different points of time are simulated from assumed (planned) tree planting and management practices (e.g. planting density, survival rate, thinning and pruning operations and their timing).

47. Tree growth (e.g. diameter or height increment) is simulated by taking into account local tree-growth data from past experience (e.g. age-diameter curves, yield tables, yield curves) while also considering relevant site factors (e.g. soil, terrain, slope, aspect, precipitation) and stand parameters.

48. Ex-ante estimation (projection) of carbon stock in tree biomass is not subjected to uncertainty control, although the project participants should use the best available data and models that apply to the project site and the tree species.

8.3. Estimation by proportionate crown cover

49. This method is applicable only for estimation of the pre-project carbon stock in tree biomass in the baseline where the mean pre-project tree crown cover is less than 20 per cent of the threshold tree crown cover reported by the host Party under paragraph 8 of the annex to decision 5/CMP.1.

Example. The host Party has reported a threshold tree crown cover of 30 per cent for defining 'forest' for the purposes of the CDM. This method is applicable only if the mean pre-project tree crown cover is less than 20 per cent of 30 per cent (i.e. less than 6 per cent).

50. Carbon stock in trees is estimated on the basis of tree crown cover at the time of the start of the project (the pre-project tree crown cover). The area within the project boundary is stratified by pre-project tree crown cover.

51. Under this method, carbon stock in tree biomass is estimated as follows:

$$C_{TREE\_BSL} = \sum_{i=1}^{M} C_{TREE\_BSL,i}$$ Equation (20)

$$C_{TREE\_BSL,i} = \frac{44}{12} \times CF_{TREE} \times b_{FOREST} \times (1 + R_{TREE}) \times CC_{TREE\_BSL,i} \times A_i$$ Equation (21)

Where

C_{TREE_BSL}	=	Carbon stock in pre-project tree biomass; t CO_2e
$C_{TREE\_BSL,i}$	=	Carbon stock in pre-project tree biomass in stratum *i*; t CO_2e
CF_{TREE}	=	Carbon fraction of tree biomass; t C $(t.d.m.)^{-1}$. A default value of 0.47 t C $(t.d.m.)^{-1}$ is used.
b_{FOREST}	=	Mean above-ground biomass in forest in the region or country where the A/R CDM project is located; t d.m. ha^{-1} Values from Table 3A.1.4 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information can be provided to justify different values.
R_{TREE}	=	Root-shoot ratio for trees in the baseline; dimensionless. A default value of 0.25 is used unless transparent and verifiable information can be provided to justify a different value.
$CC_{TREE\_BSL,i}$	=	Crown cover of trees in baseline stratum *i*, at the start of the A/R CDM project activity, expressed as a fraction (e.g. 10 per cent crown cover implies $CC_{TREE\_BSL,i}$ = 0.10); dimensionless
A_i	=	Area of baseline stratum *i*, delineated on the basis of tree crown cover at the start of the A/R CDM project activity; ha

8.4. Updating previous stock by direct estimation of change

52. Under this method, the new carbon stock in trees is obtained by adding the change in carbon stock in trees estimated by re-measurement of plots (*see* section 6.2) to the carbon stock estimated at the previous verification.

Note. This method is efficient when the number of tCERs is to be estimated and the method of direct estimation of change in carbon stock by re-measurement of sample plots is efficient. Since tCERs are based on total carbon stock, the carbon stock estimated at the previous verification must be updated by adding the change in carbon stock to arrive at the carbon stock at the second verification.

53. Under this method, carbon stock in trees in a stratum and the associated uncertainty are estimated as follows:

$$C_{TREE,t_2} = C_{TREE,t_1} + \Delta C_{TREE} \quad \text{Equation (22)}$$

$$u_2 = \frac{\sqrt{\left(u_1 \times C_{TREE,t_1}\right)^2 + \left(u_{\Delta C} \times \Delta C_{TREE}\right)^2}}{C_{TREE,t_2}} \quad \text{Equation (23)}$$

Where:

C_{TREE,t_2}	=	Carbon stock in trees at time t_2; t CO_2e

C_{TREE,t_1}	=	Carbon stock in trees as estimated at time t_1; t CO_2e Note. Even if C_{TREE,t_1} was made conservative at the time of the previous verification, it is the estimated (undiscounted) value of C_{TREE,t_1} that is used here.
ΔC_{TREE}	=	Change in carbon stock in trees during the period between times t_1 and t_2; t CO_2e
$u_{\Delta C}$	=	Uncertainty in ΔC_{TREE}
u_2, u_1	=	Uncertainties in C_{TREE,t_2} and C_{TREE,t_1} respectively

54. If u_2 estimated from Equation (23) is greater than 10 per cent, C_{TREE,t_2} is made conservative by applying uncertainty discount according to the procedure provided in Appendix 2.

9. Estimating change in carbon stock in shrubs between two points of time

55. Change in carbon stock in shrubs between two points of time is estimated as follows:

$$\Delta C_{SHRUB} = C_{SHRUB,t_2} - C_{SHRUB,t_1} \quad \text{Equation (24)}$$

Where:

ΔC_{SHRUB}	=	Change in carbon stock in shrub biomass during the period between times t_1 and t_2; t CO_2-e
C_{SHRUB,t_2}	=	Carbon stock in shrub biomass at time t_2; t CO_2-e
C_{SHRUB,t_1}	=	Carbon stock in shrub biomass at time t_1; t CO_2-e

56. Carbon stock in shrub biomass at a point of time is estimated by using the method provided in section 10.

57. Where, by applying *mutatis mutandis* the “no decrease” method provided under section 6.4 to shrubs, it can be shown that there has been no decrease in carbon stock in shrubs in one or more strata since the previous verification, the value of ΔC_{SHRUB} for those strata can be estimated as zero.

10. Estimating change in carbon stock in shrubs in a year

58. Change in carbon stock in shrubs in a year (annual change) between two successive verifications is estimated on the assumption of linear change.

59. Change in carbon stock in shrubs in a year is estimated as follows:

$$\Delta C_{SHRUB,t} = \frac{C_{SHRUB,t_2} - C_{SHRUB,t_1}}{T} \times 1\ year \quad \text{Equation (25)}$$

Where:

$\Delta C_{SHRUB,t}$	=	Change in carbon stock in shrubs within the project boundary in year *t* between times t_1 and t_2; t CO_2-e
C_{SHRUB,t_2}	=	Carbon stock in shrubs within the project boundary at time t_2; t CO_2e
C_{SHRUB,t_1}	=	Carbon stock in shrubs within the project boundary at time t_1; t CO_2e
T	=	Time elapsed between two successive estimations ($T=t_2 - t_1$); yr Note. Value of *T* does not have to be a whole number (e.g. an interval of 4 years and 5 months implies T = 4.417 yr).

11. Estimating carbon stock in shrubs at a point of time

60. Carbon stock in shrubs at a point of time is estimated on the basis of shrub crown cover. The area within the project boundary is stratified by shrub crown cover. Those areas where the shrub crown cover is less than 5 per cent are treated as a single stratum and the shrub biomass in this stratum is estimated as zero.

61. For the strata with a shrub crown cover of greater than 5 per cent, carbon stock in shrubs is estimated as follows:

$$C_{SHRUB,t} = \frac{44}{12} \times CF_s \times (1 + R_s) \times \sum_i A_{SHRUB,i} \times b_{SHRUB,i}$$ Equation (26)

$$b_{SHRUB,i} = BDR_{SF} \times b_{FOREST} \times CC_{SHRUB,i}$$ Equation (27)

Where:

$C_{SHRUB,t}$	=	Carbon stock in shrubs within the project boundary at a given point of time in year *t*; t CO_2-e
CF_s	=	Carbon fraction of shrub biomass; t C $(t.d.m.)^{-1}$. A default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value.
R_s	=	Root-shoot ratio for shrubs; dimensionless. The default value of 0.40 is used unless transparent and verifiable information can be provided to justify a different value.
$A_{SHRUB,i}$	=	Area of shrub biomass estimation stratum *i*; ha
$b_{SHRUB,i}$	=	Shrub biomass per hectare in shrub biomass estimation stratum *i*; t d.m. ha^{-1}

BDR_{SF}	=	Ratio of shrub biomass per hectare in land having a shrub crown cover of 1.0 (i.e. 100 per cent) and the default above-ground biomass content per hectare in forest in the region/country where the A/R CDM project activity is located; dimensionless. A default value of 0.10 should be used unless transparent and verifiable information can be provided to justify a different value.
b_{FOREST}	=	Default above-ground biomass content in forest in the region/country where the A/R CDM project activity is located; t d.m. ha^{-1}. Values from Table 3A.1.4 of IPCC GPG-LULUCF 2003 are used unless transparent and verifiable information can be provided to justify different values.
$CC_{SHRUB,i}$	=	Crown cover of shrubs in shrub biomass estimation stratum *i* at the time of estimation, expressed as a fraction (e.g. 10 per cent crown cover implies $CC_{SHRUB,i}$ = 0.10); dimensionless

12. Data and parameters used in the tool

62. This section describes the requirements for the data and parameters used in this tool. The requirements contained in the following data description tables should be treated as an integral part of the tool.

12.1. Data and parameters not monitored

63. The values, sources, and requirements for data and parameters which are not subject to monitoring are provided in the text of the tool along with the equations in which these are used.

12.2. Data and parameters monitored.

64. The requirements for data and parameters subject to monitoring are provided in the tables below.

Data / Parameter table 1. Area of land

Data / Parameter:	$\mathbf{A_{PLOT,i}}$, $\mathbf{A_{SHRUB,i}}$, $\mathbf{A_i}$
Data unit:	Ha
Description:	Area of a sample plot; area of a stratum
Source of data:	Field measurement
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the IPCC GPG LULUCF 2003, are applied
Monitoring frequency:	At every verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, are applied

Data / Parameter table 2. Shrub crown cover

Data / Parameter:	$\mathbf{CC_{SHRUB,i}}$
Data unit:	Dimensionless
Description:	Crown cover of shrubs in shrub biomass stratum *i*
Source of data:	Field measurement
Measurement procedures (if any):	Considering that the biomass in shrubs is smaller than the biomass in trees, a simplified method of measurement may be used for estimating shrub crown cover. Ocular estimation of crown cover may be carried out or any other method such as the line transect method or the relascope method may be applied
Monitoring frequency:	At every verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, are applied
Comment:	When land is subjected to periodic cycles (e.g. slash-and-burn, or clearing-regrowing cycles) so that the shrub crown cover oscillates between a minimum and maximum values in the baseline, an average shrub crown cover equal to 0.5 is used unless transparent and verifiable information can be provided to justify a different value

Data / Parameter table 3. Tree crown cover

Data / Parameter:	$\mathbf{CC_{TREE\_BSL,i}}$
Data unit:	Dimensionless
Description:	Crown cover of trees in the baseline stratum *i*
Source of data:	Field measurement
Measurement procedures (if any):	Considering that the biomass in trees in the baseline is smaller compared to the biomass in trees in the project, a simplified method of measurement may be used for estimating tree crown cover. Ocular estimation of tree crown cover may be carried out or any other method such as the line transect method or the relascope method may be applied
Monitoring frequency:	Measured only once (at the beginning of the project)
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, are applied
Comment:	When land is subjected to periodic cycles (e.g. slash-and-burn, or clearing-regrowing cycles) so that the tree crown cover oscillates between a minimum and maximum values in the baseline, the value of this parameter should be set equal to half the maximum tree crown cover that would be achieved under the cycle

Appendix 1. Methods of plot biomass measurement

1. This appendix provides methods for measurement of tree biomass per hectare in a sample plot (the plot biomass value). Plot biomass values are estimated from direct or indirect measurements conducted on trees in the sample plot. Table 1 presents the type of measurements and the methods for converting these measurements into tree biomass.

Table 1. Plot measurements and their conversion to tree biomass

Step	Fixed area plots	Variable area plots
Step 1. Measurement (what is measured)	Individual tree dimension (e.g. diameter at breast height, diameter at root collar, tree height)	Basal area per hectare
Step 2. Conversion (how measurements are converted into tree biomass)	1. Using allometric equations based on tree dimensions; or 2. Using biomass expansion factors; or 3. Combination of 1 and 2	1. Using allometric equations based on basal area; or 2. Using biomass expansion factors; or 3. Combination of 1 and 2

Note. Sampling by variable area plot method is also termed as 'angle count sampling' in forest inventory literature.

1. Measurement of fixed area plots

2. In this method, sample plots of the same size (e.g. $\frac{1}{10}$ or $\frac{1}{20}$ of a hectare) are installed in a stratum. All trees in a sample plot above a minimum dimension are measured and the biomass of each tree is estimated. The minimum dimension selected can be low (e.g. a diameter of 2 cm) or high (e.g. a diameter of 10 cm) depending upon the applicability of models (e.g. allometric equations or volume equations) to be used for conversion of the tree dimension into tree volume or tree biomass, and upon cost-effectiveness of measurement.

3. The biomass of the individual trees is added and the sum is divided by the area of the sample plot to obtain the plot biomass value.

Note. Where the number of saplings with diameter below the range of diameter applicable to the allometric equation is high, the mean biomass of the saplings in a sample plot can be estimated as follows: (1) Determine the diameter mid-way between the diameter of the smallest sapling existing and the smallest diameter allowed by the allometric equation. (2) Harvest from outside the plot area a few saplings having diameter close to the mid-way diameter and obtain the mean biomass per sapling; (3) Count all the saplings in the sample plot and multiply this number by the mean sapling biomass to obtain their contribution to the plot biomass.

4. The plot biomass value (i.e. per-hectare tree biomass at the centre of the plot) is estimated as follows (all time-dependent variables relate to the time of measurement):

$$b_{TREE,p,i} = \frac{B_{TREE,p,i}}{A_{PLOT,i}}$$ Equation (1)

$$B_{TREE,p,i} = \sum_{j} B_{TREE,j,p,i}$$ Equation (2)

$$B_{TREE,j,p,i} = \sum_{l} B_{TREE,l,j,p,i}$$ Equation (3)

Where:

$b_{TREE,p,i}$	=	Tree biomass per hectare in sample plot *p* of stratum *i*; t d.m. ha^{-1}
$B_{TREE,p,i}$	=	Tree biomass in sample plot *p* of stratum *i*; t d.m.
$A_{PLOT,i}$	=	Size of sample plot in stratum *i;* ha
$B_{TREE,j,p,i}$	=	Biomass of trees of species *j* in sample plot *p* of stratum *i*; t d.m.
$B_{TREE,l,j,p,i}$	=	Biomass of tree *l* of species *j* in sample plot *p* of stratum *i*; t d.m.

5. Biomass of a tree in a sample plot is estimated by using one of the following equations:

$$B_{TREE,l,j,p,i} = f_j(x_{1,l}, x_{2,l}, x_{3,l}, \dots) \times (1 + R_j)$$ Equation (4)

$$B_{TREE,l,j,p,i} = V_{TREE,j}(x_{1,l}, x_{2,l}, x_{3,l}, \dots) \times D_j \times BEF_{2,j} \times (1 + R_j)$$ Equation (5)

Where:

$B_{TREE,l,j,p,i}$	=	Biomass of tree *l* of species *j* in sample plot *p* of stratum *i*; t d.m.

$f_j(x_{1,l}, x_{2,l}, x_{3,l}, \ldots)$	=	Above-ground biomass of the tree returned by the allometric equation for species *j* relating the measurements of tree *l* to the above-ground biomass of the tree; t d.m. <u>Note.</u> The allometric equation used may be based on different units of inputs and outputs. For example, input values of diameter at breast height (dbh) may be in inches and output of biomass may be in pounds, rather than dbh in cm and biomass in kg or t d.m. In such a case, the function should be applied consistently (e.g. convert the dbh values from centimetre to inch units, obtain the tree biomass in pound, and then convert the biomass into metric tonne).
R_j	=	Root-shoot ratio for tree species *j*; dimensionless The value of R_j is estimated as $R_j = \frac{e^{(-1.085+0.9256\times\ln b)}}{b}$ where b is the above-ground tree biomass per hectare (in t d.m. ha^{-1}), unless transparent and verifiable information can be provided to justify a different value. <u>Note.</u> If trees have grown as coppice regeneration after a harvest, then the value of R_j should be multiplied by a factor equal to $^{v_{HARVEST}}/_{v_{TREE}}$ or 1, whichever is greater, where $v_{HARVEST}$ is the volume per hectare of trees harvested and v_{TREE} is the volume per hectare of trees standing in the plot at the time of measurement.
$V_{TREE,j}(x_{1,l}, x_{2,l}, x_{3,l}, \ldots)$	=	Stem volume of tree *l* of species *j* in sample plot *p* of stratum *i*, estimated from the tree dimension(s) as entry data into a volume table or volume equation; m^3 <u>Note.</u> Where the volume table or volume equation predicts under-bark volume (i.e. wood volume, rather than gross stem volume), suitable correction should be applied to estimate the over-bark volume.
D_j	=	Density (over-bark) of tree species *j*; t d.m. m^{-3} Values are taken from Table 3A.1.9 of IPCC GPG-LULUCF 2003 unless transparent and verifiable information can be provided to justify different values. <u>Note.</u> Where density (specific gravity) of the bark of a tree species is different from the density of the wood, suitable correction should be applied to estimate a conservative value of the overall (over-bark) density of tree stem.

$BEF_{2,j}$	=	Biomass expansion factor for conversion of tree stem biomass to above-ground tree biomass, for tree species *j*; dimensionless For ex-ante estimation, the value of $BEF_{2,j}$ is selected by applying, *mutatis mutandis*, the procedure described in paragraph 7 below. For ex-post estimation the conservative default value of 1.15 is used, unless transparent and verifiable information can be provided to justify a different value.

6. For ex-ante estimation the allometric equation, or volume table or volume equation applied to a tree species is selected from the following sources (the most preferred source being listed first):

   (a) Existing data applicable to local situation (e.g. represented by similar ecological conditions);

   (b) National data (e.g. from national forest inventory or national greenhouse gas (GHG) inventory);

   (c) Data from neighbouring countries with similar conditions;

   (d) Globally applicable data.

7. For ex-post estimation, the allometric equation used must be demonstrated to be appropriate for the purpose of estimation of tree biomass by applying the tool “Demonstrating appropriateness of allometric equations for estimation of aboveground tree biomass in A/R CDM project activities”, and the volume table or volume equation used must be demonstrated to be appropriate for the purpose of estimation of tree biomass by applying the tool “Demonstrating appropriateness of volume equations for estimation of aboveground tree biomass in A/R CDM project activities”.

2. Measurement of variable plots

8. This method estimates tree biomass per hectare from the basal area per hectare and therefore does not require individual tree measurements. Tree basal area is obtained at the centre of a sample plot using an angle-count instrument (e.g. a wedge prism or a relascope).

9. Tree biomass in a plot is estimated as follows:

Equation (6)

$$b_{TREE,p,i} = \sum_{j} b_{TREE,j,p,i}$$

Where:

$b_{TREE,p,i}$	=	Tree biomass per hectare in sample plot *p* of stratum *i*; t d.m. ha^{-1}

$b_{TREE,j,p,i}$	=	Tree biomass per hectare of species *j* in sample plot *p* of stratum *i*; t d.m. ha^{-1}

10. Tree biomass per hectare of a species in a sample plot is estimated by using one of the following equations:

$$b_{TREE,j,p,i} = f_j(BA_{p,i}) \times \left(1 + R_j\right) \qquad \text{Equation (7)}$$

$$b_{TREE,j,p,i} = v_{TREE,j}(BA_{p,i}) \times D_j \times BEF_{2,j} \times \left(1 + R_j\right) \qquad \text{Equation (8)}$$

Where:

$b_{TREE,j,p,i}$	=	Tree biomass per hectare of species *j* in sample plot *p* of stratum *i*; t d.m. ha^{-1}
$f_j(BA_{p,i})$	=	Above-ground tree biomass per hectare in plot *p* returned by the allometric equation for species *j* relating the basal area of the plot to the above-ground tree biomass per hectare*;* t d.m. ha^{-1}
$v_{TREE,j}(BA_{p,i})$	=	Stem volume per hectare of trees of species *j* in sample plot *p* of stratum *i* estimated by using the basal area of the plot as entry data into a volume table or volume equation; m^3 ha^{-1}

11. All other symbols have the same meanings and requirements as in Equations (4) and (5).

12. Requirements under paragraphs 7 and 8 above also apply, *mutatis mutandis*, in respect of allometric equations and volume functions used under this method.

Appendix 2. Applying uncertainty discount

1. Estimates with high uncertainty can be used in methodologies only if such estimates are conservative. This appendix provides a procedure for applying discount factors in order to make the mean estimated values of parameters conservative.

2. When the uncertainty in the estimated mean value of a parameter is more than 10 per cent, the estimated mean value is either increased or decreased by a percentage of the uncertainty. Table 1 provides the uncertainty discount factors to be applied for different ranges of uncertainty.

Table 1. Uncertainty discount factors

Uncertainty	Discount (% of U)	How applied
U ≤ 10%	0%	*Example:* Estimated mean = 60±9 t d.m ha^{-1} i.e. U=9/60x100 = 15% Discount = 25% x 9 = 2.25 t d.m ha^{-1} Discounted conservative mean: In baseline = 60+2.25 = 62.25 t d.m ha^{-1} In project = 60-2.25 = 57.75 t d.m ha^{-1}
10 < U ≤ 15	25%	
15 < U ≤ 20	50%	
20 < U ≤ 30	75%	
U > 30	100%	

Appendix 3. Calculating correlation coefficient and slope of regression

1. This appendix provides the formulae for calculation of the coefficient of correlation and the slope of regression line between two data sets. The formulae provided here can also be found in any textbook or reference book of statistics. It is only for convenience of the users and for avoiding any ambiguity in definition of these parameters that these formulae are provided here. These coefficients may also be calculated using commercial or open source computer software (e.g. statistical packages).

2. For two linearly related data sets of equal size, the correlation coefficient and the slope of regression line are calculated as follows:

$$\beta = \rho \times \frac{s_y}{s_x}$$ Equation (1)

$$\rho = \frac{\sum_{i=1}^{n}\{(x_i - \bar{x})(y_i - \bar{y})\}}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \times \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$ Equation (2)

Where:

β	=	Slope of regression line of the dependent variable (y) against the independent variable (x)
ρ	=	Sample correlation coefficient between the dependent variable (y) and the independent variable (x)
s_y, s_x	=	Sample standard deviation of the dependent variable (y) values and the independent variable (x) values respectively
x_i	=	Independent variable (x) values
$\bar{x}$	=	Mean of the independent variable (x) values
y_i	=	Dependent variable (y) values
$\bar{y}$	=	Mean of the dependent variable (y) values
n	=	Number of data values in each data set

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Document information

Version	*Date*	*Description*
04.2	24 July 2015	EB 85, Annex 22 Minor revision to correct paragraph 12, read "one or more of the following indicators apply" instead of "the following indicators apply.
04.1	16 October 2013	Editorial revision to correct paragraph and sub-heading numbers.
04.0	4 October 2013	EB 75, Annex 26 This revision: • Options of using double sampling and simplified method of 'no-decrease' were added; • Combining different methods in different strata was allowed; • A more comprehensive approach to uncertainty management was provided; • The structure was improved and some sections were moved to the appendices to improve readability; Due to the overall modification of the document, no highlights of the changes are provided.
03.0.0	23 November 2012	EB 70, Annex 35 In this revision: • Step-wise guidance was provided which explains when to use which method of estimation; • Effect of the tree bark density was taken into account to estimate tree biomass; • A method for adjustment of the estimated mean values was provided when the uncertainty of estimation exceeds the allowable maximum uncertainty. Due to the overall modification of the document, no highlights of the changes are provided.

Version	*Date*	*Description*
02.1.0	15 April 2011	EB 60, Annex 13 In this amendment: • Equations for estimation of the means and variances of tree biomass at stratum level and at project level have been included; • Estimation of tree biomass is made on a per hectare basis, so that plotless sampling (point sampling) methods can be seamlessly applied; • An approach for estimation of change in biomass based on successive measurements of the same plots has been added; (iv) some entries in data and parameter tables have been updated to include more clear guidance in commonly encountered field situations; • Bark correction has been proposed in cases where a volume table based on under-bark volume is used in conjunction with biomass expansion factors based on over-bark volume (or vice versa).
02.0.0	17 September 2010	EB 56, Annex 13 In this revision: • The scope of the tool has been expanded so that it can be applied in both baseline scenario and project scenario; • The procedure for estimation of shrub biomass has been simplified by adopting a default estimation approach based on a fraction of forest biomass; • The mathematical notation and equations have been changed so to streamline these; • General layout and style of the document has been changed so as to make it in conformity with other documents such as the recently approved A/R methodologies; and • The title was changed to “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities” from the previous title “Estimation of changes in the carbon stocks of existing trees and shrubs within the boundary of an A/R CDM project activity”. Due to the overall modification of the document, no highlights of the changes are provided.
01	25 March 2009	EB 46, Annex 18 Initial adoption.

Decision Class: Regulatory
Document Type: Tool
Business Function: Methodology
Keywords: afforestation reforestation, AR project activity, biomass, carbon pools

CLEAN DEVELOPMENT MECHANISM

AR-TOOL15

A/R Methodological tool

Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity

Version 02.0

United Nations
Framework Convention on
Climate Change

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1. Introduction

1. This tool provides a step-by-step method for estimating increase in GHG emissions resulting from displacement of pre-project agricultural activities from the project boundary of an afforestation or reforestation (A/R) project activity under the clean development mechanism (CDM). The tool estimates the increase in emissions on the basis of changes in carbon stocks in the affected carbon pools in the land receiving the displaced activities.

2. Scope, applicability, and entry into force

2.1. Scope

2. The tool applies to all types of A/R CDM project activities and programmes of activities.

2.2. Applicability

3. This tool is not applicable if the displacement of agricultural activities is expected to cause, directly or indirectly, any drainage of wetlands or peat lands.

2.3. Entry into force

4. The date of entry into force of the revision is the date of the publication of the EB 75 meeting report on 4 October 2013.

3. Normative references

5. The following documents are indispensable for the application of this tool:

   (a) Glossary of CDM terms;

   (b) The A/R methodological tool: “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities”;

   (c) The A/R methodological “Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities”.

4. Definitions

6. The definitions contained in the Glossary of CDM terms shall apply.

7. For the purpose of this tool, the following specific definitions shall apply:

   (a) **Agricultural activities -** refers to crop cultivation activities and grazing activities occurring on land;

   (b) **Crop cultivation activities -** refers to human induced activities, occurring on land, that are aimed at vegetation control for producing food, forage, fiber, oilseed crops, etc., including harvesting of the produce;

   (c) **Grazing activities -** refers to human induced activities, occurring on land, that are aimed at livestock production;

(d) **Displacement of agricultural activities -** refers to shifting of the agricultural activities from areas of land within the project boundary to areas of land outside the project boundary;

(e) **Leakage emission -** refers to the increase in GHG emissions resulting from displacement of pre-project activities.

5. Parameter

8. This tool provides procedures to determine the following parameter:

Table 1. Parameter determined by the tool

Parameter	SI Unit	Description
$LK_{AGRIC,t}$	t CO_2e	Leakage emission due to the displacement of agricultural activities in year *t*

6. Estimation of leakage emission

9. Leakage emission attributable to the displacement of agricultural activities due to implementation of an A/R CDM project activity is estimated as the decrease in carbon stocks in the affected carbon pools of the land receiving the displaced activity.

Note 1. Displacement of an agricultural activity by itself does not result in leakage emission. Leakage emission occurs when the displacement leads to an increase in GHG emissions relative to the GHG emissions attributable to the activity as it exists within the project boundary.

Note 2. Increase in GHG emission occurring outside the project boundary attributable to the secondary effects of the A/R CDM project activity (e.g. changes in demand, supply or price of goods) is considered insignificant for the purpose of this tool and hence accounted as zero.

10. Leakage emission attributable to the displacement of grazing activities under the following conditions is considered insignificant and hence accounted as zero:

(a) Animals are displaced to existing grazing land and the total number of animals in the receiving grazing land (displaced and existing) does not exceed the carrying capacity of the grazing land;

(b) Animals are displaced to existing non-grazing grassland and the total number of animals displaced does not exceed the carrying capacity of the receiving grassland;

(c) Animals are displaced to cropland that has been abandoned within the last five years;

(d) Animals are displaced to forested lands, and no clearance of trees, or decrease in crown cover of trees and shrubs, occurs due to the displaced animals;

(e) Animals are displaced to zero-grazing system.

11. In all other cases, the lands within the project boundary from which the pre-project agricultural activities are to be displaced outside the project boundary are delineated and their area is estimated. Leakage emission resulting from displacement of the activities is estimated as follows:

$$LK_{AGRIC,t} = \frac{44}{12} \times \left(\Delta C_{BIOMASS,t} + \Delta SOC_{LUC,t}\right)$$ Equation (1)

$$\Delta C_{BIOMASS,t} = [1.1 \times b_{TREE} \times (1 + R_{TREE}) + b_{SHRUB} \times (1 + R_S)] \times CF \times A_{DISP,t}$$ Equation (2)

$$\Delta SOC_{LUC,t} = SOC_{REF} \times (f_{LUP} \times f_{MGP} \times f_{INP} - f_{LUD} \times f_{MGD} \times f_{IND}) \times A_{DISP,t}$$ Equation (3)

Where:

$LK_{AGRIC,t}$	=	Leakage emission resulting from displacement of agricultural activities in year *t*; t CO_2e
$\Delta C_{BIOMASS,t}$	=	Decrease in carbon stock in the carbon pools of the land receiving the activity displaced in year *t*; t d.m. <u>Note.</u> The factor of 1.1 is used to account for the carbon stock in the dead wood and litter pools as a fixed percentage of the carbon stock in living trees.
CF	=	Carbon fraction of woody biomass; dimensionless. A default value of 0.47 is used unless transparent and verifiable information can be provided to justify a different value.
$A_{DISP,t}$	=	Area of land from which agricultural activity is being displaced in year *t*; ha
b_{TREE}	=	Mean above-ground tree biomass in land receiving the displaced activity; t d.m. ha^{-1} The value of this parameter is obtained by applying one of the applicable methods from the tool “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities” to the land receiving the displaced activity. Where the land receiving the displaced activity is unidentified, value of b_{TREE} is set equal to the applicable value of mean above-ground biomass in forest in the region or country where the A/R CDM project activity is located, as obtained from Table 3A.1.4 of the *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC GPG-LULUCF 2003) unless transparent and verifiable information can be provided to justify a different value.

R_{TREE}	=	Root-shoot ratio for trees in the land receiving the displaced activity; dimensionless. A default value of 0.25 is used unless transparent and verifiable information can be provided to justify a different value.
b_{SHRUB}	=	Mean above-ground shrub biomass in land receiving the displaced activity; t d.m. ha^{-1}. The value of this parameter is obtained by applying one of the applicable methods from the tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities" to the land receiving the displaced activity.
R_S	=	Root-shoot ratio for shrubs in the land receiving the displaced activity; dimensionless. The default value of 0.40 is used unless transparent and verifiable information can be provided to justify a different value.
$\Delta SOC_{LUC,t}$	=	Change in soil organic carbon (SOC) stock due to land-use change in the land receiving the displaced activity in year *t*; tC ha^{-1}. The value of this parameter may be set to zero if: (a) The only displaced activity being received in the land is grazing activity; or (b) The value of the parameter as estimated from Equation (3) is less than zero (i.e. negative).
SOC_{REF}	=	SOC stock corresponding to the reference condition in native lands by climate region and soil type applicable to the land receiving the displaced activity; t C ha^{-1}. The value of this parameter is taken from Table 3 of the "Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities".
f_{LUP}, f_{MGP}, f_{INP}	=	Relative SOC *stock change factors* for land-use, management practices, and inputs respectively, applicable to the receiving land before the displaced activity is received; dimensionless. The value of these parameters is taken from Tables 4, 5, and 6 of the "Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities".
f_{LUD}, f_{MGD}, f_{IND}	=	Relative SOC *stock change factors* for land-use, management practices, and inputs respectively, applicable to the receiving land after the displaced activity has been received; dimensionless. The value of these parameters is taken from Tables 4, 5, and 6 of the "Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities".
t	=	*1, 2, 3, …*years elapsed since the start of the A/R CDM project activity

12. Where pre-project activities are shifted to different types of receiving lands in a year, Equations (1), (2) and (3) shall be applied to each type of land separately and the estimated leakage emissions shall be added to obtain the value of the parameter $LK_{AGRIC,t}$

7. Data and parameters used in the tool

13. This section describes the requirements for the data and parameters used in this tool. The requirements contained in the data description tables should be treated as an integral part of the tool. The requirements contained in the tools which are referred to in this tool shall also apply.

7.1. Data and parameters not monitored

14. The values, sources, and requirements for data and parameters which are not subject to monitoring are provided in the text of the tool along with the equations in which these are used.

7.2. Data and parameters monitored

15. The requirements for data and parameters subject to monitoring are provided in the table below.

Data / Parameter table 1. Area of land

Data / Parameter:	$A_{DISP,t}$
Data unit:	Ha
Description:	Area of land from which agricultural activity is being displaced in year t
Source of data:	Field measurement
Measurement procedures (if any):	Standard operating procedures (SOPs) prescribed under national forest inventory are applied. In the absence of these, SOPs from published handbooks, or from the IPCC GPG LULUCF 2003, are applied
Monitoring frequency:	At every verification
QA/QC procedures:	Quality control/quality assurance (QA/QC) procedures prescribed under national forest inventory are applied. In the absence of these, QA/QC procedures from published handbooks, or from the IPCC GPG LULUCF 2003, are applied

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Document information

Version	*Date*	*Description*
02.0	4 October 2013	EB 75, Annex 28 This revision: • Incorporates related decisions from the Board; • Delinks leakage emission from the project carbon stocks; • Estimates leakage from actual carbon stocks in the receiving lands; • Reformats the methodology using the current template and thus enhances readability and consistency.
01	04 December 2009	EB 51, Annex 15 Initial adoption.

Decision Class: Regulatory
Document Type: Tool
Business Function: Methodology
Keywords: afforestation reforestation, grazing activities, pre-project GHG emissions