Afforestation and reforestation baseline and monitoring methodology

AR-AM0013

"Afforestation and reforestation of lands other than wetlands"

(Version 01.0.0)

I. SOURCE, DEFINITIONS AND APPLICABILITY

1. Source

This methodology is based on elements from the following methodologies:

- AR-AM0003 "Afforestation and reforestation of degraded land through tree planting, assisted natural regeneration and control of animal grazing." The baseline study, monitoring and verification plan and project design document were prepared by the General Directorate for Forests and Pastures and the International Bank for Reconstruction and Development as Trustee of the BioCarbon Fund;
- AR-NM0032-rev "San Carlos" Grassland Restoration through Afforestation. The baseline study, monitoring and verification plan and project design document were prepared by Factor CO_2 Integral Services;
- AR-AM0006-rev "Afforestation/Reforestation with Trees Supported by Shrubs on Degraded Land." The baseline study, monitoring and verification plan and project design document were prepared by the Institute of Forest Ecology and Environment, the Chinese Academy of Forestry, China; University of Tuscia, Italy and others.

For more information regarding the source methodologies and their consideration by the CDM Executive Board (the Board) please refer to <http://cdm.unfccc.int/goto/ARappmeth>.

This methodology uses the latest approved versions of the following tools, procedures, guidelines and guidances:

- Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM project activities;
- Guidance on application of the definition of the project boundary to A/R CDM project activities;
- Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities;
- Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities;
- Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities;
- Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities;

- Estimation of non-CO_2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity;
- Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity.

All the above-mentioned tools, procedures, guidelines and guidances are available at: <http://cdm.unfccc.int/Reference/tools> and <http://cdm.unfccc.int/Reference/Procedures/index.html>.

2. Definitions

This methodology uses the following specific definitions:

> "Soil disturbance" is any activity that results in release of soil organic carbon (SOC) into the atmosphere, e.g. ploughing, ripping, scarification, digging of pits and trenches, stump removal, drainage of soil, etc.

For definition of all other terms used in this methodology the project participants (PPs) should refer to the following sources:

(a) 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;

(b) "Annex A: Glossary" of the Good Practice Guidance for Land Use, Land-Use Change and Forestry by the Intergovernmental Panel on Climate Change, 2003 (IPCC GPG LULUCF 2003);

(c) Glossary of CDM terms.[1]

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

PPs shall select from among the following approaches the one deemed most appropriate for the project activity:

(a) "Existing or historical, as applicable, changes in carbon stocks in the carbon pools within the project boundary;"

(b) "Changes in carbon stocks in the carbon pools within the project boundary from a land use that represents an economically attractive course of action, taking into account barriers to investment;";

(c) "Changes in carbon stocks in the pools within the project boundary from the most likely land use at the time the project starts".

4. Applicability

The conditions under which the methodology is applicable are:

(a) The land subject to the project activity does not fall into wetland[2] category;

[1] Available at <http://cdm.unfccc.int/Reference/Guidclarif/glos_CDM.pdf>.

(b) Soil disturbance attributable to the A/R CDM project activity does not exceed 10% of area in each of the following types of land, when these lands are included within the project boundary:

(i) Land containing organic soils as defined in "Annex A: Glossary" of the IPCC GPG LULUCF 2003;

(ii) Land which, in the baseline, is subjected to land-use and management practices and receives inputs listed in annexes 1 and 2 to this methodology;

(c) The pools selected for accounting of carbon stock changes in the project activity are the same as the pools for accounting of carbon stock changes in the baseline.

Conditions contained in tools, procedures, guidelines and guidances are applicable when these are used along with the methodology.

II. BASELINE METHODOLOGY

1. Project boundary and eligibility of land

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

The "Procedures to demonstrate the eligibility of lands for afforestation and reforestation CDM project activities" shall be used for demonstrating that each discrete area of land to be included in the project boundary is eligible for an A/R CDM project activity.

The "Guidance on application of the definition of the project boundary to A/R CDM project activities" may be applied in identification of areas of land planned for an A/R CDM project activity.

The carbon pools selected/not selected for accounting of carbon stock changes are shown in Table 1.

Table 1: Carbon pools selected/not selected for accounting of carbon stock changes

Carbon pool	Whether selected	Justification / Explanation
Above-ground biomass	Yes	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 A/R CDM project activity
Dead wood Litter and Soil organic carbon	Yes (alternatively No)	Carbon stock in these pools may increase (when compared to baseline) due to implementation of the project activity. The methodology also provides the conservative choice of not accounting for carbon stock changes in any of these pools if such choice is identical for both the baseline and the project scenarios

[2] "Wetlands" as defined in "Annex A: Glossary" of the IPCC GPG LULUCF 2003.

Changes in carbon stock in pools not selected in Table 1 shall be set to zero in all equations in this methodology.

The emission sources and associated GHGs selected/not selected for accounting of GHG emissions are shown in Table 2.

Table 2: Emission sources and GHGs selected/not selected for accounting of GHG emissions

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

2. Identification of the baseline scenario and demonstration of additionality

This methodology uses the "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities" for the purpose of identification of the baseline scenario and demonstration of additionality.

3. Stratification

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 required 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.

Remotely sensed data reflecting the situation close to the time of project start and/or the occurrence of natural or anthropogenic impacts may be used for *ex ante* and *ex post* stratification.

4. Baseline net GHG removals by sinks

The baseline net GHG removals by sinks is calculated as follows:

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

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
$\Delta C_{LI\_BSL,t}$	Change in carbon stock in baseline litter 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. Actual net GHG removals by sinks

The actual net GHG removals by sinks is calculated as follows:

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

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 calculated in the tool “Estimation of non-CO2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity”; t CO_2-e

Change in the carbon stocks in project, occurring in the selected carbon pools in year *t* is calculated as follows:

$$\Delta C_{P,t} = \Delta C_{TREE\_PROJ,t} + \Delta C_{SHRUB\_PROJ,t} + \Delta C_{DW\_PROJ,t} + \Delta C_{LI\_PROJ,t} + \Delta SOC_{AL,t} \qquad \textbf{(3)}$$

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
$\Delta C_{LI\_PROJ,t}$	Change in carbon stock in litter 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
$\Delta SOC_{AL,t}$	Change in carbon stock in SOC in project, in year *t*, in areas of land meeting the applicability conditions of the tool "Tool for estimation of change in soil organic carbon stocks due to the implementation of A/R CDM project activities", as estimated in the same tool; t CO_2-e

6. Leakage

Under applicability conditions of this methodology the following types of leakage emissions can occur: GHG emissions due to activity displacement, the activity displaced being agricultural activities. Therefore, leakage is estimated as follows:

$$LK_t = LK_{AGRIC,t} \tag{4}$$

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 calculated 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

7. Net anthropogenic GHG removals by sinks

The net anthropogenic GHG removals by sinks is calculated as follows:

$$\Delta C_{AR-CDM,t} = \Delta C_{ACTUAL,t} - \Delta C_{BSL,t} - LK_t \tag{5}$$

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

7.1 Calculation of tCERs and lCERs

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) are calculated as follows:

$$tCER_{t_2} = \sum_{1}^{t_2} \Delta C_{AR-CDM,t} \tag{6}$$

$$lCER_{t_2} = \sum_{t_1+1}^{t_2} \Delta C_{AR-CDM,t} \quad \textbf{(7)}$$

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

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.

III. MONITORING METHODOLOGY

All data collected as part of monitoring should be archived electronically and be kept at least for two years after the end of the last crediting period. All measurements should be conducted according to relevant standards. In addition, the monitoring provisions contained in the tools used in this methodology apply.

1. Monitoring of project implementation

Information shall be provided, and recorded in the project design document (PDD), to establish that commonly accepted principles and practices of forest inventory and forest management in the host country are implemented. In the absence of these, 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 GPG LULUCF 2003*, is recommended.

2. Sampling design and stratification

An *ex ante* stratification, if needed, should be presented in the PDD. Further considerations relating to stratification and sampling are included in the tool “Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities”.

2.2 Precision requirements

Maximum allowable relative margin of error of the mean for estimation of tree biomass is ± 10% at 90% confidence level.

2.3 Data requirements under the methodology

Table 3 provides a list of the data and parameters that are required in order to apply this methodology. Full description of these data and parameters can be found in the tools used in this methodology.

Table 3: Data and parameters required under the methodology

Data/Parameter	Description	Unit
A. Data and parameters to be obtained from existing sources		
$BEF_{2,j}$	Biomass expansion factor for conversion of stem biomass to above-ground biomass for tree species or group of species *j*	Dimensionless
BDR_{SF}	Ratio of biomass per unit area in land having a shrub crown cover of 1.0 and default above-ground biomass content in forest in the region/country where the A/R CDM project is located	Dimensionless
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}
ΔB_{FOREST}	Default average annual increment in above-ground biomass in forest in the region/country where the A/R CDM project is located	t d.m. ha^{-1} yr^{-1}
D_j	Basic wood density for species or group of species *j*	t d.m. m^{-3}
R_j	Root-shoot ratio for species or group of species *j*	Dimensionless
R_S	Root-shoot ratio for shrubs	Dimensionless
$f_j\left(DBH,H\right)$	Allometric function for species or group of species *j* linking a tree diameter (e.g. diameter at breast height), and possibly tree height (*H*), to above-ground biomass of the living tree	t d.m. $tree^{-1}$
$V_{TREE,j}$	Stem volume of trees of species or group of species *j* for trees of given age/diameter/height	m^3
B. Data and parameters to be obtained from measurement		
A_i	(a) Area of tree biomass stratum *i*; (b) Area of SOC stratum *i* of the land meeting the applicability conditions of the SOC tool	ha
$A_{SHRUB,i}$	Area of shrub crown cover stratum *i*	ha

Data/Parameter	Description	Unit
$A_{p,i}$	Area of sample plot *p* in tree biomass stratum *i*	ha
$CC_{SHRUB,i}$	Crown cover of shrubs in lands within the project boundary, in shrubs stratum *i*, expressed as a fraction	Dimensionless
$CC_{TREE\_BSL,i}$	Crown cover of trees in the baseline, in baseline stratum *i*, expressed as a fraction	Dimensionless
DBH	Tree diameter	cm
H	Tree height	m
$B_{LI\_WET,p,i}$	Wet weight of the composite sample of litter collected from plot *p* of stratum *i*	kg
D_n	Diameter of the n^{th} piece of lying dead wood intersecting a transect line	cm

All the data and parameters obtained from measurement shall be monitored every five years from the date of the initial verification.

IV. REFERENCES AND ANY OTHER INFORMATION

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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Annex 1: Croplands in which soil disturbance is restricted[3]

Region	Land use	Management	Inputs
Boreal	Long-term cultivated cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High without manure
			High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High without manure
			High with manure
Temperate, cold, dry	Long-term cultivated cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	Medium
			High without manure
Temperate, cold, moist	Long-term cultivated cropland	Reduced tillage	High with manure
		No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High without manure
			High with manure
Temperate, warm, dry	Long-term cultivated cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	Medium
			High without manure
Temperate, warm, moist	Long-term cultivated cropland	Reduced tillage	High with manure
		No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High with manure
		No-till	High without manure
			High with manure

[3] Adapted from *2006 IPCC Guidelines for National Greenhouse Gas Inventories.*

Annex 1: Croplands in which soil disturbance is restricted[3]

Region	Land use	Management	Inputs
Tropical, dry	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	Medium
			High without manure
			High with manure
		No-till	All
Tropical, moist	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High without manure
			High with manure
		No-till	High without manure
			High with manure
Tropical, montane	Long-term cultivated cropland	No-till	High with manure
	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High without manure
			High with manure
		No-till	Medium
			High without manure
			High with manure
Tropical, wet	Short-term or set aside cropland	Full tillage	High with manure
		Reduced tillage	High without manure
			High with manure
		No-till	High without manure
			High with manure

Annex 2: Grasslands in which soil disturbance is restricted[4]

Temperature / Moisture Regime	Management	Inputs
Boreal	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, cold, dry	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, cold, moist	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, warm, dry	Improved	All
	Non-degraded	All
	Moderately degraded	High
Temperate, warm, moist	Improved	All
	Non-degraded	All
	Moderately degraded	High
Tropical, dry	Improved	All
	Non-degraded	All
Tropical, moist	Improved	All
	Non-degraded	All
	Moderately degraded	High
Tropical, montane	Improved	All
	Non-degraded	All
	Moderately degraded	High
Tropical, wet	Improved	All
	Non-degraded	High
	Moderately degraded	High

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History of the document

Version	Date	Nature of revision(s)
01.0.0	EB 60, Annex 9 15 April 2011	Initial adoption.
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4 *Ibid.*