A/R Methodological Tool

"Estimation of changes in the carbon stocks of existing trees and shrubs within the boundary of an A/R CDM project activity"

(Version 01)

I. SCOPE, APPLICABILITY AND PARAMETERS

Scope

1. This tool can be used to estimate the change in carbon stocks of live woody vegetation that exists within the A/R CDM project boundary at the time the project commences (the "existing woody vegetation"), and that would have occurred in the absence of the A/R CDM project activity. The changes in carbon stocks are accounted as a component of baseline net GHG removals by sinks.

2. The tool is applied in a stepwise manner, as follows:

Step 1: Use the approved A/R CDM *Guidance on Conditions under which the Change in Carbon Stocks in Existing Live Woody Vegetation Need not be Accounted* to determine whether the change in carbon stocks in existing live woody vegetation (i.e. in trees and shrubs), expected in the absence of the project, is insignificant. If insignificant, the parameter provided by this tool—the change in carbon stocks in existing woody vegetation at time *t*, $\Delta C_{woody,exist,t}$ —is accounted as zero, and further use of this tool is not required. Otherwise, proceed to Step 2.

Step 2: To estimate the change in carbon stocks in existing live woody vegetation at time *t* that would have occurred in the absence of the project, $\Delta C_{woody,exist,t}$, use one of the following two methodological approaches detailed in Section II.

- Method 1: carbon gain-loss approach;
- Method 2: carbon stock-change approach.

3. The change in carbon stocks of existing woody vegetation need only be determined for the proportion of the total existing woody vegetation that is not already at maturity at the time the project commences—and only for as long at it takes such woody vegetation to reach maturity. Once such existing vegetation, on average, reaches the age of maturity, $\Delta C_{woody,exist,t}$ can be considered to become insignificant, and henceforth accounted as zero.

4. Guidelines on obtaining default or field-measured data for use in these two methodological approaches—for such parameters as growth rates, root-shoot ratios, and biomass expansion factors—are given in Section IV. Guidelines on conservatively selecting default data for estimating increases in biomass due to growth in existing woody vegetation are given in the approved A/R document: *Guidelines and Guidance for Choice of Data when Estimating Biomass Stocks and Change*.

5. The tool also includes an annex that provides guidelines and guidance on: estimating the time to maturity of existing woody vegetation. This includes procedures to determine the age of maturity of existing woody vegetation (including from growth curves), and to estimate both the proportion and average age of existing woody vegetation not yet at maturity at the time the project commences.

Applicability

6. This tool can be used to estimate the change in carbon stocks in the existing live woody vegetation present within the project boundary at the commencement of the project. The change in carbon stocks during a given time period, if significant, are accounted as a component of baseline net GHG removals by sinks. Accounting continues until such time as the existing vegetation would, in the absence of the project, have been expected to reach maturity.

7. The tool is not applicable in situations in which the baseline scenario for the project includes significant expansion in the area of naturally regenerating trees or shrubs.[1] To exclude such situations, add the following applicability condition to any methodology using this tool:

- The approved methodological tool “Estimation of changes in the carbon stocks of existing trees and shrubs within the boundary of an A/R CDM project activity” may not be applied to areas within the project boundary in which significant numbers of trees and/or shrubs are expected to regenerate naturally in the absence of the project, over the project lifetime.

8. Project proponents must also provide suitable evidence in the CDM-AR-PDD to credibly demonstrate the above applicability condition is met. The numbers of naturally regenerating trees and/or shrubs shall be considered significant if over a 20 year period the estimated net rate of regeneration is likely to result in a stocking[2] (or crown cover) of new trees, or shrubs, that exceed 2%, or 10%, respectively,[3] of the final stocking (or crown cover) of trees in the forest established by the A/R project activity. The final stocking (or crown cover) of trees shall be taken as that expected prior to final harvest, or if harvesting is not to occur then the stocking after 30 years or at the end of the first crediting period (whichever comes first)—as recorded as part of the project management plan in the CDM-AR-PDD. The natural regeneration rate within the project boundary[4] may be estimated from: time sequential photographs (possibly including images from aircraft or satellites), rates derived from information in official reports or peer-reviewed studies, by credibly justified expert opinion, or by Participatory Rural Appraisal.[5]

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[1] If significant natural regeneration of trees and/or shrubs is likely in the baseline scenario, but without the trees exceeding the forest thresholds adopted by the host country, project participants (PPs) may wish to consider applying the methodology for estimating baseline net GHG removals by sinks given in the approved A/R CDM methodology AM-AR0010. The methodology is, however, necessarily somewhat complex.

[2] For the purposes of calculating stocking, species with multiple stems and a common root-stock shall be treated as a single stem.

[3] If both trees and shrubs are present, numbers must not exceed $(N_{tree} + N_{shrub}/5) \leq 0.02\ S_{forest;}$ where N_{tree} and N_{shrub} are the numbers of existing trees and shrubs respectively, and S_{forest} is the final stocking of the forest established by the A/R CDM project. Values of tree/shrub crown-cover ($m^2\ ha^{-1}$) may be used instead of tree/shrub numbers, in the above inequality, provided the final stocking parameter S_{forest} is also expressed on a crown-cover basis as the crown cover of forest established by the A/R CDM project (in $m^2\ ha^{-1}$).

[4] If studies are not available that include all or part of the project area, information from studies on land areas with characteristics similar to the proposed project area may be used. Such studies must have been performed for lands with similar existing vegetation, climate, topography, altitude, soils, and land-use. The lands must also be subject to the same legal, policy and regulatory frameworks as the proposed project area. Similar (or lesser) human population and/or grazing animal densities must also be present.

[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.

Assumptions

9. The following assumptions were made in developing this tool:

- Default or measured data available for woody vegetation growth increment are assumed to be expressed (as is most common) on a net increment basis: that is, with losses due to natural mortality implicitly accounted. No explicit accounting of such losses is provided in this tool if gross rather than net increment data are used, nor are losses from any other activities involving existing woody vegetation under baseline conditions explicitly accounted[6] (e.g., harvesting);
- If appropriate growth curves for the existing woody vegetation are not available, growth may be assumed to proceed on average at an approximately constant rate until maturity is reached, at which time the rate of growth is assumed to become zero. If information on the age of maturity is not available, maturity can be considered to occur at half the typical maximum age attained by the woody vegetation *in situ*;
- Root:shoot ratios appropriate for estimation of below-ground biomass stocks from above-ground biomass stocks under forest/continuous-cover conditions are appropriate for existing woody vegetation;
- Root:shoot ratios appropriate for estimation of below-ground biomass stocks from above-ground biomass stocks are appropriate for estimation of below-ground biomass increment from above-ground biomass increment.

Parameters

This tool provides procedures to determine the following parameters:

Parameter	SI Unit	Description
$\Delta C_{woody,exist,t}$	$t\ CO_2\ yr^{-1}$	Change in the carbon stocks in existing woody vegetation (i.e., in trees and shrubs) in year *t*

Conventions Used in this Tool

10. In applying this methodological tool, estimates of the increase in carbon stocks of existing woody vegetation are made separately for the tree and shrub vegetation classes. This is because these two vegetation classes will usually have similar within-class—but very different between-class—values of growth increment and biomass stocks. Separating the estimates of growth increments and biomass stocks by vegetation class is therefore expected to make estimation both simpler and more transparent.

- Theis J, Grady H (1991): Participatory rapid appraisal for community development. Save the Children Fund, London.

[6] This is consistent with a conservative approach to estimating baseline net GHG removals by sinks. However, in applying this tool, PPs may estimate and use net growth increments calculated from gross increment data if information on losses due to mortality and/or harvesting is available. Sources of information, and the resultant calculations, shall be recorded in the CDM-AR-PDD.

11. Although distinction between herbaceous vegetation and woody perennial shrubs presents few problems, there is no universal definition that uniquely distinguishes shrubs from smaller trees. If both smaller trees and shrubs are part of existing vegetation, then a practical working definition to distinguish these vegetation classes under field conditions shall be developed, and recorded in the CDM-AR-PDD as part of forest inventory standard operating procedures. Any such definition should be consistent with common practice in the region or country in which the project exists, and shall be applied uniformly to both existing woody vegetation, and woody vegetation established as part of A/R project implementation.

II. ESTIMATION OF THE CHANGE IN CARBON STOCKS IN EXISTING WOODY VEGETATION

II.1. Approaches to Estimating the Change in Carbon Stocks

12. The contribution of existing woody vegetation to baseline net GHG removals by sinks is equal to the rate of increase in carbon stocks in existing live woody vegetation within the project boundary. As noted in Section I, accounting by vegetation class is recommended for simplicity and transparency. Depending on the stratification scheme adopted, strata may contain either one or two woody vegetation classes (i.e. trees and/or shrubs), and with single or multiple species within each vegetation class.

13. The total change in the carbon stocks in existing woody vegetation in year *t*, $\Delta C_{woody,exist,t}$, is obtained by summing across all strata the increase in carbon stocks for all species in each vegetation class. For strata with existing woody vegetation that makes a significant contribution to baseline removals, $\Delta C_{woody,exist,t}$ can be estimated using one of the two methods given in Sections III.2 and III.3, below.

II.2. Method 1 (carbon gain-loss approach)

14. The change in carbon stocks of existing live woody biomass, for each species in each vegetation class of a stratum, can be written as:

$$\Delta C_{j,t} = \Delta C_{G,j,t} - \Delta C_{L,j,t} \quad (1)$$

where:

$\Delta C_{j,t}$	Average net change in carbon stocks of existing woody biomass for species *j*, for year *t*; $t\ CO_2\ yr^{-1}$
$\Delta C_{G,j,t}$	Average increase in carbon stocks of existing woody biomass for species *j*, for year *t*; $t\ CO_2\ yr^{-1}$
$\Delta C_{L,j,t}$	Average loss in carbon stocks of existing woody biomass for species *j*, for year *t*; $t\ CO_2\ yr^{-1}$

15. As noted under the assumptions used in developing this methodological tool, no explicit accounting of the term representing stock losses, $\Delta C_{L,j,t}$, is included in this tool: that is, $\Delta C_{G,j,t}$ is assumed to be a measure of net growth increment and thus to implicitly account for $\Delta C_{L,j,t}$.[7]

16. The average increase in carbon stocks in existing live woody biomass, for each species in a stratum, can be written as:

$$\Delta C_{G,j,t} = A_S\ G_{j,t}\ CF_j\ {}^{44}\!/_{12} \qquad (2)$$

where:

$\Delta C_{G,j,t}$	Average increase in carbon stocks of existing woody biomass for species *j*, for year *t*; *t* CO_2 yr^{-1}
A_S	Area of stratum *S*; *ha*
$G_{j,t}$	Average increase in existing woody biomass of species *j*, for year *t*; *t d.m* ha^{-1} yr^{-1}
CF_j	Carbon fraction for species *j* (default values: *0.50*, and *0.49*, for tree and shrub species, respectively[8]); *t C (t d.m.)*$^{-1}$
${}^{44}\!/_{12}$	Ratio of molecular weights of CO_2 and C; g mol^{-1} (g mol^{-1})$^{-1}$

17. The average annual increase in existing live woody biomass stocks, for each species in a vegetation class in a stratum, can be estimated from:

$$G_{j,t} = G_{AB,j,t}\left(1 + R_j\right) \qquad (3)$$

where:

$G_{j,t}$	Average increase in existing woody biomass of species *j*, for year *t*; *t d.m* ha^{-1} yr^{-1}
$G_{AB,j,t}$	Average increase in existing above-ground woody biomass of species *j*, for year *t*; *t d.m* ha^{-1} yr^{-1}
R_j	Root:shoot ratio of species *j*; t d.m. (t d.m.)$^{-1}$

18. Values of growth increment based on biomass increment ($G_{AB,j,t}$) are not usually as common as values based on volume increment. If data on only volume growth increment are available, $G_{AB,j,t}$ can be estimated from:

$$G_{AB,j,t} = I_{V,j,t}\ D_j\ BEF_{1,j} \qquad (4)$$

[7] This will be a conservative assumption if $\Delta C_{G,j,t}$ is based on values of gross growth increment.

[8] The IPCC default value of 0.50 t C (t d.m) may be used for the carbon fraction of tree biomass. For shrubs, which tend to have a larger ratio of foliage to woody material, a value of 0.49 t C (t d.m)$^{-1}$ (derived from IPCC data) may be used—see Annex 1 of the approved methodological tool: Estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of a CDM A/R project activity, EB Meeting Report 36, Annex 20.

where:

$G_{AB,\ j,t}$	Average increase in existing above-ground woody biomass of species *j*, for year *t*; $t\ d.m\ ha^{-1}\ yr^{-1}$
$I_{V,\ j,t}$	Average increment in stem (or merchantable) volume in existing woody biomass of species *j*, for year *t*; $m^3\ ha^{-1}\ yr^{-1}$
D_j	Basic wood density appropriate for stem (or merchantable) wood of species *j*; $t\ d.m.\ m^{-3}$
$BEF_{1,\ j}$	Biomass expansion factor[9] for conversion of biomass increment in stem (or merchantable) volume to the increment in total net above-ground biomass; kg kg^{-1}

II.3. Method 2 (carbon stock-change approach)

19. The change in carbon stocks of existing live woody biomass, for each species in each vegetation class in a stratum, can be written as:

$$\Delta C_{j,t} = \left(C_{j,t_2} - C_{j,t_1}\right) / \Delta t \qquad \textbf{(5)}$$

where:

$\Delta C_{j,t}$	Average change in carbon stocks of existing woody biomass for species *j*, for year *t*; $t\ CO_2\ yr^{-1}$
C_{j,t_2}	Carbon stocks in the biomass pools of existing woody vegetation for species *j*, at time t_2; $t\ CO_2$
C_{j,t_1}	Carbon stocks in the biomass pools of existing woody vegetation for species *j*, at time t_1; $t\ CO_2$
Δt	Interval between times t_1 and t_2; *yr*

20. The existing live woody biomass stocks at time *t*, for each species in a vegetation class in a stratum, can be estimated from:

$$C_{j,t} = A_S\ B_{j,t}\ CF_j\ {}^{44}\!/_{12} \qquad \textbf{(6)}$$

where:

$C_{j,t}$	Carbon stocks in the biomass pools of existing woody vegetation species *j*, at time *t*; $t\ CO_2$
A_S	Area of stratum *S*; *ha*
$B_{j,t}$	Average existing woody biomass in the biomass pools of species *j*, for year *t*; $t\ d.m\ ha^{-1}$
CF_j	Carbon fraction for species *j* (default values: *0.50*, and *0.49*, for tree and shrub species, respectively[8]); $t\ C\ (t\ d.m.)^{-1}$
${}^{44}\!/_{12}$	Ratio of molecular weights of CO_2 and C; g mol^{-1} (g $mol^{-1})^{-1}$

[9] Use age- dependent values, if available.

21. Usually, data on biomass stocks in only above-ground live woody biomass will be available. For each species in a vegetation class of a stratum, total woody biomass stocks can be estimated from above-ground biomass data as:

$$B_{j,t} = B_{AB,j,t}\left(1 + R_j\right) \quad \textbf{(7)}$$

where:

$B_{j,t}$	Average existing woody biomass in the biomass pools of species *j*, for year *t*; *t d.m ha*$^{-1}$
$B_{AB,j,t}$	Average existing woody biomass in the above-ground biomass pool of species *j*, for year *t*; *t d.m ha*$^{-1}$
R_j	Root:shoot ratio of species *j*; t d.m. (t d.m.)$^{-1}$

22. In some cases, values of above-ground biomass stocks may need to be calculated from available data on stem (or merchantable) volume, as:

$$B_{AB,j,t} = V_{S,j,t}\ D_j\ BEF_{2,j} \quad \textbf{(8)}$$

where:

$B_{AB,j,t}$	Average existing woody biomass in the above-ground biomass pool of species *j*, for year *t*; *t d.m ha*$^{-1}$
$V_{S,j,t}$	Stem (or merchantable) volume in existing woody biomass of species *j*, for year *t*; m^3 ha^{-1}
D_j	Basic wood density appropriate for stem (or merchantable) wood of species *j*; *t d.m. m*$^{-3}$
$BEF_{2,j}$	Biomass expansion factor[9] for conversion of biomass in stem (or merchantable) volume to total net above-ground biomass; kg kg^{-1}

III. ESTIMATION OF CARBON STOCK CHANGES IN EXISTING WOODY VEGETATION

III.1. Selection of an Accounting Approach

23. In principle there is no preference in terms of transparency or conservativeness in selecting either the carbon gain-loss or stock-change approach given in Sections II.2 and II.3 for estimation of baseline net GHG removals by sinks. However, because an *ex ante* estimate of baseline removals by sinks is required by the time of project validation, it will usually not be practical to use the stock-change approach to derive this estimate. This is because it requires field measurements at two points in time. Unless field measurements are available from permanent sample plots installed some years prior to validation, *ex ante* determination of baseline removals by existing woody vegetation within the project boundary will need to use the carbon gain-loss approach.

24. *Ex ante* estimates of net GHG baseline removals by sinks normally use a carbon gain-loss approach based on default data. However, if project participants (PPs) are concerned that available default data are too conservative, *ex ante* baseline removals by sinks may also be determined from values of mean annual increment determined from a one-time set of field measurements made on existing woody vegetation felled during site preparation— provided that the age of the felled vegetation can be reliably estimated, a practical approach for this is provided in Section III.3.a below.

25. If the age of existing woody vegetation cannot be reliably estimated (e.g., because in some tropical regions growth rings are often indistinct), and PPs consider *ex ante* estimates of net GHG baseline removals by sinks made using default data are too conservative, then baseline removals can be determined *ex post* using the carbon stock-change approach. An approach for this is provided in Section III.3.b below.

26. When choosing a particular approach, the following should be considered:

- Selection should be based primarily on the quality and relevance of data available to support calculations under the different methods;
- If default data are available for biomass or volume increment, it is recommended that the carbon gain-loss approach in Section III.2 be used;
- If estimation is to be based on field measurements of mean annual increment obtained from analysis of existing woody vegetation felled during site preparation, use the carbon gain-loss approach in Section IV.3.a. This approach requires that the age of the existing woody vegetation be estimated (e.g. by growth ring counting);
- If *ex post* measurement of baseline net GHG removals by sinks is to be used to confirm *ex ante* estimates, then the carbon stock-change method in Section IV.3.b will have to be used. The need for this approach is only likely to arise when the age of existing woody vegetation is difficult to estimate with acceptable accuracy (e.g., under some tropical conditions, where growth rings may be indistinct).

27. For either the carbon gain-loss or stock changes approach, parameters used in equations to calculate net GHG removals by sinks shall be chosen conservatively, so that baseline removals are not likely to be under-estimated. Guidance on conservative choice of parameters—while avoiding being over-conservative—is provided in the approved A/R document: *Guidelines and Guidance for Choice of Data when Estimating Biomass Stocks and Change in Existing Woody Vegetation*.

III.2. Estimating Change in Carbon Stocks using Default Data

28. The carbon gain-loss approach (Section II.2) can be used to estimate the annual change in carbon stocks of existing woody biomass using default data, when suitable data are available. The method requires values for the following parameters, by vegetation class and species:

- $G_{AB,j,t}$ and R_j if estimates are based on biomass increment;
- $I_{V,j,t}$, D_j, $BEF_{1,j}$ and R_j if estimates are based on volume increment.

29. Default values for the above parameters may be obtained from forest or GHG inventory reports, peer-reviewed studies, or IPCC literature. When selecting values of default data, note that:

- The data in national inventory, peer-reviewed studies and IPCC literature are usually applicable to closed canopy forest, whereas in most circumstances trees existing within the project boundary at the time the project starts will be growing in open situations—with such trees likely to be carrying more biomass in branches/foliage per unit of stem biomass than trees in closed-canopy situations. Consequently, for trees existing at the time the project commences:
    - It is recommended that selected default *BEF*s be increased by 30%;
    - Default values of biomass, or volume, increment are multiplied by the fractional crown cover of existing trees or shrubs.[10]
- *BEF*s are age dependent, and use of average data may result in errors for both young and old stands. Age-dependent values for *BEF*s should therefore be used whenever available;
- Values of $G_{AB,j,t}$ and $I_{V,j,t}$ may be expressed as either current annual increment (CAI), or mean annual increment (MAI). If the age of the existing woody vegetation is known, values of CAI appropriate to that age should be used,—for example, values derived from growth/yield curves. Otherwise, if age is not approximately known, use maximum values of CAI recorded in growth/yield curves. Alternatively, use MAI values, which are usually long-term averages over the active growth phase, and thus may be used for woody vegetation of any age. Values of both $G_{AB,j,t}$ and $I_{V,j,t}$ can be considered to become zero when, in the absence of the project, the existing woody vegetation would have reached maturity;
- If no better data are available, IPCC default values for $G_{AB,j,t}$, $I_{V,j,t}$, D_j, R_j, $BEF_{1,j}$ and $BEF_{2,j}$ can be found in the *Good Practice Guidance for Land Use, Land-use Change and Forestry*. (*GPG-LULUCF*; IPCC 2003), with values also available in the *Guidelines for National Greenhouse Gas Inventory. Volume 4; Agriculture, Forestry and Other Land* (*AFOLU Guidelines*; IPCC 2006). See Tables 3A.1.5 to 3A.1.10[11] of the *GPG-LULUCF* (IPCC 2003), or Tables 4.4, 4.5[12], 4.9–4.11, 4.13, and 4.14 of the *AFOLU Guidelines* (IPCC 2006);
- If no better data are available, the following default values, derived from IPCC literature,[13] may be used for R_j: 0.26 for trees, and 0.4 for shrubs.

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[10] Visual estimates of crown cover are acceptable. Data may also be obtained by plot-based sampling, or from analysis of aerial photographs or satellite images.

[11] Note that the ranges for BEFs given in Table 3A.1.10 in the *GPG-LULUCF* correspond to variations in age/stocking, and should be applied to project circumstances accordingly.

[12] Values of $BEF_{1,j}$ must be derived from the parameter $BCEF_I$ in Table 4.5, according to the equation $BEF_{1,j} = BCEF_I / D_j$. Similarly, values of $BEF_{2,j}$ must be derived from the parameter $BCEF_S$ in Table 4.5, according to the equation $BEF = BCEFS / D_j$. Age-dependent values of wood density should be used, if available.

[13] Derivation of default values for root:shoot ratios is discussed in Annex 1, Section A.I.3, of the approved A/R methodological tool: Estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of an A/R CDM project activity (EB Meeting Report 36, Annex 20).

III.3. Estimating Change in Carbon Stocks Based on Field Measurements

30. Existing woody vegetation may often comprise tree and/or shrub species of little commercial value. As such, suitable default values for estimating the change in carbon stocks using the carbon gain-loss approach, presented in Section III.2 above, may therefore often not be available—even for related species in the same *genus*. In this situation, determination of growth rates by field measurement may be required. PPs may also prefer to use measured data rather than default data, or may need to verify that default data are applicable if such data are not for the same species or *genus* to those comprising the existing woody vegetation.

31. There are two possible approaches to determining carbon stocks in existing woody vegetation using field measurements:

(i) Method 1: a carbon gain-loss approach, which makes use of growth increment data derived from measurements made on trees and shrubs felled as part of site preparation (described in Section III.3.a below);

(ii) Method 2: a carbon-stock change approach, based on measurements of carbon stocks in the existing trees and shrubs at two points in time, at sample plots where vegetation existing prior to project commencement has been protected from site preparation (described in Section III.3.b below).

32. Method 1 is preferred, as this can provide accurate data as part of determining *ex ante* estimates of net GHG baseline removals by sinks. Use of either method requires estimates of tree or shrub biomass, by destructive harvest, allometric, or biomass-expansion-factor approaches.[14] Method 2 has the advantage that no assumptions need be made about the time at which the existing vegetation reaches maturity, and removals become zero.

III.3.a. Method 1 (carbon gain-loss approach)

33. In this approach the MAI of existing woody vegetation is determined from trees or shrubs felled during site preparation. It has the advantage of being able to provide an accurate measurement-based assessment of removals by existing woody vegetation for use in *ex ante* estimates of baseline net GHG removals by sinks, yet without the complexities of monitoring over time required by the carbon-stock-change method (Method 2 below). However, it does require that information on individual tree and shrub age be available, and this can sometimes be difficult to obtain. Assuming that age information is available (e.g., from growth-ring counting) estimates of MAI are made by:

(i) Selecting a sample of large (but not mature) trees, or shrubs, felled during site preparation (by species, or species group, as necessary depending on expected growth-rate variation);

(ii) Obtaining above-ground biomass for each tree or shrub by destructive harvest or using allometric equations;[14]

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[14] Guidance on determining all components of tree and shrub biomass, by allometry or destructive harvest, can be found in Annex 1, Section II of the approved A/R methodological tool: *Estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of a CDM A/R project activity* (EB 36 Meeting Report, Annex 20). If biomass estimates are being derived from volume and wood density, then unless better local wood density data are available use of default wood is recommended unless [e.g., from Tables 3A.1.9-1 and 3A.1.9-2, GPG-LULUCF (IPCC 2003); or from the Global Wood Density Database at <http://www.worldagroforestrycentre.org/ Sea/Products/AFDbases/WD/Index.htm>]

(iii) Determine the age for each tree or shrub; for example, by growth-ring counting, or by using locally-applicable age/diameter or age/height equations, or by any other credible method;

(iv) Dividing the above-ground biomass of each tree or shrub by its age, to get the MAI;

(v) Obtaining an average MAI for above-ground biomass in the tree and shrub sample sets.

34. The procedure above provides average values of annual biomass MAI for an individual, actively growing (i.e., non-mature) tree or shrub. Average values of biomass increment per tree and/or shrub can be converted to per hectare values by multiplying by stocking—stems per hectare for trees, or plants per hectare for shrubs, determined by sampling prior to site preparation.

35. The resulting value is equal to $G_{AB,j,t}$, the increase in existing above-ground woody biomass of species *j*, for year *t*. Use this value, together with Eqs. 3 and 4, to determine the average increase in carbon stocks of existing woody biomass for species *j*, for year *t*. A value of the root: shoot ratio is required to complete the calculation using those equations. If no better data are available, the following default values, derived from IPCC literature,[1], may be used: 0.26 for trees, and 0.4 for shrubs.

36. The values of $G_{AB,j,t}$ obtained should be applied until, in the absence of the project, the median age of existing trees or shrubs is equal to that at which such trees or shrubs are expected to reach maturity. At that time, removals by existing trees or shrubs can be considered insignificant, and accounted as zero. Annex 1 (Section A.II) provides guidelines on how to determine whether trees or shrubs are already at maturity, and otherwise how to estimate the time at which this is likely to occur. If there is insufficient information to determine whether existing trees or shrubs are already at maturity, or when they are likely to reach maturity, then the value of $G_{AB,j,t}$ determined above must be applied over the project lifetime.

III.3.b. Method 2 (carbon stock-change approach)

37. In this approach the biomass stocks in existing woody vegetation are determined from measurements made at permanent sample plots at two points in time, and converted to a change in carbon stocks using Eqs. 6 and 9. Unless estimation of biomass stocks has begun some time prior to commencement of the project, the carbon stock-change approach can only be used for *ex post* assessment of removals by existing woody vegetation sinks. As such, use of the carbon stock-change approach will require that some typical areas of existing woody vegetation within the project boundary[15, 16] be set aside for sampling, and thus not cleared as part of site preparation. The areas must be sufficiently separated from forest established as part of project A/R project activities to avoid competition from trees planted as part of the A/R project, and must represent the range of growing conditions within each stratum.

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[15] If the areas have the potential to become forest, they must be smaller than the area threshold adopted by the host country in which the project is located, otherwise they would have to be excluded from the project boundary.

[16] It is strongly recommended that areas outside the project boundary not be used for monitoring of biomass stocks, even if such areas are under the control of the PPs, as it is usually difficult to establish in a transparent manner that such areas are equivalent to those inside the project boundary.

38. A "baseline campaign" can be used to determine changes in biomass stocks in these un-cleared areas:

- Use plot-based sampling of stem diameters, heights and other relevant parameters as the basis for determining above-ground biomass of trees and/or shrubs using allometric equations or BEF approaches[15]—by species, *genus* or family as applicable. Use of default values for root:shoot ratios is recommended when calculating total biomass.[12] The two measurements of biomass stocks required to estimate the stock change shall be performed at least three years but no more than four years apart. The first measurement shall also be performed before any site preparation occurs;
- If destructive harvesting techniques are to be used as part of biomass determination, woody vegetation that would be felled during site preparation can provide a convenient source of material.

39. Monitoring of sample areas should continue until the calculated change in carbon stocks per hectare in the existing woody vegetation, estimated using above approach, becomes less than 2% of project removals by sinks. When this occurs, the contribution of removals by existing woody vegetation to net GHG removals by sinks can be considered insignificant, and accounted henceforth as zero.

References

IPCC 2003. *Good Practice Guidance for Land Use, Land-use Change and Forestry*. This is available from the IPCC Secretariat (www.ipcc.ch), or may be downloaded from the National Greenhouse Gas Inventory Programme at http://www.ipcc-nggip.iges.or.jp.

IPCC 2006. *Guidelines for National Greenhouse Gas Inventory. Volume 4; Agriculture, Forestry and Other Land*. Available from the IPCC Secretariat (www.ipcc.ch), or downloadable from the National Greenhouse Gas Inventory Programme at http://www.ipcc-nggip.iges.or.jp.

Annex 1

ESTIMATING THE TIME TO MATURITY OF EXISTING WOODY VEGETATION

A.I.a. Introduction

1. Default values of growth increment in published literature (including IPCC literature) are usually derived from long-term studies over the active part of the growth cycle (i.e., they are mean annual increments, MAIs). To be consistent with this, it is required in this tool (Section IV.3.a.) that values of growth increment determined by measurements on trees or shrubs felled during site preparation also represent average growth during the active part of the growth cycle—because non-mature trees or shrubs are selected for analysis. Use of MAI values to determine changes in carbon stocks of baseline woody vegetation raises two issues:

(i) Values of MAI should also only be used until the existing trees or shrubs become mature. Once trees or shrubs are mature, little net biomass accumulation occurs;

(ii) If growth increments are to be developed by destructive harvest, and are to represent the average growth over the active growth phase (i.e., the MAI), existing trees or shrubs used for analysis should be as large as possible (to reduce overall error), but not mature.

2. To address these issues, it is necessary to estimate the:

(a) The age of maturity of existing trees or shrubs;

(b) The proportion of total existing trees and shrubs not yet at maturity;

(c) The time taken for the trees and shrubs not yet at maturity to, on average, reach maturity: that is, the difference between the current average age of existing trees and shrubs not yet at maturity and their average age at maturity.

3. The above information may be estimated at the species or *genus* level, depending on information available.

A.I.b. Determining the Age of Maturity

4. If the age of maturity of existing trees and shrubs is unknown, it may be determined using one of the following (in order of preference):

(a) If the age of maturity for a particular species is unknown, but that of a species of the same *genus* is known, use that age provided the age has been determined under similar environmental conditions to those within the project boundary;

(b) If a growth curve for a particular species is available, or a curve is available for a species in the same genus growing under environmental conditions similar to those within the project boundary, estimate the age of maturity from the curve as described in Section A.II.b below;

(c) If the maximum age of a particular species—or of species in the same *genus*—is known, under similar environmental conditions to those within the project boundary, the use that age divided by two;

(d) Construct a growth curve for the species, from measurements of stem cross-sectional area by age (i.e., from the measured area inside annual growth rings). The median stem cross-sectional area (taken at the base) by age, from five of the largest trees or shrubs (of the same species, or same *genus*) felled during site preparation, should be used to construct the growth curve. Section A.II.c provides further details;

(e) By expert opinion, in a transparent and credible manner. The rationale used to arrive at the age of maturity shall be documented in the CDM-AR-PDD, including full references all literature cited, and taking into account regional environmental conditions. A CV for the consulting expert should also be included.

A.I.c. Determining when Existing Trees and Shrubs would have become Mature

5. Determining when existing tree and shrubs within the project boundary would, in the absence of the project, have become mature involves two steps:

(i) Estimating the proportion of total existing trees and shrubs not yet at maturity;

(ii) Estimating the average time taken for the trees and shrubs not yet at maturity to reach maturity: that is, the difference between the current average age of such existing trees and shrubs, and their average age at maturity.

6. The age of maturity (by species, or *genus*, as applicable) will be known from applying the approaches given in Section A.II.b above. The proportion of existing trees or shrubs that are not yet at this age, and the average age of those trees or shrubs, can be estimated by random sampling.[17] Trees or shrubs felled during site preparation will usually provide a convenient source of material for such sampling. The age of existing trees or shrubs in the sample plots may be determined by any of the following:

- Growth ring counting of trees and/or shrubs;
- Using time-sequential aerial or satellite imagery with sufficient spatial and temporal resolution to show the establishment of woody vegetation over time;
- Measuring stem diameter at breast height (for trees) or at the base (for shrubs), and calculating age from a credibly established relationship between stem diameter and age;
- Measuring height (for trees, or columnar shrubs), and calculating age from a credibly established relationship between height and age;
- By determining for shrubs with a spheroid or quasi-spheroid canopy shape the canopy volume (e.g., as mean canopy height multiplied by mean canopy cross-sectional area), and calculating age from a credibly established relationship between canopy volume and age;
- By expert opinion, or Participatory Rural Appraisal methods, that credibly documents the land-use events and history that have controlled the establishment of existing trees and shrubs within the project area.

[17] Sampling on a fixed grid with a random start point is recommended, and making measurements of all trees and shrubs felled for site preparation with a fixed radius of a grid point.

7. The certainty of determining the proportion of trees or shrubs not yet at maturity, and their average age, decreases in moving down the list given above. Values should therefore be assigned more conservatively (i.e., the proportion increased, and the average age reduced) if methods lower on the list are used.

A.II.d. Guidelines on Interpreting Growth Curves to Determine Age at Maturity

8. The increase in biomass with time[18] of individual trees or shrubs can often be reasonably represented by a sigmoidal growth curve, broken into three growth phases: an initial phase of juvenile growth when biomass accumulates more slowly, an extensive period of quasi-linear growth (if uninterrupted by drought or pests/disease) at the maximum rate achievable at the site, and a (normally quite rapid) transition to a mature growth phase where biomass accumulation is static or sufficiently slow to be considered negligible. Vegetation often stays in the mature growth phase for about half its maximum lifetime, depending on climo-edaphic conditions.

9. Growth curves may exist for some species of interest, but for many existing species encountered in CDM projects such curves will not be available. For the purposes of determining the age at maturity, a growth curve can be just as adequately constructed as a graph of stem cross-sectional area versus age. Data on stem cross-sectional area versus age can often be obtained by measuring the area within annual growth rings in basal slices taken from trees or shrubs felled during site preparation. A typical growth curve prepared from such data is depicted in Figure A.1 below. The age of maturity may be taken as the point of intersection of a line drawn as the tangent to the growth curve in the mature growth phase, and a second line drawn as a best fit through the linear growth phase—that is, at point "2" shown in Figure A.1. It is accepted this will usually be an approximate determination, and it should accordingly be interpreted in a conservative manner.

[18] Or equivalently, the increase in stem cross-sectional area, or if not available height (though this is less sensitive) with time.

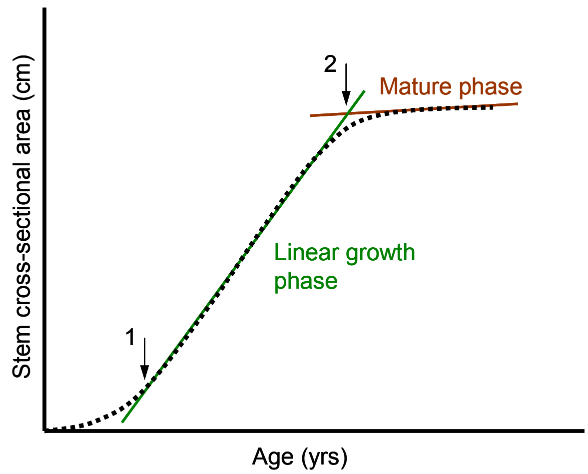

Figure A.1. Schematic of a typical sigmoidal growth curve, and the broad growth phases: juvenile growth (up to the point on the curve indicted by arrow 1), the (quasi-)linear growth phase (between arrows 1 to 2), and the mature growth phase (beyond arrow 2). The age of maturity may be taken approximately as that at the location of arrow 2.

ANNEX 2

PARAMETERS NOT MONITORED; AND PARAMETERS TO BE MONITORED OR ESTIMATED

Data or Parameters not Estimated or Measured

Data ID	Data or Parameter		Source of Data	References and Comments
	Description	Value		
T3.1–1	CF_j — Carbon fraction for species *j*	*0.50*, and *0.49 t C (t d.m.)*$^{-1}$ for tree and shrub species, respectively	IPCC default values, or derived from these default values	Carbon fraction of trees: value for wood from *GPG-LULUCF*[1], Chapter 3, Section 3.2.1.1.1.1 (IPCC 2003); or *AFOLU Guidelines*[2], Volume 4, Chapter 6, Section 6.3.1.4 (IPCC 2006). Carbon fraction of shrubs: mean of values for wood and herbaceous vegetation (same references as above)..

[1] Good Practice Guidance for Land Use, Land-use Change and Forestry. IPCC 2003. Available from the IPCC Secretariat (www.ipcc.ch), or downloadable from the National Greenhouse Gas Inventory Programme at <http://www.ipcc-nggip.iges.or.jp>.

[2] Guidelines for National Greenhouse Gas Inventory. Volume 4, Agriculture, Forestry and Other Land. IPCC 2006. Available from the IPCC Secretariat (www.ipcc.ch), or downloadable from the National Greenhouse Gas Inventory Programme at <http://www.ipcc-nggip.iges.or.jp>

Data or Parameters to be Estimated or Measured

Data ID	Data or Parameter			Source of Estimated or Measured Data	Estimation or Measurement Procedures, and Comments
	Symbol	Description	Determined at		
T3.2–1	A_S	Area of stratum *S*; *ha*	Planning and monitoring of project activities	Maps, orthorectified images, field-based GPS measurements	Horizontal projected area required
T3.2–2	$B_{AB,j,t}$	Average existing woody biomass in the above-ground biomass pool of species *j*, for year *t*; *t d.m ha*$^{-1}$	Field sampling of biomass	Plot-based biomass inventory	References to the *GPG-LULUCF*[3], *AFOLU Guidelines*[4], or approved A/R methodological tools[5] given in *Section IV.3*.
T3.2–3	$BEF_{1,j}$	Biomass expansion factor for conversion of biomass increment in stem (or merchantable) volume to the increment in total net above-ground biomass; kg kg^{-1}	Project start[1]; or during field sampling of biomass[2]	Conservative estimate from IPCC or other default data[1]; or by destructive harvest of woody vegetation that would be felled during site preparation[2]	References to the *GPG-LULUCF*[3] or *AFOLU Guidelines*[4] given in *Sections IV.2* and *IV.3*. (Determining BEFs by destructive harvest is not explicitly referred to in these sections but methodolgical details may be found in the approved A/R methodological tool referenced in note 5, below.)
T3.2–4	$BEF_{2,j}$	Biomass expansion factor for conversion of biomass in stem (or merchantable) volume to total net above-ground biomass; kg kg^{-1}	Project start[1]; or during field sampling of biomass[2]	Conservative estimate from IPCC or other default data[1]; or by destructive harvest of woody vegetation that would be felled during site preparation[2]	References to the *GPG-LULUCF*[3] or *AFOLU Guidelines*[4] given in *Sections IV.2* and *IV.3*. (Determining BEFs by destructive harvest is not explicitly referred to in these sections but methodolgical details may be found in the approved A/R methodological tool referenced in note 5, below.)

T3.2–5	D_j	Basic wood density appropriate for stem (or merchantable) wood of species *j*; $t\ d.m.\ m^{-3}$	Project start	Conservative estimate from IPCC or other default data	References to the *GPG-LULUCF*[3] , *AFOLU Guidelines*[4] and internet databases given in *Section IV.3*.
T3.2–6	$G_{AB,j,t}$	Average annual increase in existing above-ground woody biomass of species *j*, for year *t*; $t\ d.m\ ha^{-1}\ yr^{-1}$	Project start[1]; or during field sampling of biomass[2]	Conservative estimate from IPCC or other default data[1]; or by destructive harvest of woody vegetation that would be felled during site preparation[2]	References to the *GPG-LULUCF*[3], *AFOLU Guidelines*[4], or approved A/R methodological tools[5] given in *Section IV.3*.
T3.2–7	$I_{V,j,t}$	Average annual increment in stem (or merchantable) volume in existing woody biomass of species *j*, for year *t*; $m^3\ ha^{-1}\ yr^{-1}$	Project start[1]; or during field sampling of biomass[2]	Conservative estimate from IPCC or other default data[1]; or by destructive harvest of woody vegetation that would be felled during site preparation[2]	References to the *GPG-LULUCF*[3], *AFOLU Guidelines*[4], or approved A/R methodological tools[5] given in *Section IV.3*.
T3.2–8	j	Number of species within a vegetation class; $1, 2 \ldots n_s$	Project start	During field survey of project area	
T3.2–9	R_j	Root:shoot ratio of species *j*; dimensionless	Project start[1]; or from analysis of field sampled biomass data[2]	Conservative estimate from IPCC or other default data[1]; or by destructive harvest of woody vegetation that would be felled during site preparation[2]	References to the *GPG-LULUCF*[3], *AFOLU Guidelines*[4], or approved A/R methodological tools[5] given in *Section IV.3*.
T3.2–10	t	Time elapsed since the start of the project; *yrs*	Planning and monitoring of project activities	From PDD or project records	

T3.2–11	Δt	Interval between times t_1 and t_2; *yr*	Planning and monitoring of project activities	From PDD or project records	
T3.2–12	$V_{S,j,t}$	Stem (or merchantable) volume in existing woody biomass of species *j*, for year *t*; $m^3\ ha^{-1}$	Project start[1]; or from analysis of field sampled stem volume data[2]	Conservative estimate from IPCC or other default data[1]; or by destructive harvest of woody vegetation that would be felled during site preparation[2]	References to the *GPG-LULUCF*[3], *AFOLU Guidelines*[4], or approved A/R methodological tools[5] given in *Section IV.3*.

Notes:

[1] If estimated.

[2] If measured.

[3] Good Practice Guidance for Land Use, Land-use Change and Forestry. IPCC 2003. Available from the IPCC Secretariat (www.ipcc.ch), or downloadable from the National Greenhouse Gas Inventory Programme at <http://www.ipcc-nggip.iges.or.jp>.

[4] Guidelines for National Greenhouse Gas Inventory. Volume 4, Agriculture, Forestry and Other Land. IPCC 2006. Available from the IPCC Secretariat (www.ipcc.ch), or downloadable from the National Greenhouse Gas Inventory Programme at <http://www.ipcc-nggip.iges.or.jp>

[5] Guidelines on estimating above- and below-ground live biomass using allometric or BEF approaches in plot-based sampling schemes, or by destructive harvest (including of BEFs and root:shoot ratios) are given in *Annex 1, Section A.II* of the approved A/R methodological tool for *Estimation of emissions from clearing, burning and decay of existing vegetation due to implementation of a CDM A/R project activity* (EB Meeting Report 36, Annex 20).

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History of the document

Version	Date	Nature of revision(s)
01	EB 46, Annex 18 25 March 2009	Initial adoption.