



A/R Methodological Tool

“Demonstrating appropriateness of allometric equations for estimation of aboveground tree biomass in A/R CDM project activities”

(Version 01.0.0)

I. SCOPE, APPLICABILITY AND ASSUMPTIONS

Scope

1. This tool allows demonstration of appropriateness of an allometric equation for estimation of aboveground tree biomass in A/R CDM project activities.

Applicability

2. This tool has no internal applicability conditions.

Definitions

3. “Allometric equation” is an equation that predicts tree biomass on the basis of one or more measurements of a tree (e.g. DBH and/or tree height).

Parameters

4. This tool enables the user to demonstrate whether an allometric equation is appropriate for estimation of aboveground tree biomass in an A/R CDM project activity.

II. APPROPRIATENESS OF ALLOMETRIC EQUATIONS

Use of an equation for *ex ante* estimation of tree biomass in project scenario

5. For *ex ante* estimation of aboveground tree biomass in project scenario any allometric equation can be used.

Use of an equation in *ex post* estimation of tree biomass

6. A species-specific or group-of-species-specific allometric equation derived from trees growing in edapho-climatic conditions similar to those in the project area is considered appropriate, and hence can be used for *ex post* estimation of tree biomass, if at least one of the following conditions is satisfied:

- (a) The equation is used in the national forest inventory, or the national GHG inventory, of the host Party;
- (b) The equation has been used in commercial forestry sector of the host Party for ten years or more;
- (c) The equation was derived from a data set of at least 30 sample trees, and the value of coefficient of determination (R^2) obtained was not less than 0.85.

7. An allometric equation that does not meet the criteria listed under paragraph 6 above can be used for *ex post* estimation of aboveground tree biomass only if its appropriateness is



demonstrated on the basis of field data obtained from sample trees as described in paragraphs 8 to 19 below.

Selection of sample trees

8. For each species or group of species of trees for which the allometric equation was developed and will be used in the A/R CDM project, not less than ten sample trees growing in similar edapho-climatic and landscape conditions to those in the area where the A/R CDM project activity is implemented (preferably within the project boundary) are selected. Sample trees are selected in such a way that the full range of tree measurements (e.g. DBH and/or tree height) present within the project boundary and expected to be included in the applicability range of the equation is covered in a representative way.¹ If a tree species is growing in more than one stratum within the project boundary, selection of trees should span across all such strata for which appropriateness of the equation is to be demonstrated.

Estimation of predicted biomass of sample trees

9. The tree measurements (e.g. DBH and/or tree height) used as input data in the allometric equation are obtained for the sample trees.

10. The predicted biomass of each sample tree is calculated by inserting the tree measurements (e.g. DBH and/or height) into the allometric equation.

Measurement of biomass of sample trees

Option I: Direct measurement of biomass of sample trees

11. The sample trees are felled and the total aboveground biomass of each sample tree is determined from field measurements.

Option II: Direct measurement of stem volume and estimation of biomass of sample trees

12. The stem volume of a sample tree is measured using one of the following methods:

(a) Water displacement method:

The sample tree is felled and its stem is cut into sections that fit into a water tank (e.g. a xylometer). The pieces are then put into the tank (below the water) and the volume of water displaced is measured. The process is repeated for all the sections of the stem and volumes of the sections are summed up to obtain the tree stem volume V_{STEM} .

(b) Sectional diameters method:

(i) The stem of the tree (standing or felled) is divided into sections not exceeding 2 m in length, and stem diameter at the middle point of each section is measured. The volume of a section of stem is calculated as:

$$V_i = \frac{\pi * D_{M,i}^2 * L_i}{4} * 10^{-4} \quad (1)$$

¹ “Representative” coverage does not mean uniform coverage in the spatial sense, representative is meant in the statistical sense; if a certain range of diameters is dominant, then more trees are selected in that range.

where:

V_i Volume of i^{th} section of stem; m^3

$D_{M,i}$ Diameter at the middle point of the i^{th} section of stem; cm

L_i Length of the i^{th} section of stem; m

- (ii) Tree stem volume is obtained by summing up the volumes of the sections of stem:

$$V_{STEM} = \sum_i V_i \quad (2)$$

where:

V_{STEM} Tree stem volume; m^3

V_i Volume of i^{th} section of stem; m^3

13. A conservative estimation of aboveground tree biomass is obtained by multiplication of a stem volume, as measured under paragraph 12(a) or 12(b) above, by the appropriate basic wood density and by the default BEF value of 1.15.

14. Project participants shall provide a justification to be assessed by a DOE contracted by them if they wish to apply any other conservative value of BEF under paragraph 13 above.

Comparing the measured and the predicted tree biomass

15. Agreement of the predicted tree biomass with the measured tree biomass is tested by applying a paired t -test to the two datasets of tree biomass which returns the probability (the p value) that the two datasets have the same mean. A step-by-step procedure for calculating the p value returned by a paired t -test is contained in Annex I to this tool. Alternatively, a paired t -test is applied using statistical software.

Use of the equation for estimating mean biomass in the baseline and in the project

16. The allometric equation is appropriate for estimation of tree biomass, in the baseline and in the project, if the p value returned by the t -test is equal to or greater than 0.90 (see Annex I).

Conservative use of the equation for estimating tree biomass in baseline (but not in project)

17. The allometric equation is appropriate for estimation of tree biomass in the baseline (but not in the project) if the mean of measured tree biomass is less than the mean of predicted tree biomass and any one of the following conditions is satisfied:

- (a) The p value returned by the t -test is less than 0.20 (see Annex I);
- (b) The confidence interval of the mean difference, at 90% confidence level, does not contain zero (see Annex II).



Conservative use of the equation for estimating tree biomass in project (but not in the baseline)

18. The allometric equation is appropriate for estimation of tree biomass in the project (but not in the baseline) if the mean of measured tree biomass is greater than the mean of predicted tree biomass and any one of the following conditions is satisfied:

- (a) The p value returned by the t -test is less than 0.20 (see Annex I);
- (b) The confidence interval of the mean difference, at 90% confidence level, does not contain zero (see Annex II).

Modification of an equation

19. An allometric equation which is not confirmed as appropriate under paragraphs 16, 17, or 18 may be modified (e.g. by using a multiplier or by modifying coefficients) in such a way that it becomes appropriate under any of these paragraphs.

III. DATA AND PARAMETERS USED IN THE TOOL

20. 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 not measured

Data / Parameter:	y_i
Data unit:	t d.m.
Used in equations:	Equation (1), Equation (2) of Annex I; Equation (1), Equation (2) of Annex II
Description	Biomass of the i^{th} sample tree as predicted by the allometric equation
Source of data:	Predicted tree biomass is calculated by inserting the relevant tree measurements (e.g. DBH and/or height) into the allometric equation

Data and parameters measured

Data / Parameter:	Y_i
Data unit:	t d.m.
Used in equations:	Equation (1), Equation (2) of Annex I; Equation (1), Equation (2) of Annex II
Description:	Biomass of the i^{th} sample tree as obtained from field measurements



Measurement procedures:	<p>Total tree biomass of a felled sample tree is estimated by determining the fresh weight of the tree and dividing the fresh weight by fresh-to-dry ratio of weights. The fresh-to-dry ratio of weights is different for different tree components (i.e. stem, branches, foliage). One of the following approaches is used:</p> <ul style="list-style-type: none">(a) The fresh weight of the entire tree is divided by the fresh-to-dry ratio of weights for the entire tree taken from existing sources (i.e. national forest inventory, national GHG inventory, peer-reviewed publications, industry sources);(b) Fresh weight of each tree biomass component (i.e. stem, branches, foliage) is determined by weighing. Representative samples of each tree biomass component are taken and oven-dried to obtain the fresh-to-dry ratios of weights. The fresh weight of each biomass component is divided by the respective fresh-to-dry ratio to obtain the dry weight of the component. Dry weights of the tree components are summed up to obtain the dry weight of the tree. <p><u>Note:</u> It is allowed to use the following simplified approaches:</p> <ul style="list-style-type: none">(a) If the variability of the fresh-to-dry ratio of a tree biomass component is found to be statistically insignificant after the first five sets of data have been obtained, then further determination of these ratios is not required;(b) For demonstrating appropriateness of an allometric equation for estimation of aboveground tree biomass in project scenario, the conservative choice of excluding a tree component from estimation is allowed. For example, the PPs may choose, for reasons of simplicity, to exclude branch and/or foliage biomass while determining tree biomass by measurement
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IV. REFERENCES

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.
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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.
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Annex I
Step by step procedure for calculation of p value in a paired t -test
(see paragraph 15)

1. Calculate the following values:

$$A = \sum_{i=1}^n (Y_i - y_i) \quad (1)$$

$$B = \sum_{i=1}^n (Y_i - y_i)^2 \quad (2)$$

where:

Y_i Biomass of the i^{th} sample tree as determined from field measurement; t d.m.

y_i Biomass of the i^{th} sample tree as predicted by the allometric equation; t d.m.

Value A is a sum of differences between the biomass as estimated from field measurement and as predicted by the equation.

Value B is a sum of squared differences between the biomass as estimated from field measurement and as predicted by the equation.

2. Calculate value S as follows:

$$S = \frac{n * B - A^2}{n * (n - 1)} \quad (3)$$

where:

n Number of sample trees

Value S is known as variance of the difference between tree biomass as determined from field measurement and as predicted by the allometric equation.

3. Calculate value E as follows:

$$E = \sqrt{\frac{S}{n}} \quad (4)$$

Value E is known as standard error of the mean difference of tree biomass.

4. Calculate test value t as follows:

$$t = \frac{A}{n * E} \quad (5)$$

The value t is known as *Student's t statistic* with $n-1$ degrees of freedom.



5. Once a t statistic is determined, the corresponding p -value can be found using a table of values from Student's t -distribution. Alternatively, the p -value for a given t -value can be looked up using a spreadsheet function, such as the Excel function $TDIST(t,df,a)$ as follows:

$$p = TDIST(t,df,a)$$

where:

$df=n-1$ and

t t -value calculated in Equation (4)

a Apply $a = 2$ for cases described in the paragraphs 16–18

**Annex II****Step by step procedure for testing when a confidence interval of the mean difference, at 90% confidence level, does not contain zero (see paragraphs 17–18)**

1. Calculate the following values:

$$A = \sum_{i=1}^n (Y_i - y_i) \quad (1)$$

$$B = \sum_{i=1}^n (Y_i - y_i)^2 \quad (2)$$

where:

Y_i Biomass of the i^{th} sample tree as determined from field measurement; t d.m.

y_i Biomass of the i^{th} sample tree as predicted by the allometric equation; t d.m.

Value A is a sum of differences between the biomass as estimated from field measurement and as predicted by the equation.

Value B is a sum of squared differences between the biomass as estimated from field measurement and as predicted by the equation.

2. Calculate value S as follows:

$$S = \frac{n * B - A^2}{n * (n - 1)} \quad (3)$$

where:

n Number of sample trees

Value S is known as variance of the difference between tree biomass as determined from field measurement and as predicted by the allometric equation.

3. Calculate value E as follows:

$$E = \sqrt{\frac{S}{n}} \quad (4)$$

Value E is known as standard error of the mean difference of tree biomass.

4. A confidence interval of the mean difference, at 90% confidence level, does not contain zero if:



$$\left| \frac{A}{n} \right| > T * E \tag{5}$$

where:

T Two-tailed critical *t* value, in Student’s *t*-distribution for *n-1* degrees of freedom, at significance level $\alpha = 0.2$ (which is equal to a one-tailed value for $\alpha = 0.1$), read from *t*-distribution tables. Alternatively, the *t* value can be looked up using a spreadsheet function, such as the Excel function *TINV(0.2,df)* as follows:

$$T = TINV(0.2,df)$$

where:

$$df = n - 1$$

n Number of sample trees

History of the document

Version	Date	Nature of revision
01.0.0	EB 65, Annex 28 25 November 2011	Initial adoption.
Decision Class: Regulatory Document Type: Tool Business Function: Methodology		