



## A/R Methodological Tool

### “Demonstrating appropriateness of volume 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 a volume equation, in combination with biomass expansion factors (BEFs) and basic wood density, for estimation of aboveground tree biomass in A/R CDM project activities.

### Applicability

2. This tool has no internal applicability conditions.

### Definitions

3. “Volume equation” is an equation that predicts tree stem volume 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 a volume equation, in combination with selected BEFs and basic wood density, is appropriate for estimation of aboveground tree biomass in an A/R CDM project activity.

## II. ASSESSMENT OF APPROPRIATENESS OF VOLUME EQUATIONS FOR ESTIMATION OF TREE STEM VOLUME

### Estimation of tree stem volume

5. A species-specific or group-of-species-specific volume 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 stem volume, 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 ( $R^2$ ) was not less than 0.85.

6. A volume equation that does not meet the criteria provided under paragraph 5 above can be used for *ex post* estimation of tree stem volume only if its appropriateness for stem volume estimation is demonstrated on the basis of field data obtained from sample trees as described in paragraphs 7 to 15 below.

*Selection of sample trees*

7. For each species or group of species of trees for which the volume equation was developed and will be used in the A/R CDM project, not less than ten sample trees growing in edapho-climatic conditions similar 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 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.<sup>1</sup> 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 stem volume of sample trees*

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

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

*Measurement of stem volume of sample trees*

10. 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:

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

where:

$V_i$  Volume of  $i^{\text{th}}$  section of stem; m<sup>3</sup>

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

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

<sup>1</sup> “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.



- (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<sup>3</sup>

$V_i$  Volume of  $i^{\text{th}}$  section of stem; m<sup>3</sup>

#### *Comparing the measured and the predicted stem volume*

11. Agreement of the predicted stem volume with the measured stem volume is tested by applying a paired  $t$ -test to the two datasets of stem volume 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 the Appendix I of this tool. Alternatively, a paired  $t$ -test is applied using statistical software.

#### *Use of the equation for estimating mean stem volume in baseline and in project*

12. The volume equation is appropriate for estimation of tree stem volume, 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 Appendix I).

#### *Conservative use of the equation for estimating stem volume in baseline (but not in project)*

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

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

#### *Conservative use of the equation for estimating stem volume in project (but not in baseline)*

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

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

#### **Modification of an equation**

15. A volume equation which is not confirmed as appropriate under paragraphs 12, 13, or 14 may be modified (e.g. by application of a multiplier or by modifying coefficients) in such a way that it becomes appropriate under any of these paragraphs.



### III. USE OF VOLUME EQUATIONS FOR ESTIMATION OF ABOVEGROUND TREE BIOMASS

#### Estimation of tree biomass based on volume equation

16. Estimation of aboveground tree biomass requires a volume equation to be used in combination with BEF and basic wood density.
17. The DOE shall assess that the product of volume (calculated using the appropriate volume equation) and the value of BEF proposed by project participants and basic wood density yields conservative estimates of aboveground tree biomass using the latest version of the “Guidelines on conservative choice and application of default data in estimation of the net anthropogenic GHG removals by sinks”.

### IV. DATA AND PARAMETERS USED IN THE TOOL

18. 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

<b>Data / Parameter:</b>	$y_i$
<b>Data unit:</b>	$m^3$
<b>Used in equations:</b>	Equation (1), Equation (2) of I
<b>Description</b>	Stem volume of the $i^{th}$ sample tree as predicted by the volume equation
<b>Source of data:</b>	Predicted stem volume is calculated by inserting the relevant tree measurements (e.g. DBH and/or height) into the volume equation

#### Data and parameters measured

<b>Data / Parameter:</b>	$Y_i$
<b>Data unit:</b>	$m^3$
<b>Used in equations:</b>	Equation (1), Equation (2) of I
<b>Description:</b>	Stem volume of the $i^{th}$ sample tree as obtained from field measurements
<b>Measurement procedures:</b>	Measured as described under paragraph 10(a) or 10 (b) of this tool

<b>Data / Parameter:</b>	$D_{M,i}$
<b>Data unit:</b>	cm
<b>Used in equations:</b>	Equation (1)
<b>Description:</b>	Stem diameter at middle point of the $i^{th}$ sample tree



Measurement procedures:	The tree stem is divided into sections not exceeding 2 m in length. At the middle point of each section, diameters in two perpendicular directions are measured and their geometric mean is used as the diameter of the section
<b>Data / Parameter:</b>	$L_i$
Data unit:	m
Used in equations:	Equation (1)
Description:	Length of a $i^{\text{th}}$ stem section
Measurement procedures:	The end points of a stem section are marked and its length of the section is measured with a tape

## V. 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.

<<http://www.ipcc-nggip.iges.or.jp/public/gpplulucf/gpplulucf.html>>.

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.

<<http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html>>.



**Appendix I**  
**Step by step procedure for calculation of  $p$  value in a paired  $t$ -test**  
**(see paragraph 11)**

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:

$Y_i$  Stem volume of the  $i^{\text{th}}$  sample tree as determined from field measurement; t d.m.

$y_i$  Stem volume of the  $i^{\text{th}}$  sample tree as predicted by the volume equation; t d.m.

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

Value  $B$  is a sum of squared differences between the stem volume 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 stem volume as determined from field measurement and as predicted by the 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 stem volume.

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

**Appendix 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 13–14)**

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:

$Y_i$  Stem volume of the  $i^{\text{th}}$  sample tree as determined from field measurement; t d.m.

$y_i$  Stem volume of the  $i^{\text{th}}$  sample tree as predicted by the allometric equation; t d.m.

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

Value  $B$  is a sum of squared differences between the stem volume 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 stem volume 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 stem volume.

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

$$\left| \frac{A}{n} \right| > T * E \quad (5)$$





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 29 25 November 2011	Initial adoption.
<b>Decision Class:</b> Regulatory <b>Document Type:</b> Tool <b>Business Function:</b> Methodology		