T-VER-P-TOOL-01-08

Calculation of Appropriate Number of Sample Plots for Carbon Measurements in Forest Project Activities

Version 01

1. Introduction

This document is a tool for calculating the appropriate number of sample plots in estimating the aboveground tree biomass as well as the carbon stocks and change in carbon stocks of trees in forest project activities. This tool can be used to estimate greenhouse gas emissions in both baseline and project scenarios.

2. Relevant definitions and reference values

Details appear in Annex 1

3. Characteristics of relevant activities and conditions

This tool is suitable for calculating the number of plots suitable for estimating tree biomass to measure carbon stock and changes in carbon stock of trees in forest activity. The nature of the activities fall into the scope and conditions of use as follows:

1) This tool is used to calculate the optimal number of plots for tree biomass estimation using field measurement methods for base case and project implementation.

2) This tool is used to calculate optimal number of plots based on the accuracy level of biomass to be assessed.

3) Parameters involved in biomass calculation at the sample plot such as biomass expansion factor (BEF) and root-shoot ratio are defined as fixed constants. Similarly, all equations used in biomass calculation at sample plot level such as allometric equation, volume equation and volume table are considered correct.

4. Hypothesis

The assumptions for calculating the optimal number of sample plots are as follows:

1) Value of the area of each stratum within the project boundary is known

2) Value of the variance of biomass stocks in each stratum is known

3) The project area is stratified into one or more strata.

Where:

n	means	Number of sample plots suitable for estimation of biomass stocks within the project boundary .
n_i	means	Number of sample plots in stratum i for estimation of biomass stocks within the project boundary.

n_{BSL}	means	Number of sample plots suitable for estimation of biomass stocks within the project boundary for the baseline.
$n_{PROJ,i}$	means	Number of sample plots in stratum i for estimation of biomass stocks within the project boundary for project implementation.

5. Stratification

When the project area is heterogeneous, it is required a stratification to assess carbon stock in biomass in more accurate manner. Stratification must be done according to appeared conditions. For example, similar stratum must possess the most similar characteristics with the greatest differences between strata. Characteristics that can be used as criteria for stratification are such as type of land use, forest type, plant type, altitude above sea slope level, soil fertility, the age class of vegetation and their management. These characteristics can be stratified using remote sensing data such as satellite images, aerial photographs, and images from Google Earth.

In addition, the stratification is based on differences in the amount of carbon stock in the biomass to be assessed. Therefore, the difference in the amount of carbon stock in the biomass is used as a criterion to determine the size of the area in each stratum, if the total biomass carbon stock to be assessed comes from two or more sites, the stratification priority will be given to sites with greater carbon stock. We can define stratum according to their characteristics as follow:

- 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
- For net GHG removal forecast, it is sufficient to stratify the area according to major vegetation and forest management
- For net GHG removal (monitoring during post implementation), the stratification depends on major vegetation and actual forest management. In the case of project impacts from natural or human disasters, such as storms or other factors such as sediment loads, which cause the trend of the project's biomass carbon sequestration to change. It is necessary to re- stratification accordingly.

6. Size of sample plot

Sample plots in estimating the aboveground tree biomass as well as the carbon stocks and change in carbon stocks of trees in forest project activities may be in square, rectangle or circle shape. This is consistent with the principle of plotting specimens in forest resource surveys. For sample plot sizes, the most popular and generally accepted sample plot sizes can be used. Recommended size means a square plot with dimensions of 40 x 40 meters (size 1 rai). In case the project area is not suitable for placing a sample plot of 40 x 40 meters, consider placing the sample plot in other shapes and sizes as required. The size of the plot is the parameter required for calculating the number of plots suitable for estimating the aboveground tree biomass to measure carbon stock and changes in carbon of trees in forest project activities.

7. Calculating the total number of sample plots

The sample plots required for estimating the aboveground tree biomass depends on the required accuracy and precision and the quantitative variation in biomass to be assessed. In this calculation tool, the accuracy and accuracy is set to a confidence level of 90 percent or as specified by the TGO.

The project area is stratified according to the estimated biomass variability. and determine the approximate area of each stratum. If biomass is the sum of biomass in two or more sites, the stratum is then stratified based on biomass variability in primary carbon stock, e.g. carbon deposits with the highest biomass, for example.

For this calculation tool, the variation of biomass quantity is determined in the form of standard deviation. The estimated standard deviation of the biomass content in each stratum can be used from the existing data of the project site. Data from research or reports of similar areas or estimated from the preliminary survey or from the opinions of experts This tool calculates the number of sample plots required for biomass estimation in the project area using a repeatable method. which has the following steps:

Step 1 The first cycle is the calculation of the number of sample plots required for biomass stock in the project s boundary as shown in Equation (1).

$$n = \frac{N \times {t_{VAL}}^2 \times (\sum_i w_i \times s_i)^2}{N \times E^2 + {t_{VAL}}^2 \times \sum_i w_i \times {s_i}^2} \quad (1)$$

Where

n	means	Number of sample plots required for estimation of biomass stocks within the project boundary (no unit)
N	means	Total number of possible sample plots within the project boundary, i.e. Population or Sampling Distance (no unit).

t_{VAL}	means	Two-sided Student's t-value, at infinite degrees of freedom (∞) for a given level of confidence (no unit) is hereby defined as a 90% confidence level.
w_i	means	Relative weight of the area of stratum i (no unit)
s_i	means	Estimated standard deviation of biomass stock in stratum i. (tons of dry weight or tons of dry weight per rai)
E	means	Acceptable margin of error is half the confidence interval in the project boundary estimation of biomass stock (tons of dry weight or tons of dry weight per rai)
i	means	1, 2, 3, ... biomass stock estimation strata within the project boundary

Step 2 If the number of sample plots n calculated from equation (1) is 30 or more, no further calculations are required. Number of sample plots n calculated in the first step. is the number of sample plots that can be used.

Step 3 If the number of n-sample plots calculated from equation (1) is less than 30, iterate into equation (1) using a t-value with the number of free values n-1 and the calculated number of sample plots n in the second round is the number of sample plots that can be used.

Step 4 In case the proportion of the sample area is less than 5% of the project area A simple equation can be used to calculate the number of sample plots as in equation *(2)*.

$$n = \left(\frac{t_{VAL}}{E}\right)^2 \times \left(\sum_i w_i \times s_i\right)^2 \qquad (2)$$

n	means	Number of sample plots required for estimation of biomass stocks within the project boundary (no unit)
t_{VAL}	means	Two-sided Student's t-value, at infinite degrees of freedom (∞) for a given level of confidence (no unit) is hereby defined as a 90% confidence level.
w_i	means	Relative weight of the area of stratum I (no unit)
s_i	means	Estimated standard deviation of biomass stock in stratum i (tons of dry weight or tons of dry weight per rai)

E means Acceptable margin of error is half the confidence interval in the project boundary estimation of biomass stock (tons of dry weight or tons of dry weight per rai)

Step 5 In the case that the proportion of the sample area is more than 5% of the project area. The equation can be used to calculate the number of adjusted sample plots as in equation (3).

$$n_a = n \times \frac{1}{1+n/N} \tag{3}$$

n_a means Adjusted sample plot count for the project boundary estimation of biomass stock (no unit)

n means Number of sample plots required for the project boundary estimation of biomass stock (no unit)

N means The total number of possible sample plots in the project boundary, i.e. Population or Sampling Distance (no unit)

8. Distribution of the number of sample plots in each stratum

Appropriate distribution of the number of sample plots in each stratum (the optimum allocation) is calculated by using the number of sample plots in each stratum as shown in equation (4) below:

$$n_i = n \times \frac{w_i \times s_i}{\sum_i w_i \times s_i} \tag{4}$$

n_i means Number of sample plots allocated to stratum i (no unit)

n means Number of sample plots required for estimation of biomass stocks within the project boundary (no unit)

w_i means Relative weight of the area of stratum i (no unit)

s_i means Estimated standard deviation of biomass stock in stratum i (tons of dry weight or tons of dry weight per rai)

i means 1, 2, 3, … biomass stock estimation strata within the project boundary

9. Spreadsheet program for calculation

To calculate the total number of sample plots and the distribution of sample plots in each stratum of biomass estimation can be calculated using a spreadsheet program of

Winrock International called “WINROCK SAMPLE PLOT CALCULATOR SPREADSHEET TOOL”.
or website: Winrock International

10. Relevant parameters

10.1 Parameters not required monitoring

Parameter	t_{VAL}
Unit	No unit
Definition	Two-sided Student’s t-value at infinite degrees of freedom for the required confidence level (no unit)
Relevant equation	equation (1) and (2)
Source of information	Student’s t-value table in Annex 2
Remark	A 90% confidence level is required in calculating tree biomass in forest project activities, in addition to the determination of other confidence levels as specified in the methodology or as specified by TGO

Parameter	E
Unit	Tons of dry weight or tons of dry weight per rai
Definition	Acceptable margin of error in estimation of biomass stock within the project boundary
Relevant equation	equation (1) and (2)
Source of information	Student’s t-value table in Annex 2
Remark	The tolerance was equal to 10% of the mean biomass of trees in the project area other than the determination of other acceptable variances as specified in the methodology or as prescribed by TGO

10.2 Parameters required monitoring

Parameter	N
Unit	No unit
Definition	Total number of possible sample plots within the project boundary, i.e. population or sampling distance.
Relevant equation	equation (1) and (3)

Source of information	Field measurement
Measurement method	Total number of possible sample plots within the project boundary is equal to the total project boundary divided by the sample plot size
Remark	Example: project area is 1,000 rai and the sample plot is 1 rai. N is equal to 1000.

Parameter	w_i
Unit	No unit
Definition	Relative weight of the area of stratum i
Relevant equation	equation (1) (2) and (4)
Source of information	Field measurement
Measurement method	Relative weight of the area of stratum is equal to the area of each floor divided by the total project boundary
Remark	-

Parameter	s_i
Unit	Tons of dry weight or tons of dry weight per rai
Definition	Estimated standard deviation of biomass stock in stratum i
Relevant equation	equation (1) (2) and (4)
Source of information	Field measurement
Measurement method	Estimated standard deviation of biomass stock in stratum I may be known from the existing information of the project boundary or the boundary that is similar to the project or the basic information of the project.
Remark	-

9. Reference documents

1) A/R Methodology Tool "Calculation of the number of sample plots for measurements within A/R CDM project activities"
2) 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry
3) 2006 IPCC Guidelines for National Greenhouse Gas Inventories
4) 2019 Refinement to 2006 IPCC Guidelines for National Greenhouse Gas Inventories
5) T-VER tool: T-VER-TOOL-FOR/AGR-01 Calculation for Carbon Sequestration (version 4)
6) Thailand Voluntary Emission Reduction Program Reference Manual: Forestry and agriculture sector.

Annex

Annex 1 Relevant Definitions

Aboveground biomass	The dry weight of all parts of the tree above the ground, including trunks, branches, leaves, flowers and fruits, including saplings and bamboo.
Belowground biomass	dry weight of the underground part of the tree
Standard deviation (s)	Statistical tools are used to measure the distribution of data to determine the mean data characteristics. A small standard deviation indicates that each measurement is close to the mean
Variance (s^2)	Statistical tools are used to measure the distribution of data to determine the mean data characteristics which is the square of standard deviation
Confidence level	The probability that the population parameter falls within the estimated range. For example, given that tree biomass estimates have a 90% confidence level, this means that the probability that the estimated biomass values are less than the minimum. (lower limit) or more, the maximum (upper limit) of only 10 percent.
Confidence interval	A range of parameters that cover the true value of a population. For example, the assessment of biomass carbon sequestration of reforestation activities sets at a 90 percent confidence level.

Annex 2 Parameters with statistical references

Table 2.1 Student's t-value at infinite degrees of freedom in the first iteration and at degrees of freedom equal to (n-1) in subsequent iterations, for the required confidence level.

	Confidence level				
Df	80%	90%	95%	98%	99%
1	3.078	6.314	12.706	31.820	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.897	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.625	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.584	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.779
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
30	1.310	1.697	2.042	2.457	2.750
∞	1.282	1.645	1.960	2.326	2.576

Df – Degree of freedom

Document information

Version	Amendment	Entry into force	Description
01	--	1 March 2023	-