PV CLIMATE MODULE

PU008

Module for Estimating Uncertainty of Carbon Benefits from Small-scale Agroforestry

Version 1.0

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1 Summary

This *Module* provides a method for estimation and propagation of sampling and model *uncertainty*, and calculation of a corresponding adjustment factor. Model and sample *uncertainty* are calculated using confidence interval, the residuals, and the mean *biomass* value in the validation set. The final *uncertainty* adjustment is represented by parameter U, and implies that the adjustment factor is calculated on a *Project Area Level*.

2 Sources

This *Module* is based on the following *Module*:

- **PU005** Estimation of uncertainty of carbon benefits estimates in Plan Vivo Projects v1.1 2024

Besides, the following *Tool* is applied within this *Module*:

- **PT006** Tool for Ground Truth Sampling v1.0

Finally, this *Module* is applied within the following *Methodology*:

- **PM002** Methodology for Quantifying Carbon Benefits from Small-scale Agroforestry v1.0

3 Definitions

All terms in this document follow the PV Climate Glossary and **PM002**, with the addition of the following definition:

Stratum
A group into which members of a population/*Project Area(s)* are divided into stratified sampling based on specific characteristics. In this *Module* an *ecoregion* is considered a *stratum*. Where necessary, further stratification can be done through, for example, a variety of *pre-project tree biomass* or *Project* activities.

4 Applicability Conditions

For this *Module*, the applicability conditions of *Methodology* **PM002** should be met.

5 Procedures

If *Aboveground Biomass* in a *Project Area* is estimated using a modeling approach, the u*ncertainty* in the temporal change of the *Aboveground Biomass* in a *Project Area* can be calculated using Equation

1[1] to 5. The *uncertainty* per *Project Area* includes both sampling and model error of the *AGB* derived from the *ground truth data*.

$$U = \frac{\sqrt{\left(u \cdot AGB_{t-p}\right)^2 + (u \cdot AGB_t)^2}}{\left|\left(AGB_t - AGB_{t-p}\right)\right|}$$

Equation 1

Where:

U	= *Uncertainty* per *Project Area* for *Aboveground Biomass* change estimated in *Measurement Period*
AGB_t	= *Aboveground Biomass* per *Project Area* at the most recent measurement point in time *t* (tonne)
AGB_{t-p}	= *Aboveground Biomass* per *Project Area* at the most recent measurement point in time *t* minus *Measurement Period p* (tonne)
u	= *Uncertainty* for *Aboveground Biomass* estimated per *stratum* (see Equation 2)

The variable u is calculated using Equation 2:

$$u = \frac{CI}{\overline{AGB}_{validation(m)}}$$

Equation 2

Where:

u	= *Uncertainty* for *Aboveground Biomass* estimated per *stratum*
CI	= Half-width of a 90% confidence interval derived from model residuals (tonne/ha)
$\overline{AGB}_{validation(m)}$	= Mean measured *Aboveground Biomass* of ground truth *Project Areas in the validation set* (tonne/ha)

[1] Derived from Equation 3.2 in **IPCC GPG** 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 1: General Guidance and Reporting. Chapter 3: Uncertainties.

The confidence interval is calculated on the measured and predicted values of the validation dataset using Equation 3:

$$CI = z \cdot SEM$$

Equation 3

Where:

CI	= Half-width of a 90% confidence interval
SEM	= Standard error of mean
z	= 1.645 which is the critical point for a normal distribution on a 90% based on confidence interval

The standard error is calculated on the residual of the measured and predicted values of the validation *Project Areas* using Equation 4[2]:

$$SEM = \frac{std(e)}{\sqrt{n}}$$

Equation 4

Where:

SEM	= Standard error of mean
$std(e)$	= Standard deviation of residual
n	= Number of validation *sample plots*

The residual value, which is the difference between predicted and measured *AGB* of the validation dataset is calculated using Equation 5. The validation set are the "n" validation *Project Areas* for each *Project*. *AGB* is measured in the field following the *ground truth data* collection described in **PT006.** ($AGB_{measured}$). The calibrated model is applied on the validation dataset and predicted values are produced ($AGB_{predicted}$):

$$e = AGB_{validation(m)} - AGB_{validation(p)}$$

[2] As used in: Stein, A., van der Meer, F.D. and Gorte, B. eds., 1999. *Spatial statistics for remote sensing* (Vol. 1). Springer Science & Business Media.

Equation 5

Where:

e	= Residual value (tonne/ha)
$AGB_{validation(p)}$	= Predicted *Aboveground Biomass* derived by the model on the validation set (tonne/ha)
$AGB_{validation(m)}$	= Measured *Aboveground Biomass* derived from *ground truth data* of the validation set (tonne/ha)

Subsequently, Equation 6 is applied to derive an adjustment factor value per *Project Area*. If Equation 6 results in a negative value, $AdjU$ will be 'zero'; if the value is greater than 1, it will be 'one'.

$$AdjU = 0.25\ (U - 0.5)$$

Equation 6

The adjustment factor is deducted from the *carbon benefit* per *Project Area*.

6 Parameters

Data/Parameter	$AGB_{t,t-p}$
Units	Tonne
Description	Predicted *Aboveground Biomass* of a *Project Area* at the most recent measurement point in time *t*; Predicted *Aboveground Biomass* of a *Project Area* at the most recent measurement point in time *t* minus *Measurement Period p*, allowing for a multiyear measurement if *Project Area uncertainty* does not meet the threshold of 50%.
Equations	Equation 1
Source	**PU006**
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	The change in *biomass* needs to be adjusted for the *uncertainty* of the predicted *biomass* during the *Measurement Period*. Both these predictions have an *uncertainty* based on the model and the *Project*.
Purpose of Data	Calculating *uncertainty* of the change in *biomass* per *Project Area*
Comments	-

Data/Parameter	$\overline{AGB}_{validation(m)}$

Units	Tonne/ha
Description	Mean measured *Aboveground Biomass* of all *Project Areas* in validation set
Equations	Equation 2
Source	*Ground truth data* (see ***PT006***)
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	The confidence interval is based on the residuals between measured and predicted values of the validation set. The mean measured value is used to convert this into a relative value
Purpose of Data	Calculating *uncertainty* per *Project*
Comments	-

Data/Parameter	$AGB_{validation(m),(p)}$
Units	Tonne/ha
Description	Measured *Aboveground Biomass* of a validation *Project Area*; Predicted *Aboveground Biomass* of a validation *Project Area*;
Equations	Equation 5
Source	*Ground truth data* (see **PT006**); **PU006**
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	This parameter is necessary in order to calculate residual values.
Purpose of Data	Calculating residual between measured and predicted values
Comments	-

Data/Parameter	*n*
Units	n/a
Description	Number of *sample plots* in validation set
Equations	Equation 4
Source	General statistics
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	Calculating half width of the confidence interval
Purpose of Data	
Comments	-

Data/Parameter	$std(e)$
Units	n/a
Description	Standard deviation of residual

Equations	Equation 4
Source	General statistics
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	Common statistics
Purpose of Data	Standard error
Comments	-

Data/Parameter	z
Units	n/a
Description	1.645 based on the 90 % confidence interval
Equations	Equation 3
Source	Student's t-distribution
Value	1.645
Justification of choice of data or description of measurement methods and procedures applied	1.645 is the critical point for a normal distribution on a 90% based on confidence interval
Purpose of Data	Calculating half width of the confidence interval
Comments	-

7 References

Stein, A., van der Meer, F.D. and Gorte, B. eds., (1999). *Spatial statistics for remote sensing* (Vol. 1). Springer Science & Business Media.