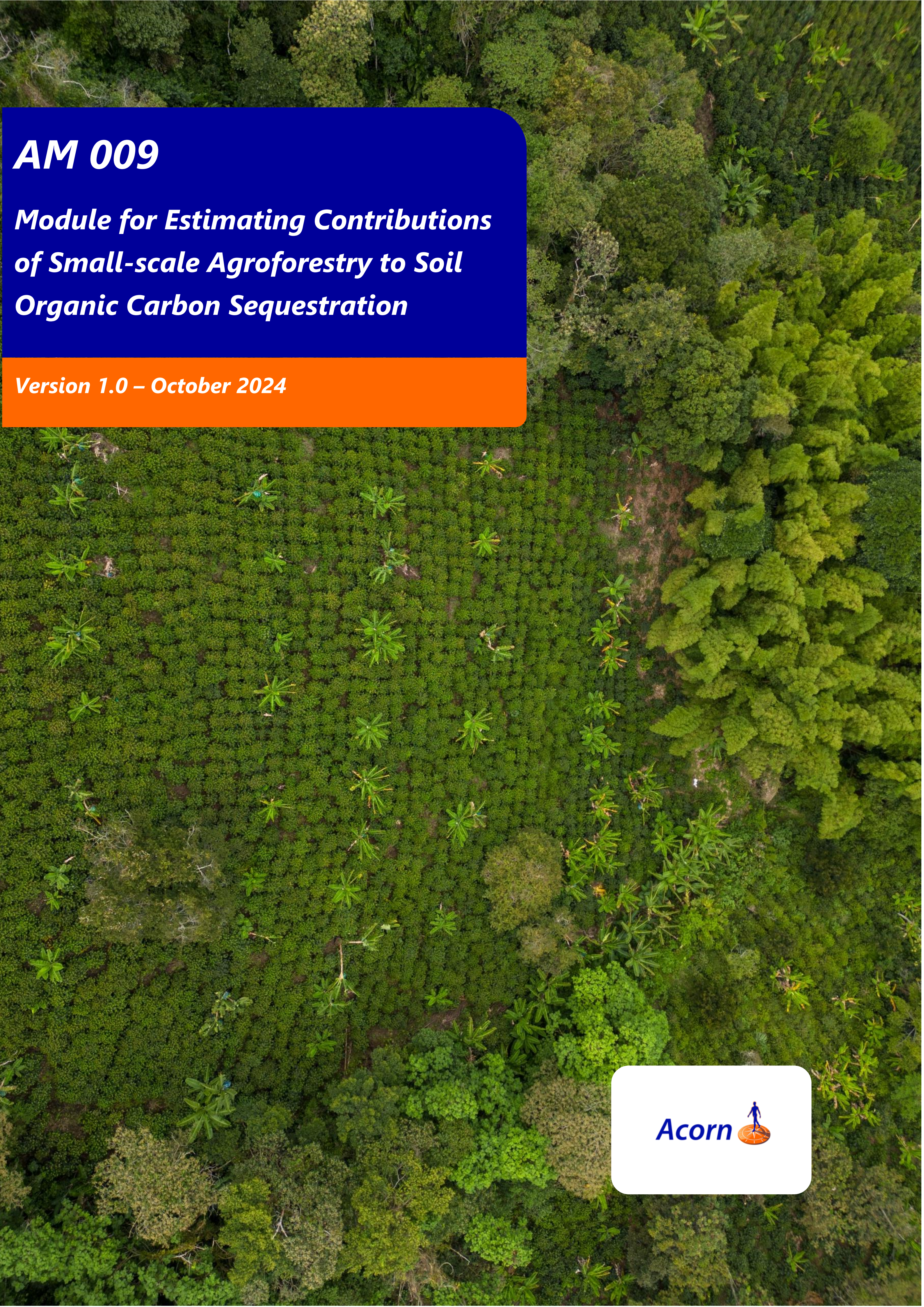

AM 009

Module for Estimating Contributions of Small-scale Agroforestry to Soil Organic Carbon Sequestration

Version 1.0 – October 2024

Acorn

Contents

1 Summary

In this module, we provide a methodology for the estimation of change in *Soil Organic Carbon (SOC)* sequestration as a function of change in *Aboveground Biomass*. Following existing methodologies and published literature, the module presents an approach to establishing the *carbon baseline*, sequestration rate and verification.

This module aims to quantify the amount of *SOC*, which has been sequestered as a result of *agroforestry* practices in a *Smallholder Farmer* setting. Any additional practices, such as no-till or other agricultural methods that might contribute to higher *SOC* values, are not included in our calculation. As such, the change in *SOC* due to a positive increase in *Aboveground Biomass* is added to the *Carbon Removal Unit (CRU)*and complies with all applicability conditions listed in the framework and methodology of the *Acorn program*.

2 Sources

This module partially follows procedures from the following tool:

- **PT001** – Small-holder Agriculture Monitoring and Baseline Assessment (SHAMBA) Tool

In this module, we referred to Woollen et al., (2017) to establish a baseline for the *Acorn project*. For the remaining component of *SOC* estimation, we have chosen to determine *SOC* as a function of *Aboveground Biomass*. The justification behind this choice is that we aim to quantify only the fraction of *SOC*, which has been sequestered as a result of positive *agroforestry* practices. Any additional practices, such as no-till or other agricultural methods that might contribute to higher *SOC* values, are not included in our calculation. As such, the change in *SOC* due to a positive increase in *Aboveground Biomass* is added to the *CRU* and counts as one combined *CRU* value.

- **AM-003** Module for Ground Truth Sampling v1.0

3 Definitions

Definitions used in this module follow the latest version of the Acorn Glossary available on the [Acorn website].

4 Applicability Conditions

For this module the applicability conditions of the Acorn Methodology **AM-001 v2.0** should be met.

The module is designed to quantify only the fraction of *SOC*, which has been sequestered as a result of *agroforestry* practices, and should be used only in combination with the Acorn methodology for the generation of *CRUs* from *Aboveground Biomass*.

5 Procedures

5.1 Stratification

The stratification approach of Acorn Methodology follows the use of *ecoregions* as defined by WWF (Olson 2001), and elaborated on in **AM-003.** These are ecological areas that capture the individual *ecoregions* and habitats favorable to particular forest types. Within each *ecoregion,* there is a unique combination of various environmental parameters including (but not limited to) altitude, natural vegetation type, climate conditions, and soil type. Each *Acorn project* belongs to one or multiple *ecoregions*.

5.2 Carbon baseline

Carbon baseline follows closely the calculation by Woollen et al., (2017), where the global soil data layer referred to by the authors 'Harmonized World Soil Database' is replaced by its updated version SoilGrids (ISRIC, 2020).

Per *stratum*, *SOC* and soil texture (% sand, silt, and clay) information is extracted from the SoilGrids data layer (0-30cm depth) for the location of the *Acorn Project*. The values are extracted per pixel according to the relevant resolution provided by SoilGrids. A single soil type is assigned per polygon. Whenever all pixels from SoilGrids with the centroid inside the polygon are from multiple soil types, the soil type with the lowest bulk density (Table 1, USDA 1987) is assigned to the plot, resulting in the most conservative value. The organic carbon values per plot is an average of all pixels from SoilGrids with the centroid inside the polygon, ignoring pixels without a value is calculated to define the *carbon baseline* per plot (Hastie et al., 2009). The texture parameters are combined, and the project texture class is calculated according to the Soil Texture Triangle (USDA, 2023).

5.3 Maximum sequestration potential

Following Woollen et al., (2017), *SOC* at equilibrium (measured in soil carbon tonne/ha) is 25% higher than the value given by SoilGrids and defined as *carbon baseline* (based on Guo and Gifford 2002, Don et al., 2011). The assumption is that the land was wooded before disturbance and that woodland or forest cover represent a pre-disturbance state where *SOC* was in equilibrium. If defaults are not applicable, local data on equilibrium and initial *SOC* and soil clay content should be used instead. The bulk density values from texture class is derived by following Table 1 (USDA 1987) and is used in Equation 1 to calculate *SOC* per *stratum* (Gvt of Western Australia, 2023).

$$SOC_{s,s} = SOC_s \cdot BD \cdot 100$$

Equation 1

Where:

$SOC_{s,s}$ = Average SOC per stratum (tC/ha). per hectare

SOC_s = *SOC* per sample (t /hg/m3)

BD = Bulk Density (g/cm3 * depth per Table 1 below)

Table 1. General relationship of soil bulk density to root growth based on soil texture

Soil texture	Ideal bulk density for plant growth (grams/cm^3)	Bulk density that affects root growth (grams/cm^3)	Bulk density that restricts root growth (grams/cm^3)
Sand, loamy sand	<1.60	1.69	>1.80
Sandy loam, loam	<1.40	1.63	>1.80
Sandy clay loam, clay loam	<1.40	1.60	>1.75
Silt, silt loam	<1.40	1.60	>1.75
Silt loam, silty clay loam	<1.40	1.55	>1.65
Sandy clay, silty clay, clay loam	<1.10	1.49	>1.58
Clay (>45 percent clay)	<1.10	1.39	>1.47

*Does not apply to red clayey soils and volcanic ash soils.

5.4 Contribution of small-scale agroforestry to soil carbon

SOC at equilibrium defines the maximum *SOC* in tonne/ha that can be sequestered by the soil within the *project area*.

Maximum *SOC* sequestration rate is assumed to be 0.5 tC/ha/yr, following Oldfield et al., (2019), and Woollen et al., (2017). This rate is assumed to be a conservative estimate of change in organic *carbon* without excess amount of chemical fertilizer use.

As stated by Chan, et al., (2022), there is a direct relationship between satellite-based estimation of *Aboveground Biomass* and soil *carbon*. From the data and analysis, it can be seen that sequestered carbon in soils, is approximately within the range of 20% and 30% of the total carbon sequestered by *Aboveground Biomass* and *Belowground Biomass* depending on the type of agricultural system. As stated by Chatterjee et al., (2018), changes in soil *carbon* in soils due to transition to *agroforestry*, are on average 28% from that of *Aboveground Biomass* estimated values across all agroecological regions.

A default value of 0.2 (20%) of the change in *Aboveground Biomass* up to *SOC* of 0.5 tonne/ha/year. To estimate the change in *SOC* as a function of change in *Aboveground Biomass*, therefore, Equation 2 should be followed:

$$SOC_{\Delta,\mathrm{y}} = AGB_{\Delta,\mathrm{y}} \cdot X$$

Equation 2

Where:

$SOC_{\Delta,y}$	= Change in *SOC* in year y to a maximum of 0.5 tonne/ha/year
$AGB_{\Delta,\mathrm{y}}$	= Change in *Aboveground Biomass* during in year y (tonne/ha)
X	= Change rate for *SOC*

5.5 Verification

The baseline estimation is verified within the first 3 years by collecting a minimum of 30 soil samples per *stratum*. Following a standard procedure for soil sampling (i.e., ISO 18400-104:2018), soil samples are to be collected at 15-30 cm depth and analysed for their *SOC* content using dry combustion method and texture at a certified laboratory. The location of the samples is defined following a stratified random approach, corresponding to the sampling strategy for *Aboveground Biomass* (**AM-003**).

The procedure is then followed every three years to ensure that the maximum *SOC* equilibrium of 25% from baseline is not exceeded, or *CRUs* are no longer generated if it is.

Therefore, estimated SOC will be used to 1) verify the baseline estimated using SoilGrids, and 2) re-calibrate the baseline if the difference in estimate is larger than 30% on a *project level* (70% accuracy is assumed), 3) verify the eligibility of the *Acorn project* to continue issuing *CRUs* relative to the equilibrium value.

6 Parameters

Data/Parameter	$AGB_{\Delta,y}$
Units	Tonne/ha
Description	The change in *Aboveground Biomass* during the same period *t*
Equations	Equation 2
Source	*Biomass* model (see AM-004)
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	Delta of AGB is derived from AM-004
Purpose of Data	Input parameter for *SOC* calculation
Comments	N/A

Data/Parameter	BD
Units	Soil categories
Description	Bulk density – spatial distribution of soil properties across the globe
Equations	Equation 1
Source	ISRIC
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	Soil type is an important indicator of *biomass* growth
Purpose of Data	To estimate the *SOC* baseline
Comments	N/A

Data/Parameter	SOC_s
Units	Tonne/ha
Description	*SOC* per sample
Equations	Equation 1
Source	Field sample
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of Data	*SOC* sequestration calculation

Comments	N/A

Data/Parameter	X
Units	No unit
Description	Change rate 0.2
Equations	Equation 2
Source	Oldfield et al., (2019) & Woollen et al., (2017)
Value	Number
Justification of choice of data or description of measurement methods and procedures applied	The most conservative expected change rate of *SOC*
Purpose of Data	The estimated contribution of *agroforestry* to *SOC*
Comments	N/A

7 References

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