SCM0004 - Methodology for the Regeneration of Spekboom Thicket

Document Prepared by the Social Carbon Foundation

Title	Methodology for the regeneration of Spekboom Thicket
Version	V1.2

Date of Issue	28/09/2023
Type	Methodology
Sectoral Scope	Scope 14 – Afforestation and Reforestation
Prepared By	Social Carbon Foundation
Contact	128 City Road, London, United Kingdom, EC1V 2NX

Acknowledgements

We thank the following individuals for their contribution towards the development of this methodology: Divaldo Rezende, Jeremy Barton, Marius van de Vyver, Michael Davies, Philip Smith

Contents

Methodology Details

1. Sources

This methodology uses the following sources:

- SOCIALCARBON Standard v6.0
- SOCIALCARBON Standard Definitions
- CDM Tool for the demonstration and assessment of additionality version 5.2
- CDM Tool for the Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities
- van der Vyver, ML. and Cowling, R. (2019) Aboveground biomass and carbon pool estimates of Portulacaria afra (spekboom)-rich subtropical thicket with species-specific allometric models

2. Summary description of the Methodology

This methodology provides a means to quantify net GHG emission removals (NERs) from project activities that restore and regenerate Spekboom. The methodology quantified net emissions of CO2 only. As per the applicable project activities, the Spekboom must be planted in its native geography and activities must be implemented to prevent grazing from livestock. Measurement of the NERs is conducted through allometric models backed by peer-reviewed literature and subject matter experts.

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

Spekboom thicket (ST) is a semi-arid subtropical thicket type found in south-eastern South Africa. It typically consists of a matrix of the large succulent shrub Portulacaria afra (Spekboom), within which other canopy species, both woody and succulent, often form clumps. Academic literature[1] highlights Spekboom's ability to function as an ecosystem engineer, restoring local landscape by altering the abiotic environment enough for other species.

Livestock degraded ST vegetation is estimated to currently extend over 1.2 million hectares in South Africa, with degraded ST states resembling savanna landscapes with a sparse cover of remnant trees and shrubs. In the Eastern Cape Province of South Africa, only about 17%[1] of the original Spekboom thicket is intact. Unmanaged goats have decimated Spekboom since the 1930s. The goats eat the Spekboom from

[1] Spekboom Carbon Sequestration and Rehabilitation Project in South Africa. Source: https://www.weadapt.org/placemarks/maps/view/1224

the bottom up and small plantlets find it difficult to establish. This prevents vegetative spreading and as seeds and seedlings rarely survive or are absent in thicket vegetation, Spekboom struggles to recover from browsing by goats. This methodology offers an opportunity for Spekboom restoration to be incentivised and financed through the carbon markets.

3. Definitions

In addition to the definitions set out in the latest version of the SOCIALCARBON Standard Definitions, the following definitions apply to this methodology revision:

Baseline control site
Defined area that is not impacted by the project activities for direct measurement of baseline SOC stock change and is linked to one or more sample units and representative of the land which is subject to a soil carbon project.

Crown Diameter
The mean horizontal distance, as seen in plan view, from one edge of the Spekboom's branches (drip-line) to the other.

Fire management
Set of practices that either inhibit fire or burn vegetation on purpose to achieve desired goals for vegetation and soil carbon.

Grazing animal
Mammals that eat primarily herbaceous plants or the leaves of shrubs; in this methodology, applies to livestock species subject to control by the project proponent.

Native
A plant that was historically (post A.D. 1850) or is naturally present in a geographic area and was not introduced by humans.

Plant Height
The distance between the highest vegetative tissue of the plant and the ground level.

Sample unit
Defined area that is selected for measurement, and monitoring, such as a field or sample point. Sample unit and sample field are used interchangeably in the methodology. The entire project area is divided into sample units that are assumed to be homogenous for the purposes of modelled estimates including those from simple models. The estimate of emission effect of the whole project is the total difference in fluxes between project and baseline for the population of all the sample units. For SOC, the sample unit is

defined by the sampling design and is the smallest area for which SOC measurements are applied to make a single estimate of SOC for that sample unit. When a stratified random sampling is used, the sample units will be the strata, if grid sampling is used, the sample unit will be the grid cells, and if simple random sampling of fields is used, the sample units will be the fields.

Species
An organism that is a recorded species of the Spekboom genus.

Spekboom
Portulacaria afra, also called Spekboom, is a small-leaved succulent plant found in South Africa. These succulents commonly have a reddish stem and leaves that are green, but also a variegated cultivar is often seen in cultivation.

4. Applicability Conditions

This methodology is applicable under the following conditions:

- The land subject to the project activity is degraded Spekboom Thicket habit, or within Spekboom's native geography.
- If the project area is co-habited with livestock, the project must be structured to keep livestock within the project area, and the project proponent must be able to enforce the boundaries of the project area.
- The project proponent must be able to enforce that annual grazing of the Spekboom by livestock is negligible (less than 5 percent), especially for the first 10 years of plant growth.
- The project proponent must implement measures to prevent the occurrence of fires within the project area.
- The project activity must not lead to the destruction of native plants, forests or existing non-Spekboom thickets within the project area.
- Planted truncheons shall be fenced to prevent herbivory consumption from browsing mammals at least for the first 7-10 years of planting date, afterwards it is recommended the fences be removed enabling managed consumption from native herbivores to stimulate growth.
- Truncheons to be planted by the project must be locally sourced and sustainably harvested (see Appendix 3: Sustainable Truncheon Harvesting Protocol), with no more than 30% of the plant being harvested, with the top of the plant being harvested to replicate natural herbivore consumption. Evidence of compliance with this applicability criterion must be documented.

5. Project Boundary

The spatial extent of the project boundary encompasses all lands subject to regeneration of Spekboom thicket.

Table 2 below identifies the carbon pools included or excluded from the project boundary.

Table 2: Selected Carbon Pools under Baseline and Project Activity

Carbon Pools	Included?	Explanation
Aboveground woody biomass	Yes	Major pool considered in the project scenario.
Aboveground non-woody biomass	No	Aboveground non-woody biomass is typically decomposed within the same year of its production and therefore is not a major sink and is considered in balance with CO2 uptake, respiration by plants, and annual decomposition.
Belowground biomass	Optional	Belowground biomass from Trees and Spekboom roots may be considered in the project scenario.
Deadwood	No	Negligible under applicability conditions
Litter	Optional	Litter may be considered in the project scenario because of Spekboom's ability to create a thick mulch of litter.
Soil Organic Carbon (SOC)	Optional	Soil Organic Carbon may be considered in the project scenario.

There are no emission sources included in this methodology. Emissions from fossil fuel consumption within the project area have been excluded from the project boundary. This is because planting of Spekboom truncheons is predominantly manual and the intensity of ongoing management is comparatively low compared to typical crops, particularly when the truncheons are protected by a fence for the first 10 years. As a result, any change in fossil fuel consumption resulting from the project is expected to be negligible.

6. Baseline Scenario

The baseline scenario of the project activity shall be identified by applying the CDM tool *"Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities".*

7. Additionality

This methodology uses a project method for the demonstration of additionality.

Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the SOCIALCARBON Methodology Requirements.

Step 2: Project Method

The project activity shall apply the additionality analysis method set out in the latest version of the *SOCIALCARBON Tool for the Demonstration and Assessment of Additionality for AFOLU project activities (SCT0001)* to determine that the proposed project activity is additional.

8. Quantification of GHG Emission Removals

8.1 Baseline Removals

If no Spekboom thickets or trees are present in the project area Baseline carbon removals shall be considered negligible.

$$C_{BSL} = C_{AGB\_ST_{BSL}} + C_{Litter_{BSL}} + C_{Trees_{BSL}} + C_{Root_{BSL}} + C_{Soil_{BSL}} \quad \text{(Equation 1)}$$

Where:

C_{BSL}	=	Baseline net GHG carbon stocks by sinks; tCO2e
$C_{AGB\_ST_{BSL}}$	=	Baseline carbon stock from aboveground Spekboom Thicket biomass within the project boundary, as estimated in Equation 2; tCO2e
$C_{Litter_{BSL}}$	=	Baseline carbon stock from Spekboom Thicket litter within the project boundary; tCO2e
$C_{Trees_{BSL}}$	=	Baseline carbon stock from the trees within the project boundary, as estimated in the tool "*Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*"; tCO2e
$C_{Root_{BSL}}$	=	Baseline carbon stock from roots within the project boundary; tCO2e
$C_{Soil_{BSL}}$	=	Baseline Soil Organic carbon stock within the project boundary; tCO2e

Estimation of carbon stock from aboveground Spekboom Thicket biomass

The following equations are based on the 2019 peer-reviewed study by Marius L. van der Vyver and Richard M. Cowling "*Aboveground biomass and carbon pool estimates of Portulacaria afra (spekboom)-rich subtropical thicket with species-specific allometric models*". This equation shall be used for calculating the carbon stock from aboveground Spekboom Thicket biomass, both for the baseline and project scenario.

$$C_{AGB\_ST} = AGB_{Corrected} \times 0.27 \times 0.48 \times \frac{44}{12} \quad \text{(Equation 2)}$$

Where:

C_{AGB_ST}	=	Baseline carbon stock from aboveground Spekboom Thicket biomass within the project boundary, as estimated in Equation 2; tCO2e
$AGB_{Corrected}$	=	The Aboveground Biomass for Spekboom following estimate correction factor; tonnes
0.27	=	The wet:dry ratio for Spekboom
0.48	=	The conversion of dry biomass to carbon for Spekboom
$\frac{44}{12}$	=	Equation to convert carbon (tC) to carbon dioxide equivalent (tCO2e)

$$AGB_{Corrected} = \sum_{y} exp\left(log(AGB_{Naive}) + \frac{\sigma^2}{2}\right) \quad \text{(Equation 3)}$$

Where:

$AGB_{Corrected}$	=	The Aboveground Biomass for Spekboom following estimate correction factor; tonnes
AGB_{Naive}	=	The Aboveground Biomass for Spekboom prior to correction factor; tonnes
σ^2	=	The Standard Deviation of the recorded Aboveground Biomass

$$AGB_{Naive} = exp(-11.15) \times (Crown\ Area \times Height)^{0.94} \times exp\ (\varepsilon) \quad \text{(Equation 4)}$$

Where:

AGB_{Naive}	=	The Aboveground Biomass for Spekboom prior to correction factor; tonnes
$exp(-11.15)$	=	The Constant exp(log(a)) value for the Spekboom allometric model; unitless
$Crown\ Area$	=	The area of the plant crown; cm^2
$Height$	=	The distance between the highest vegetative tissue of the plant and the ground level; cm

0.94	=	The Constant (b) value for the Spekboom allometric model; unitless

$$Crown\ Area = \pi \times \left(\frac{Crown\ Diameter}{2}\right)^2 \quad \text{(Equation 5)}$$

Where:

$Crown\ Area$	=	The area of the plant crown; cm^2
$Crown\ Diameter$	=	The mean horizontal distance, as seen in plan view, from one edge of the Spekboom's branches (drip-line) to the other; cm

Estimation of carbon stock from Spekboom Thicket Litter

Carbon stocks for Litter can be calculated through sampling and using the approach outlined in the latest version of the CDM tool "*Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities*". The default value for the wet:dry ratio shall be 0.27.

Estimation of carbon stock from the trees within the project boundary

This should be calculated using the latest version of the CDM tool *"Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities".* This estimate must be limited to trees and exclude any existing shrubs, excluding Spekboom.

If belowground biomass is included in the project scope, the belowground biomass of native trees and shrubs (excluding Spekboom) shall also be calculated using the latest version of the CDM tool *"Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities".*

Estimation of carbon stock from belowground biomass of Spekboom within the project boundary

There are two main aspects of sampling for root carbon, namely the sampling design and the actual extraction and processing of the sample to arrive at an estimate of root carbon for each stratified unit. Since no root:shoot ratios for neither Spekboom nor for most other vegetation in the ecosystem exist, there is a need to sample root carbon directly. This procedure can be included in the soil organic carbon sampling process outlined in this methodology and follow the same sampling design where from each of the soil layer samples root biomass can be extracted by wet sieving from the same samples used for determining bulk density.

$$C_{ST\_Root} = B_{Root} \times 0.47 \times \frac{44}{12} \quad \text{(Equation 6)}$$

Where:

C_{ST_Root}	=	Carbon stock from Spekboom root biomass within the project boundary; tCO_2e
B_{Root}	=	Root biomass within the project boundary; tonnes

0.47	=	The conversion of dry biomass to carbon for Spekboom roots
$\frac{44}{12}$	=	Equation to convert carbon (tC) to carbon dioxide equivalent (tCO2e)

Estimation of Soil Organic Carbon for the Baseline Scenario

The estimation of carbon within a sample requires the analysis of organic C concentration (ISO 10694, 1995 or ISO 14235, 1998), bulk density (ISO 11272, 1998), the content of fine and coarse particles (and associated OC and N) (ISO 11277, 2009), and soil depth (ISO 25177, 2008). At larger scales (e.g., landscape, regional, national), high-throughput techniques such as infrared spectroscopic methods may be used to quantify SOC in large soil sample sets (ISO 17184:2014) (Bispo et al., 2017).

$$C_{Soil} = \sum_{i=1}^{n} 10 \times p_i \times SOC_i \times BD_i \times (1 - CP_i) \quad \text{(Equation 7)}$$

Where:

C_{Soil}	=	Soil Organic Carbon stock within the project boundary; tCO2e
$\mathrm{p_i}$	=	Thickness of the soil layer of layer i; metres
$\mathrm{SOC_i}$	=	Organic carbon concentration of layer i in fine soil; g/kg
$\mathrm{BD_i}$	=	Bulk density of layer i in fine soil; kg/dm^3
$\mathrm{CP_i}$	=	Percentage of coarse particles of layer i
n	=	Number of soil layers

8.2 Project Removals

This methodology considers the emissions from vehicles / equipment to be negligible. Project proponents should use the following equations to quantify the project removals achieved. If $y - 1$ is the Baseline year (i.e. y is the first monitoring report), replace TC_{y-1} with C_{BSL} .

$$TER_y = (TC_y - TC_{y-1}) - LK_y \quad \text{(Equation 8)}$$

Where:

TER_y	=	Total Emission Removals in year y; tCO2e
TC_y	=	Total Carbon Stocks in year y; tCO2e
TC_{y-1}	=	Total Carbon Stocks in year $y - 1$; tCO2e

LK_y	=	GHG emissions due to leakage in year y, as calculated using Equation 15; tCO2e

Total carbon stocks as calculated as follows:

$$TC_y = C_{AGB\_ST,y} + C_{Trees,y} + C_{Litter,y} + C_{Root,y} + C_{Soil,y} \quad \text{(Equation 9)}$$

Where:

TC_y	=	Total Carbon Stocks in year y; tCO2e
$C_{AGB\_ST,y}$	=	Project carbon stock from aboveground Spekboom Thicket biomass within the project boundary, as estimated in Equation 2; tCO2e
$C_{Litter,y}$	=	Project carbon stock from litter biomass within the project boundary in year y; tCO2e
$C_{Trees,y}$	=	Project carbon stock from the trees within the project boundary in year y, as estimated in the tool "*Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*"; tCO2e
$C_{Root,y}$	=	Project carbon stock from belowground biomass (roots) within the project boundary in year y, as estimated using Equation 6, Equation 10 or Equation 11; tCO2e
$C_{Soil,y}$	=	Soil Organic Carbon Stock within the project area in year y, as estimated using Equation 7 or Equations 12 - 14; tCO2e

Modelling changes in Spekboom belowground biomass

Due to the destructive nature of this sampling method, as with the soil organic carbon, it is recommended that sampling be repeated once every 5 years. Project Proponents may also model belowground carbon of Spekboom (planted as part of the project activities) to estimate the annual carbon stocks in between the 5-year sampling intervals. This will enable them to estimate changes in Spekboom roots on an annual basis, rather than in 5-year intervals. Linear models of belowground carbon (root) yield in tCO2e per annum since planting shall be used according to two sampling depths: 0-50 cm and 0-100 cm. The same sampling depth model shall be applied throughout the project duration to ensure consistency. The model selected shall use the same sampling depth as planned field sampling depths. It is recommended that the sampling depth aligns with the Soil Organic Carbon sampling strategy to minimise sampling duplication.

Sampling at 50cm soil depth

$$C_{ST\_Root} = -2 + (1.1 \times t) \quad \text{(Equation 10)}$$

Where:

C_{ST_Root}	=	Carbon stock from Spekboom root biomass within the project boundary; tCO2e per hectare

t	=	Years since planting; years

Sampling at 100cm soil depth

$$C_{ST\_Root} = 0.96 + (1.1 \times t) \quad \text{(Equation 11)}$$

Where:

C_{ST_Root}	=	Carbon stock from Spekboom root biomass within the project boundary; tCO2e per hectare
t	=	Years since planting; years

If the above model is used, the project proponent must make adjustments to the C_{ST_Root} value directly measured every 5 year interval. If the measured value is greater than the modelled value for the same time period, the measured value shall be used and no adjustments are needed. If the modelled value is greater than the measured value, the difference between the two values must be deducted from the measured valued. Any adjustments must be documented in the respective verification report.

Modelling changes in Soil Organic Carbon

As with sampling of root carbon, it is recommended that SOC sampling be repeated once every 5 years. Project Proponents may also model Soil Organic Carbon Concentration to estimate the annual carbon stocks in between the 5-year sampling intervals. Linear models of SOC yield in tCO2e per annum since planting shall be used according to three sampling depths: 0-30 cm, 0-50 cm and 0-100 cm. The same sampling depth model shall be applied throughout the project duration to ensure consistency. The model selected shall use the same sampling depth as planned field sampling depths. These models are based on the annual tCO2e yield models derived from soil sample data provided by Mills & Cowling, 2006. For more information see Appendix 2.

The modelled approach shall only be applied to newly planted Spekboom Thicket (not present at the project start date).

Sampling at 30cm soil depth

$$C_{Soil,y} = -4.3 + (7.5 \times t) \quad \text{(Equation 12)}$$

Where:

$C_{Soil,y}$	=	Modelled Soil Organic Carbon Stock from within the project boundary; tCO2e per hectare
t	=	Years since planting; years

Sampling at 50cm soil depth

$$C_{Soil,y} = 11 + (8.9 \times t) \quad \text{(Equation 13)}$$

Where:

$C_{Soil,y}$	=	Modelled Soil Organic Carbon Stock from within the project boundary; tCO2e per hectare
t	=	Years since planting; years

Sampling at 100cm soil depth

$$C_{Soil,y} = 13 + (13 \times t)$$ (Equation 14)

Where:

$C_{Soil,y}$	=	Modelled Soil Organic Carbon Stock from within the project boundary; tCO2e per hectare
t	=	Years since planting; years

If the above models are used, the project proponent must make adjustments to the $C_{\mathrm{Soil},y}$ value directly measured every 5 year interval to the modelled value from Equations 12 - 14. If the measured value is greater than the modelled value for the same time period, the measured value shall be used and no adjustments are needed. If the modelled value is greater than the measured value, the difference between the two values must be deducted from the measured valued. Any adjustments must be documented in the respective verification report.

Table 3 below summarises the annual belowground carbon (root) and soil organic carbon projections in tCO2e/ha from the above models after the uncertainty discount is applied. Note the R-Code used to calculate the uncertainty-adjusted values will be made available on the SOCIALCARBON website (https://socialcarbon.org).

Table 3: Annual belowground biomass and Soil Organic Carbon projections in tCO2e/ha from the various models outlined above after uncertainty discount is applied.

Age	SOC 30cm *	SOC 50cm **	SOC 100cm ***	Root 50cm ****	Root 100cm *****
0	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00
3	5.87	7.36	4.89	0.01	0.00
4	13.36	16.23	18.39	1.12	1.01
5	20.84	25.11	31.88	2.23	2.15
6	28.32	33.98	45.38	3.34	3.30
7	35.80	42.86	58.88	4.46	4.44
8	43.29	51.74	72.38	5.57	5.59
9	50.77	60.61	85.87	6.68	6.73
10	58.25	69.49	99.37	7.79	7.88
11	65.73	78.37	112.87	8.90	9.02
12	73.22	87.24	126.37	10.01	10.17

13	80.70	96.12	139.86	11.12	11.31
14	88.18	104.99	153.36	12.24	12.45
15	95.66	113.87	166.86	13.35	13.60
16	103.15	122.75	180.36	14.46	14.74
17	110.63	131.62	193.85	15.57	15.89
18	118.11	140.50	207.35	16.68	17.03
19	125.59	149.37	220.85	17.79	18.18
20	133.08	158.25	234.35	18.90	19.32
21	140.56	167.13	247.84	20.01	20.47
22	148.04	176.00	261.34	21.13	21.61
23	155.52	184.88	274.84	22.24	22.76
24	163.01	193.75	288.34	23.35	23.90
25	170.49	202.63	301.83	24.46	25.04
26	177.97	211.51	315.33	25.57	26.19
27	185.45	220.38	328.83	26.68	27.33
28	192.94	229.26	342.33	27.29	28.48
29	200.42	238.13	355.82	28.91	29.62

* Soil Organic Carbon up to 30 cm depth
** Soil Organic Carbon up to 50 cm depth
*** Soil Organic Carbon up to 100 cm depth
**** Belowground Carbon (Root) up to 50 cm depth
***** Belowground Carbon (Root) up to 100 cm depth

8.3 Leakage

Leakage shall be estimated as follows:

$$LK_y = LK_{Agri,y} \qquad \text{(Equation 15)}$$

Where:

LK_y = GHG emissions due to leakage in year y; tCO2e

$LK_{Agri,y}$ = Leakage due to the displacement of agricultural activities year y, as estimated in the CDM tool "*Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity*"; tCO2e

8.4 Uncertainty

When establishing baseline and subsequent monitoring protocols, uncertainties should be reduced as far as is practically possible. For all carbon estimations, all sources of uncertainty estimation should be made explicit and the method of used in quantification and modelling outlined during both the baseline assessment process and subsequent monitoring protocols.

When values are directly measured, sampling uncertainty shall be calculated in accordance with the CDM Methodological tool *"Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"*, particularly its measurement of uncertainty.

To minimize sampling uncertainty, the project proponents should align with the CDM A/R Methodological Tool for the calculation of the number of sample plots for measurements within A/R CDM project activities facilitates the selection of number of field sample plots, based on the size of an individual sample, the area of the stratum being sampled and the target precision (acceptable margin of error) required. The 90% confidence level is considered an acceptable margin of error by the Methodological tool for estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities and may be applied for root and SOC estimates also. The same tool also provides discount factors based on the uncertainty calculation:

$$\text{Uncertainty} = \pm\left(\frac{1.692 \times \sigma}{\mu}\right) \times 100\%$$

When the uncertainty in the estimated mean value of a parameter is more than 10 percent, the estimated mean value is either increased or decreased by a percentage of the uncertainty. Table 4 below provides the uncertainty discount factors to be applied for different range of uncertainty. This is based on the CDM Methodology tool: "*Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities".*

Table 4 – Uncertainty discount factors

Uncertainty Range	Discount (% of Uncertainty)	How applied
U ≤ 10%	0%	**Example:** Estimated mean = 60±9 t d.m ha^{-1} i.e. U=9/60x100 = 15% Discount = 25% x 9 = 2.25 t d.m ha^{-1} Discounted conservative mean: In baseline = 60+2.25 = 62.25 t d.m ha^{-1} In project = 60-2.25 = 57.75 t d.m ha^{-1}
10 < U ≤ 15	25%	
15 < U ≤ 20	50%	
20 < U ≤ 30	75%	
U > 30	100%	

Note: when the belowground carbon and soil organic carbon is modelled using equations 10 – 14, the values outlined in Table 3 are already discounted for uncertainty and do not need to be discounted further.

8.5 Net GHG Emission Removals

Net GHG emission removals are calculated by deducting the calculated Buffer amount from the Total Emission Removals calculated using equation 7.

$$NER_y = TER_y - LK_y - BUFFER_y \quad \text{(Equation 16)}$$

Where:

NER_y	=	Net emission removals during year y; tCO2e
TER_y	=	Total emission removals in year y; tCO2e
LK_y	=	GHG emissions due to leakage in year y; tCO2e
BUFFER_y	=	The number of Buffer credits to be deducted in year y, calculated by $TER_y \times Non - Permanence\ Risk\ Score\ (\%)$; tCO2e

9. Monitoring

Where discretion exists in the selection of a value for a parameter, the principle of conservativeness must be applied (as described in Section 2.3 of the latest version of the SOCIALCARBON Standard).

9.1 Data and Parameters Available at Validation

Data / Parameter	$Crown\ Area$
Data unit	cm^2
Description	The crown area of the Spekboom Biomass at baseline scenario.
Equations	4, 5
Source of data	Collected either through on-site measurements or remote sensing (only if remote sensing approach has sufficient resolution to accurately measure Crown Area).
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.

Purpose of Data	Calculation of baseline Aboveground biomass of existing Spekboom.
Comments	N/A

Data / Parameter	$Height$
Data unit	cm
Description	The distance between the highest vegetative tissue of the plant and the ground level.
Equations	4
Source of data	Collected either through on-site measurements or remote sensing (only if the remote sensing approach has sufficient resolution to accurately measure Height)
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline Aboveground biomass of existing Spekboom.
Comments	N/A

Data / Parameter	$Crown\ Diameter$
Data unit	cm
Description	The mean horizontal distance, as seen in plan view, from one edge of the Spekboom's branches (drip-line) to the other.
Equations	4, 5
Source of data	Collected either through on-site measurements or remote sensing (only if the remote sensing approach has sufficient resolution to accurately measure Crown Diameter)
Value applied	N/A
Justification of choice of data or description of	This parameter shall be determined at y=0.

measurement methods and procedures applied	
Purpose of Data	Calculation of baseline Aboveground biomass of existing Spekboom.
Comments	N/A

Data / Parameter	Litter Biomass
Data unit	tonnes
Description	Total weight of litter in y=0.
Equations	N/A
Source of data	Collected either through on-site measurements depending on whether there is Spekboom thicket present within the project area at year = 0.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline Litter.
Comments	N/A

Data / Parameter	$Area$
Data unit	hectares
Description	Total area of the project area
Equations	N/A
Source of data	Delineation of the project area may use a combination of GIS coverages, ground survey data, remote imagery (satellite or aerial photographs), or other appropriate data. Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points.

Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline and project emissions
Comments	N/A

Data / Parameter	σ^2
Data unit	unitless
Description	The Standard Deviation of the recorded Aboveground Biomass.
Equations	3
Source of data	Variance of estimates Aboveground Biomass (prior to correction factor)
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline and project emissions
Comments	N/A

Data / Parameter	$C_{Trees_{BSL}}$
Data unit	tCO2e
Description	Baseline carbon stock from the trees within the project boundary
Equations	1
Source of data	Based on equations, data and parameters used in the latest version of the CDM tool, *"Estimation of carbon stocks and change in carbon*

	stocks of trees and shrubs in A/R CDM project activities”. This must exclude Carbon from Spekboom.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline and project emissions
Comments	This must exclude Carbon from Spekboom.

Data / Parameter	$Area_{Spekboom}$
Data unit	Hectares
Description	Total area covered by Spekboom Thicket.
Equations	N/A
Source of data	Collected either through on-site measurements or remote sensing (only if remote sensing approach has sufficient resolution to accurately measure $Area_{Spekboom}$).
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline and project emissions
Comments	This is used to extrapolate the individual measurements/estimates and calculate the total Spekboom Aboveground Biomass and Litter.

Data / Parameter	$C_{Soil_{BSL}}$
Data unit	tCO2e
Description	Soil Organic Carbon measured at the sample unit i at year 0

Equations	7
Source of data	Collected through on-site measurements.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of year 1 SOC change
Comments	This shall be calculated both for areas where Spekboom Thicket already exists (pre-project start date) and where the Spekboom truncheons are planned for planting.

Data / Parameter	C_{ST_Root}
Data unit	tCO2e
Description	Carbon stocks of Spekboom thicket roots
Equations	6
Source of data	On field measurements in the project area.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline Spekboom thicket root carbon stocks
Comments	This only need be measured if there is Spekboom thicket present in the project area at year=0.

Data / Parameter	p_i
Data unit	Metres

Description	Thickness of the soil layer of layer i
Equations	7
Source of data	Measured in the project area.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline Soil Carbon Stocks
Comments	NA

Data / Parameter	SOC_i
Data unit	g/kg
Description	Organic carbon concentration of layer i in fine soil
Equations	7
Source of data	Measured in the project area.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline Soil Carbon Stocks
Comments	N/A

Data / Parameter	$\mathrm{BD_i}$
Data unit	kg/dm^3

Description	Bulk density of layer i in fine soil
Equations	7
Source of data	Measured in the project area.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline Soil Carbon Stocks
Comments	N/A

Data / Parameter	CP_i
Data unit	Percentage
Description	Percentage of coarse particles of layer i
Equations	7
Source of data	Measured in the project area.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline Soil Carbon Stocks
Comments	N/A

Data / Parameter	n
Data unit	Number

Description	Number of soil layers
Equations	7
Source of data	Measured in the project area.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at y=0.
Purpose of Data	Calculation of baseline Soil Carbon Stocks
Comments	N/A

9.2 Data and Parameters Monitored

Data / Parameter:	$Crown\ Area$
Data unit:	cm^2
Description:	The crown area of the Spekboom Biomass at year y.
Equations	4, 5
Source of data:	Calculated based on the Crown Diameter either through on-site measurements or remote sensing (only if the remote sensing approach has sufficient resolution to accurately measure Crown Diameter)
Description of measurement methods and procedures to be applied:	See section 9.3
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Calculation of project Aboveground biomass of Spekboom

Calculation method:	$\text{Crown Area} = \pi \times \left(\frac{\text{Crown Diameter}}{2}\right)^2$
Comments:	N/A

Data / Parameter:	$Height$
Data unit:	cm
Description:	The distance between the highest vegetative tissue of the plant and the ground level.
Equations	4
Source of data:	Collected either through on-site measurements or remote sensing (only if the remote sensing approach has sufficient resolution to accurately measure Height)
Description of measurement methods and procedures to be applied:	Project proponents should measure the distance between the highest vegetative tissue of the plant and the ground level.
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Calculation of project Aboveground biomass of Spekboom
Calculation method:	See section 9.3
Comments:	N/A

Data / Parameter:	$Crown\ Diameter$
Data unit:	cm
Description:	The mean horizontal distance, as seen in plan view, from one edge of the Spekboom's branches (drip-line) to the other.
Equations	4, 5

Source of data:	Collected either through on-site measurements or remote sensing (only if the Spekboom is of sufficient size to warrant remote sensing).
Description of measurement methods and procedures to be applied:	Project proponents should measure the horizontal distance, as seen in plan view, from one edge of the Spekboom's branches (drip-line) to the other.
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Calculation of project Aboveground biomass of Spekboom.
Calculation method:	See section 9.3.1
Comments:	N/A

Data / Parameter:	σ^2
Data unit:	Unitless
Description:	The Standard Deviation of the recorded Aboveground Biomass.
Equations	3
Source of data:	Variance of estimates Aboveground Biomass (prior to correction factor)
Description of measurement methods and procedures to be applied:	Square root of the variance in Aboveground Biomass (prior to correction factor)
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	See section 9.3.1
Purpose of data:	Calculation of project Aboveground biomass of Spekboom.
Calculation method:	See section 9.3.1

Comments:	N/A

Data / Parameter:	$C_{Trees,y}$
Data unit:	tCO2e
Description:	Baseline carbon stock from the trees within the project boundary in year y
Equations	1
Source of data:	Based on equations, data and parameters used in the latest version of the CDM tool, *"Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities".* This must exclude Carbon from Spekboom.
Description of measurement methods and procedures to be applied:	See description of measurement methods and procedures to be applied.
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	See CDM tool, *"Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities"*
Purpose of data:	Calculation of project Aboveground biomass of Spekboom.
Calculation method:	See description of measurement methods and procedures to be applied.
Comments:	This must exclude Carbon from Spekboom

Data / Parameter:	$Area_{Spekboom}$
Data unit:	Hectares
Description:	Total area covered by Spekboom Thicket.
Equations	N/A

Source of data:	Collected either through on-site measurements or remote sensing (only if remote sensing approach has sufficient resolution to accurately measure $Area_{Spekboom}$).
Description of measurement methods and procedures to be applied:	N/A
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	N/A
Purpose of data:	Calculation of project Aboveground biomass of Spekboom
Calculation method:	N/A
Comments:	This is used to extrapolate the individual measurements/estimates and calculate the total Spekboom Aboveground Biomass and Litter.

Data / Parameter:	C_{Soil}
Data unit:	tCO2e/area unit
Description:	Areal-average soil organic carbon stocks in the project scenario for sample unit i in year y
Equations	7
Source of data:	Collected through on-site measurements.
Description of measurement methods and procedures to be applied:	Measured soil organic carbon must be determined from samples collected from sample plots located within each sample unit. All organic material (e.g., living plants, crop residue) must be cleared from the soil surface prior to soil sampling. Soil must be sampled to a minimum depth of 30 cm, ideally as contiguous cores divided into many short increments (e.g., 5 or 10 cm in length) to enable following the equivalent soil mass (ESM) approach (Ellert and Bettany, 1995). To eliminate the need for extrapolation outside of the measured range, soils should be sampled one increment deeper than the minimum 30 cm required. Soil organic carbon stocks must be estimated from measurements of both soil organic carbon content and bulk density taken at the same time. Note that bulk density measurements are not necessarily required to determine SOC stock changes on an ESM basis.

If organic amendments are applied, projects should delay sampling or re-sampling to the latest time possible after the previous application and the shortest time possible before the next one. Sampling and re-sampling campaigns between years should be conducted during the same season.

Bulk density as soil mass per volume of sampling cores shall not include the mass of soil >2mm, i.e. gravel/stones and plant material. Beem-Miller, et al. (2016) provides a useful approach to ensuring high-quality sampling in rocky soils. Analysis of soil carbon content should be performed on the same samples for which dry soil mass is measured.

Geographic locations of intended sampling points must be established prior to sampling. The location of both the intended sampling point and the actual sampling point must be recorded.

If multiple cores are composited to create a single sample, these cores must all be from the same depth and be fully homogenized prior to subsampling. Soil samples must be shipped to the laboratory within 5 days of collection and should be kept cool until shipping. Sample preparation should follow standards, such as ISO 11464.

Acknowledging the wide range of valid monitoring approaches, and that relative efficiency and robustness are circumstance-specific, sampling, measurement and estimation procedures for measuring are not specified in the methodology and may be selected by project proponents based on capacity and appropriateness. Stratification may be employed to improve precision but is not required. Estimates generated must:

- Be demonstrated to be unbiased and derived from representative sampling
- Accuracy of measurements and procedures is ensured through employment of quality assurance/quality control (QA/QC) procedures (to be determined by the project proponent and outlined in the monitoring plan)

Soil sampling should follow established best practices, such as those found in (Cline, 1944; Petersen and Calvin, 1986; Gruijter et al., 2006; Soil Science Division Staff, 2017; FAO, 2019; Smith et al., 2020).

When measuring SOC via conventional analytical laboratory methods, the use of dry combustion is recommended over other techniques. Determination of percent soil organic carbon should follow established laboratory procedures, such as those found in: (Nelson and Sommers, 1982; ISO, 1995; Schumacher, 2002).

Standardization of soil measurement methods is a globally recognized need (for example: ISRIC World Soil Information Service (WoSIS) (Ribeiro, Batjes and van Oostrum, 2018)). Measurement procedures for soil organic carbon and bulk density should be thoroughly described, including all sample handling, preparation for analysis, and analysis techniques.

Frequency of monitoring/recording:	Every 5 years
QA/QC procedures to be applied:	Standard QA/QC procedures for soil inventory including field data collection and data management must be applied. Use or adaptation of QA/QCs available from published handbooks, such as those published by FAO and available on the FAO Soils Portal[2] or from the IPCC GPG LULUCF 2003 is recommended.
Purpose of data:	Calculation of change in SOC
Calculation method:	See measurement methods description above.
Comments:	The soil organic carbon stocks at time y=0 are calculated based on directly measured soil organic carbon content and bulk density at y=0 or (back-) modelled to y =0 from measurements collected within +/-1 years of y=0. Soil organic carbon stocks in the project scenario for sample unit i must be reported every year. Where re-measurement of soil organic carbon stocks indicates lower stocks than previously estimated by modelling, procedures in the most current version of the SOCIALCARBON Registration and Issuance Process for loss or reversal events are followed, as appropriate.

Data / Parameter:	SOC_i
Data unit:	g/kg
Description:	Organic carbon concentration of layer i in fine soil
Equations	7
Source of data:	Measured in the project area.
Description of measurement methods and procedures to be applied:	When measuring SOC content via conventional analytical laboratory methods, the use of dry combustion is recommended over other techniques.
Frequency of monitoring/recording:	Every 5 years

[2] http://www.fao.org/soils-portal/soil-survey/sampling-and-laboratory-techniques/en/

QA/QC procedures to be applied:	Determination of percent soil organic carbon should follow established laboratory standard operation procedures, such as those found in: (Nelson and Sommers, 1982; ISO, 1995; Schumacher, 2002).
Purpose of data:	Calculation of change in SOC
Calculation method:	When measuring SOC content via conventional analytical laboratory methods, the use of dry combustion is recommended over other techniques.
Comments:	N/A

Data / Parameter:	Litter Biomass
Data unit:	tonnes
Description:	Total weight of litter in y
Equations	N/A
Source of data:	Field measurements
Description of measurement methods and procedures to be applied:	See section 9.3.3
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	See section 9.3.3
Purpose of data:	Calculation of project Spekboom Litter.
Calculation method:	See section 9.3.3
Comments:	N/A

Data / Parameter:	C_{ST_Root}
Data unit:	tCO2e

Description:	Carbon stocks of Spekboom thicket roots
Equations	6
Source of data:	On field measurements in the project area.
Description of measurement methods and procedures to be applied:	See section 9.3.2
Frequency of monitoring/recording:	Every 5 years.
QA/QC procedures to be applied:	See section 9.3.2
Purpose of data:	Calculation of project Spekboom thicket root carbon stocks
Calculation method:	See section 9.3.2
Comments:	N/A

Data / Parameter:	LK_y
Data unit:	tCO2e
Description:	Leakage in year y
Equations	15
Source of data:	Field studies
Description of measurement methods and procedures to be applied:	Leakage due to the displacement of agricultural activities year y, as estimated in the CDM tool "*Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity*"; tCO2e
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	See CDM tool "*Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity*"

Purpose of data:	Calculation of Net Project Emissions
Calculation method:	See CDM tool "*Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity*"
Comments:	N/A

Data / Parameter:	$Sample\ Location$
Data unit:	GPS Co-ordinate
Description:	A GPS co-ordinate of each sample site / control site must be recorded to enable auditability of projects.
Equations	N/A
Source of data:	GPS
Description of measurement methods and procedures to be applied:	See Appendix 3
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	See Appendix 3
Purpose of data:	Provide ability for auditing of project SOC measurements by remote sensing in the future.
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	S
Data unit:	Dimensionless
Description:	Standard deviation of the difference in SOC and Spekboom Root Carbon stocks between y and y_{-1}

Equations	N/A
Source of data:	Estimation of the smallest difference in SOC and Spekboom Root Carbon stock between two monitoring events that can be detected as statistically significant.
Description of measurement methods and procedures to be applied:	See section 9.3
Frequency of monitoring/recording:	Every 5 years
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Development of sampling strategy for baseline setting or measurements for monitoring.
Calculation method:	See section 9.3
Comments:	Calculation of the number of required samples to detect a minimum difference is optional for projects

9.3 Description of the Monitoring Plan

Project proponents must detail the procedures for collecting and reporting all data and parameters listed in Section 9.2. The monitoring plan must contain at least the following information:

- A description of each monitoring task to be undertaken, and the technical requirements therein;
- Definition of the accounting boundary, spatially delineating any differences in the accounting boundaries and/or quantification approaches;
- Parameters to be measured, including any parameters required for the selected model (additional to those specified in this methodology);
- Data to be collected and data collection techniques and sample designs for directly-sampled parameters;
- Anticipated frequency of monitoring, including anticipated definition of "year";

- Quality assurance and quality control (QA/QC) procedures to ensure accurate data collection and screen for, and where necessary, correct anomalous values, ensure completeness, perform independent checks on analysis results, and other safeguards as appropriate;
- Data archiving procedures, including procedures for any anticipated updates to electronic file formats. All data collected as a part of monitoring process, including QA/QC data, must be archived electronically and be kept at least for two years after the end of the last project crediting period; and
- Roles, responsibilities and capacity of monitoring team and management.

9.3.1 Sampling Aboveground Carbon Pools

Projects shall use the CDM methodology tool "*Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*" section 8 for the estimation of carbon stock in trees (excluding Spekboom) at a point in time. Estimations by measurement of sample plots shall be estimated either through Stratified random sampling or Doubling sampling.

Project Proponents are permitted to utilise emerging technology (e.g., Unmanned Aerial Vehicles) with high resolution image sensors and known uncertainty to measure the relevant data required by the applicable allometric models. These emerging technology approaches must be supported by peer-reviewed literature which validates their accuracy and uncertainty. Justification for the chosen approach should be documented in the Project Description Document supplemented with appropriate evidence. Any uncertainty in the approach used must be discounted for.

9.3.2 Sampling Belowground Carbon Pools

The destructive nature of belowground carbon pool sampling means that a combination of directly measured and model-derived annual sequestration values for root and soil carbon pools are required. A combination of field sampling and existing models may be feasible to aid with the financial viability of potential projects. Soil organic carbon and root carbon must be sampled at a minimum of every 5 years. This is to limit the destructive nature of sampling these two carbon pools and their relatively slower accumulation rates. Since there is a lot of die-off of planted truncheons within the first year, it is recommended to assess the first round of carbon sequestered at least one, or preferably two full years after planting.

Both soil and organic carbon sampling can be combined through a single effort of sampling successive soil layers of a predetermined depth with three or more adjacent samples as cubes extracted from each layer.

The projections below should give some guidance on potential sequestration rates based on actual data from revegetated stands over various time intervals. Should litter be also accounted for, a baseline estimate needs to be established before the revegetation project starts (in the case of new projects) or with the help of a suitable proxy area (in the case of already established revegetated stands).

Soil Organic Carbon

Soil organic carbon estimation methodology involves three main components:

i) the sampling design established at baseline estimation; and

ii) the sampling process repeated with each soil depth layer; and

iii) the required values obtained from a sample through post-sample processing and subsequent laboratory analysis.

The sampling design needs to be able to detect significant change in carbon stock over time and account for uncertainty. A stratified random sampling approach is required, and to be established at baseline estimation before the revegetation or any restoration action commence, or by sampling an adjacent area to an already planted stand proven to be of the same characteristics of soil type, slope, aspect and degradation status. De Gruijter et al. (2015) and Gruijter et al. (2018) and Gruijter et al. (2019) provide a method and associated software (replicated in the R packages ospats and Sampling Strata) for determining an efficient sampling design based on predictions and quantifying uncertainty. Stratification should be explicitly mapped within the target planting area and be based on known variables that affect variation on soil SOC, such as position in the landscape (e.g. footslope, midslope, crest), soil type, vegetation type and aspect. Other stratification variables can also be derived from remote sensing data.

In the absence of any available fine-scale data of soil organic carbon or a digital SOC map at a landscape (or farm) scale, a grid sampling approach is initially required for each stratified unit, in order to capture variation in SOC at a relevant local scale and determine measures of uncertainty. Each stratification unit should have at least 5-20 sample points, depending on size. Ideally, each of the sample points should consist of at least 4-10 separate sample points, each spaced by a about 1 meter to capture local variability. The general aim of this approach is to capture a representative range of variation within a stratified unit, both on a stand level and at a landscape scale. Since this procedure implies high sampling effort and costs, depending on target area identified, the procedure outlined by Gruijter et al. (2018) is recommended to provide the best stratification map and the number of required samples to detect significant change over time and based on the costs of sampling, uncertainty and prediction error.

Sampling of individual soil layers requires a decision on the total estimated soil depth for which SOC is accounted for on a project level, and the depth of each soil layer sampled. Some estimates of potential gain from different sampling depths are presented as Appendix 2. The depth of each individual sample layer may be selected based on site characteristics or project sampling preference. The number of soil depth layers determine the number of samples needed for separate laboratory analysis and thus affects sampling costs. It is recommended that the minimum total soil depth layer be 10 cm – which can extend to a maximum of 1 m deep and beyond. Aiming to go deeper is often limited on shallower soils (usually at depths > 50 cm) where bedrock is close to the surface, but on deeper soil has the added advantage of accounting for longer-term (35+ years) carbon accumulation there. Typically, sample soil layer depth is often set at between 10-20 cm per layer, where each layer is excavated as two or three adjacent 10 cm x 10 cm cubes preferably using chisels and spoons, successively up to the chosen total soil depth. It is recommended that at least two soil depth layers should be sampled at each sampling point. Should a soil probe (instead of an excavated 10 cm by 10 cm cube) be used for this purpose instead, it is important to note that its use introduces bias to bulk density and eventually soil SOC estimates due to compaction of the surface layer of soil in relation to the diameter of the probe, as reported by Sharma et al. (2020). Thus, if using a soil sampling probe for the sampling of individual soil layers, it is important to follow the equivalent soil mass (ESM) method (Sharma et al., 2020) instead of calculating SOC stock via a biased bulk density value.

Prior to the excavation of soil pits, all leaf litter and live plant material are to be removed from the soil surface. At baseline estimation and after 10-12 years of project development, this top layer of litter may be taken as a litter sample (see litter carbon sampling method below). Cubes of soil (10 cm × 10 cm × soil layer depth) should be carefully excavated out of each layer. Each sample point should take samples of two (or three) adjacent 10 cm by 10 cm soil cubes, separated by not more than 20 cm (but preferably next to one another) and be bagged. One of these samples will be used to determine soil bulk density, rock volume and root biomass, the other will be sent to the lab for determining SOC concentration at that depth level. Fine-scale variation of different soil depth layers is generally not necessary, provided that both the samples sent for lab analysis and for bulk density determination are adequately mixed across the depth of the sample profile.

The estimation of carbon within a sample requires the analysis of organic C concentration (ISO 10694, 1995 or ISO 14235, 1998), bulk density (ISO 11272, 1998), the content of fine and coarse particles (and associated OC and N) (ISO 11277, 2009), and soil depth (ISO 25177, 2008). At larger scales (e.g., landscape, regional, national), high-throughput techniques such as infrared spectroscopic methods may be used to quantify SOC in large soil sample sets (ISO 17184:2014) (Bispo et al., 2017).

Samples sent for lab analysis should be air-dried, and sieved to separate <2 mm fraction of the soil and analysed for organic carbon using either the Walkley–Black method Walkley (1947), or other standard laboratory methods with published evidence of its efficacy.

The separate samples (of the same dimensions) from each layer to calculate bulk density and rock volume should be dried in an oven at 60°C until constant mass, weighed and then wet-sieved to obtain the fine grained soil component (<2 mm). The volume of the residual rock and coarser fragments should be determined by water displacement in a measuring cylinder.

Spekboom root sampling

There are two main aspects of sampling for root carbon, namely the sampling design and the actual extraction and processing of the sample to arrive at an estimate of root carbon for each stratified unit. Since no root:shoot ratios for neither Spekboom nor for most other vegetation in the ecosystem exist, there is a need to sample root carbon directly. This procedure can be included in the soil organic carbon sampling process outlined in this methodology, and follow the same sampling design where from each of the soil layer samples root biomass can be extracted by wet sieving from the same samples used for determining bulk density.

Due to the destructive nature of this sampling method, as with the soil organic carbon, sampling for root carbon starts with baseline or reference level stock assessments, and thereafter shall be repeated once every 5 years.

9.3.3 Sampling Litter

Peer-reviewed literature indicates that tCO2e litter from Spekboom is only significant after 13 years. However, proponent proponents are permitted to measure Litter for both Spekboom and other species before this. If project proponents' measure Litter, they must measure carbon stocks from Litter based on the following minimum time schedule: year 0 (validation), year 6 and year 12. This data will provide important data to support the continued scientific analysis of Spekboom thickets and their impact on broader species.

Sampling of litter should align with the procedures for litter sampling outlined in the latest version of the CDM tool *"Estimation of carbon stocks and change in carbon stocks in dead wood and litter in A/R CDM project activities".*

The same procedure of sample site selection (random stratified sampling) should be used with the litter carbon pools as with the other sites. Since the smaller sample frame will likely introduce more uncertainty, it is necessary to include more sample points within a stratified unit.

The litter component of aboveground carbon can be sampled by collecting all litter in a 25cm × 25 cm frame at seven localities in each of the stands, and then drying samples in an oven at 60°C until constant mass.

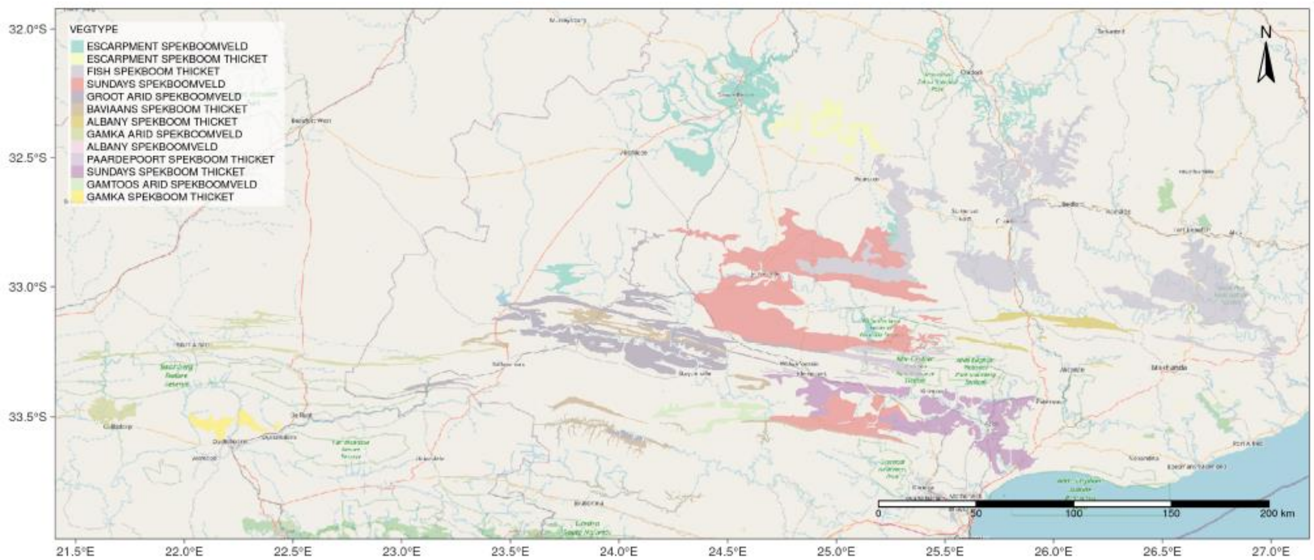
10. References

1. Beem-Miller, J.P., A.Y.Y. Kong, S. Ogle, and D. Wolfe, 2016: Sampling for soil carbon stock assessment in rocky agricultural soils. *Soil Sci. Soc. Amer. J.*, 80, no. 5, 1411-1423, doi:10.2136/sssaj2015.11.0405
2. Bispo, A. *et al.* (2017). 'Accounting for carbon stocks in soils and measuring GHGs emission fluxes from soils: do we have the necessary standards?' In: *Frontiers in Environmental Science* 5, p. 41.
3. Cline, M.G. (1944) 'Principles of soil sampling'. doi:10.1097/00010694-194410000-00003
4. De Gruijter, J., B. Minasny, and A. McBratney (2015). 'Optimizing stratification and allocation for design-based estimation of spatial means using predictions with error'. In: *Journal of Survey Statistics and Methodology* 3.1, pp. 19–42.
5. Duker, R. *et al.* (2015a). 'Frost, Portulacaria afra Jacq., and the boundary between the Albany Subtropical Thicket and Nama-Karoo biomes'. In: *South African Journal of Botany* 101, pp. 112– 119.
6. Duker, R. *et al.* (2015b). 'Community-level assessment of freezing tolerance: frost dictates the biome boundary between Albany subtropical thicket and Nama-Karoo in South Africa'. In: *Journal of Biogeography* 42.1, pp. 167–178.
7. Ellert, B.H. and Bettany, J.R. (1995) 'Calculation of organic matter and nutrients stored in soils under contrasting management regimes', Canadian Journal of Soil Science, 75(4), pp. 529–538. doi:10.4141/cjss95-075.
8. Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-14-v4.2.pdf
9. FAO (2019) Measuring and modelling soil carbon stocks and stock changes in livestock production systems: Guidelines for assessment (Version 1). Rome: FAO (Livestock Environmental Assessment and Performance (LEAP) Partnership).
10. Gruijter, J. de et al. (2006) Sampling for Natural Resource Monitoring. Berlin, Heidelberg: Springer.
11. Gruijter, J. de, I. Wheeler, and B. Malone (2019). 'Using model predictions of soil carbon in farm-scale auditing-A software tool'. In: *Agricultural Systems* 169, pp. 24–30.
12. Gruijter, J. J. d. *et al.* (2018). 'Farm-scale soil carbon auditing'. In: *Pedometrics*. Springer, pp. 693– 720.
13. IEA (2004) Energy statistics manual. Paris, France: OECD/IEA. Available at: https://ec.europa.eu/eurostat/documents/3859598/5885369/NRG-2004-EN.PDF.pdf/b3c4b86f8e88-4ca6-9188-b95320900b3f?t=1414781129000.
14. IPCC (2000) Land Use, Land-Use Change, and Forestry. UK: IPCC, p. 375. Available at: https://www.ipcc.ch/report/land-use-land-use-change-and-forestry/.
15. IPCC (2003) Good practice guidance for land use, land-use change and forestry /The Intergovernmental Panel on Climate Change. Ed. by Jim Penman. Edited by J. Penman. Hayama, Kanagawa.
16. IPCC (2013) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, p. 1535. Available at: https://www.ipcc.ch/report/ar5/wg1/.
17. IPCC (2019) 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Switzerland: IPCC. Available at: https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipccguidelines-for-national-greenhouse-gas-inventories/.
18. Mills, A. J. and R. M. Cowling (2006). 'Rate of carbon sequestration at two thicket restoration sites in the Eastern Cape, South Africa'. In: *Restoration Ecology* 14.1, pp. 38–49.

19. Nelson, D.W. and Sommer, L.E. (1982) Total Carbon, Organic Carbon and Organic Matter. Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties, 2nd Edition. ASA-SSSA, Madison, 595-579.
20. Nickless, A., R. J. Scholes, and S. Archibald (2011). 'A method for calculating the variance and confidence intervals for tree biomass estimates obtained from allometric equations'. In: *South African Journal of Science* 107.5 & 6, pp. 1–10.
21. Ogle, S. M. *et al.* (2019). 'Generic methodologies applicable to multiple land-use categories'. In.
22. Petersen, R.G. and Calvin, L.D. (1986) 'Sampling', in Methods of Soil Analysis. John Wiley & Sons, Ltd, pp. 33–51. doi:10.2136/sssabookser5.1.2ed.c2.
23. Ribeiro, E., Batjes, N.H. and van Oostrum, A. (2018) World Soil Information Service (WoSIS) - Towards the standardization and harmonization of world soil data. ISRIC Report 2018/01. Wageningen, Netherlands: ISRIC.
24. Schumacher, B. (2002) NCEA-C- 1282 EMASC-001 April 2002 methods for the determination of total organic carbon (toc) in soils and sediments.
25. Sharma, S. *et al.* (2020). 'Sampling probes affect bulk density and soil organic carbon measurements'. In: *Agricultural & Environmental Letters* 5.1, e20005.
26. Shen, H. and Z. Zhu (2008). 'Efficient mean estimation in log-normal linear models'. In: *Journal of Statistical Planning and Inference* 138.3, pp. 552–567. issn: 0378-3758. doi: http://dx.doi.org/10.1016/j.jspi.2006.10.016. url: http://www.sciencedirect.com/science/article/pii/S0378375807000523.
27. Smith, P. et al. (2020) 'How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal', Global Change Biology, 26(1), pp. 219–241. doi:10.1111/gcb.14815.
28. Spekboom Carbon Sequestration and Rehabilitation Project in South Africa. https://www.weadapt.org/placemarks/maps/view/1224
29. van der Vyver, M. L. and R. M. Cowling (2019). 'Aboveground biomass and carbon pool estimates of Portulacaria afra (spekboom)-rich subtropical thicket with species-specific allometric models'. In: *Forest Ecology and Management* 448, pp. 11–21.
30. van der Vyver, M. L. *et al.* (2013). 'Spontaneous return of biodiversity in restored subtropical thicket: Portulacaria afra as an ecosystem engineer'. In: *Restoration Ecology* 21.6, pp. 736–744.
31. van der Vyver, M. L., A. J. Mills, and R. M. Cowling (2021a). 'A biome-wide experiment to assess the effects of propagule size and treatment on the survival of Portulacaria afra (spekboom) truncheons planted to restore degraded subtropical thicket of South Africa'. In: *PloS one* 16.4, e0250256.
32. van der Vyver, M. L. *et al.* (2021b). 'Herbivory and misidentification of target habitat constrain regionwide restoration success of spekboom (Portulacaria afra) in South African subtropical succulent thicket'. In: *PeerJ* 9, e11944.
33. Vlok, J. *et al.* (2003). 'Acocks' Valley Bushveld 50 years on: new perspectives on the delimitation, characterisation and origin of subtropical thicket vegetation'. In: *South African Journal of Botany* 69.1, pp. 27–51.
34. von Haden, A.C., Yang, W.H. and DeLucia, E.H. (2020) 'Soils' dirty little secret: Depth-based comparisons can be inadequate for quantifying changes in soil organic carbon and other mineral soil properties', Global Change Biology, 26(7), pp. 3759–3770. doi:10.1111/gcb.15124.
35. Walkley, A. (1947). 'A critical examination of a rapid method for determining organic carbon in soils—effect of variations in digestion conditions and of inorganic soil constituents'. In: *Soil science* 63.4, pp. 251–264.

36. Wendt, J.W. and Hauser, S. (2013) ‘An equivalent soil mass procedure for monitoring soil organic carbon in multiple soil layers’, European Journal of Soil Science, 64(1), pp. 58–65. doi:10.1111/ejss.12002.
37. Zou, G., C. Y. Huo, and J. Taleban (2009). ‘Simple confidence intervals for lognormal means and their differences with environmental applications’. In: *Environmetrics* 20.2, pp. 172–180.

Appendix 1: Distribution Maps of Spekboom Thicket Habitat in the Eastern Cape of South Africa



The regional-scale distribution of subtropical Spekboom thicket habitat in the Eastern Cape of South Africa (Vlok et al. 2003), where Spekboom naturally occurs as a canopy dominant species. Note that there is a large measure of variability in habitat even within this delineated area and landscape- or farm-scale habitat delineation of target planting areas are highly recommended.

Appendix 2: Restoration protocol

The current protocol for restoration of degraded and transformed terrain that was once Spekboom-rich, is through the mass planting of Spekboom cuttings or truncheons harvested from large mature plants. Studies on plots that have been planted in this way with a monoculture of Spekboom truncheons (van der Vyver et al., 2013), suggests that the protocol facilitates increasing biodiversity regeneration along with increasing carbon sequestration over time. Harvesting protocol involves cutting truncheons from the topmost branches, and ensuring that not more than one third of the source plant is harvested in this way, to not deplete current source populations. It is also important to harvest truncheons from nearby the target revegetation site, to maintain current genetic diversity patterns (see Appendix 3: Sustainable Truncheon Harvesting Protocol).

Truncheons of various sizes have been used, and the standard is usually truncheons with a stem diameter of 30 mm, or roughly 60-100 cm in length. Smaller truncheons are also used (10-15 mm stem diameter), but are generally slower to grow and establish, yet preliminary data show these truncheons can be just as effective if planted in higher densities. Planting depth is generally around 5-15 cm. The planting pattern most often utilised is that of a 2 m by 2 m grid, but a 1 m by 1 m grid has also been shown to be more effective for rapid growth and carbon sequestration (see Figure 5 and Table 3). High mortality (> 60%) of planted truncheons have been recorded throughout previous restoration efforts (van der Vyver et al., 2021a), suggesting that potential improvements are likely in planting protocols with increased practice and experimentation. Planting of nursery-grown seedlings in bags, hardened through exposure to full sun and limiting water addition have been shown to be more effective, but these incur higher planting effort and costs.

Target site selection

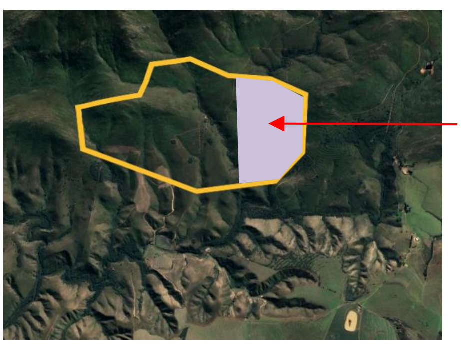
Spekboom-rich vegetation types are entwined with various other vegetation types mostly hostile to Spekboom establishment across its range, and a high degree of patchiness in its distribution and that of its associated carbon pools are observed at a landscape scale. Successful revegetation with Spekboom relies on favourable habitat conditions and thus the selection of a feasible target planting site with an imposed limit on browsing herbivores accessing planted stands for the first years since being planted (van der Vyver et al., 2021b). Frost and exposure to herbivores during the first 5-10 years of planting are factors that negatively affect restoration success (Duker et al., 2015b; Duker et al., 2015a; van der Vyver et al., 2021b). The former can be eliminated through the selection of an appropriate target site, while the latter may be kept in check through erecting fences or other barriers preventing herbivore access, particularly large antelope like Kudu (and Impala where they have been introduced) and domestic herbivores such as goats and cattle.

Appendix 3: Sustainable Truncheon Harvesting Protocol

Due to the significant degradation of wild Spekboom populations, risks arise in the harvesting of truncheons from these wild populations for restoration projects; sustainable harvesting provisions are necessary to prevent further degradation of wild Spekboom populations. Projects that source their truncheons exclusively from local nurseries are considered sustainable and do not need to comply with the following procedures.

The following requirements outline the procedures project proponents must comply with to demonstrate sustainable sourcing of Spekboom truncheons. Compliance with these requirements is mandatory. Non-compliance with any of the requirements will result in the project not being eligible for certification during the crediting period.

1. **Designated Harvest Area**
   Where the truncheons are harvesting from wild Spekboom, projects must select and document Designated Harvest Areas (DHA). Once selected, projects must exclusively harvest from these areas according to the defined protocol below. The DHA must be unique to the project (it is not being used by another project and has not previously been used by a project in the last 10 years). SOCIALCARBON will maintain a public record of all DHAs used by projects. As part of validation and verification, projects must demonstrate that their DHA is unique.



Example Designated Harvest Area (DHA) and allocated area for harvesting (30%)

   Projects are permitted to return to a DHA after 10 years of natural regeneration or add new DHAs after validation, provided they can evidence that their existing DHAs comply with the requirements outlined in this document.

2. **Baseline Scenario**
   At validation, project proponents must provide details on the baseline land-use in the DHA and submit a spatial file of the area's boundaries. In addition, the identified area shall be sampled with sufficient resolution to detect change before any harvesting takes place to establish a baseline of aboveground Spekboom biomass within the DHA.

   There are two possible methods to achieve this:

- The most cost-effective procedure would be through using UAV (drone) technology and should include high-resolution geo-referenced images of the specific area, labelled according to the date of sampling. Digital RGB images are sufficient, and the third dimension (height) should also be provided as a digital point cloud. This can be achieved through sampling the area with a drone-mounted LiDAR sensor or by using Structure from Motion (SfM) algorithms derived from overlapping RGB images.
- Alternatively, the area shall be sampled manually by measuring the height and canopy diameter (as two perpendicular measurements) of all Spekboom plants with continuous canopy (regardless of number of stems) within the DHA. Should this method be used, gps coordinates and a photo of each measured plant shall also be recorded.

The required boundary spatial files, and either georeferenced images, and point cloud file, or photographs, coordinates and measurement data of the DHA should be recorded in the Project Description Document.

3. Harvesting Protocols

Only 30% of Spekboom plants within the total DHA can be harvested within each crediting period (10 years). This ensures that the wild population is not over-harvested and can suitably recover and survive herbivore consumption in parallel to the harvesting.

In addition to this, only 30% of each plant's baseline biomass can be harvested within each crediting period. Harvesting of the truncheons must mimic that of large wild herbivores and focus on the top of the plant. See Figure 1 below.

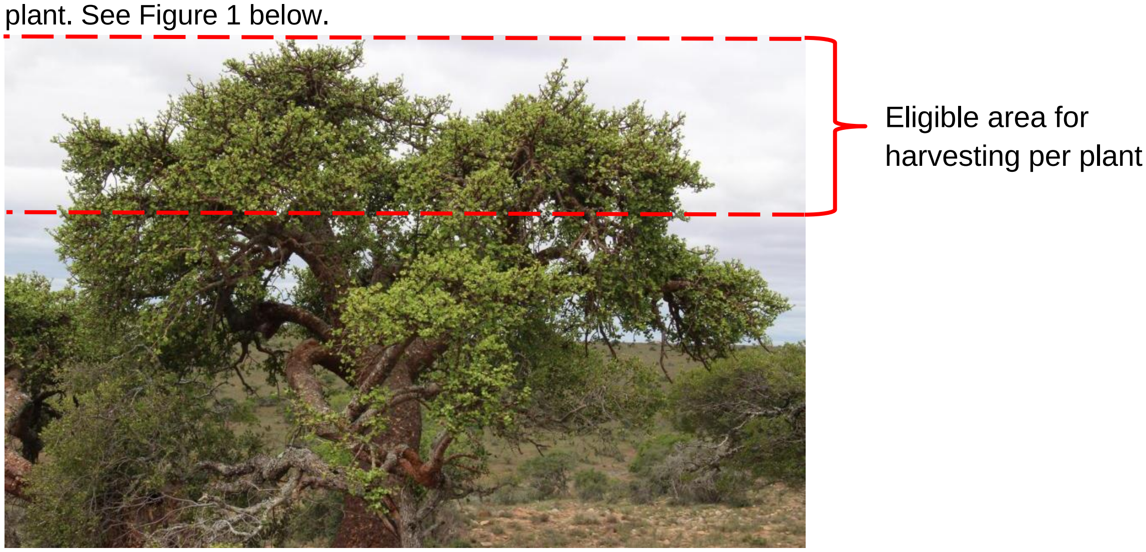


Figure 1: Spekboom Plant Harvesting protocol (Photo: ispotnature.org)

4. Record keeping

During the crediting period project proponents must record the following data related to harvesting, depending on the method used to establish the baseline of the DHA.

For both methods the boundary shapefile of the DHA shall be provided, as well as allocated areas for harvesting within the DHA (if the DHA is 1 ha or more in size).

If the UAV method for sampling the baseline of the DHA is used, the following is required:

- Images and point clouds of the sampled area within 30 days after harvesting has taken place, replicating the same procedure before harvesting.

If the manual measurement method is used:

- Timestamped photos of harvested plants before and after harvest with geographical coordinates.

The timestamped photo after harvesting, must be taken within 30 calendar days of the 'before' harvesting photo. The camera position and orientation must remain the same for both photos. In addition, the number of truncheons collected per plant must be recorded.

Where possible, procedures must be put in place to prevent a change in land-use within the DHA (e.g., introduction of livestock). If this is not possible the project proponent must prove that if the land-use change or the harvested area has been impacted beyond baseline levels, it is not due to project related activities such as additional harvesting or potential land-use changes induced by the project. The only exemption is if the land-use change will have direct benefits to the wild Spekboom population e.g., through the relocation of livestock from the DHA to pastureland that does not expose other wild Spekboom populations to consumption.

Appendix 4: Version Control

Version	Date	Comment
V1.0	11/10/2022	Initial version released
V1.1	23/05/2023	Included appendix to outline the steps projects must follow to ensure they don't degrade wild populations further when harvesting truncheons for planting.
V1.2	28/09/2023	• Fixed typo in equation 4 • Refinement of language in section 9.3.3 to provide clarity on Litter measurements