The Lake Victoria Watershed Agroforestry Carbon Project
Verified Carbon Standard (VCS) and
Carbon Stock Monitoring Plan

Trees for the Future (TREES)
Kisumu, Homa Bay and Migori in Western Kenya

Prepared by: Winrock International

September 2023

1 Introduction

Trees for the Future (TREES) has developed the Lake Victoria Watershed Agroforestry Carbon Project, which enables rural farmers to develop sustainable landscapes through targeted training and support. The project utilizes the VERRA methodology VM0042 for Agricultural Land Management to generate VCUs. The project is a grouped project with 3,800 individual farmers included in the first project instance (1,500 ha) and is located in Kisumu, Homa Bay and Migori counties in Western Kenya.

The aim of the project is to train and equip smallholder farmers with the skills and resources to transform the landscape into productive diverse agroforestry systems. Combining applications of ecological agriculture, agroforestry, and Indigenous farming practices, TREES implements the "Forest Garden Approach" including training modules and sustainable land management support. The project timeline is 40 years and is expected to bring exceptional climate, community, and biodiversity benefits to the region.

TREES is a 501c(3) providing direct agroforestry training and resources to farming communities in Africa. Through sustainable land practices, farmers participants are engaged in education about climate change and provided technical training and focused assistance. TREES utilizes the program TAROWORKs for its monitoring and reporting in order to streamline multiple sources of data on a regular basis with farmers who are geographically scattered around the region of the project area.

2 Description of the Monitoring Plan

The monitoring of the climate adaptation benefits under CCB requirements for the program is implemented through the collection and reporting of data that is obtained *once during each CCB monitoring period.* Community and Biodiversity components of the CCB monitoring are collected on an ongoing basis and are not included in this monitoring plan. This monitoring plan's scope is to provide details on the climate components of the monitoring requirements under the Lake Victoria Watershed Agroforestry Carbon Project. This monitoring plan meets the CCB X.X requirements, where climate mitigation and GHG quantification monitoring, as defined in the Lake Victoria Watershed Agroforestry Carbon Project Project Document (PD) and in each monitoring report under the Climate Section, is in accordance with the VCS 4.0 and methodology VM0042. The climate monitoring for the Lake Victoria Watershed Agroforestry Carbon Project is divided by carbon pools. VCS Climate monitoring is conducted once each monitoring period, through the collection of field data for biomass and soil carbon stock inventory.

The main objective of monitoring is to quantify stock change of soil organic carbon (SOC) and emissions and removals of CO_2, CH_4, and N_2O resulting from the project scenario during the verification period. TREES has detailed the procedures for collecting and reporting all data and parameters listed in the PD. Provided at each verification of the project, TREES will include in the monitoring report the results of the activity baseline and monitoring surveys, according to indicators identified in the PD, including record data on the biomass of existing woody perennials for the baseline and project scenarios, any other existing data related to the project area, and data required to carry out the Roth-C model for measuring soil organic carbon content.

Commented [FLK1]: *Describe the process and schedule for obtaining, recording, compiling and analyzing the monitored data and parameters set out in Section 3.3.2 (Data and Parameters Monitored) above. Include details on the following:*
The methods for measuring, recording, storing, aggregating, collating and reporting data and parameters. Where relevant, include the procedures for calibrating monitoring equipment.
The organizational structure, responsibilities and competencies of the personnel that will be carrying out monitoring activities.
The policies for oversight and accountability of monitoring activities.
The procedures for internal auditing and QA/QC.
The procedures for handling non-conformances with the validated monitoring plan.
Any sampling approaches used, including target precision levels, sample sizes, sample site locations, stratification, frequency of measurement and QA/QC procedures.
Where appropriate, include line diagrams to display the GHG data collection and management system.

Commented [FLK2R1]: Description of the Monitoring Plan
The main objective of monitoring is to quantify stock change of SOC and emissions ofCO_2, CH_4andN_2Oresulting from the project scenario during the verification period.
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:
- • 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 sampledparameters;
- • Baseline control site management plans, whereapplicable, including location, boundaries and demonstration of similarity criteria (see Table 7) for each baseline control site, with adequate detail to permit implementation of the annual schedule of activities for the linked sample unit(s);

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Commented [ED5R3]: At least in terms of permanence, the crediting period can be less. Need to double check with Brandy

Commented [FLK6]: Definition of the accounting boundary, spatially delineating any differences in the accounting boundaries and/or quantification approaches;

Commented [FLK7]: Need to check

This monitoring plan also provides guidance on organizational structure and monitoring responsibilities of the various implementing partners, data quality, management, and quality control quality assurance (QA/QC) procedures, data variables to be collected and the methods for collection, dissemination protocols, and adaptive management procedures. The Lake Victoria Watershed Agroforestry Carbon Project, and its implementing partners, will conduct the requirements of this monitoring plan. This will be conducted during the project crediting period. This is to guarantee that the changes in the soil carbon stocks, and biomass are measured and assessed of leakage and non-permeance are conducted on a regular basis.

3 Organizational Structure and Monitoring Responsibilities

There are three main actors for the VCS monitoring of the Lake Victoria Watershed Agroforestry Carbon Project.

1. TREES, which ensures that the management team facilitates subcontractors to conduct carbon stock, biomass, and soil organic carbon surveys once per verification and support the program through the verification, validation, and audit. TREES also follows the project workplan and theory of change for implementation of project activities and collaborates directly with the participating farmers and communities on gathering data and monitoring.
2. Participating Farmers, who engage with TREES staff and external consultants and provide inputs for biomass and soil organic carbon data, including meeting monitoring teams at farm locations to conduct monitoring procedures to be applied.
3. External Consultants are responsible for conducting biomass and soil organic carbon surveys with the guidance of the TREES team.

Through the articulation of these three groups, and the proper use of the monitoring mechanisms, the success and positive impact of the Lake Victoria Watershed Agroforestry Carbon Project can be evidenced and measured. Each actor will accomplish the roles described below.

3.1 TREES for the Future

- Attend and participate in biomass, soil organic carbon studies, and facilitate audit visits with the VCS
- Engage with participating farmers, communities, and external consultants for the monitoring of the program.
- Report any grievances on a timely basis.
- Prepare for validation and verification

3.2 Participating Farmers

- Provide support to TREES staff and external consultants on monitoring and reporting mechanisms
- Report any grievances on a timely basis to TREES through their FGRM
- Support TREES and external consultants through audit by meeting with audit teams as necessary

3.3 External Consultants

- Create and manage biomass and soil organic carbon inventory of carbon stocks according to VCS requirements.
- Engage with TREES staff and participating farmers to collect data related to biomass and soil organic carbon stocks according to VCS requirements.
- Support on validation and verification of the project.

Figure 1. GHG data collection and management system for the Lake Victoria Watershed Agroforestry Carbon Project.

4 Data Quality, Management, and QA/QC

The data quality will be maximized and ensured during all aspects of the monitoring process through quality assurance and quality control (QA/QC) procedures. To monitor the quality of field inventory data for biomass and soil, there are two rounds of QA/QC that must be conducted. First by the individual/institutions who are collecting the data and then by TREES. The QA/QC procedures include specific criteria to evaluate the quality of analytical data that has been gathered. The QA/QC procedures are therefore an absolute essential part of monitoring.

When data is being collected through either field measurements or surveys, consistent units are used to describe the input. For example, all areas are recorded in hectares, all dates are recorded in the same format (i.e., mm/dd/yyyy). In addition, field workers use caution when reporting quantitative data either as a total (kg) or as a total per unit area (kg/ha). Units for each variable are given in a supplemental spreadsheet and attached in Appendix 1 of the SOP for Carbon Stock.

Data is collected that is relevant to the sample unit of interest. In this project, farms that are measured in the baseline scenario may have a portion of their land set aside for future forest garden implementation, and ***all baseline data*** that was collected is relevant to only the portion of land that is implementing project activities rather than the entire farm area. When this is not the case, it was noted in the data collection form that the survey responses and measurements are relevant to the full farm area as opposed to the sub-section where forest garden activities are being implemented—this information was used during QA/QC of the baseline.

Field workers record all data on mobile data collection devices using the designed survey on the TaroWorks platform. Data collected is synchronized as often as possible (i.e., at the end of each field day) to store a backup of information. One member of the field crew records organized notes on handheld data collection documents or notepads and consolidates this information with the digitally collected data at the end of each field day. There are two forms of documentation, one in TaroWorks,

Commented [FLK8]: *The policies for oversight and accountability of monitoring activities.*
The procedures for internal auditing and QA/QC.
Any sampling approaches used, including target precision levels, sample sizes, sample site locations, stratification, frequency of measurement and QA/QC procedures.
- • Quality assurance and quality control (QA/QC) procedures to ensure accurate data collection; 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, including QA/QC data, must be archived electronically, and kept for at least two years after the end of the last project crediting period;

Commented [ED9]: Really good point.

Commented [ED10R9]: The precise sample size/design hasn't been developed because the number of farms dor the next enrollment is in flux. It will be a stratified simple random plan for monitoring, and, depending on how many farms are enrolled and other details, additional sampling may be required for updating the baseline and a hand-written document to serve as backup. All data, electronic and hand-recorded, is downloaded and stored properly for future verification events.

The field crew leader is responsible for checking and verifying all measurement work. The following procedures are followed *before* the field crew leaves the farm.

- The field crew leader makes sure *every* mandatory line in the data form is filled out. This is the field crew leader's responsibility, and each datasheet is completed. Any missing data point or points is documented.
- When the datasheets are complete, the field crew leader double checks the Forest Garden ID, GPS coordinates, tree DBH and tree species for obvious outliers.
- Photo attachments are verified and determined not blurry, and the coordinates are legible and recorded in the correct format (i.e., lat/lon, decimal degrees, etc.).
- Before moving to the next farm or plot, the field crew leader ensures that all data collection forms have accurately recorded the Forest Garden/Farm ID and the date/time of sampling.
- To verify that the measurement/survey is complete, the field crew leader signs their name in the Data Review Box on the coversheet.
- To verify that the measurement/survey is accurate and representative of farmer practices, the farmer must sign their name on an attestation form.

The QA/QC procedures for biomass and soil carbon stock monitoring are provided in detail in the SOP for carbon including details on data entry checks, data storage and archiving and best practices for recording field data.

5 Climate Monitoring

This monitoring plan has been developed to ensure that the project requirements are met and the changes in biomass and soil carbon stocks are measured, recorded, and assessed for any potential issues of non-permanence or leakage. This monitoring plan (and related annexes, including the SOP for Carbon) includes information on the data and parameters to be measured during validation and verification, the methods for measuring, recording, storing, and reporting on data and parameters. Following the implementation of the monitoring plan, an independent, third-party validation/verification body, selected by TREES and approved by Verra, will validate the project, and determine that the project complies with the VCS Program rules and the selected methodology, and verify the emissions reductions generated and reporting. While the project will be required to be verified every 5 years at least, VCUs will only be issued based on the results of verification events. Therefore, the project will weigh the costs of verification events with the frequency with which they want VCUs to be issued.

As indicated in the VM0042 v2.0 methodology, TREES has utilized the "General Guidelines for Sampling and Surveys for Small-Scale CDM Project Activities" as a reference when establishing sampling and survey approaches. The most current version of this guideline (Ver04.0 CDM-EB67-A06-GUID[1] is the

Commented [FLK11]: *The methods for measuring, recording, storing, aggregating, collating, and reporting data and parameters. Where relevant, include the procedures for calibrating monitoring equipment.* Modeling plan, where Quantification Approach 1 is applied. The project modeling plan must describe the model(s) selected, describe the datasets that will be used for model validation and calibration, including their sources, and specify the baseline schedule of ALM activities for each sample unit (fixed exante).

Parameters to be measured, including any parameters required for the selected model (additional to those specified in this methodology); ring task to be undertaken, and the technical requirements therein;
Data to be collected and data collection techniques and sample designs for directly sampled parameters;
Baseline control site management plans, where applicable, including location, boundaries, and demonstration of similarity criteria (see Table 7) for each baseline control site, with adequate detail to permit implementation of the annual schedule of activities for the linked sample unit(s);
Ten-year baseline re-evaluation plan, detailing source of regional (sub-national) agricultural production data and procedures to revise the baseline schedule of activities;

Commented [FLK12]: Can this be confirmed?

[1] Available at https://cdm.unfccc.int/Reference/Guidclarif/index.html

same for small and large projects and provides guidance on different sampling approaches that the project will implement.

TREES has conducted activity baseline and monitoring surveys to establish a baseline and will implement these same surveys during the project during each verification event. Data will be collected for each of the sources of emissions or removals. TREES conducts biomass and soil measurement activities at randomly sampled farms within the project area. Baseline biomass and soil measurements occurred in Spring 2023 and will be conducted again in 2024 . TREES will lead the monitoring and verification of the project, following the SOP for Carbon Stock Measurement, provided as an annex to this monitoring plan. The sections below describe the different data that needs to be collected for each source and when these data need to be collected.

Commented [FLK13]: How often does TREES plan on holding verification?

Commented [FLK14R13]: It would be good to provide that timeframe here.

[provide a description of here of TAROWORKs and how it supports the monitoring of the project]

5.1 Data Collection at Each Verification

Data collection for the carbon monitoring plan will occur once every verification. If the verification schedule is set for every two years, the process of collecting ecological data will occur every two years. If the VCU delivery schedule and verification schedule change throughout the lifetime of the project, this data will be collected anew at each verification event. Data collection will be collected through a series of biomass surveys and soil organic carbon sampling. Data collection procedures are initially conducted through an external third party, but in order to build capacity within the program, it may eventually be conducted more locally by TREES staff after training and engagement. The Lake Victoria Watershed Agroforestry Carbon Project is designed with specific Standard Operating Procedures (SOP) in place for the biomass and soil sampling surveys to maintain consistency in data collection and monitoring to determine overall impacts of program activities. These surveys help TREES determine if the program outcomes have been achieved in the program implementation timeline and prove to the Validation and Verification Body (VVB) that the program meets all VCS and CCB requirements.

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5.2 Carbon Stock Inventories

The purpose of carbon inventories is to generate the necessary data to measure the quantity of carbon sequestered within the Project Area. The carbon inventories take place in accordance with guidelines established in the Standard Operating Procedure, and the findings contribute to both the climate impact monitoring and biodiversity impact monitoring for the Lake Victoria Watershed Agroforestry Carbon Project. The activities related to biomass inventories do not fall under the responsibility of the management plan and are not fully identified in this document. This is covered in Annex 1: Standard Operating Procedure for Carbon. TREES staff attend training on biomass inventories as well as assist external consultants conducting the assessment. Participating farmers are encouraged to learn new forest inventory and biomass assessment skills so that they may engage themselves in supporting monitoring of the program. The monitoring component is addressing the climate needs of the Lake Victoria Watershed Agroforestry Carbon Project.

Commented [ED16]: Transect sampling will be added to this doc.

The SOP for Carbon Monitoring (included with this monitoring plan as an Annex), describes the methods for measuring, recording, storing, aggregating, and reporting on the data and parameters set forth in the PD. The procedures utilized in establishing the baseline and conducting future monitoring are described in the SOP for Carbon Monitoring. This procedure also includes details on field safety, roles and responsibilities of field crews, specific carbon pools and sampling plans utilized. The SOP covers the procedures for measuring and documenting carbon in soil, trees and shrubs, nitrogen fixing species, and crop residues and yields.

5.2.1 Sampling Design

As given in VM0042 v 2.0, a stratified random sampling design will need to be conducted using area weighted approaches from the CDM guidelines as was used for baseline sampling. The precise number, and placement of plots will be determined based on field conditions and the spatial distribution of the project related tree and shrub biomass. As in the baseline, point sampling can be used for scattered individual stems or stands of trees < 20 m in diameter, and plot sampling for stands of trees > 20 m in diameter. Transect sampling must be used for tree alley crops or other activities where trees are planted in purposeful, linear distributions (e.g. tree alleys).[2] Given a 40 year time horizon for project activities, coarse woody debris may accumulate. If coarse woody debris from trees accumulates within forested sections of project activities, line intersect sampling should be used to asses fallen trees[3] (if this occurs), alternatively, farmers may use fallen trees for fuel wood, or trees may be chipped and added to compost.

Commented [ED17]: Verify with TREES

5.2.2 Measuring Soil Carbon

The mass of soil carbon is estimated using soil cores to determine the carbon content and bulk density at 0-15cm depth and 15-30cm depths. Soil carbon is modeled using the Roth-C model, compiling significant data at the start of the project and at each verification event. Table 1 provides the data and variables utilized in the Roth-C model. The data included in Table 1 includes all the data required to be collected to measure the baseline and project GHG emissions and removals from soil, which has been modified from Table XX in the VM0042 methodology. A detailed description of the measuring soil carbon is provided in Annex 1 SOP for Carbon. Data will need to be collected every 5 years for model true-up; e.g. to re-estimate model prediction error and recalibrate the model.

Commented [FLK18]: Need to check this

Table 1. Data required to run Roth-C

Commented [FLK19]: Ethan, do you want to update this table to reflect the Roth-C model?

Data/ parameter	Unit	Description	Recording frequency	Source
$BA_{C,Mc,t=0}$	Ha	Baseline areas in cropland with management practice, m_c	Project start	Measurements/surveys as part of baseline
PA_{FG}	Ha	Forest Garden project area	Every verification event	Measurements/surveys as part of baseline

[2] (17) (PDF) Measuring & Monitoring Plant Populations (researchgate.net)
[3] TR03 all.p65 (uidaho.edu)

Data/ parameter	Unit	Description	Recording frequency	Source
$SOC_{C,MC,t=0}$	tC/ha	Soil organic carbon density, to a depth of 30 cm, at equilibrium for cropland with management practice, m_c, based on measurements of bulk density and %C	Project start	Measurements/surveys as part of baseline and verification
$SC_{C,MC}$		Monthly soil cover (bare or vegetated) for cropland with management practice, m_c	Project start and at every verification event	Measurements/surveys as part of baseline
$\overline{Temp}_m$	°C	Average temperature per month	Project start	Data relevant to the project area
$\overline{Prec}_m$	mm	Average precipitation per month	Project start	Data relevant to the project area
$\overline{Evap}_m$	mm/day	Average evapotranspiration per month	Project start	Data relevant to the project area

Data/ parameter	Unit	Description	Recording frequency	Source
CCC,NC	%	Clay content of the soil	Project start	Data relevant to the project area
DPM/RPM	%	Estimate of the decomposability of the incoming plant material (Decomposable Plant Material/Resistant Plant Material)	Project start for baseline and project	Data relevant to the project area (if project-specific data is not available), Roth-C can provide default values that can be used)
PRIC,MC,t=0	Tonnes of carbon ha-1	Monthly input of plant residues	Project start and at every ABMS event[4]	Measurements/surveys as part of baseline and verification

[4] Amount of crop residues does not need to be measured directly. It can also be estimated from the crop production using equations listed in Table 11.2 in Volume 4 of the 2006 IPCC Guidelines.

Data/ parameter	Unit	Description	Recording frequency	Source
MIC,MC,t=0	Tonnes of carbon ha-1	Monthly input of farmyard manure	Project start and at every ABMS event	Measurements/surveys as part of baseline and verification

Measurements in the field follow the same coring method used in the baseline SOP. Soil from cores must not contain particles greater than 2mm in diameter (gravel, stones, and rocks), all other field sampling procedures will follow the same protocol used in the baseline. Baseline laboratory procedures used Standard Operating Procedures of the Soil-Plant Spectral Diagnostics Laboratory of World Agroforestry Centre (ICRAF) this must be repeated during monitoring using the same lab to reduce error.

Soil carbon estimates using Roth-C used baseline measurements from composite soil samples that were randomly distributed across the Forest Garden polygon. Winrock recommends separate soil sampling for each project activity as this will give the most robust results. However, this may not be possible given soil sampling costs. During monitoring events, pre-testing of soil carbon across strata using an ANOVA analysis will determine if there is a statistically significant difference across project activities using a confidence interval of 95% and a margin of error of 10%. If there is no difference between strata, then as in the baseline, randomly distributed points across the entire project polygon can be used for sampling. Strata which do show statistically significant differences should be sampled separately, and suggested strata from this monitoring plan will be updated accordingly. Randomly distributed points will be determined for each of project activities grouped into the following suggested strata (pending statistical ANOVA verification):

Commented [ED20]: If we have better OM additions, specific to project activities, we can use RothC to identify suggested strata, as is, without project activity specific OM additions, we can't use the model to inform stratification. Getting accurate, stratum specific OM additions would be difficult, that is why I am shifting to recommending pre-sampling using actual stocks.

Commented [ED21R20]: SOC accumulates slowly, there is a good chance there will be no difference at first, this can be demonstrated using ANOVA and will save sampling costs. Then overtime, at each monitoring event, as SOC accumulation differentiates across activities, the monitoring plan can be adjusted accordingly.

Table X

Commented [ED22]: Update or drop as RothC and project develops.

Carbon Components of FG	Combined Area sq m (model)	Est of Area (1HA)	Till/no till	Removals OR additions/cover	OM Additions (Kg/m2)	Combined Area (sq m)
Staple crop alleys	1500-2000 m2 (-400 for tree/grass alleys)	1,600	**annual till, cover crop**	Cultivated in rainy season; Cover crop during dry season	0.15	**1,600**
Hedgerows	410m (l) x 2m (w) = 820m2	820	**no till, composting, mulching, manure**	Addition of mulch from hedgerows/alleys, compost, manure; limited shade	0.46	**7,620**
	10 rows x 80m (l) x .5 m (w) = 800m2	400				
Permagardens	Family: 100-200 m2 Market: 500-1000 m2	1,200				
Fodder Plot	600-1000m2 (on 50% of FGs)	1,000				
Fruit Trees	small: 300-600 m2 large: 1000-1600m2	2,200				
Timber Plot	1500-2000 m2	2000				
Non cultivated	Est 980 for homestead, workspace, compost, corral, walkways, etc	780	NA	NA	NA	780

5.2.3 Measuring Trees and Shrubs

5.2.3.1 Criteria for measuring existing trees and shrubs

According to the CDM guidelines referenced by VM0042, ex-ante (baseline) and ex-post (monitoring) woody biomass carbon stocks can be assumed to be zero if **all** the following conditions are met:

1. "The pre-project trees are neither harvested, nor cleared, nor removed throughout the crediting period of the project activity (e.g., the existing trees on the baseline farms will not be removed during implementation of Forest Garden project activities).
2. The pre-project trees do not suffer mortality because of competition from trees planted in the project, or damage because of implementation of the project activity, at any time during the crediting period of the project activity.
3. The pre-project trees are not inventoried along with the project trees in monitoring of carbon stocks, but their continued existence is monitored throughout the crediting period of the project activity."

If the above three criteria are met, then the location of biomass must be photographed and recorded to ensure that trees are not inventoried during monitoring. Additionally, the farmer must sign an attestation form that they will not clear or kill any trees present before project activities were implemented.

Trees or shrubs that were killed or cleared for sample unit *i* in year *t* were calculated using the *CDM A/R tools Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities.* TREES, as part of the start of the project, recorded data on biomass of existing woody perennials (trees and bushes) for the baseline scenario and will continue to utilize Annex 1: SOP for Carbon Stock to measure in the project scenario for verification and monitoring.

For newly planted trees from project activities that will monitored during verification events, tree carbon stocks are estimated using measurements of tree height and diameter at breast height (DBH). Height and diameter measurements will be used in allometric equations to estimate the increase in carbon stock in trees if they have undergone pruning. s. Importantly, because there is pruning of newly planted trees in hedgerows, fruit orchards, and other portions of forest garden activities, such that trees will be maintained at breast height or otherwise shortened for fuel wood, green fertilizers, or harvesting of fruit, the allometric equations based that only used DBH will have to replaced with new equations that use height and DBH to estimate biomass stocks.[5] The specific equations and procedures will need to be developed as part of verification standard operating procedures and field measurement instructions. Allometric equations from the baseline can be used if trees are managed to grow without height restrictions. Shrub biomass estimates will use the same ocular based procedures as was used in the baseline.

$$\Delta C_{TREE} = C_{TREE,t_2} - C_{TREE,t_1}$$

$$u_{\Delta C} = \frac{\sqrt{(u_1 \times C_{TREE,t_1})^2 + (u_2 \times C_{TREE,t_2})^2}}{|\Delta C_{TREE}|}$$

Equation 1. Estimating change in carbon stock in trees between two points in time: Difference of two independent stock estimations

Commented [FLK23]: Not sure if these are the equations we want to highlight here exactly

$$\Delta C_{SHRUB} = C_{SHRUB,t_2} - C_{SHRUB,t_1}$$

Equation 2. Estimating change in carbon stock in shrubs between two points in time

Where:

Data/ parameter	Unit	Description	Recording frequency	Source
ΔC_TREE	t CO2e/ha	Change in carbon stock in trees during the period between two points of time t1 and t2	Each monitoring event	Determined in the project area

[5] Methods of Estimating Forest Biomass: A Review | IntechOpen

Data/ parameter	Unit	Description	Recording frequency	Source
C_TREE,t1	t CO2e/ha	Carbon stock in trees as estimated at time t1; t CO2e (at first verification event, equal to carbon stock in pre-project tree biomass	Each monitoring event	Determined in project area
ΔC_SHRUB	t CO2e/ha	Change in carbon stock in shrub biomass during the period between times t1 and t2	Each monitoring event	Determined in project area
C_SHRUB,t1	t CO2e/ha	Carbon Stock in shrub biomass at time t1	Each monitoring event	Determined in the project area

The monitoring of trees and shrubs and the changes in woody biomass on the farm garden plots will be measured at each verification event and analyzed against the results from the previous monitoring period, and the baseline. The results are recorded according to the size of the area (<>20 m diameter area) and whether or not the field containing shrubs, individual trees, stands of trees, or hedgerows and living fences has biomass that will be killed or cleared as a result of project activities.

With exceptions of biomass data for trees and shrubs, and soil carbon, all other data comes from the farmer surveys.

5.2.4 Measuring Nitrogen Fixing Species and Use of Crop Residues and Crop Yields

5.2.4.1 Nitrous oxide emissions from N-fixing species

Table 2 includes the data the project will collect as part of its monitoring plan in order to estimate N20 emissions from N-fixing species and crop residues in the baseline and project scenario. tThese data were collected at baseline and utilized throughout the project timeline.

$$N2O\_Nfix_{bsl,i,t} = (F_{CR,bsl,i,t} \times EF_{Ndirect} \times \frac{44}{28} \times GWP_{N2O})/A_i$$

Equation 3. Nitrous oxide emissions due to use of N-fixing species

$$F_{CR,bsl,i,t} = \sum_{g=1}^{G} MB_{g,bsl,i,t} \times N_{content,g}$$

Equation 4. Amount of N in N-fixing species (aboveground and belowground biomass returned to soils in the baseline and project scenario for sample unit i in year t; t N

Where:

Data/ parameter	Unit	Description	Recording frequency	Source
N20Nfix_bsl,i,t	tCO2e/ha	Nitrous oxide emissions due to use of N-fixing species in baseline scenario for sample unit I in year t; t CO2e/unit area	Each monitoring event	Measurements/surveys as part of baseline and verification
F_CR,bsl,i,t	t N	Amount of N in N-fixing species (above and belowground) returned to soils in the baseline scenario for sample unit i in year t	Each monitoring event	Measurements/surveys as part of baseline and verification
EF_Ndirect	t N20-N/t N applied	Emission Factor for nitrous oxide emissions from N additions from synthetic fertilizers, organic amendments, and crop residues	Each monitoring event	2019 IPCC Vol 4, Ch 11, Table 11.1
GWP_N20	GWP	Global warming potential for N20	Each monitoring event	IPCC 4th assessment report
A_i	Unit area ha	Area of sample unit i	Project start	Measurements/surveys as part of baseline and verification
i	Forest Garden ID	Sample unit	Project start	Measurements/surveys as part of baseline and verification

Data/ parameter	Unit	Description	Recording frequency	Source
F_CR,bsl,i,t	t N	Amount of N in N-fixing species (above and belowground) returned to soils in	Project start and at each monitoring event	Measurements/surveys as part of baseline and verification

		the baseline scenario for sample unit i in year t		
MB_g,bsl,i,t	t dm	Annual dry matter, including aboveground and belowground, of N-fixing species g returned to soils for sample unit i in year t	Project start and at each monitoring event	Measurements/surveys as part of baseline and verification
N_content,g	t N/t dm	Fraction of N in dry matter for N-fixing species g	Project start and at each monitoring event	Measurements/surveys as part of baseline and verification
g	type of nitrogen fixing species	Type of N-Fixing species	Project start and at each monitoring event	Project start and at each monitoring event

5.2.4.2 Nitrous oxide emissions from manure deposition (indirect and direct)

Table 3 includes the data the project will collect as part of its monitoring plan in order to estimate N20 emissions from nitrogenous synthetic fertilizer application. The equations used to determine nitrous oxide emissions from manure deposition (indirect and direct) are provided below.

$$N2Omd_{bsl,i,t} = N2Omd_{bsl,direct,i,t} + N2Omd_{bsl,indirect,i,t}$$

Equation 5, Nitrous oxide emissions from manure deposition (indirect and direct)

$$N2Omd_{bsl,direct,i,t} = (\sum_{l=1}^{L} F_{bsl,manure,l,i,t} \times EF_{N2O,md,l} \times 44/28 \times GWP_{N2O})/A_i$$

Equation 6. Direct Nitrous oxide emissions from manure deposition

$$N2Omd_{bsl,indirect,i,t} = (N2O_m d_{bsl,volat,i,t} + N2O_m d_{bsl,leach,i,t})/A_i$$

Equation 7. Indirect Nitrous oxide emissions from manure deposition

Where:

Data/ parameter	Unit	Description	Recording frequency	Source
N20md_bsl,i,t	tCO2e/ ha	Nitrous oxide emissions due to manure deposition in baseline scenario for sample unit I in year t	Project start	Measurements/surveys as part of baseline and verification
N20md_bsl,direct,i,t	tCO2e/ ha	Direct nitrous oxide emissions due to manure deposition in the baseline scenario for sample unit i in year t; t CO2e/unit area	Project start	Measurements/surveys as part of baseline and verification
N20md_bsl,indirect,i,t	tonne-N_2O-N (tonne-N input)$^{-1}$	Indirect nitrous oxide emissions due to manure deposition in the baseline scenario for sample unit i in year t; t CO2e/unit area	Project start	Measurements/surveys as part of baseline and verification

And

Data/ parameter	Unit	Description	Recording frequency	Source
F_bsl,manure,l,i,t	t N	Amount of nitrogen in manure and urine deposited on soils by livestock type l in sample unit i in year t	Project start	Measurements/surveys as part of baseline and verification
EF_N20,md,l	kg N20-N/kg N input	Emission factor for nitrous oxide from manure and urine deposited on soils by livestock type l	Project start	2019 IPCC Vol 4, Ch 11, Table 11.1
GWP_N20	GWP	Global warming potential for N20	Project start	IPCC 4th assessment report
A_i	ha	Area of sample unit i, unit area	Project start	Measurements/surveys as part of baseline and verification

i	Forest Garden ID	Sample unit	Project start	Measurements/surveys as part of baseline and verification
l	Type of livestock	Type of livestock	Project start	Measurements/surveys as part of baseline and verification

And

Data/ parameter	Unit	Description	Recording frequency	Source
N20mD_bsl,volat,i,t	t CO2e	Indirect nitrous oxide emissions produced from atmospheric deposition of N volatized due to manure deposition for sample unit I in year t	Project start	Measurements/surveys as part of baseline and verification
N20mD_bsl,leach,i,t	t CO2e	Indirect nitrous oxide emissions produced from leaching and runoff of N, in regions where leaching and runoff occurs, due to manure deposition for sample unit i in year t; tCO2e. Equal to 0 where annual precip is less than potential evapotranspiration, unless irrigation is employed	Project start	Measurements/surveys as part of baseline and verification
A_i	ha	Area of sample unit I, unit area	Project start	Measurements/surveys as part of baseline and verification
i	Forest Garden ID	Sample unit	Project start	Measurements/surveys as part of baseline and verification

5.2.4.3 Non-CO_2 emissions from biomass burning

Table 4 includes the data the project will need to compile as part of its monitoring plan in order to estimate CH_4 and N_2O emission due to biomass burning.

$$N2Obb_{bsl,i,t} = \left(\frac{GWP_{N2O} \times \sum_{c=1}^{C} MB_{bsl,c,i,t} \times CF_c \times EF_{c,N2O}}{10^6}\right)/A_i$$

Equation 8. Nitrous oxide emissions from biomass burning

$$CH4bb_{bsl,i,t} = \left(\frac{GWP_{CH4} * \sum_{c=1}^{C} MB_{bsl,c,i,t} * CF_c * EF_{c,CH4}}{10^6}\right)/A_i$$

Equation 9. Methane emissions from biomass burning

Where:

Data/ parameter	Unit	Description	Recording frequency	Source
N20bb_bsl,i,t	tCO2e/ha	Nitrous oxide emissions in the baseline scenario from biomass burning for sample unit i in year t	Project start and each verification	Measurements/surveys as part of baseline and verification
MB_bsl,c,i,t	kg	Mass of agricultural residues of type c burned in baseline scenario for sample unit I in year t	Project start and each verification	IPCC
CF_c	dimensionless	Combustion factor for ag residue type c; proportion of pre-fire fuel biomass consumed	Project start and each verification	2019 IPCC Vol 4, Ch 2, Table 2.6
EF_c,N20	g N20/kg d.m. burnt	Nitrous oxide emission factor for the burning of ag residue type c	Project start and each verification	2019 IPCC Vol 4, Ch 2, Table 2.5

Data/ parameter	Unit	Description	Recording frequency	Source
c	Type of agricultural reside	Type of agricultural reside	Project start and each verification	Measurements/surveys as part of baseline and verification

And

Data/ parameter	Unit	Description	Recording frequency	Source
CH4_bb_bsl,i,t	tCO2e/ha	Methane emissions in baseline scenario from burning biomass for sample unit I in year t	Project start and each verification	Measurements/surveys as part of baseline and verification
MB_bsl,c,i,t	kg	Mass of agricultural residues of type c burned in baseline scenario for sample unit I in year t	Project start and each verification	IPCC
CF_c	dimensionless	Combustion factor for ag residue type c; proportion of pre-fire fuel biomass consumed	Project start and each verification	2019 IPCC Vol 4, Ch 2, Table 2.6
EF_c,CH4	gCH4/kg d.m. burnt	Methane emission factor for the burning of ag residue type c	Project start and each verification	2019 IPCC Vol 4 Ch 2, Table 2.5
c	Type of agricultural reside	Type of agricultural reside	Project start and each verification	Measurements/surveys as part of baseline and verification

5.2.4.4 Emissions from the use of fossil fuels in agricultural management

Table 5 includes the data the project will need to compile as part of its monitoring plan in order to estimate CO_2 emissions from the burning of fossil fuels.

$$CO2ff_{bsl,i,t} = (\sum_{j=1}^{J} EFF_{bsl,j,i,t})/A_i$$

Equation 10. Carbon Dioxide emissions from fossil fuel combustion

$$EFF_{bsl,j,i,t} = FFC_{bsl,j,i,t} \times EF_{CO2,j}$$

Equation 11. Carbon dioxide emissions from fossil fuel combustion in baseline scenario in vehicle, equipment type j for sample unit i in year t; tCO2e

Where:

Table 5. Data requirements to estimate emissions from fossil fuel

Data/ parameter	Unit	Description	Recording frequency	Source
CO2_ff_bsl,i,t	tCO2e/ha	CO2 emissions from fossil fuel combustion in the baseline scenario for sample unit i in year t	Project start and each verification	Measurements/surveys as part of baseline and verification
EFF_bsl,j,i,t	tCO2e	CO2 emissions from fossil fuel combustion in the baseline scenario in fossil fuel vehicle/equipment type j for sample unit I in year t	Project start and each verification	Measurements/surveys as part of baseline and verification
A_i	ha	Area of sample unit I, unit area	Project start and each verification	Measurements/surveys as part of baseline and verification
j	n/a	Type of fossil fuel (gas or diesel)	Project start and each verification	Measurements/surveys as part of baseline and verification

And

Data/ parameter	Unit	Description	Recording frequency	Source
FFC_bsl,j,i,t	liters	Consumption of fossil fuel type j for sample unit I in year t	Project start and each verification	Measurements/surveys as part of baseline and verification
EF_CO2,j	tCO2e/liter	Emission factor for the type of fossil fuel j combusted	Project start and each verification	Measurements/surveys as part of baseline and verification

5.3 Disseminating Results

The results from monitoring plan implementation will be disseminated to the participating farmers and communities through field site visits during ongoing technical support and monitoring. The Lake Victoria Watershed Agroforestry Carbon project will produce an annual monitoring results summary report that is also disseminated to participating farmers and communities through the same process. The monitoring results summary report will include climate and carbon stock monitoring in the local language and will be available in softcopy and hard copy for review. Lastly, the monitoring report and local language summary will be disseminated to project partners through the VCS/CCB website, https://verry.org/.

6 Adaptive Management

Adaptive management is necessary in any ALM project where activities need to consider a changing set of climate dynamics. Ecological and community needs will shift over the project timeline. TREES staff, participating farmers and their communities are best situated to address changes in monitoring as needed throughout the project implementation. The project activities will be adjusted at some point in the project timeline as well as the program evolves, thus changing which indicators and outcomes are monitored. As the Lake Victoria Watershed Agroforestry Carbon Project continues, participating farmers and the needs of their communities may also shift. During the lifetime of the Project, participating farmers and communities will aid in project design through four main avenues.

Table 1. Adaptive Management Feedback Channels

Feedback Channel	Details	Timing
1. General meetings	General meetings are encouraged to provide a safe space for participating farmers and communities to express concerns over Program Activities or details	Biannually

Commented [FLK24]: TREES will need to confirm that meeting like this occur, and if not, what mechanisms are used for this purpose as outlined in the VCS requirements.

2.	**Direct employment through Program Activities**	Employees hired for monitoring and implementation of Program Activities are provided opportunities to give feedback in trainings and day to day	Ongoing
3.	**The Feedback, Grievance and Redress Mechanism (FGRM)**	The FGRM is active and the Lake Victoria Watershed Agroforestry Carbon Program will follow procedures put in place	Ongoing
4.	**PRAs that occur at each verification**	Communities will be asked during the Participatory Rural Appraisal (PRA) to identify new and effective project activities overtime and describe the risk of implementation of each project activity. Risks are considered during implementation.	Once per verification

Commented [FLK25]: The PD will require the FGRM to be active. Need to confirm with TREES

These feedback channels will continue throughout the Lake Victoria Watershed Agroforestry Carbon Project lifetime and associated program activities will be updated at every verification based on feedback provided. This process involves annual reviews of the project workplan with the core stakeholder groups, including management teams, as applicable, and external consultants. The related program activities are reviewed alongside the monitoring data parameters that is collected on an ongoing basis at each verification. The data that is collected under this VCS Carbon Monitoring Plan provides the information needed to implement adaptive management for the Lake Victoria Watershed Agroforestry Carbon Project.

7 Annexes

7.1 Annex 1 – Standard Operations Procedures for the TREES Lake Victoria Watershed Agroforestry Carbon Project - Agricultural Carbon Stocks Measurements

Please see attachments.

7.2 Annex 2 – Standard Operations Procedures for TREES Forest Garden Carbon Project - Agricultural Carbon Stocks Measurements Quick Reference Guide

<u>Forest Garden Standard Operating Procedure Quick Reference Guide</u>

Step 1: Obtain all equipment from the **equipment checklist**

Step 2: Identify the **Forest Garden Boundary** with the farmer, ask the farmer about trees/shrubs that will be cleared due to forest garden implementation

Step 3: Complete the **Farmer Survey** using manual notes and tables

Step 3: Complete the **Soil Sampling** procedures

Step 4: Complete the **Tree & Shrub Inventory & Measurement** procedures

Step 5: (optional) Sketch the Forest Garden (last page)

Step 5: Enter the data manually recorded from the farmer survey into TaroWorks. Perform field-based QA/QC and review data. Ensure that all GPS points, pictures, and additional notes have been recorded.

Equipment Checklist

First aid kit	
Appropriate clothing (boots, long sleeves and pants, rain gear, gloves)	
Radio / Mobile Cell Phone	
Fire extinguisher (within the car)	
Water bottle (re-usable)	
Umbrella	
Waterproof field bag	
TaroWorks mobile collection device	
Data collection tables/forms/notepad	
Clipboard	
Smartphone	
Backup battery charger	
Compass	
Measuring Tapes (100m)	
Tree DBH/Circumference tape	
1.3 m poles	
Chalk stick/tree tag labels	
Soil corer (to min 30cm depth)	
Soil containers and labels (from KEFRI)	
Bucket and tarp for quartering soils	
Non-breakable rod	
Permanent Marker	
A garden hoe (jembe) or machete (panga)	

Soil Sampling Procedure

Organic carbon samples (3):

- Navigate to GPS sample point location
- Record GPS location of actual sampling point if you must relocate
- Remove all vegetation and litter from surface
- Insert soil corer to 30cm depth
- Place soil sample into composite bucket
- Thoroughly mix samples together and avoid contamination with grease or other organic materials
- Place soil onto tarp and use quartering technique to mix samples.

- Place composite core into container and label with:
  - Farm/Forest Garden ID
  - Date
  - "Organic Carbon"

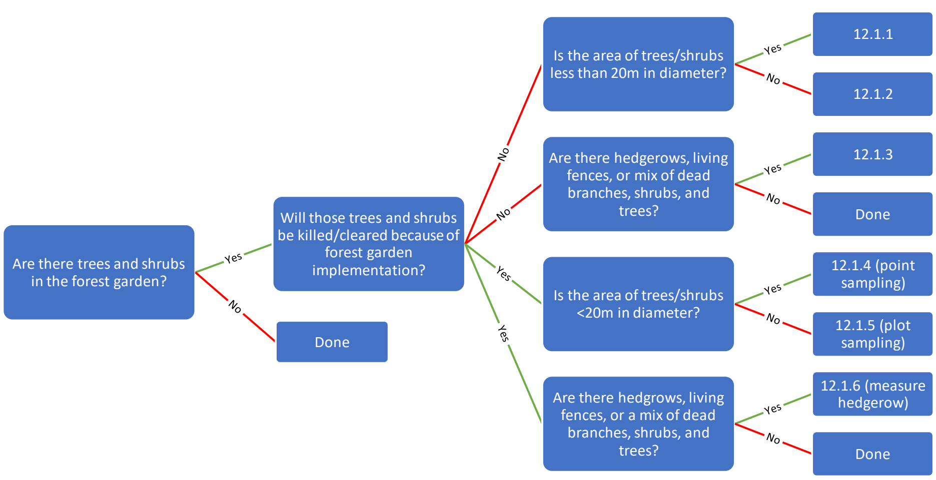
Bulk density sample (1):

- Navigate to GPS sample point location
- Record GPS location of actual sampling point if you must relocate
- Remove all vegetation and litter from surface
- Insert soil corer to 30cm depth
- Keep sample core as intact as possible – prevent the loss of soil when removing from core
- Place into container and label with:
  - Farm/Forest Garden ID
  - Date
  - Depth sampled (if different than 30cm)
  - "Bulk Density"

Tree / Shrub Sampling Procedure

Commented [DE26]: Need to update diagram with transect sampling, and make specific to project activities.

Follow the decision tree diagram below:



7.2.1 Fields containing shrubs, individual trees, or stands of trees that cover < 20 m diameter area that are not killed or cleared by project activities

- Record Lat/Long of each living tree >5cm DBH (15.5cm circumference)

- Record the total number of living trees >5cm DBH (15.5cm circumference)
- Take picture of each living tree >5cm DBH (15.5cm circumference) (or take picture of group of trees)
- Estimated % shrub crown cover in area where individual trees have been recorded

7.2.2 Stands of trees that cover > 20 m diameter area that are not killed or cleared by project activities

- Create polygon around forested stand of trees (take lat/long of corners/vertices)
- Take picture of forested stand
- Record the number and lat/long of stumps >5cm DBH (15.5cm circumference) within forested stand
- Estimate % shrub crown cover within forested stand

7.2.3 Hedgerows; living fences; or a mix of dead branches, live shrubs, and trees; that are not killed or cleared by project activities

- Record the Lat/Long of each living tree >5cm DBH (15.5cm circumference) within hedgerow/living fence
- Record the total number of living trees >5cm DBH (15.5cm circumference) within the hedgerow/living fence
- Take picture of each living tree >5cm DBH (15.5cm circumference) within hedgerow/living fence
- Estimate % shrub crown cover within the hedgerow

7.2.4 Fields containing individual trees or stands of trees that cover < 20 m diameter area that are killed or cleared by project activities (point sampling)

- Record the Lat/Long of each living tree >5cm DBH (15.5cm circumference)
- Record the total number of living trees >5cm DBH (15.5cm circumference)
- For trees >5cm DBH (15.5cm circumference), identify tree species or indicate unknown
- For trees >5cm DBH (15.5cm circumference), estimate DBH and mark with chalk/flagging tape
- Estimate % shrub crown cover

7.2.5 Stands of trees that cover > 20 m diameter area that are killed or cleared by project activities (plot sampling)

- Create polygon around forested stand of trees (or take lat/long of corners/vertices)
- Walk to center of forested stand that will be cleared/killed. Create a 20-meter diameter plot (see below). The entire plot should be within the forested area.
- Take GPS location of biomass plot center
- For trees >5cm DBH (15.5cm circumference), identify tree species or indicate unknown
- For trees >5cm DBH (15.5cm circumference), estimate DBH and mark with chalk

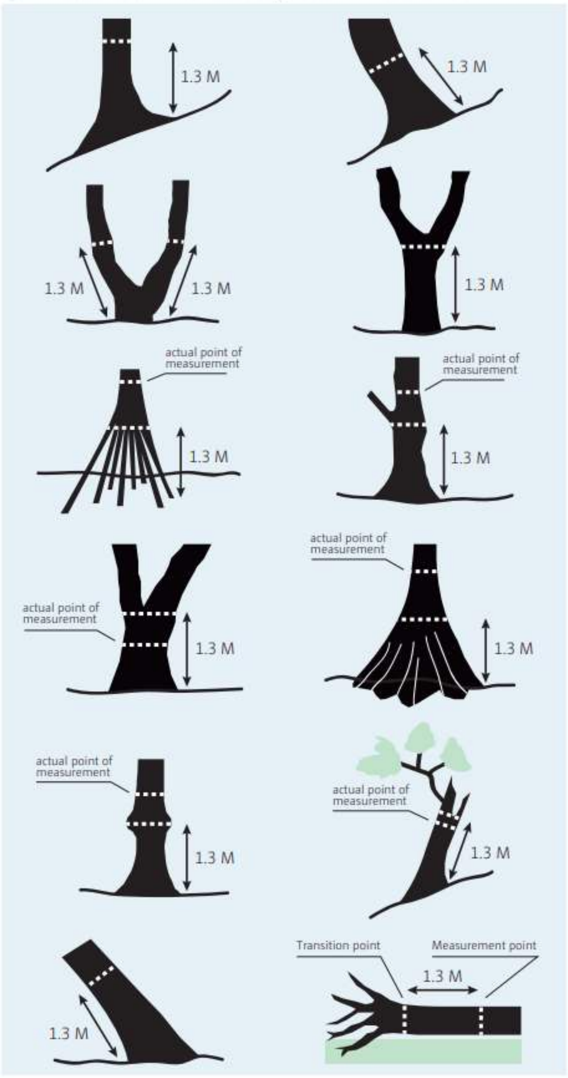
- Estimate % shrub crown cover

7.2.6 Hedgerows; living fences; or a mix of dead branches, live shrubs, and trees; that are killed or cleared by project activities

- Measure the length and width of the hedgerow starting at the corner.
- Then measure the length until another corner/vertex is reached. When you reach another corner, measure the width again
- Repeat until the length and width of the entire hedgerow is complete.
- For trees >5cm DBH (15.5cm circumference), identify tree species or indicate unknown
- For trees >5cm DBH (15.5cm circumference), estimate DBH and mark with chalk
- Estimate % shrub crown cover

Estimate Diameter at Breast Height (DBH) (>5cm diameter, >15.5cm circumference)

Figure 4: DBH Measurements for Irregular and Normally Shaped Trees

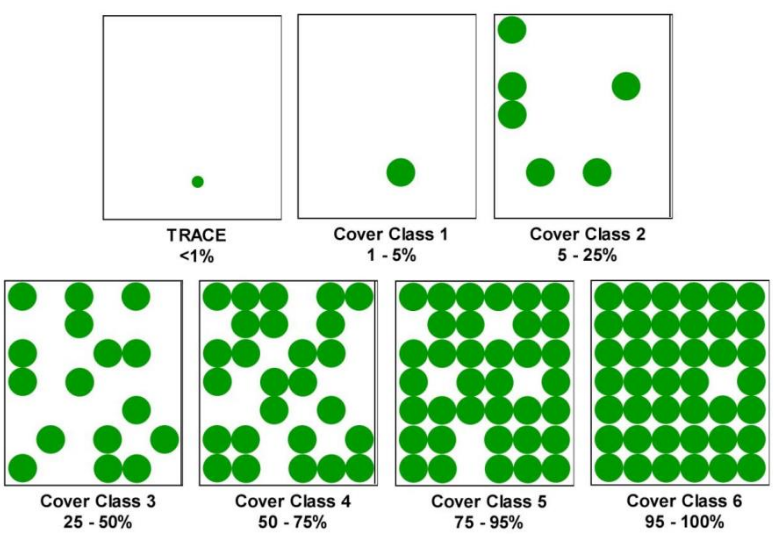


Estimate % Shrub Crown Cover

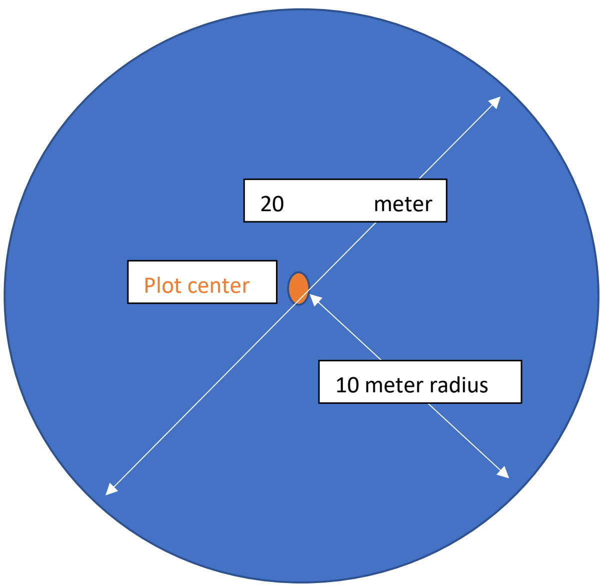
- Have two people walk through and look at the area of interest (i.e., forested stand of trees or hedgerow) and estimate % shrub crown cover
- If two estimates are not within the same range but are no more than one canopy cover interval apart, the mean of the two estimates can be used
- If two estimates are not within the same range and are further apart than one canopy cover interval, redo estimate.

Table 4: Ocular Cover Classes for Shrub Sampling

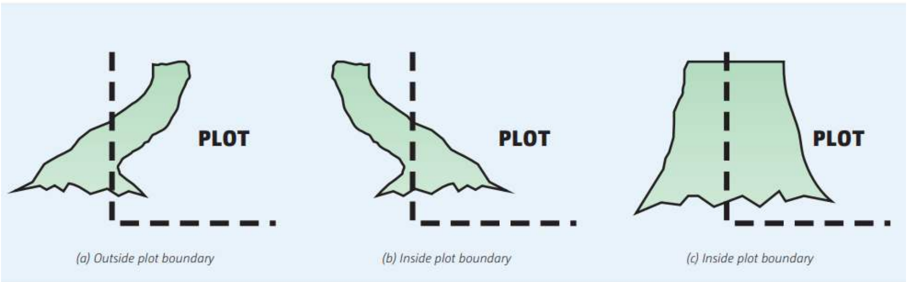
Cover class	Range of Coverage	Midpoint of Range
1	< 5%	0, not needed by method
2	6 – 25%	15.5%
3	26 – 50%	37.5%
4	51 – 75%	62.5%
5	76 – 95%	85%
6	> 96%	97.5%



Plot design



20 meter
Plot center
10 meter radius



PLOT
PLOT
PLOT
(a) Outside plot boundary
(b) Inside plot boundary
(c) Inside plot boundary

Soil Core Labeling:

Forest Garden ID

Organic Carbon (OC) or Bulk Density (BD)

Date of Sample

Forest Garden Sketch