Technical Specification
Coffee Agroforestry: From Rust to Resilience

CommuniTree Carbon Program

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Version: 2017-04-05

ENRACINE TAKING ROOT

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Executive Summary

The cultivation of shade grown coffee is an effective carbon sink that plays an important role in Nicaraguan livelihoods. However, warmer temperatures associated with climate change have facilitated an ongoing outbreak of *Hemileia vastatrix*, a fungus known as leaf rust. This leaf rust has ravaged coffee agroforests in Nicaragua and across Central America, crippling production and threatening the livelihoods of millions who depend on the coffee industry. Leaf rust particularly affects coffee farms at lower elevations where temperatures are the warmest and thus the most susceptible. In addition to climate-induced rust outbreaks, cycles of low coffee prices are pushing families to clear coffee agro-forests to other land-uses with much less forest including clearing or abandonment of coffee plantations, destruction of the shade forest for timber and fuelwood and growing of new non-coffee crops.

This technical specification: *Coffee Agroforestry: From Rust to Resilience* is designed to help smallholders establish new high-yielding rust resistant coffee agroforestry systems at higher elevations in order to improve smallholders' income while mitigating climate change. Financial incentives in the form of payments for ecosystem services will incentivize the establishment of new coffee agroforestry systems at higher elevations where temperatures are cooler and therefore less susceptible to rust attacks. Furthermore, high quality rust resistant coffee varieties such as *Marsellesa* along with technical training will be provided.

Coffee Agroforestry: From Rust to Resilience, consists of a four-strata coffee-agroforestry system with a total of 3,827 trees per hectare (TPH). The lowest stratum consists of three to four thousand coffee trees, the primary economic engine of the system. The second and third strata consist of banana and fruit trees (16 TPH) primarily for household consumption. The fourth stratum consists of 138 large shade trees that form the canopy of the system, sequestering large amounts of CO_2 while providing a biodiverse habitat for other plant and animal species.

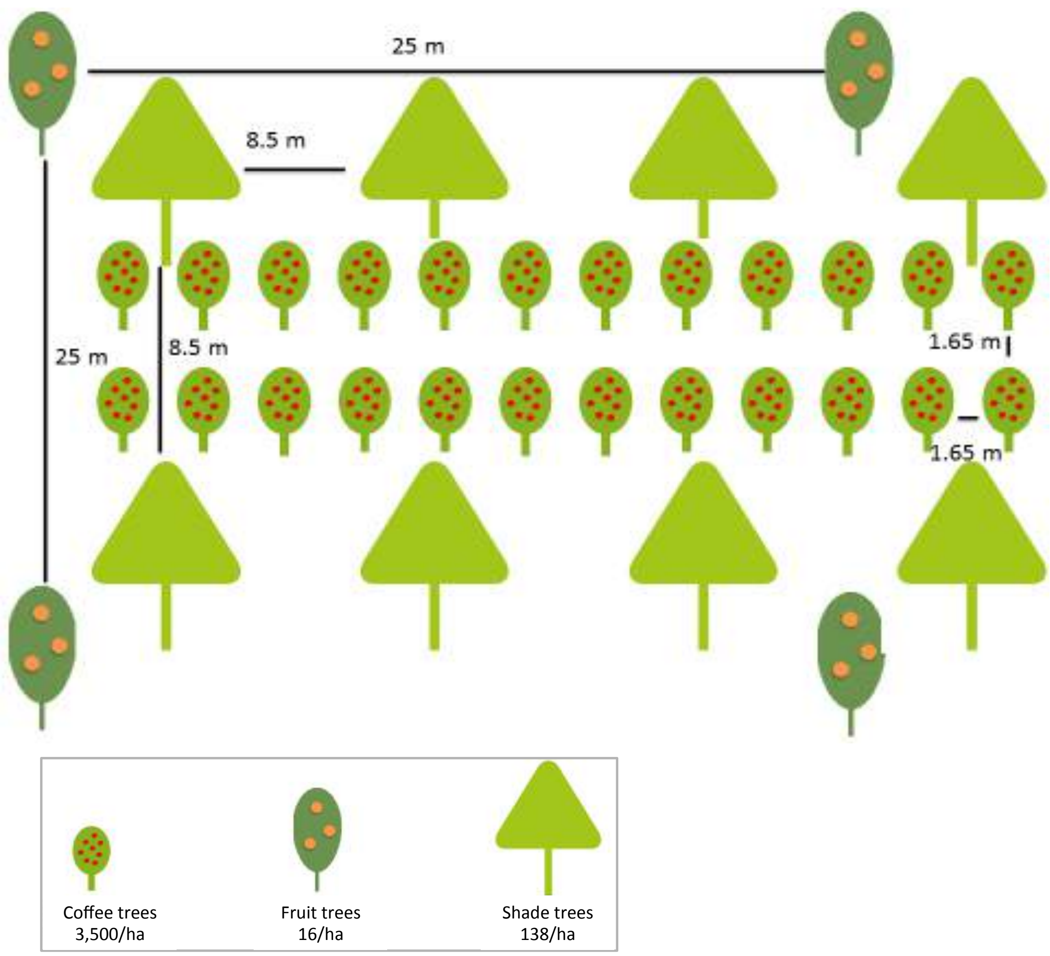
The CO_2 sequestered per hectare in new coffee agroforestry systems is expected to reach over 400 tonnes within woody plant biomass. However, given the conservative carbon accounting approach used where the carbon sequestered is calculated as the average over the crediting period minus a baseline of 13.64 tCO2 and a 15% risk buffer, a net total of 203.23 tCO_2/ha is being accounted for.

G.1.Project Intervention and Activities

G.1.1. Intervention

This technical specification, *Coffee Agroforestry: From Rust to Resilience,* consists of a four-strata coffee-agroforestry system as illustrated in Figure 0-1 below with a density of ~ 3,654 trees per hectare. The first stratum consists of coffee plants planted at a density of three to four thousand coffee trees per hectare (TPH), which is the primary economic driver of the system providing an annual cash crop starting in the third year of planting. The second stratum consists of *musaceae* (banana) at densities determined by participating smallholders. The third stratum consists of a variety of fruit trees that are planted at a density of 16 TPH, providing food crops for consumption and sale while providing filtered shade for the coffee. The fourth stratum consists of a mixture of mixed native tree species providing a diverse canopy for partial shade, wildlife habitat and carbon sequestration. These trees occupy the upper level of the canopy and are planted at a density of 138 TPH. See Appendix Table G-7 and G-8 for a full list of species that can be used in this technical specification for the third and fourth strata.

Figure 0-1 – Coffee-agroforestry project design



The coffee trees will consist of new varieties that are resistant to *Hemileia vastatrix*, a fungus known as leaf rust. This leaf rust has ravaged coffee agroforests in Nicaragua and across Central America, crippling production and threatening the livelihoods of millions who depend on the coffee industry. Despite the existence of rust resistant cultivars, the speed of re-planting in coffee producing countries with improved varieties has generally been slow. Therefore, a primary focus of this technical specification is promoting the adoption of coffee trees that are resistant to leaf rust but that also produce high yields that command attractive market prices.

One of such varieties that this technical specification will employ is Marsellesa due to its resistance to rust and high cup quality. Marsellesa is one of the newest varieties in Central America, a pure line hybrid Sarchimor developed through a partnership between CIRAD, a French agricultural research and international cooperation organization and ECOM Trading, a major coffee trading company that provides the genetic material through Atlantic, its Nicaraguan subsidiary. In addition to being resistant to coffee rust, Marsellesa is known for good cup quality. It has higher acidity than the Caturra variety, one of the prevailing standards for beverage quality that new varieties should aim to match or exceed (Bertrand, Montagnon, Georget, Charmetant & Etienne, 2012).

Applicability conditions

In order to be eligible to participate in the project, farmers must meet the following applicability conditions:

- Their land must not be forested. Farmers cannot clear forested land to gain eligibility.
- Their land must be within the suitable areas of the current program boundary.
- Their land must be at elevations above 700 masl.
- They must be able to demonstrate clear land title to their farm.

G.1.2. Activities and Inputs

This technical specification includes four types of activities: 1) the establishment and maintenance of coffee agroforestry systems; 2) technical training on the best coffee management practices in order to increase yield, and control for pests and disease such as leaf rust; 3) improved market access so that farmers receive a higher price for their coffee; and 4) the use of carbon money from the sale of carbon offsets as partial collateral so that farmers can access the financing needed to professionally manage their coffee production. 60% of the price received from the sale of carbon offsets relating to the use of this technical specification will be placed into a revolving Coffee Fund to the benefit of coffee farmers as follows:

- The Coffee Fund will be used as collateral so that the cohort of farmers using this technical specification in a given year can access loans from a creditor at preferential interest rates in order to purchase the required inputs to establish high value coffee agroforestry systems as described in this technical specification.

- Should farmers' default on their loans, the Coffee Fund will be used to reimburse the creditor to a maximum of the value of the Fund.
- After the cohort of farmers successfully pays off all of its loans to the creditor, farmers will receive the amount paid in interest as a cash bonus to a maximum of the value of that cohort's contribution to the Coffee Fund. This results in farmers receiving their loans at a 0% interest rate.
- Any money remaining in the Coffee Fund after repaying any defaults on farmers' loans and farmers' cash bonuses will be used to support a new cohort of farmers for the same purposes.

Improved market access will take place once the first systems start producing coffee cherries. The objective is for farmers to receive the highest possible price for their coffee and this will be done either through existing coffee Cooperatives or direct market access. Technical training will be provided on an ongoing basis through Taking Root's Community Technicians as part of regular farm visits. Initial training for Community Technicians comes from the provider of the superior coffee varietals, Atlantic.

A summary of project inputs and activities for the establishment and maintenance of coffee agroforestry systems is presented in **Error! Reference source not found.** below.

Table G-1 – Description of establishment activities and estimated costs per hectare

Nursery Establishment and management		
Description	**Quantity**	**Total Cost ($US)**
Coffee plants from improved genetic material and other required inputs	3,673	1,338
Grafter fruit trees	14	11.20
Shade trees	138	13.80
Various nursery inputs	Variable	73.71
Nursery bags	~4,000	12.95
Labour days for nursery management	45.70	240.38
Preparation of Land and Planting		
Labour (clearing land, digging holes, planting of seedlings, maintenance)	94.3	495.94
Total		**$2,187.83**

Cost per year 1 through 3		
Description	**Quantity**	**Total Cost ($US)**
Labour	30	157.80
Fertilizers		586.95
Foliar sprays		85.06
Lime		24.99
Totals		**$854.80**

Geophysical Conditions

This technical specification in the municipality of San Juan de Rio Coco (SJRC), in the department of Madriz, is located in the north-central highlands of Nicaragua. Madriz is a rural area with steep topography and a climate that is classified as highland savanna but SJRC has humid conditions at higher elevations and drier conditions at lower elevations. As temperatures rise due to climate change, coffee production is increasingly less suitable at lower altitude zones. Optimal elevations are between 700 and 1,700 masl. This project will assist coffee producers to establish new coffee agroforestry plantations at elevations above 700 masl.

G.2. Additionality and Environmental Integrity

The carbon benefits proposed by the project interventions are all additional to current practices in the project area. To ensure no double counting, PES agreements can only be entered into and signed by producers who are not participating in any other carbon offset programs. There are currently no other PES initiatives in the project area.

The additionality of the project was assessed using the methodology set out by the Clean Development Mechanism (CDM) Rules (2007). Additionality and barriers to implementation are summarized in Table G-2. Without the actions outlined in the Table that will be implemented, the project would not take place and thus the ecosystem service benefits would not occur.

Table G-2 – Additionality test

Additionality Test	Initial Scenario	Action
Regulatory Surplus	There are no existing laws and regulations that require or mandate land-use practices in the project area.	Improve local livelihoods and food security through agroforestry and PES incentives.
Common Practice	Leaf rust and low coffee prices have forced many farmers to deforest their farms in order to shift towards other crops.	Introduce improved genetic coffee stock that is resistant to coffee rust, provide technical training on managing new coffee varieties and management to minimize rust outbreaks, establish new plantations above 700 masl where temperatures are cooler and thus less susceptible to coffee rust.
Implementation barriers		
Financial	No money to develop the project. No PES system currently in place. Limited access to credit.	The project will provide financial incentives through PES payments. CRS is funding the first 13,875 offsets. Additional carbon offsets will be marketed and sold by Taking Root for further expansion.
Technical	Lack of knowledge among coffee farmers about the benefits of improved coffee cultivars, inefficient systems for their multiplication and distribution, and scepticism among coffee traders of their cup quality (van der Vossen, Bertrand & Charrier, 2015)	This program utilizes the expertise of Atlantic, a Nicaraguan coffee exporter and developer of rust resistant coffee varieties to provide the coffee plants and a market for the coffee. Taking Root's Community technicians have received training from Atlantic about appropriate coffee management that will be brought into the community. This expertise will be complimented by Taking Root's expertise in managing smallholder projects.

G.2.1 Avoidance of double-counting

The program uses rigorous and transparent record keeping procedures through its SCPIMS to avoid double counting of carbon offsets. Every reforested farm is geo-referenced, provided with a unique ID and published through Taking Root's website. Through this unique ID, the offsets issued from that farm are published in Taking Root's annual report and available through Taking Root and Plan Vivo's websites. The offsets are then issued through the independent Markit Environmental registry and every offset is assigned a unique serial number that is published on Markit's website. Finally, third party audits are conducted every 5 years to report against published results.

At the international level, Nicaragua does not currently participate in international carbon offset schemes therefore the offsets issued through this program can not be double-counted through such initiatives. This is because the country has not submitted an intended nationally determined contribution (INDC) as part of the U.N. Framework Convention on Climate Change (UNFCCC). Should the situation change, Taking Root will notify the Plan Vivo Foundation and appropriate measures will be taken.

G.3. Project Period

Taking Root project interventions are designed to be ongoing without a specified end date. For carbon quantification purposes, the project has a rolling crediting period of 50 years starting the year the smallholders plant their first trees. The carbon benefit from the project is calculated using the average carbon sequestered over the crediting period. A period of 50 years was selected in accordance with all other technical specifications within the CommuniTree Carbon Program. 50 years allows sufficient time to show the long-term trend in sequestered carbon stock and dynamic growth trends. Since the carbon benefit is calculated as the long-term average carbon stock sequestered over the crediting period, 50 years is not the amount of time required for the carbon to be sequestered. Rather, the total carbon benefit will be sequestered by the 17th year.

G.4. Baseline Scenario

G.4.1. Current Conditions and Trends

Located in the highlands of Nicaragua, SJRC is well suited for growing arabica coffees (*Coffea arabica*). High altitudes and lower temperatures are required for the successful production of high quality coffee arabica coffees, which are usually sold at twice the price of robustas (*Coffea canephora*). However, crop productivity and yield in San Juan de Rio Coco is highly variable and lower than the national average due to poor management and genetic selection. Furthermore, increasing temperatures due to climate change is leading to declining productivity and cup quality (van der Vossen et al., 2015).

Increasing temperatures also poses a threat to arabica coffee producers through higher incidence of pests and diseases (van der Vossen et al., 2015). For example, it is fueling the growth of *Hemileia vastatrix*, a fungus known as leaf rust, which is ravaging coffee agro-forests in Central America. The disease causes coffee leaves to fall prematurely, reducing yields by 10-40% (Silva et al., 2006). SJRC was the most affected municipality in Nicaragua after a widespread outbreak of leaf rust during the 2012-2013 crop year (Blundo Canto, Perez, Gonzalez & Laderach, 2015). Currently, 80% of coffee stands in Central America possess susceptibility to leaf rust. However, the majority of coffee farmers cannot afford to switch to disease resistant varieties. Replacing current coffee plants with improved varieties requires a high level of initial investment and farmers must also wait several years before the new plants mature and begin producing yields (Avelino et al., 2015).

Temperatures in Madriz currently range between 23-32°C, and annual precipitation is between 650-800 mm in the driest municipalities and 1200-1400 mm in SJRC (INETER). Based on climate models, by 2050, annual rainfall will decrease by 93 mm, a reduction of 6–14% depending on the location, and temperatures will increase by 2.1ºC in SJRC.

In addition to climate-induced rust outbreaks, cycles of low coffee prices are pushing families to clear coffee agro-forests to other land-uses with much less forest cover (Vaast, Beer, Harvey & Harmand, 2005). For example, following the decline of coffee prices in 2000 and 2001, Central American coffee producers faced a variety of problems, including clearing or abandonment of coffee plantations, destruction of the shade forest for timber and fuelwood and growing of new non-coffee crops (Varangis, Siegel, Giovannucci & Lewin, 2003).

G.4.2. Carbon Pools

Table G-3 describes the choice and justification for the carbon pools included and excluded in the carbon baseline.

Table G-3 – Carbon pools

Carbon Pool	Includes	Included	Excluded with Reasoning
Above & below ground non-woody biomass	Grasses, Musaceae, etc.	No	Carbon pool is expected to be very small and it is difficult and costly to measure. Excluding it makes the analysis more conservative since it is expected to increase with project activities.
Above & below ground woody biomass (DBH >= 5 cm)	Shade and fruit trees: stems, branches, bark, roots	Yes	
Above & Below ground woody biomass (DBH < 5 cm)	Shrubs, small trees etc.	No	Carbon pool is expected to be very small and it is difficult and costly to measure.
	Roots of shrubs, small trees etc.	No	
Soil	Organic material	No	Carbon pool is costly to measure accurately. Excluding it makes the analysis more conservative since it is expected to increase with project activities.
Litter & Lying dead-wood	Leaves, small fallen branches, lying dead wood	No	Carbon pool is expected to be very small and it is difficult and costly to measure.

G.4.3. Baseline Methodology

Initial Carbon Stock

The first phase of conducting the baseline was determining the initial carbon stock present in above and below ground woody biomass. The objective of this first phase is to obtain an estimate of carbon stocks with a precision of plus or minus 20% of the mean with a 90% confidence level (two-tailed).

To do so, the methodology described in the sections below was based on the Winrock International Sourcebook for Land Use, Land-Use Change and Forestry Projects (Pearson & Walker, 2005). An overview of the methodology is as follows:

1. **Stratification:** The project boundary was stratified into non-eligible and one eligible vegetation cover class.

2. **Required sampling size**: A pilot biomass survey was conducted to estimate the required sampling size within the eligible stratum. The eligible stratum was then sampled to estimate the initial carbon stock.
3. **Field measurements**: Nested subplots were used to measure trees of varying sizes at varying intensities.

Stratification

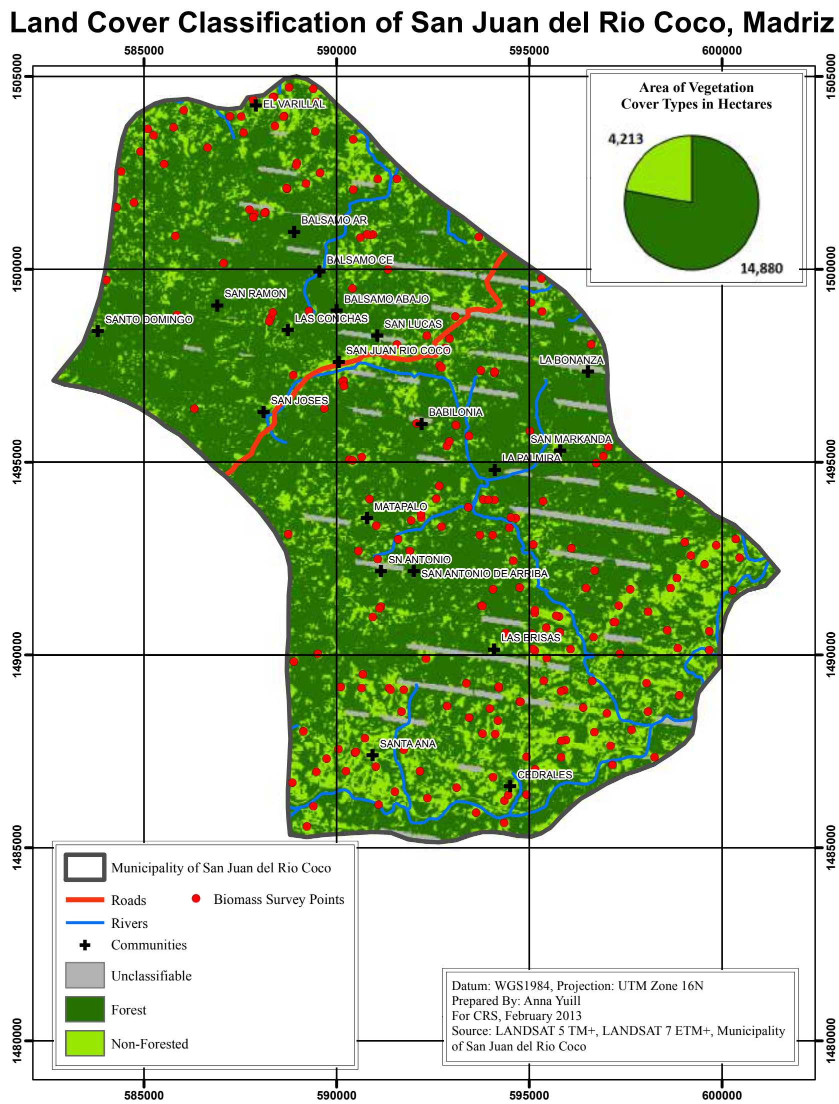
Two images, Landsat 5 TM+ (date acquired) and Landsat 7 EMT+ (date acquired) were acquired from the United State Geological Survey (USGS) website along with a digital elevation model (DEM) in January 2013. These two 30-meter spatial resolution images were selected based on the limited amount of atmospheric contamination (clouds and cloud shadows) and seasonality. Seasonality was an important consideration in choosing the images due to the significant atmospheric contamination over the humid and tropical latitudes, especially during the rainy season. For the municipality of SJRC, clouds and cloud-shadows proved to be a significant problem that required image manipulation by removing and overlaying the two Landsat images to create one cloud free image.

To create a composite of a cloud free image, a FMASK algorithm created by Zhu and Woodcock (2012) was used to identify clouds and cloud shadows and generate a cloud mask for each image independently of one another. IR-MAD and MAD algorithms were then used independently on the two images to create normalized images so that the pixel values in each image could be matched to one another (Canty & Nielsen, 2008). The cloud masks were then applied to each normalized image, to create two cloud free images. Using the Landsat 7 ETM+ image as the base layer, the two images were merged using image manipulation where the cloudy pixels from the first image were filled with the cloud free pixels from the second image. Any missing data from the first image were also filled from the data of the second image. This ensured a more complete, cloud and cloud-shadow free image.

An unsupervised classification was then performed on the new image using ISODATA (Iterative Self Organizing Data Analysis Technique). ISODATA calculates the averages of the data then clusters the remaining data based on the minimum distance to other pixels with the same spectral signature. Using ISODATA, fifteen classes were generated and then merged into two classes: forest and non-forest. The merging of fifteen classes into two classes was based upon imagery from Google earth and ground truthing of 50 randomly generated points throughout SJRC during a pilot biomass survey. With the completed classification map, a total of 301 biomass survey points were randomly generated and placed within the non-forested classification. Finally, the accuracy of the ISODATA classification was evaluated after ground truthing by comparing the number of randomly generated points that were actually non-forested relative to the total number of points generated. In total, 224 of the survey points fell within the non-forested classification, leading to 74.4% classification accuracy.

The final map is illustrated in Figure G-2 below.

Figure G-2 – Land cover classification of San Juan del Rio Coco, Madriz



Required sampling size

In order to meet the required sampling size, a pilot biomass survey was conducted in January where biomass estimates were taken from randomly generated points (n=50) within the eligible project stratum in January 2013 using the following 4 steps:

1) With the data acquired from the pilot survey, the average amount of carbon per hectare within that land-use classification was determined using the following equation:

$$\overline{y_{ST}} = \sum(\overline{y_h} \times W_h)$$

Where $\bar{y}_{ST}$ = Estimate of the overall mean; $\bar{y}_h$ = Mean carbon value in metric tons of stratum *h*; and W_h = Weight assigned to stratum *h* defined as:

$$W_h = \frac{N_h}{N}$$

Where N = Population of samples; and N_h = Population of samples is stratum *h*.

The slope of the plot was corrected for using the formula:

$$L = L_s \times \cos(S)$$

Where L = the true horizontal plot radius; L_s = the standard radius measured in the field along the steepest slope; S = the slope in degrees; Cos = the cosine of the angle. By taking the steepest slope, the carbon in each sample is overestimated. This methodology is concurrent with the baseline being calculated in a conservative manner.

The results of each plot were expanded to a per hectare basis using the following expansion factor:

$$EF = \frac{10000}{A}$$

Where EF= Expansion factor; A= Area of sub-plot in m^2. Using an allometric equation developed for tropical dry forests (Brown, 1997), with annual precipitations > 900 mm, the above ground biomass was calculated as:

Biomass (kg) = exp(-1.996+2.32 x ln(DBH))

The expansion factor multiplied by the total calculated biomass of trees on the sample sub-plot gave an estimate of the aggregate of all trees on the hectare of land.

Below ground biomass was calculated by multiplying the AGB by 0.56 when AGB < 20 t/ha and by 0.28 when AGB >= 20 t/ha (IPCC, 2006).

The aggregate of above ground and below ground biomass were summed together to get total biomass (TB), which was converted to Total Carbon (TC) by multiplying (TB) by the carbon fraction: (IPCC, 2006)

TC = 0.49 * TB

2) The variance in carbon per hectare was estimated using the following equation:

$$S_{\bar{y}_{ST}} = \sqrt{\sum\left(s_{\bar{y}_h}^2 \times W_h^2\right)}$$

Where $S_{\bar{y}_{ST}}$= Standard Deviation of the overall mean; and $S_{\bar{y}_h}$= standard deviation of the mean of stratum *h*.

3) With these results, a Neyman allocation (sometimes known as optimal allocation) was used to determine the minimal sample size required to meet the specified allowable error using a sampling without replacement approach. This allocation procedure was chosen because it takes into account both variation within the different strata and the size of each stratum. The equation for determining the total number of samples required and the number within each stratum is as follows:

$$n = \frac{t^2 \times \left(\sum W_h s_{y_h}\right)^2}{AE^2 + \frac{t^2 \times \sum W_h s_{y_h}^2}{N}}$$

and

$$n_h = \frac{W_h s_{y_h}}{\sum W_h s_{y_h}} \times n$$

Where AE = Allowable sampling error; n = number of samples required; S_{y_h} = Standard deviation of the sample of stratum h; $S_{y_h}^2$ = Variance of the observations of stratum h; and *t* = student's random variable from *t*-distribution.

4) To construct confidence limits, the appropriate degrees of freedom for the estimate need to be estimated since the required sample size is yet to be determined. As such, the effective degrees of freedom (EFD) were used and calculated as follow:

$$EDF = \frac{\left(s_{\bar{y}_{ST}}^2\right)^2}{\sum \frac{\left(\frac{N_h^2}{N^2} \times s_{\bar{y}_h}^2\right)^2}{n_h - 1}}$$

Where all the variables are as previously defined.

It was determined from the pilot biomass survey that 156 valid sample plots were needed for the non-forested classification to obtain the desired level of precision. Biomass measurements were recorded on 163 of the original 224 points created during the stratification. The choice of 163 was simply the result of time and budget constraints but that is above the estimated requisite of 156 points from the pilot survey.

Field Measurements

Nested sub-plots of varying sizes were used within the sample plots to measure trees according to Table G-4 below. All trees with a diameter at breast height (DBH) greater than 5 cm were included in the survey. Results from the biomass survey were scaled to estimate average carbon stock per hectare.

Table G-4 – Size of sampling plots, sub-plots and trees measured

Sub-plot	Square	Area	Trees
Small	20 m	0.04 ha	>5 cm DBH
Medium	40 m	0.16 ha	>20 cm DBH
Large	60 m	0.36 ha	>50 cm DBH

In the field, a standard methodology was used to record the necessary information for the baseline calculation. The GPS coordinates were located using a hand-held GPS receiver and the project boundary map. Once located, the coordinates represented the south west corner of the square nested plot.

The DBH of each tree was measured and the height of one representative small, medium and large tree were recorded using a clinometer. If this location was not representative of the tree's diameter due to an irregular growth, a second measurement was taken slightly above the growth and the point of measurement was used as opposed to the DBH. All small trees in the small sub-plot were measured, all medium trees were measured in the small and medium sub-plot and all large trees were measured in the entire plot. If the tree bifurcated below the point of measurement, it was measured as two separate trees. The information with the tree's local name was noted in the data sheet along with the slope of the land at its steepest point.

Change of Carbon Stock in Absence of Project

The baseline will be assumed to stay constant, which is consistent with simplified baseline and monitoring methodologies for small-scale A/R CDM project activities. (UNFCCC, 2010). This is very much a conservative estimate since deforestation and land-use change is reported in the literature and is visible from the communities for the reasons described in the baseline scenario.

G.4.4. Baseline Emissions

Baseline Results

The carbon stock baseline is an area-weighted average of all eligible land, a mix between semi-abandoned pastures, pastures, and agricultural land. The baseline for this land is 3.72 tC/ha (13.64 tCO_2/ha). The results of the initial carbon stock are presented in Table G-5 below:

Table G-5 – Baseline results

	Area (ha)	Above ground woody biomass (t C/ha)	Below ground woody biomass (t C/ha)	Total (t C/ha)
Non-forested land	14,880	2.76	0.96	3.72

Anecdotal evidence from the time of writing this report and the date that the data was collected suggests that the area of non-forested land has shrunk as more farmers transition towards other crops and thus the importance of this program.

G.4.5. Data Sources

This document provides as much information as possible concerning data sources, methodologies, default factors and assumptions used. The data used to inform this report is the most relevant and updated information available. See the References section for a complete list of data sources.

G.5. Ecosystem Service Benefits

Coffee agroforestry systems can provide a wide range of ecosystem services. A brief overview of the main benefits, as discussed by Vaast, Beer, Harvey and Harmand (2005) is provided in Table G-6 below.

Table G-6 – Ecosystem service benefits

Ecosystem Service	Description
Reducing soil erosion and improving soil fertility	Shade trees help reduce runoff, resulting in less soil erosion and greater availability of nutrients in the soil. Leaf litter provides an increase in soil organic matter. Leguminous trees can also help improve the availability of nitrogen, which is the most limiting nutrient for coffee production.
Conservation of water (quantity and quality)	Shade trees reduce probability of flooding and increase water retention in the soil. Less soil erosion and nutrient leaching also reduces ground water contamination, thus improving water quality and soil water recharge.
Carbon sequestration	Carbon sequestration potential is greatly enhanced by existence of shade trees when compared to full sun coffee monoculture. Coffee agroforestry systems can also increase carbon sequestration through increasing the amount of organic matter in the top soil layer.

Biodiversity conservation in fragmented landscapes	Increase of forest cover through native tree species results in increase of wildlife habitat. Coffee agroforests can also contribute to biodiversity protection in buffer zones around parks and protected areas.

G.5.1. Climate Benefits Methodology

In order to calculate the carbon benefits over the project lifetime, a carbon sequestration model for 50 years of tree growth was created. The methodology was sourced from various quantitative methodologies and data from relevant journals and allometric growth equations created in-house.

The coffee agroforestry system was separated into four cohorts (shade trees, fruit trees, *musaceae* and coffee plants) predominantly based on the stratum of the canopy occupied. Each cohort was modeled independently.

The in-house allometric equations predict the height and diameter of three cohorts of woody biomass (coffee, fruit trees, shade trees) over the project period. Using this data, a predictive model is used to determine the above ground biomass (stems, branches, and foliage). Using this model combined with a biomass model, the specific gravity of the cohorts, and a below ground biomass model, we estimate the biomass per hectare.

G.5.1.1. Assumptions

Climate benefits were quantified according to the following assumptions:

Root to shoot biomass ratio

The root to shoot ratio was chosen among various values developed by Cairns, Brown, Helmer and Baumgardner (1997). The value was selected for its applicability to tropical latitudinal zones.

Biomass equations

For the coffee trees, the model used was developed by Segura, Kanninen and Suarez (2006). The model is specific to coffee and was developed in Nicaragua. Compared to other coffee biomass models available in the literature, this model is much more conservative with estimates of 20% to 66% of what other models predict (Schmitt-Harsh, Evans, Castellanos & Randolph, 2012).

For the fruit and shade trees, a general biomass model by Chave et al., (2005) is used as opposed to species-specific model to account for the great diversity of tree species used and naturally regenerating in the coffee agroforestry systems. This general model is widely used for carbon modelling given its broad applicability. The model is specific to the climatic region of the project and allows for different tree densities. Segura, Kanninen and Suarez (2006) created allometric equations for coffee agroforestry systems in Nicaragua that we ultimately did not use for the following reasons: 1) shade cohort models were built using diameter at 15 cm as opposed to DBH, which is conventionally measured in the field of forestry and is the measurement used in this project; and 2) the shade cohort was modelled by combining fruit trees and shade trees, which are significantly different in size, thus biasing any model that doesn't use the same ratio of fruit and shade trees. Given this, the project uses a more general model for the region to account for the great diversity of tree species present in these coffee agroforestry systems.

Growth and yield

Growth and yield of fruit trees and shade trees are highly dependent on management and different growth conditions. No species-specific models were available for this project region and therefore a new model was built in-house. For a full description see section G.5.1.2.

Growth and yield for coffee plants were built based on simple linear relationships of conservatively reported height and diameter at 15 cm in height of reported values in Segura, Kanninen and Suarez (2006) over an assumed 10-year rotation period.

Specific gravity (density of wood)

Given the variety of shade trees in this coffee agroforestry system, the density of wood was obtained by finding the average value among a variety of shade trees for the project's climatic region proposed by Chave et al. (2006). The density of fruit trees was obtained by averaging the species-specific values for citrus trees and avocado trees, as they are the most commonly planted fruit trees in the project area.

Emissions from fertilizer use

Coffee farmers in San Juan de Rio Coco regularly use synthetic fertilizers to increase the productivity of their coffee, which emit greenhouse gas emissions[1]. While Taking Root does not provide farmers with synthetic fertilizers and prefers organic means of production, farmers are likely to use them.

For the purposes of carbon modelling, the calculations assume that farmers will use the amounts recommended by technical best practices provided by Atlantic. This is almost surely a conservative assumption since farmers generally use substantially less given cash-flow problems. Furthermore, Taking Root intends to promote the use of organic methods such as biochar, which could even be carbon negative.

[1] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

G.5.1.2 Growth and Yield

The growth and yield modeling exercise was based on a DBH driven model from which height was derived. Nonlinear models were fitted using PROC MODEL of SAS version 9.3 and variables were tested for statistical significance using $\alpha = 0.05$.

Data was collected between the month of January and March 2013 from 30 coffee agroforestry systems. A variety of ages were purposively sampled across the municipality of San Juan de Rio Coco (SJRC). At each sampled location, nested sub-plots of varying sizes were used within the sample plots to measure trees using the same sampling plot types as the carbon baseline and described in Table G-4. Efforts were made to sample stands with the full variety of ages used for the proposed modelling exercise and to sample stands of homogenous ages. Unfortunately, few older aged stands were available with homogenous aged trees because farmers commonly established their coffee agroforestry systems progressively over time with remnant trees. In order to minimize the effects of really large trees from positively biasing the data within the time frame of this modelling exercise, trees with DHB > 50 cm were recorded as having a DBH of 50 cm.

Modeling DBH

To estimate the growth and yield of DBH, a Chapman-Richard function form was used, which is common in forestry given its flexibility and suitability to biological applications (Clutter, Fortson, Pienaar, Brister, & Bailey, 1983). Specifically:

$$DBH_{t,c} = \beta_{1_c}\left(1 - e^{-\beta_{2_c} \times t}\right)^{\beta_{3_c}} + \varepsilon_{t,c}$$

Where $DBH_{t,c,}$ is mean DBH for cohort *c* at time *t*; *t* = time in years; *e* is the base of the natural logarithm, which is a constant = 2.71828; β_1, β_2 and β_3 are fixed-effects parameters to be estimated; and $\varepsilon_{j,c}$ = error term of the equation.

It is important to note that this analysis was performed using cross-sectional data to make time-series inferences, thus biasing the results (Schabenberger & Pierce, 2002). This is because one does not end up modeling individual stands over time but rather a number of different stands of different ages without having information on some of the characteristics that might have affected a particular stand's growth trajectory. Nonetheless, this analysis provides the best estimate available for modeling growth and yield curves given the paucity of available time series data.

Modeling Height

Height prediction models were used as proposed by (Staudhammer & LeMay, 2000) where:

$$Ht_c = 1.3 + \beta_{1_c}\left(1 - e^{\beta_{2_c} \times DBH^{\beta_{3_c}}}\right) + \varepsilon_c$$

Where Ht_c = average height of cohort *c*. Initially, Taking Root tried to develop a height prediction model per species but given that there were numerous incidences where only one or two specimens per species were available, an average value per cohort was ultimately used.

G.5.1.3. Results

Musaceae cohort

The mass of carbon for *Musaceas* was estimated using an equation developed by Arifin (2001) and it was concluded that modeling and monitoring the carbon contained in *musaceas* as a part of this coffee agroforestry system is not worth the potential gain. Therefore, no growth and yield models were developed.

Fruit tree cohort

Across all plots, the average tree density within the fruit cohort was 14 trees. The models for DBH and height are presented below along with their associated R^2. Given the variety in species and densities across the sites sampled, approximately 30% of the variation of DBH and height was explained by the independent variables.

$DBH_t = 26.69 \times (1 - e^{-0.085 \times t})^{0.599}$ R^2= 0.2963

$Ht = 1.3 + 9.27 \times (1 - e^{-0.025 \times DBH})^{1.392}$ R^2= 0.3259

In total, five tree species were found within the coffee agroforestry systems sampled in SJRC. The species and the number of times they occurred within our sample are outlined in Appendix Table G-7.

Shade tree cohort

Across all plots, the median tree density within the shade cohort was 167 trees. The models for DBH and height are presented below along with their associated R^2. Slope and density were not found to be statistically significant and were therefore dropped from the models.

$DBH_t = 49.54 \times (1 - e^{-0.0855 \times t})^{1.17}$ R^2=0.65

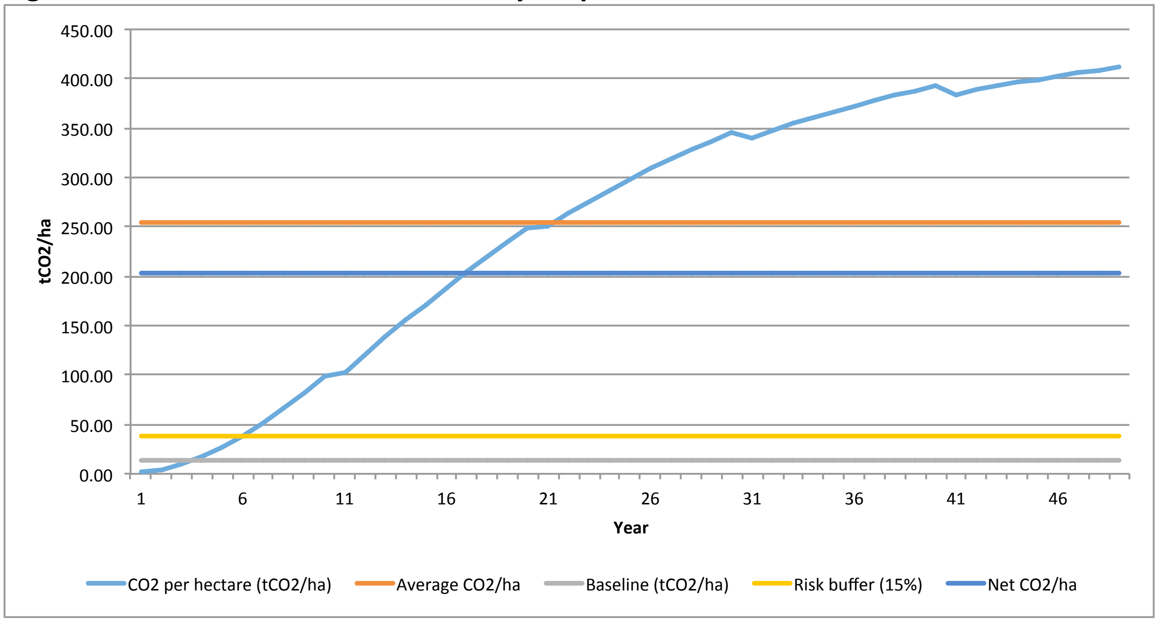
$Ht = 1.3 + 50 \times (1 - e^{-0.053 \times DBH})^{0.579}$ R^2= 0.27

In total, 56 tree species within the shade-tree cohort were found within the coffee agroforestry systems sampled in SJRC. The species and the number of times they occurred within our sample are outlined in Appendix Table G-8 (some species produce edible fruit but are not domesticated and occupy the upper canopy of the system and were therefore considered as a part of this cohort).

G.5.2. Expected Climate Benefits

The results from the carbon benefit model are presented in Figure G-3 and Appendix Table G-9.

Figure G-3 – Carbon benefit over a 50-year period



The results from this study are well within the range of the those found in various peer-reviewed studies of coffee systems (Dossa et al., 2007; Soto-Pinto et al., 2009). Furthermore, the amount of CO_2 found in the various coffee agroforestry systems sampled by Taking Root in SJRC to obtain data for this modeling exercise was as high as 532 tCO_2 per hectare in above ground biomass. Therefore, these results are considered conservative.

G.6. Leakage and Uncertainty

In this project, leakage could occur through the displacement of livelihood activities, such as livestock pasture and basic grain cultivation, by coffee agroforestry systems. However, individual land areas are so small that we do not foresee any leakage in this project. Additionally, participating farmers must demonstrate that they own sufficient additional land to meet their agricultural needs.

In calculating the carbon benefits, some level of uncertainty is inherent in any model. The goodness of fit and key assumptions for each model are presented in more detail in Section G.5.1.1.

To ensure the validity of these assumptions over the course of the project, the technical specifications will be updated every 5 years if they are still being used to sign to PES agreements. Specifically:

• Growth and yield models will be re-calibrated with the data collected annually from the monitoring procedures as described in monitoring plan in Section K.1.1. Specifically, DBH and height data from the previous five years of monitoring data will be added to the total dataset so that growth and yield models are re-run with the latest dataset;

• All default values and models taken from academic literature reviews used in this Technical Specification will be updated should newer information become available based on an updated literature review; and

• The size of the risk buffer will be readjusted based on previous experience.

___. Livelihood Benefits (Section F of PDD)

The implementation of this technical specification is expected to have a number of livelihood benefits as described in the table below

Food and agricultural production	Financial assets and incomes	Environ-mental services (water, soil, etc.)	Energy
Increased *musaceae* and fruit trees within coffee plantations	Increased income through cultivation of quality coffee	Increased soil accumulation in agroforestry systems compared to baseline	Possibly increased supply of firewood for household consumption from tree litter and pruning but not expected to have a large impact.
Increased coffee production	Increased income through PES	Increased water retention in agroforestry system compared to baseline.	

Table continued…

Timber & non-timber forest products	Land & tenure security	Use-rights to natural resources	Social and cultural assets
Possible use of non-timber forest products from agroforestry systems but no significant impact is expected.	No additional impact expected	No additional impact expected. The project does not work on community lands. All planting takes place on private lands so that everyone has rights to what they produce.	No additional impact expected

Possible negative impacts and mitigation measures to address them

The following possible negative effects were considered in project design with the associated mitigation measure:

Jealousy of non-participating households: All households that meet the eligibility criteria are invited to participate in the program on a first come first serve basis each year to the extent that financial resources are available to welcome new participants.

Eligible households that would like to participate are added to a waiting list until the following year when new funding is available.

Jealousy of non-eligible households:

Households that do not have non-forested land but do produce coffee in existing agroforestry systems might become jealous of the technical services, financial assistance and improved market access provided to participants. In order to mitigate these effects, the program is in the early stages of evaluating the viability of offering these services on fee for service basis and facilitating market access for coffee to all coffee producers regardless of whether they are eligible to participate in the program.

___. Ecosystem & biodiversity Benefits (Section F3 of PDD)

The implementation of this technical specification is expected to have a number of ecosystem and biodiversity benefits as described in the table below[1]. A socio-economic baseline and indicators are reported in Section G of the PDD. Furthermore, financial and socio-economic data on project participants and their farms are collected and tracked on an ongoing using Taking Root's proprietary Smallholder Carbon Project Information Management System (SCPIMS)[2].

Biodiversity impacts	Water/watershed impacts	Soil productivity/ conservation impacts	Other impacts
Increased cover of native tree species and therefore an increase in wildlife habitat, particularly for bird species.	Reduced probability of flooding in the wet season and increasing water infiltration and retention as a result of increased tree cover, especially of slopped land.	Nitrogen fixing species provide nutrients to the soil. Leaf litter to increase soil organic matter. Root systems facilitate the cycling of nutrients from deeper layers to the surface. Roots systems reduce erosion and nutrient leaching.	Create a temperature stabilizing microclimate to guard against extreme weather. Form natural wind and rain breaks. Sequesters CO_2.

[1] Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry Systems. 76 (1). pp 1–10. doi:10.1007/s10457-009-9229-7. Available at: http://link.springer.com/article/10.1007/s10457-009-9229-7

[2] Baker, K (2015). Reducing costs of data collection and analysis. European Tropical Forest Research Network. Issue 57,p189.

Possible negative impacts and mitigation measures to address them

Soil and water contamination through the use of agro-chemicals:

This technical specification does provide agro-chemicals. However, many farmers in the region commonly use agro-chemicals as they reportedly play an important role in boosting farm productivity. There are therefore important trade-offs between farmers' incomes, which is directly linked to their adoption of agroforestry practices and thus carbon sequestration, and the use of these chemicals. Therefore, Taking Root does not prohibit their use. As a mitigation measure, Taking Root rather seeks to promote the progressive transition away from agro-chemicals towards organic practices through a careful and iterative process. Such mitigation measures include an active biochar program to reduce the need for chemical fertilizers[1] and the development of partnerships with organic coffee agronomists with a proven track record.

___. Risk Identification (Section H1 of PDD Template)

Same as all other technical specifications used in the CommuniTree Carbon Program

K. Monitoring

K.1. Monitoring of Ecosystem services benefits

K.1.1 Monitoring plan

Same as all other technical specifications used in the CommuniTree Carbon Program

K.1.2 Community involvement

Same as all other technical specifications used in the CommuniTree Carbon Program

K.1.3 Monitoring indicators

Same as all other technical specifications used in the CommuniTree Carbon Program

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[1] See: https://takingroot.org/2016/05/making-green-charcoal-nicaragua-diaries-industrial-combustion-specialist/
and see: https://takingroot.org/2013/09/update-biochar-pilot-project/

Please note – Since the creation of this technical specification, the project has refined and improved its monitoring approach. This has resulted in a minor deviation from methods described in this section. More information about this is provided in Appendix 2. A larger update to this technical specification is expected later in 2021.

K.1.4 Performance indicators

Performance indicators and the payment plan are summarized in Table K.1.4. Level one starts at year one. To progress to the next level, the target needs to be met. 100% of payments represent the total contract price minus the project's contribution to inputs outlined in Table G-1.

Table K.1.4 – Performance indicators

Level	Basis of payment	Threshold	Target	% of payment received
1	Planting trees at specified density, weeding	Minimum density of 100 trees/ha	Density of 134 trees/ha	Cost of trees
2	Tree survival	Minimum density of 100 trees/ha	Density of 134 trees/ha	Coffee plants + inputs
3	Tree survival	Minimum density of 100 trees/ha	Density of 134 trees/ha	25%
4	Tree survival	Minimum density of 100 trees/ha	Density of 134 trees/ha	25%
5	Basal area	Basal are no less than 75% of target	Basal area no less than 1.95 m^2/ha	0%
6	None			0%
7	Basal area	Basal are no less than 75% of target	Basal area no less than 3.65 m^2/ha	25%
8	None			0%
9	None			0%
10	Basal area	Basal are no less than 75% of target	Basal area no less than 6.45 m^2/ha	25%

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Appendix

Appendix Table G-7 – Occurrence of fruit tree species within sample plots

Fruit Tree Cohort Species	Count
Naranja	14
Mandarina	6
Aguacate	3
Mango	3
Limon real	1

Appendix Table G-8 – Shade tree species

Shade Cohort Species	Count
Guava blanca	163
Guava negra	78
Roble Encino	31
Aguacate de montaña	20
Bucaro	16
Limonsillo	15
Majague	11
Cuerna vaca	8
Cedro pochote	7
Chaperno	7
Guasimo	7
Jocote	7
Laurel	7
Cola de pava	6
Mata palo	6
Cedro real	5
Guarumo	4
Iguera	4
Muñeco	4
Nogal	4
Sangre gado	4
Tenpisque	4
Izote	3
Lechoso	3
Lengua de vaca	3
Tabacon	3
Chilamate	2
Cuero de toro	2
Elequeme	2
Higuera	2
Liquidanbar	2
Mano de leon	2

Manpas	2
Nancite	2
Quebracho	2
Sapote	2
Anona	1
Areno	1
Caoba	1
Capulin	1
Ciruela	1
Cojon de burro	1
Guallaba	1
Guavilan	1
Hachote	1
Lengua de toro	1
Macueliso	1
Madero negro	1
Palo blanco	1
Palo de garabato	1
Pico de pajaro	1
Pino	1
Siruela	1
Tatascan	1
Tiguilote	1
Varilla fina	1

Appendix Table G-9 – Carbon sequestration per hectare

Year	CO2 per hectare (tCO2/ha)	Average CO2/ha	Baseline (tCO2/ha)	Risk buffer (15%)	Net CO2/ha
1	1.90	255.15	13.64	38.27	203.23
2	5.02	255.15	13.64	38.27	203.23
3	10.23	255.15	13.64	38.27	203.23
4	17.72	255.15	13.64	38.27	203.23
5	27.41	255.15	13.64	38.27	203.23
6	39.08	255.15	13.64	38.27	203.23
7	52.45	255.15	13.64	38.27	203.23
8	67.20	255.15	13.64	38.27	203.23
9	83.01	255.15	13.64	38.27	203.23
10	99.58	255.15	13.64	38.27	203.23
11	103.38	255.15	13.64	38.27	203.23
12	120.77	255.15	13.64	38.27	203.23
13	138.23	255.15	13.64	38.27	203.23
14	155.54	255.15	13.64	38.27	203.23
15	172.56	255.15	13.64	38.27	203.23

16	189.18	255.15	13.64	38.27	203.23
17	205.30	255.15	13.64	38.27	203.23
18	220.87	255.15	13.64	38.27	203.23
19	235.84	255.15	13.64	38.27	203.23
20	250.17	255.15	13.64	38.27	203.23
21	250.58	255.15	13.64	38.27	203.23
22	263.69	255.15	13.64	38.27	203.23
23	276.17	255.15	13.64	38.27	203.23
24	287.99	255.15	13.64	38.27	203.23
25	299.15	255.15	13.64	38.27	203.23
26	309.69	255.15	13.64	38.27	203.23
27	319.63	255.15	13.64	38.27	203.23
28	328.99	255.15	13.64	38.27	203.23
29	337.79	255.15	13.64	38.27	203.23
30	346.08	255.15	13.64	38.27	203.23
31	340.61	255.15	13.64	38.27	203.23
32	348.02	255.15	13.64	38.27	203.23
33	355.02	255.15	13.64	38.27	203.23
34	361.61	255.15	13.64	38.27	203.23
35	367.79	255.15	13.64	38.27	203.23
36	373.59	255.15	13.64	38.27	203.23
37	379.05	255.15	13.64	38.27	203.23
38	384.19	255.15	13.64	38.27	203.23
39	389.02	255.15	13.64	38.27	203.23
40	393.58	255.15	13.64	38.27	203.23
41	384.62	255.15	13.64	38.27	203.23
42	388.77	255.15	13.64	38.27	203.23
43	392.73	255.15	13.64	38.27	203.23
44	396.47	255.15	13.64	38.27	203.23
45	400.01	255.15	13.64	38.27	203.23
46	403.36	255.15	13.64	38.27	203.23
47	406.54	255.15	13.64	38.27	203.23
48	409.56	255.15	13.64	38.27	203.23
49	412.43	255.15	13.64	38.27	203.23
50	415.18	255.15	13.64	38.27	203.23

Appendix 2: CommuniTree's Monitoring Approach Largely Consistent with Performance Indicators Outlined in its Technical Specifications

Context

The CommuniTree Caron Program is a Plan Vivo Certified afforestation project managed by Taking Root and funded through the sale of ex-ante carbon credits. Ex-ante carbon credits are issued after the trees have been planted, monitored and reported through an annual report submitted to Plan Vivo. The same report also includes the results of periodic monitoring of land reforested in previous years against a number of performance indicators. The results of the monitoring events are used to 1) assure that the growth of the trees is aligned with carbon sequestration expectations, and 2) to form the basis of the conditional payments given to farmers for the silvicultural activities needed to achieve the targeted growth. The methods used to monitor the performance indicators related to tree growth and silvicultural activities are described and approved in the project's technical specifications.

While Taking Root continues to report monitoring results of newly planted land, members of the Plan Vivo secretariat have raised concerns that the way it reports the monitoring results of land planted from previous years imply the use of methods that differ from those outlined in its technical specifications.

As a result, the Plan Vivo secretariat has requested that Taking Root provides clarity on how the performance indicators are being monitored and how they differ from what is reported in its approved technical specifications.

As detailed in the sections below, despite the level of increased sophistication in how the CommuniTree carbon program operates since last updating its technical specifications in 2017, monitoring of performance indicators is surprisingly unchanged. The monitoring and frequency of performance indicators related to carbon sequestration is largely unchanged, the monitoring and frequency of performance indicators related to silvicultural activities is largely unchanged, but a number of discrepancies in CommuniTree's technical specifications create confusion and therefore need to be updated.

1. Monitoring and Frequency of Performance Indicators Related to Growth and Carbon Sequestration is Largely Unchanged

The carbon modelling used in CommuniTree's technical specifications is based on estimating carbon as a function of measurements of a sample of individual trees' DBH and extrapolating that to the population of trees planted. Specifically, Table K.1.4 on p. 26 says that basal area per hectare (i.e. the sum of all the trees' diameters) are measured twice over a 10 year period (i.e. in years 4 and 7) and Section 11.1 (in other technical specifications, of which this one follows) specifies that such measurements take place using forest inventories.

To this day, this is how monitoring of performance indicators related to tree growth and carbon sequestration take place and is reported against in CommuniTree's annual reports. Taking Root has even started implementing a plan to increase the frequency of its forest inventories from two to four times over a 10-year period, in years 1, 3, 5, and 10.

2. Monitoring and Frequency of Performance Indicators Related to Activities is largely unchanged

CommuniTree's technical specifications specify that a number of silvicultural activities need to take place so that the trees reach the expected growth milestones, but that are themselves not directly related to carbon sequestration. These activities form the basis of farmer payments and include things like planting, weeding and pruning (see Table K.1.4).

The documentation also says that in the early years, after a new piece of land is added to the program, multiple different payments are made to cover the costs of doing these required activities. The two paragraphs below Table K.1.4 (p.26), also specify that completion of these activities is assessed by the supervising technician's judgment (i.e. not forest inventories).

To this day, this is how activity-based monitoring operates within the CommuniTree Carbon Program. Specific details are provided in Appendix 2.1. Silvicultural activities are assessed based on technician visits to visually determine whether activities have been performed such as trees planted, weeded, etc. Given that these activities are very time sensitive and critical to the project's success, the frequency can be as high as 17 visits per year. For such activities, the technician visits the site and takes a picture as evidence that the activity was performed before releasing payment. The summary on the number of this activity-based monitoring is reported in Taking Root's latest annual report in Table 7 on socio-economic data under Social Impact. In 2020, 18 889 of these events took place within the program.

3. Discrepancies in Approved Technical Specifications that need to be Updated

There are a number of relevant discrepancies in the CommuniTree's technical specifications that cause confusion and therefore need to be addressed in the PDD update scheduled for later this year.

Section 11.1 in the other technical specifications (of which this technical specification's monitoring follows) is called "Annual Monitoring Methodology" and explains how forest inventories are performed. While the forest inventory takes pace annually, this does not mean that every parcel of land is monitored annually using forest inventories. This confusion is amplified by the fact that many of the monitoring targets are very quantitative (e.g. 375 trees per hectare).

However, the following areas of the same document make clear that this was not intended to imply that every piece of land has a forest inventory performed every year:

- Some of the performance targets detailed in Table K.1.4 are not easily addressed through forest inventories like the status of fences. Rather, forest inventories should only be used to measure the size of trees so that carbon estimates can be extrapolated.

- The text in the paragraph below Table K.1.4 makes clear that activity-based monitoring takes place multiple times in one year, and that wouldn't sensibly be done using forest inventories.

Furthermore, no sensible forestry organization in the world performs ground-based forest inventories annually on the same piece of land given the cost and complexity of doing so. This holds true for large timber concessions, so it is especially untrue for smallholder programs that need to monitor thousands of small pieces of land spread over large distances.

These discrepancies are likely the result of an imperfect update in 2017 to the original version of the technical specifications published in 2010.

To fix this issue, the technical specifications need to be updated. Specifically, Section K should clearly specify that carbon sequestration targets are monitored using forest inventories and that these forest inventories are done at least every five years. It should also specify that activity-based monitoring of silvicultural activities is done more frequently by technician site visits.

Appendix 2.1 - Process made for monitoring activities and releasing payments to farmers

Payments to farmers are made using the following annual process:

1. The technician works with the farmer on a case-by-case basis to assess the activities required for the optimal establishment and growth of the trees (e.g. fencing the property, preparing the land for planting, preparing tree nurseries, planting, weeding, pruning, etc.).

2. The technician and the farmer agree on a budget for the given activity based on the state of the parcel, which has to be inferior to that year's annual budget based on their performance-based agreement.

3. The technician requests the budget from their regional coordinator, who confirms the availability of funds and that the request is reasonable based on completing and signing a request for funds form. If the request for funds is > $700, the head of operations (i.e. the regional coordinator's superior) also needs to approve.

4. The regional coordinator passes the signed request for funds form to the administration department, which does a final review against the allocated budget and issues a cheque for that amount in the farmer's name.

5. The technician reviews the completion of the farmer's activity and records the results, including a geo-tagged picture in FARM-TRACE, and gives the farmer the cheque. Should the activity not be completed, the farmer does not receive the payment.

6. When multiple activities are not complete and/or the farmer demonstrates an unwillingness to carry out the activities as outlined by the PES agreement, they are removed from the program and new land is recruited as a substitute.