TAKING ROOT ENRACINE

Social reforestation & Carbon offsets

Technical Specification
Mixed Species Forest Plantation

Registered Plan Vivo Project:
The CommuniTree Carbon Program

(Formally known as the Limay Community Carbon Project)

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Version: 2014-08-14

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1. Executive Summary

The CommuniTree Carbon program (formally know as the Limay Community Carbon Project) is a community-based reforestation initiative that regroups small-scale farming families in the municipality of San Juan de Limay and Somoto, Nicaragua, to develop ecosystem services for the voluntary carbon market. The program is developed by Taking Root, a non-profit organization based in Montreal, Canada, in partnership with the Nicaraguan organization, APRODEIN.

The CommuniTree Carbon program uses reforestation as a tool to restore ecosystems, improve livelihoods and tackle climate change. Taking into account the causes of deforestation, the program works with smallholder farmers to reforest and maintain under-utilized portions of their land in exchange for payments for ecosystem services.

Reforestation within the program boundary is imperative as the region is situated upon a critical watershed that feeds into one of the country's most important estuaries, the Estero Real. This estuary is home to one of the biggest extensions of mangroves and migratory birds in the region, and has been recognized by the Ramsar Convention on Wetlands of International Importance. By reforesting this region, the program plays an important role in regulating the hydrological cycle, providing important water and biodiversity benefits both locally and internationally.

This Mixed Species Forest Plantation design consists of five native tree species, alternating in rows of nitrogen fixing species produced for fuelwood and longer-lived timber species. The fuelwood species are coppiced at a young age, providing an early harvest while fertilizing the soil and providing more room for the other trees to grow. These trees are progressively thinned out to provide a sustainable source of posts and timber while allowing room for the natural regeneration of new tree species. The plantation starts off as an intensely managed woodlot and evolves into a sustainably managed native forest.

The ex-ante sale of ecosystem services generated through the program is used to fund the establishment and maintenance of new family-led projects while the sustainable production of forest products provides an ongoing source of value in the medium and long run.

This Technical Specification was developed through a community-led design process where participating communities and local professionals determined details such as the plantation species, planting method, and payment process. Each program participant was then responsible for developing and following their own personalized farm management plans (*plan vivo*). Participants are involved in every step of the process, including pre-planting, planting, maintenance and management activities. The average net carbon benefit of this technical specification is 81.7 tonnes of carbon per hectare. This carbon benefit was calculated by estimating the average carbon stock expected under the baseline scenario while subtracting a risk buffer of 15%.

In order to be eligible, farmers must own economically under-utilized land within the program boundary that is in need of reforestation. They must also demonstrate that participating in the program will not conflict with their subsistence activities, notably cattle ranching and agriculture.

To guarantee the accuracy and success of the program, Taking Root had developed a rigorous monitoring system. Systematically distributed permanent plots have been established on a minimum of 10% of the areas using this technical specification and annual monitoring is conducted to gather information on species composition, mortality, height, and diameter at breast height. Based on these results, participating participants receive ecosystem service payments upon successfully meeting established management and growth targets. Furthermore, this monitoring, along with research results, is used to modify management on a continual basis to ensure that carbon sequestration objectives are being met. This system of adaptive forest management is achieved by allowing room to account for natural regeneration and early or delayed harvest of fuelwood species based on actual stand growth.

2. Introduction

The CommuniTree Carbon Program (CTCP) is a community-based reforestation initiative in the municipalities of San Juan de Limay and Somoto, Nicaragua, located in the departments of Estelí and Madríz, respectively. Although once entirely forested, the region has suffered from heavy environmental degradation predominantly due to unsustainable agricultural practices. To this day, the majority of livelihoods are dependent on agriculture and raising cattle despite low productivity caused by poorly distributed rainfall.

The CTCP invites smallholder-farming families to work together to reforest underutilized portions of their land in exchange for ecosystem service payments, technical training and market development for their plantation products. To participate in the reforestation activities described in this specification, smallholder farmers must have a clear land title to land that is not being used for agricultural purposes and that is not currently forested.

The ecosystem services provided by the program are sold as Plan Vivo certificates, which represent long-term sequestration of one tonne of carbon dioxide (tCO_2), as well as livelihood and ecosystem benefits. In addition to these benefits, the program plays an important role in the regulation of the hydrological cycle as it is developed on one of the region's most critical watersheds.

Taking Root, a Canada-based non-profit organization, coordinates CTCP in partnership with APRODIEN, a Nicaraguan service provider and partner.

This technical specification provides details on the program intervention, planting methodology, calculation of the carbon baseline scenario, calculation of the carbon benefit, how long-term carbon sequestration is assured, what measures are taken to avoid leakage, the additionality of the program, the monitoring plan and additional ecosystem benefits.

3. Program Intervention

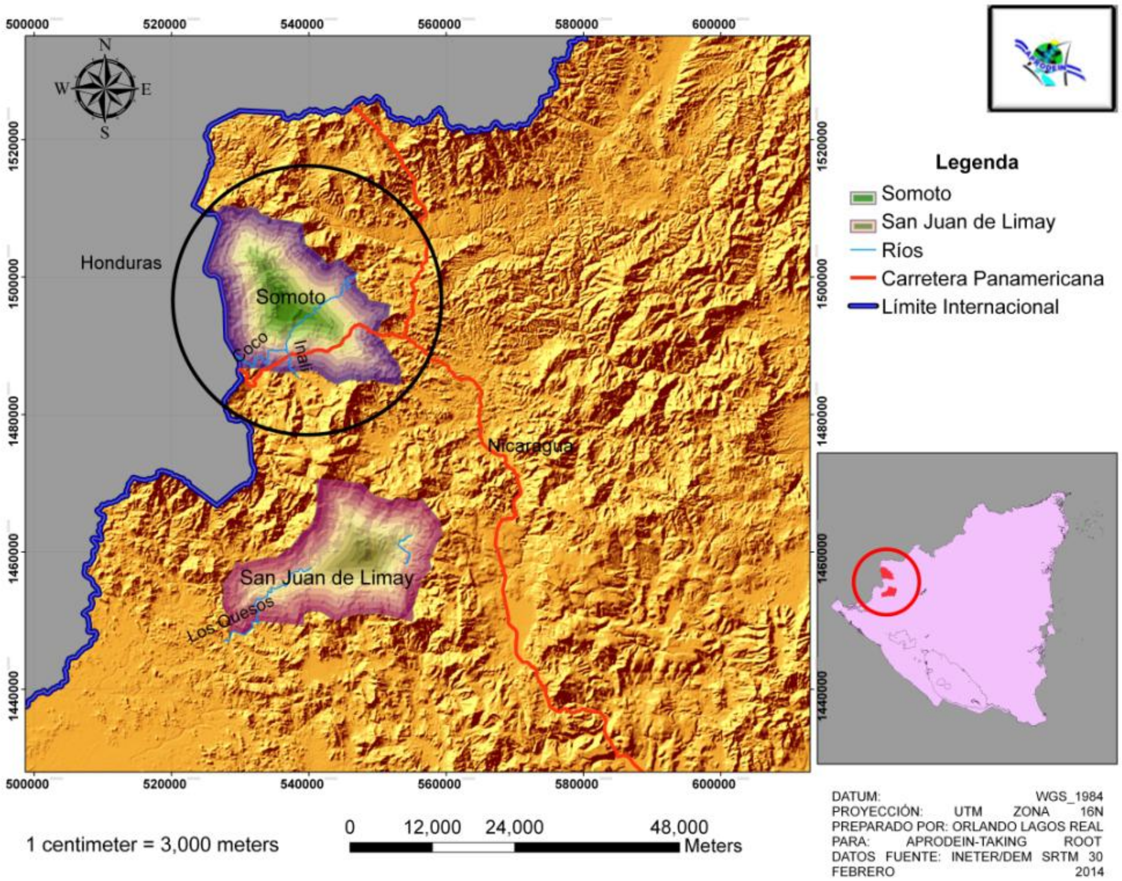
The Mixed Species Forest Plantation technical specification is reforestation using native tree species. As a whole, the components of the CTCP are designed to reduce carbon emissions through forest plantation carbon sequestration and the production of sustainably produced fuelwood and timber products.

3.1. Applicability

In order to be eligible to participate in the program, farmers must have underutilized land that falls within suitable areas of the current program boundary. This boundary corresponds with the municipal boundary of San Juan de Limay and Somoto, highlighted in Figure 1.

Additionally, participating farmers must make personalized farm management plans (Plan Vivos) that demonstrate they own additional land sufficient for their agricultural needs. Farmers cannot clear forested land to gain eligibility and they must demonstrate clear land title to their farm.

Figure 1 – Program boundaries in the municipalities of San Juan de Limay and Somoto



3.2. Elevation Requirements

Due to the selected tree species, optimal growth for the selected plantation design must take place at elevations below 900 metres above sea level. An elevation map of the program boundary is illustrated in Figure 2 and Figure 3.

Figure 2 – Elevation map of San Juan de Limay

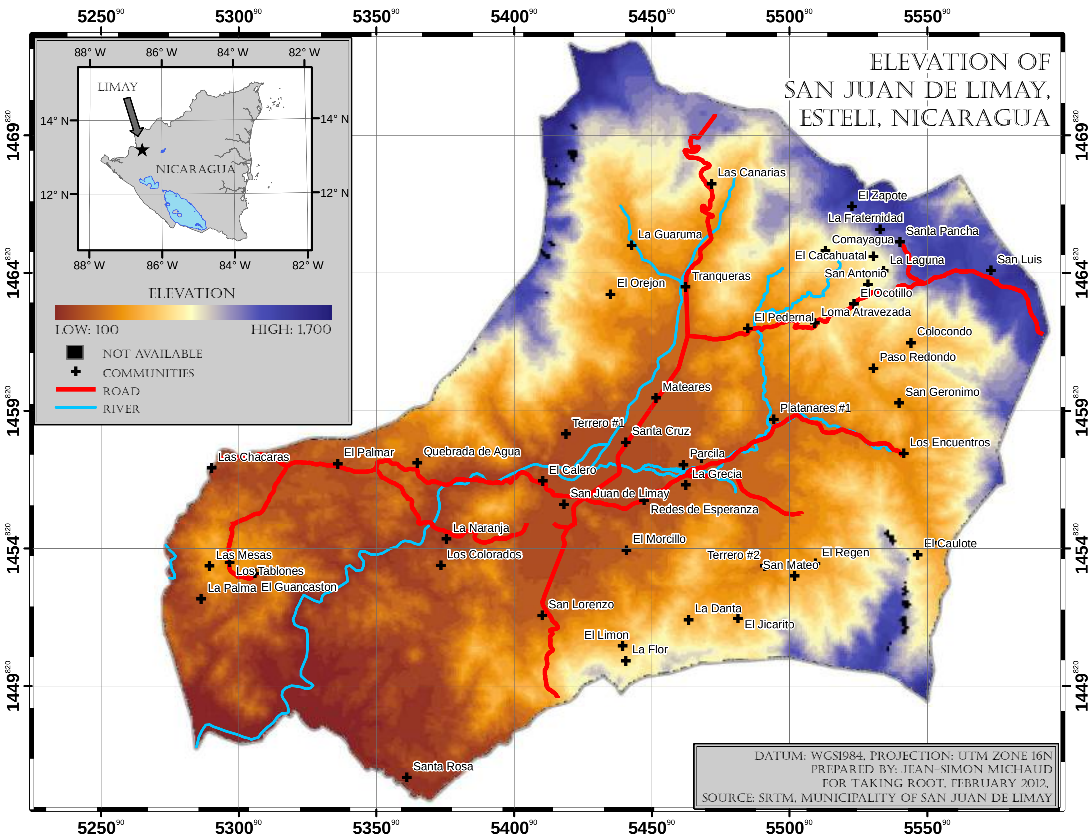
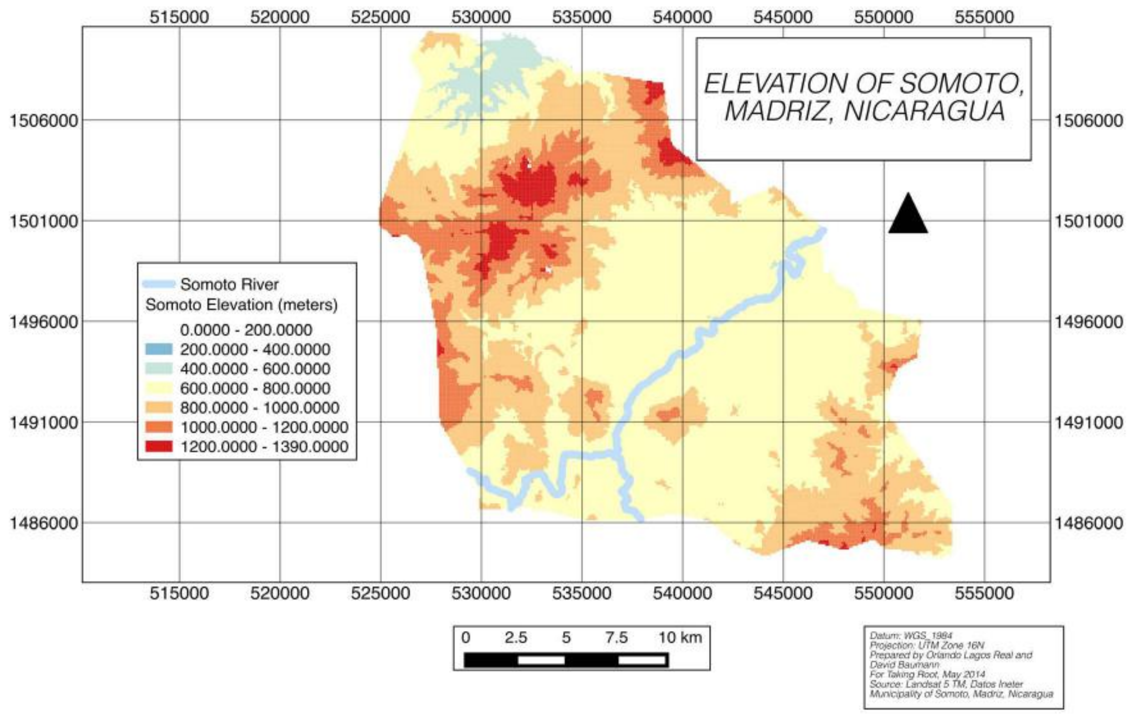


Figure 3 - Somoto Elevation Map



3.3. Land-Use and Land cover

The land use and land cover of the program area have changed drastically over the past century. Once blanketed in forest with abundant precipitation and wildlife, the program area was transformed during the "Green Revolution" of the 1950s when vast areas of land were cleared for large-scale cotton production. By the end of the 1980s, a drop in world cotton prices left farmers in ruins. The area faced heavy erosion and was contaminated with toxic pesticides, leaving behind what is now a seasonal desert with only small patches of secondary forest at higher elevations. [1]

The steeper summits of taller mountains still contain some old pine forests, and remnants of the giant trees that were once typical in the region remain scattered throughout the valley. The most common mature large trees are *Enterolobium cyclocarpum*, *Ceiba pentandra*, and *Albizia saman*. These are extremely fast growing trees that are not particularly valuable timbers. Valuable timber trees such as, Pacific Mahogany (*Swietenia humilis*) and Spiny Cedar (*Bombacopsis quinata*), that were once abundant in the area are close to eliminated.

Presently, the predominant land-use in the area is cattle grazing. However, due to the prolonged 6-month dry season, it requires an estimated 1.4 hectares of pasture to support just one head of cattle. A common land-use strategy in the region is to grow grains for a couple of years then convert the area to cattle pasture. Once the area becomes too degraded to support pasture, it is abandoned for several years and is eventually cleared again for agriculture.

3.4. Climatic Conditions

The region's climate is characterized as dry tropical savannahs with a small sub-humid zone at altitude. Temperatures range between 24-34^{o} C with distinct wet and dry seasons. The wet season begins in May and ends in October. Annual precipitation within the program boundary is 1,394 mm per year, almost all of which falls during the wet season.

3.5. Social Context

The regions of San Jan de Limay and Somoto, as well as the whole of Nicaragua, have undergone drastic political shifts throughout the last century. Clashes between the Sandinista National Liberation Front, the Contras and the Somoza dynasty caused much turmoil for the economy, the people and the land.

International financial institutions, such as the World Bank and the International Monetary Fund, have placed strict regulations on the Nicaraguan government while it pays back external debts that were amassed during this time. As a result, the government has had to cut back on spending, including huge slashes to environmental programs and law enforcement. [1]

3.6. Population

The following socio-economic information is available for the municipality of San Juan de Limay:[4]

Urban inhabitants: 3,668
Rural inhabitants: 9,787
Total inhabitants: 13,455
Population density: 31.5/km^2
Indigenous population: 5,519

The following socio-economic information is available for the municipality of Somoto:

Urban inhabitants: 15,974
Rural inhabitants: 16,406
Total inhabitants: 32,380

Somoto is a "young town", with nearly half of the population in the age groups of 0-4 years (15.5%), 5-9 years (14.2%), and 10-14 years (14.5%) as of 2000.

3.7. Predominant Religions

Catholic and Evangelical Christianity are the primary religions in the program area.

3.8. Local Economy

The local labour force in the program area is divided as follows (Figure 4):

58% smallholder farmers, earning sustenance directly from the cultivation of beans, corn, sorghum dairy and cattle (program target group)

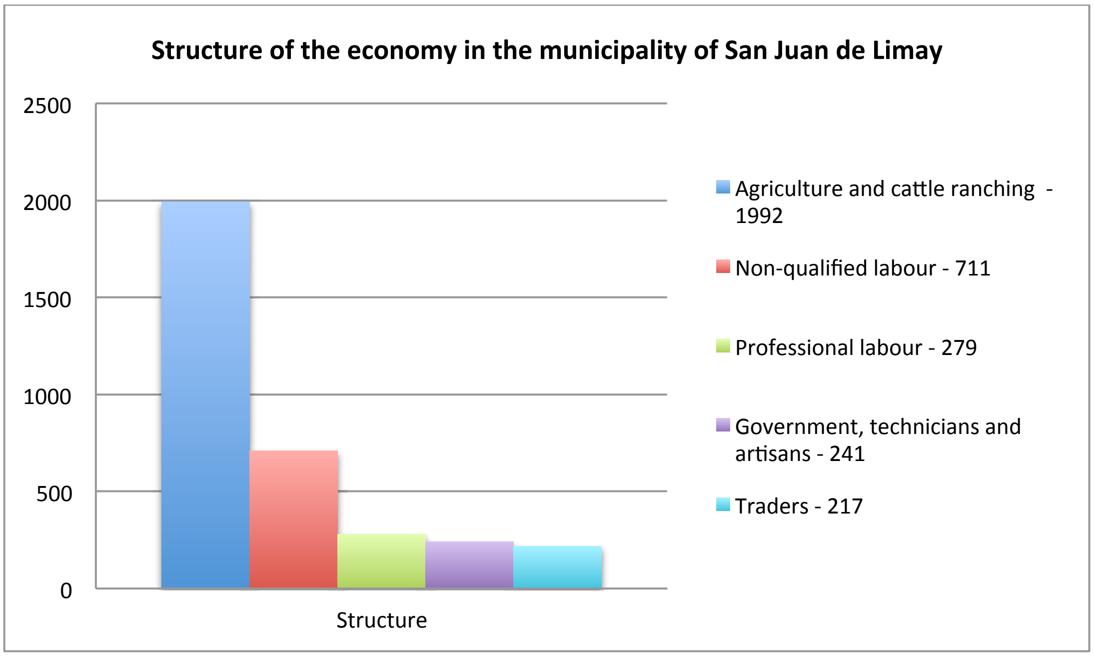
21% non-qualified labours, generally working as contractors on other farms or doing general construction work

8% office-based professionals or technicians

7% government employees and artisans, predominantly carving soapstone

6% traders, generally buying and selling farmers agricultural surplus

Figure 4 – Structure of local economy in San Juan de Limay[4]



Agriculture is the most important sector of the economy and encompasses both the production of agricultural goods as well as processing and trading. However, agricultural activities commonly take place with no regard to zoning or optimizing the potential of the area. Although farmers in the region of San Juan de Limay have relatively large properties with fertile soils, most farming is done purely for subsistence rather than business and is not very productive. This is largely due to the poorly distributed rainfall, lack of irrigation, and a lack of access to financing.

Presently, only a small area is dedicated to agriculture within the municipality of San Juan de Limay. The main crops are sorghum, corn, and beans. In regions with higher elevations, coffee is cultivated. The average yields of most crops are low.

A combination of poor management of the available resources and excessive deforestation has contributed to food insecurity and adversely affected people's economic opportunities.

Fuelwood Use

Within the municipality, 95.5% of the population use fuelwood for cooking. Outside of the urban centre and within the program boundary, this percentage increases to 99.2%[5]. The collection of fuelwood is a continual cause of degradation for the surrounding forest, as virtually none of it is sustainably produced. Regional and national deforestation is increasing along with the demand for fuelwood. This makes finding accessible sources of fuelwood difficult.

A secondary consequence of burning fuelwood in households is the negative health effect it has on people's vision and respiratory tracts as a result of excessive smoke inhalation. This adversely affects the women in the families as they spend a higher proportion of their time in the kitchen area.

3.9. Community Led Design

As is the standard of all Plan Vivo projects, the development process of the program intervention was highly influenced by a process of Community Led Design (CLD). CLD gives participants a vital role in shaping the program according to their needs and allows them to develop a strong sense of ownership. This process is implemented on a continual basis throughout the program lifetime.

3.10. Community Led Process Determination

The Mixed Species Forest Plantation requires multiple steps, from conception, to payment, to cultivation. These steps are continually revaluated and improved upon to ensure efficient and equitable results for the participants and the participating communities. The following are examples of decisions made through the CLD process concerning the program development:[*]

The selection of the program boundary to encompass watershed management

The tree species used

The fencing and labour loan system

The timing of payments

See the Taking Root's *Plan Vivo project Design Document – CommuniTree Carbon Program* for more information.[6]

4. Description of Activities

Intervention: Reforestation
Title: Mixed Species Forest Plantation

Brief Description

This system involves the planting and intensive management of multi-purposed mixed species forest plantations. All of the selected species are, or were, commonly found within the municipalities of Limay and Somoto and are native to the region. The plantations consist of alternating rows of fast growing fuelwood species and longer-lived timber species. The fuelwood species are nitrogen fixing and will be coppiced at a young age, providing an early harvest of fuelwood while fertilizing the soil. The timber species are of variable growth rates and shapes allowing for variable thinning before the entire stand reaches maturity.

This system is designed to provide benefits to participants in the short, medium and long-term. In the short term, participants receive payments for the ecosystem services; in the medium-term, participants benefit form the subsistence harvest or sale of fuelwood; and in the long-term

[*] All of the meetings mentioned in this section have been recorded and are available upon request.

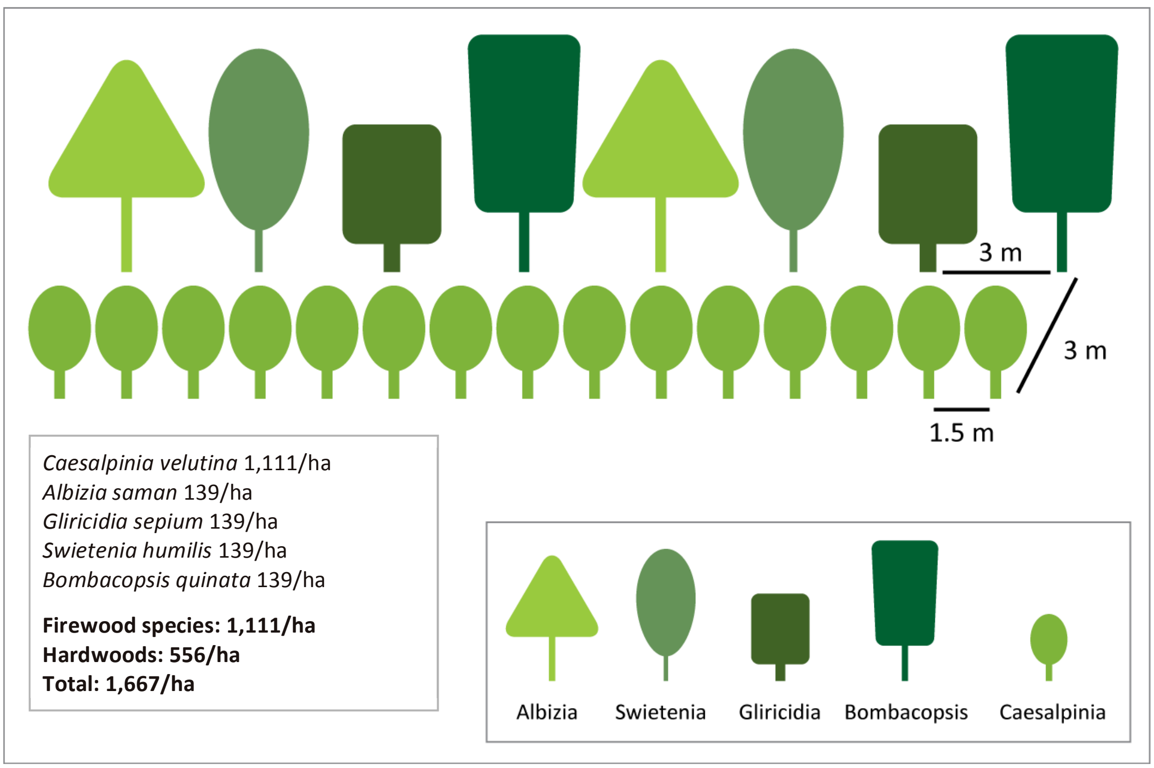
participants benefit from the harvest and sale of high valued timber. The revenue from the sustainable managed harvests create incentive for the farmers to continue participating in the program since the revenue is expected to be larger than the ecosystem payments of the first phase of the program.

During the span of the program, participants will receive continual education on the environmental, economic and social benefits of the program.

4.1. Planting Design

Density: The planting design consists of alternating rows of fuelwood species and timber species. The fuelwood species are planted in rows with 1.5 metres between trees. The longer-lived timber species are planted with 3 metres between each tree. Fuelwood and timber rows are planted 3 metres apart, as illustrated in Figure 5.

Figure 5 – Planting Schematics



4.2. Activity Plan

The activity plan sets forth the various steps that need to be undertaken for the proper establishment of the technical specification and outlines the responsibilities of program members. The plan is designed through a process of consultation between various stakeholders, participant groups and regional experts. Since it is the participants who are responsible for their own part of the program, the activity plan serves as the minimum standard required for the program to be effective and payments are based on the successful implementation of the activity plan. However, individual participants have the freedom to exceed the standards set forth by the plan.

Pre-Planting Activities

Each year, prior to planting, the following activities are carried out.

Seed Collection

Seeds from native tree species are collected and purchased throughout the region by program staff and participating participants. Whatever cannot be found locally is purchased from outside communities.

Nursery Development

Many of the seedlings are grown in communal nurseries, established by the year's participating participants and supervised by the community technicians to ensure the highest quality of seedlings (see Figure 6). Some nurseries are established directly on participants' land to simplify transportation.

The earth for the seedlings is a mixture of sand from the riverbed, on-site soil, and manure. Seedling bags are filled with the earth mixture and placed in trenches approximately 10 centimeters deep. The seeds are sewn between February and April depending on the species.

Figure 6 – Nursery establishment

Fence Building

Prior to the planting season, each area is fenced-in to prevent cattle from grazing on the seedlings. The participants purchase the materials themselves, often using interest-free advanced loan payments.

Clearing

Prior to the planting season, the parcels that will be reforested are cleared of all brush and small bushes. Due to the dispersed nature of these parcels, the barren land between them functions as natural firebreaks.

Planting Activities

Participants and members of the community carry out the following activities during the planting season.

Planting Site Demarcation

Rope with knots or labels at even distances is used to demarcate where the trees will be planted according to the planting design (see Figure 7).

Clearing

A 2-metre diameter circle is cleared around each site demarcation to remove competing grasses and shrubs before the seedling is planted.

Hole Digging

At the centre of each clearing, a hole slightly larger than the seedling rootstock is dug (see Figure 8).

Tree Planting

The seedling is carefully removed from the nursery bag and planted in the hole. Particular attention is paid to ensure the correct species are planted according to the planting design. Each seedling is planted at ground level (or slightly deeper) so that water accumulates around the seedling (see Figure 9).

Figure 7 – Site demarcation

Figure 8 – Hole digging

Figure 9 – Tree planting

Maintenance and Management Activities

Once the seedlings have been planted, the following activities are carried out to ensure their survival.

Clearing

A 2-meter diameter circle is cleared as needed around each tree with a machete to remove competing grasses, shrubs and lianas.

Pruning

For timber species, the lateral branches of the bottom two thirds of the tree are sawn off to encourage upward apical growth and to minimize knotting. Montero and Viquez suggest that pruning schedules should be based on tree height as opposed to age and that a cost effective schedule should start when the trees reach between 5 and 6 metres in height.[7] Branches are to be removed from the bottom two metres of the tree. The second pruning should take place when the trees reach between 8 and 9 metres, and branches from the bottom 4 metres of the tree are removed. A third and final pruning should take place when the trees reach 12 metres and the bottom 7 metres are cleared of lateral branches. All pruning should take place during the dry season and should be done using well-sharpened tools to avoid damaging the tree as much as possible; this will subsequently aid in avoiding pests and diseases.[7] Pruning is not required for *Caesalpinia velutina* since these trees will only be used for fuelwood and the presence of knots is not important.

The above activities as well as their time requirements, frequency and estimated costs are summarized in Table 1 below.

Table 1 – Summary of Activity Plan

Tasks	Responsible parties	Time-frame	Resource requirements	Time requirements (ha)	Estimated initial cost per ha	Estimated annual cost per ha
Construction of tree nurseries	Community technicians + participating families	January until May	Machete, rope, shovel, wheelbarrow, barbed wire, sifter, bags, manure, sand, earth, water, seeds.	Size dependent	$81.17	n/a
Fencing area; Maintaining or repairing property fence	Participating families	Prior to planting	Fencing and wire	Dependent on needs	140.81	n/a
Clearing property for planting	Participating families	April	Machete	Property dependent	$72.01 (Participant's work contribution)	n/a
Planting activities	Participating families + guidance from community technicians	After the first big rain (~May 15th)	Shovel, rope, machete, wheelbarrows.	~16 person working days	$63.00 (Participant's work contribution)	n/a
Clearing around trees	Participating families	1st few years	Machete	30 person working days	n/a	$117.00 (Participant's work contribution)
Building and maintenance of fire breaks	Participating families + guidance from community technicians	Every Year	Machete, Shovel	As required	n/a	~10.00 Participant's work contribution
Pruning	Participating families	Ongoing as needed	Saw or pruning scissors	As required	n/a	$8.00 (Participant's work contribution)

4.3. Thinning and Harvests–Individual Tree Monitoring (Years 1-25)

Table 2 outlines what species are harvested, the year of harvesting, the intended use, the processing factor (the proportion of the harvest that is utilized and continues storing carbon), and the volume that is represented through these activities over the initial 25 years of the program.

Table 2 –Harvest years and associated volume of merchantable timber per hectare

Beginning of Year	Species	Harvested stem volume (m^3 / ha)	Product	Processing factor	Merchantable volume (m^3 / ha)
8	*Caesalpinia velutina*	13.9	Fuelwood	1.0	13.9
8	*Gliricidia sepium*	1.2	Posts	.8	1.0
14	*Albizia saman*	102.0	Sawn-wood	0.35	35.7
25	*Bombacopsis*	22.5	Sawn-wood	0.35	7.9
25	*Swietenia humilis*	22.5	Sawn-wood	0.35	7.9

4.4. Thinning and Harvests – Stand Management Phase (Yr 26-50)

After the first 25 years, the stand will have approached its optimal rotation cycle and ongoing selective harvesting will commence. The mature trees will be harvested at a rate comparable to the long-term growth rate of the stand. As a whole, the overall volume and carbon stocks fluctuate around the long-term average. Starting in year 26, 45 cubic metres of wood products per hectare will be selectively cut from the stand every 5 years. (See Appendix 3 - Stand Growth Modelling for more information.)

4.5. Incentives for Participation in the Program

There are various goods from this program that incentivize the participating smallholders to stay in the program during its 50-year lifetime. They are as follows:

- Regular ecosystem payments of the first 10 years

Wood products harvested in the first 25 years

Wood products harvested during the stand phase over the next 25 years

Facilitated market access for participants wood products

Note: The wood products used in this program are all of high value and should provide a large amount of income surpassing the carbon payments of the first 10 years. Through the program contract, the participating smallholders have a legal obligation to stay in the program for 50 years.

4.6. Species Selection

The Mixed Species Forest Plantation is based on five species of varying growth, use and shape. All species are well adapted to the climatic conditions of the region and are valued by the participating smallholders, technical experts, and local markets.

Species Selection Process

The species selection process has been conducted in the following order:

1. Participants were consulted to determine the favoured native species with which to work;
2. Experts were also consulted to determine the favoured species with which to work within the technical specification;
3. The species that overlap with both participants and experts were selected; and
4. From experience using older versions of this technical specification, species selection has been refined based on experience in the field.

4.7. Species Description

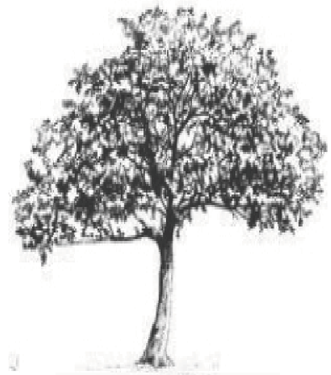
The following species were selected for the technical specification. All information on the species was taken from the *Guia de especies forestales de Nicaragua*.[8]

Name: *Bombacopsis quinata* (recently renamed to Pachira quinata)
Common names: Pochote, Spiny Cedar
Family: Bombacacea
Distribution: Found naturally from Nicaragua to Columbia and Venezuela
Elevation: 0-900 metres above sea level
Precipitation: 800-2200 millimetres
Description: The tree is deciduous with numerous thorns and grows to 30 metres in height with medium sized buttresses. It is highly prized for its reddish brown wood and has been overexploited in many parts of its natural range.
Uses: Sawn-wood

Name: *Swietenia humilis*
Common names: Caoba, Pacific Coast Mahogany, Honduran Mahogany
Family: Meleaceae
Distribution: Found naturally from Mexico to Costa Rica
Elevation: 0-1,200 metres above sea level[9]
Precipitation: 1100-1400 millimetres
Description: The tree reaches heights between 25 and 40 metres
Pests: Hypsipyla grandella, a shoot-borer that attacks and kills young shoots causing excessive branching. This only takes place during the first 2 to 3 years and thus requires pruning. This species should not be planted in monocultures.
Uses: Sawn-wood

Name: *Caesalpinia velutina*
Common names: Mandagual
Family: Caesalpiniaceae
Distribution: Dry regions from Southern Mexico to Northern Nicaragua
Elevation: 50-1000 metres above sea level
Precipitation: 400-1200 millimetres
Description: Fast growing leguminous tree that thrives in dry conditions, Mandagual rarely reaches heights above 10 metres and diameters of 30 centimeters.
Uses: Posts, fences and soil fertilization

Name: *Albizia saman*
Common names: Genisaro, Rain Tree
Family: Mimosaceae
Distribution: Mexico to Brazil
Elevation: 0-1,300 metres above sea level[9]
Precipitation: 760-3,000 millimetres
Description: Fast growing nitrogen-fixing tree that can reach heights of up to 30 metres and diameters of 1.2 metres.
Uses: Sawn-wood, fodder and soil fertilization



Name: *Gliricidia sepium*
Common names: Madreado, Michigüiste, Gliricidia
Family: Fabaceae
Distribution: Mexico to Columbia
Elevation: 0-1,200 metres above sea level
Precipitation: 500-3,500 millimetres; grows best between 900-3,500 millimetres/year
Description: Small to medium sized nitrogen-fixing tree that is commonly used in agro-forestry systems due to its ability to be grown from stakes.
Uses: Living fences, firewood, posts and soil fertilization
Special note: G. sepium leaves are rich in protein, highly digestible, and low in fibre and tannin. The wood burns slowly without sparking and with little smoke, so it is important fuelwood in the sub-humid tropics. As a green manure, G. sepium increases soil organic matter and aids in recycling of soil nutrients as it produces much litter. It also improves soil aeration and reduces soil temperature. It is a drought-resistant and valuable water-conserving species because in the dry season it sheds most of its leaves, hence reducing water loss through transpiration. Its fast growth, ease of propagation, nitrogen fixing ability and light canopy makes it ideal as live stakes.

5. Baseline

The first phase of determining baseline conditions consists of establishing the initial carbon stock present within the above ground woody biomass and the below ground woody biomass. Deadwood was excluded from this baseline because its presence is negligible, as confirmed by an original baseline calculation in a sub-region of the current program boundary. The objective is to obtain an estimate of initial carbon stocks with a precision of plus or minus 15% with a 90% confidence level (two-tailed). To estimate the initial carbon stock, the program boundary was stratified into various vegetation land-covers and sampled. The methodology in the section is based on the Winrock International Sourcebook for Land Use, Land-Use Change and Forestry Projects.[10] The second phase consists of determining the trend of the carbon stock over time in the absence of the program.

Baseline calculations for the San Juan de Limay program area were performed in 2011. Baseline calculations for the new program area in Somoto were preformed in 2014.

5.1. Stratification

First, two Landsat 5 TM+ images (2010-12-23, 2011-01-08) of the scene 17-51 were acquired from the United State Geological Survey (USGS) web site.[11] These 30-meter spatial resolution images were selected by considering seasonality of the imagery, minimum variation in reflectance related to dry or wet season vegetation characteristics, and atmospheric contamination. Atmospheric correction was computed on the two images, which yielded reflectance values corrected from the contamination effect of atmospheric particles that absorb and scatter the radiation from the Earth’s surface. Clouds and cloud-shadow presence are also a significant problem when using remote sensing images over humid and tropical latitudes.[12] Therefore, in addition to the reflectance computation, it was necessary to mask clouds and cloud-shadows when encountered.

Second, a fieldwork campaign was conducted to develop a stratification scheme of the different vegetation types and also to train and test the classification products. Patches of uniform vegetation cover of different sites across the study area were identified with handheld GPS units. Based on the initial surveys, the program area was stratified into three broad classes: (i) agriculture-pasture, (ii) bushy vegetation and (iii) forest.

Thirdly, clouds were identified using a decision tree based on the brightness values of the band 1 (blue) and band 6 (thermal). Cloud shadows were identified using a threshold of the band 4 (near infra-red). A 90-meter buffer was computed on areas masked from clouds and cloud-shadow to ensure that all scenes were free of cloud contamination. Following this procedure, an unsupervised classification was performed on each individual scene (TM+ image) and purged of cloud contamination using the ISODATA (Iterative Self Organizing Data Analysis Technique) approach. ISODATA, one of the most common unsupervised classification algorithms,[13] assigns given pixels to a specific cluster based on the multidimensional space attributes and aggregates clusters together based on their spectral similarity.[14] The classification approach was conducted over a combination of products derived from the Landsat 5 TM+ spectral bands. A Normalized Difference Vegetation Index (NDVI) was calculated from the red and near-infrared bands. NDVI is an indicator of the density of healthy vegetation. NDVI is useful in the program ecosystems as it normalizes the substantial illumination effects in mountainous regions, which can yield significant inaccurate reflectance values. In addition to NDVI, the Principal Component Analysis (PCA) technique was conducted over all the Landsat 5 TM+ bands, except band six (thermal band) to exclude the noise and summarise most of the variance. PCA is a useful variable reduction technique that is commonly employed with environmental remote sensing imagery.[15] The PCA components containing most of the variance (PCA1, PCA2, and PCA3) were coupled with NDVI and used as input in the classification algorithm. After performing the classification on each individual image, the two classifications were combined by giving priority to the 2010-12-23 scene, as this scene had less cloud contamination and thus provided a more uniform representation of the landscape.

Lastly, the accuracy of the final classification product was evaluated by comparing vegetation cover types recorded in the pilot biomass survey (further described in Section 0) to the vegetation cover types classified by the algorithm (see

Table 3). Agriculture and forest vegetation cover classes were accurately classified, but the bushy vegetation strata had lower accuracy (i.e., user's accuracy of 50%). However, most of the erroneous classification for this stratum was due to agriculture (lower carbon stock) being classified as bushy vegetation (higher carbon stock). This misclassification is acceptable as it results in a conservative carbon estimate. Once the classification was computed, a random sampling approach was used to establish 416 plots across the study area where forest is not present.

Table 3 – Confusion matrix of predicted classes of vegetation classification in San Juan de Limay

	Predicted class			
Observed class	**Agriculture**	**Bushy Vegetation**	**Forest**	**Σ**
Agriculture	11	9	3	23
Bushy Vegetation	1	11	6	18
Forest	0	2	11	13
Σ	12	22	20	54
User's accuracy (%)	91.67	50.00	55.00	
Overall accuracy (%)	61.10			

Table 4.1 & 4.2 – Confusion matrix of predicted classes of vegetation classification in Somoto from LANDSAT IMAGES 2010 & 2011

Table 4.1 - 2010 Image

Observed class	Agriculture & Pasture	Bushy Vegetation	Forest	Σ
Agriculture & Pasture	443	4	3	450
Bushy Vegetation	157	24	19	200
Forest	27	0	183	210
Σ	627	28	205	860
User's accuracy (%)	70.65	85.71	89.27	
Overall accuracy (%)	75.58			

Table 4.2 2011 Image

Observed class	**Agriculture & Pasture**	**Bushy Vegetation**	**Forest**	**Σ**
Agriculture & Pasture	423	25	1	449
Bushy Vegetation	188	42	21	251
Forest	16	12	394	422
Σ	627	79	416	1122
User's accuracy (%)	67.46	53.16	94.71	
Overall accuracy (%)	76.56			

The stratification results for Limay are illustrated in Figure 10 and the results for Somoto in Figure 11 below.

Figure 10 – Vegetation cover stratification below 900 metres for Limay

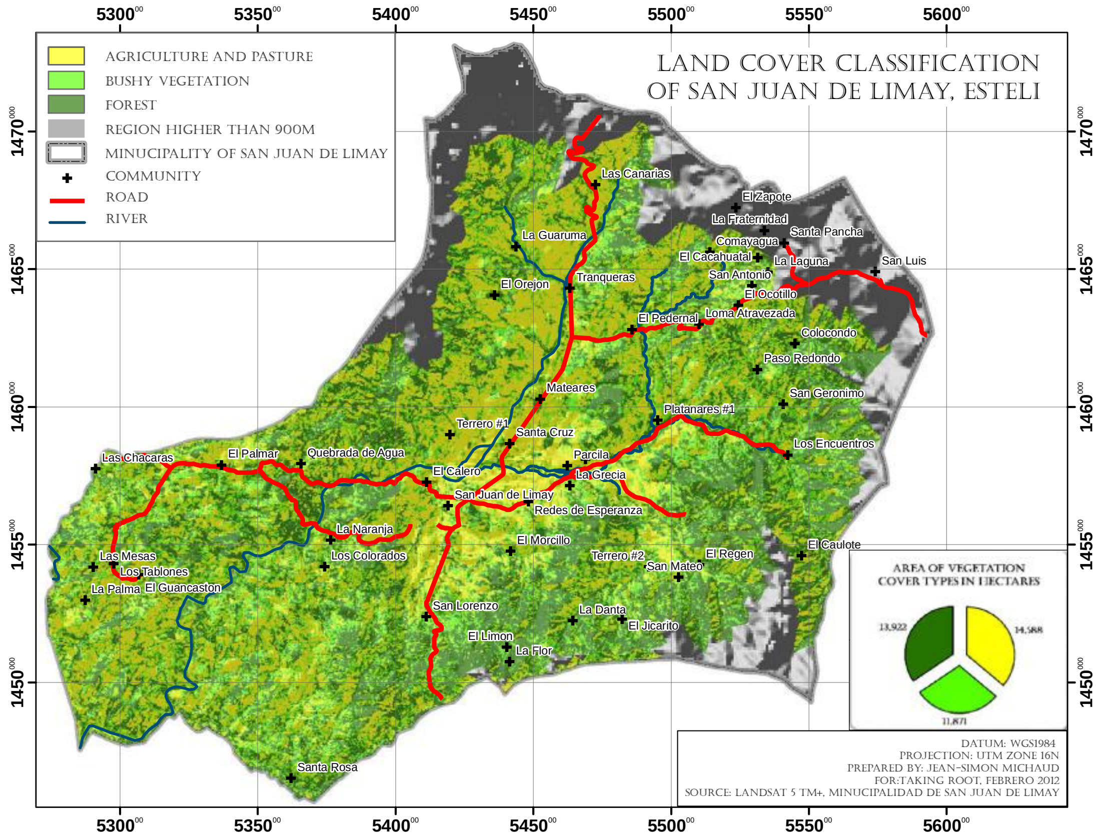
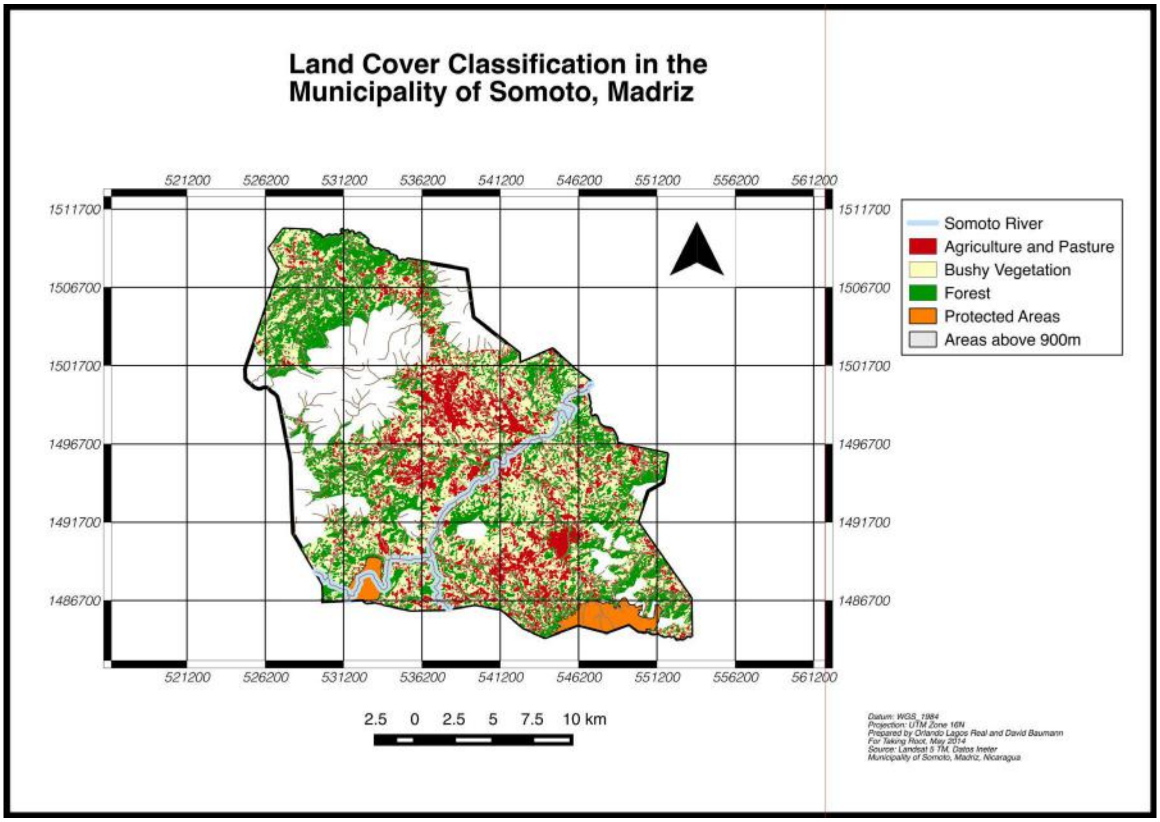


Figure 11 – Vegetation cover stratification below 900 metres for Somoto



5.2. Sampling

Initially, a biomass pilot survey was established (n=52) using a non-stratified random sampling approach. With the data acquired from the pilot survey, the average amount of carbon within the eligible areas for reforestation was determined using the following equation.

$$\bar{y}_{ST} = \sum\left(\bar{y}_h \times \frac{N_h}{N}\right) = \sum\left(\bar{y}_h \times W_h\right) \quad \text{(a)}$$

Where $\bar{y}_{ST}$ = Estimate of the overall mean; $\bar{y}_h$= Mean carbon value in metric tons of stratum *h*; N= Population of samples; $\overline{N}$= Population of samples is stratum h; and W_h = Weight assigned to stratum *h*.

The variance was estimated using the following equation:

$$S_{\bar{y}_{ST}} = \sqrt{\sum\left(S_{\bar{y}h} \times \frac{N^2{}_h}{N^2}\right)} = \sqrt{\sum\left(S^2_{\bar{y}_h} \times W_h^2\right)} \quad \text{b)}$$

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

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 sampling without replacement. 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:

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

and

$$n_h = \frac{W_h s_{y_h}}{\sum W_h s_{y_h}} \times n \quad \text{(d)}$$

Where AE = Allowable sampling error; n = Number of samples required; S_{y_h}= Standard deviation of the sample of stratum h; $S^2_{y_h}$ = Variance of the observations of stratum h; *t* = Student's random variable from *t*-distribution; and W_h = Weight assigned to stratum *h*.

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 was used.

$$EDF = \frac{\left(s^2_{\bar{y}_{ST}}\right)^2}{\sum \frac{\left(W_h^2 \times s^2_{\bar{y}_h}\right)^2}{n_h - 1}} \quad \text{(e)}$$

Where all the variables are the same as in the previous equations.

From the calculation of effective degrees of freedom, it was determined that an additional 340 sample plots were needed in the bushy vegetation classification. An additional 347 additional points were established throughout the stratum using a random sampling approach but with a 60-metre buffer (the length of the largest plot) to ensure that sampling plots would not overlap with a different vegetation cover type. The locations of these sample plots are illustrated below in Figure 12 & Figure 13 below.

Figure 12 – Location of biomass samples in San Juan de Limay

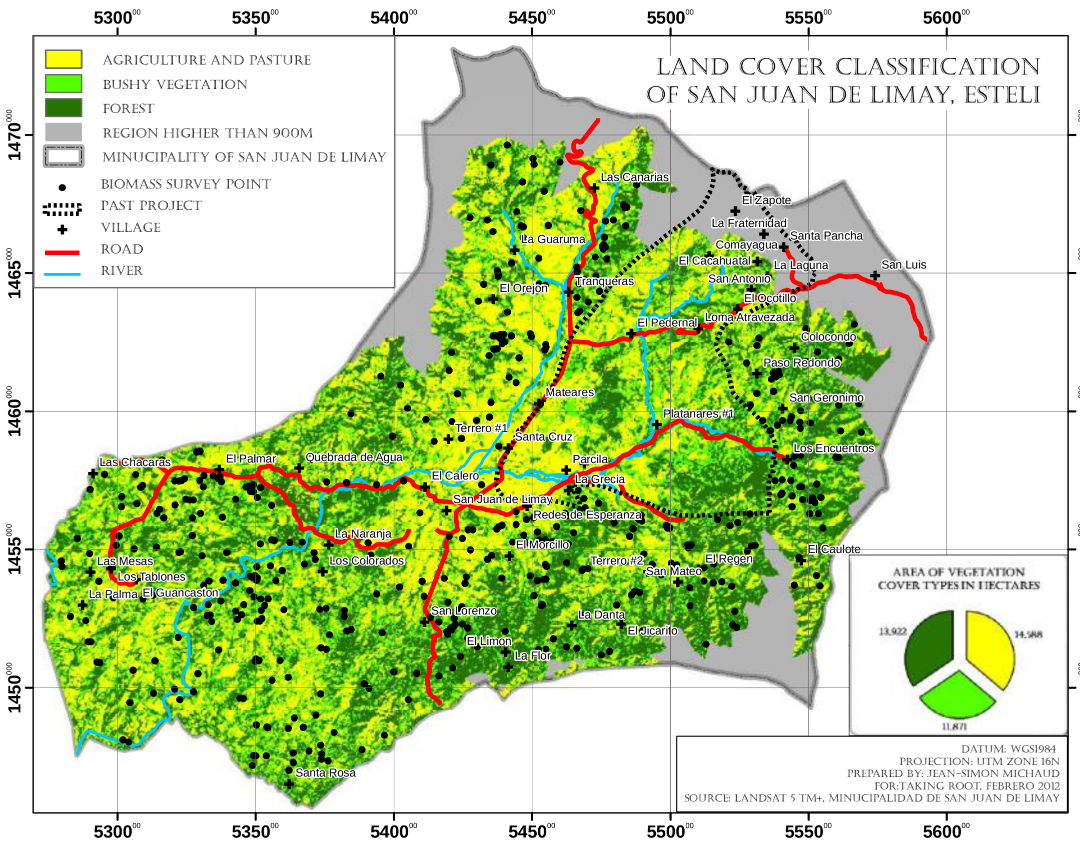
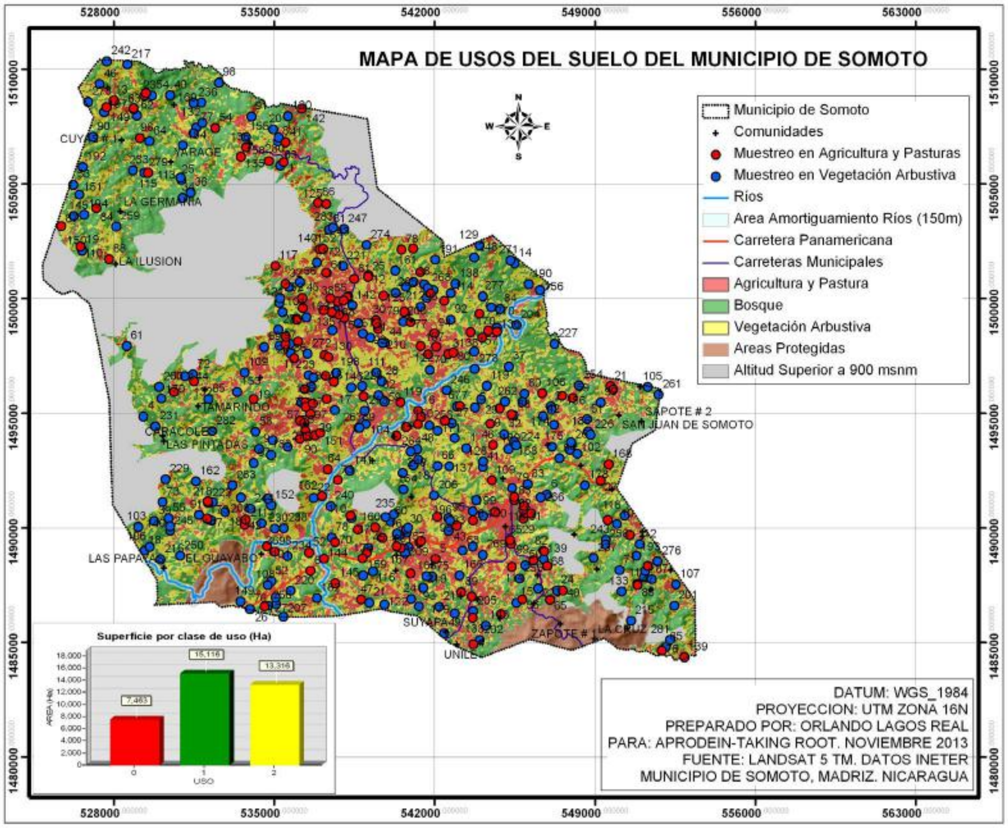


Figure 13 – Location of biomass samples in Somoto



5.3. Biomass Survey Methodology

A biomass survey was carried out at each sample plot to estimate the quantity of woody biomass within the agriculture and pasture stratum, and the bushy vegetation stratum. All trees with a diameter at breast height (DBH) greater than 5 centimetres were included in the survey. Nested sub-plots of varying sizes were used within the sample plots to measure trees according to the Table 5 below.

Table 5 – 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

Field Measurements

In the field, a standard methodology was used to record the necessary information for the baseline calculation. GPS coordinates were located using a hand-held GPS receiver and the program 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. 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. This information along with the local tree name was noted in the data sheet along with the slope of the land at its steepest point.

Estimating the Average Carbon Stock Per Hectare

To calculate the average carbon stock per stratum per hectare, various calculations were made.

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

$$L = L_s \times \cos(S) \quad \text{(f)}$$

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 consistent with a conservative baseline calculation.

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

(g) $$EF = \frac{10000}{A}$$

Where EF= Expansion factor; A= Area of sub-plot in m^2

Using an allometric equation developed for dry tropical forests,[16] with annual precipitations > 900 mm, the above ground biomass was calculated as:

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

3) 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.

4) 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.[17]

5) 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.[17]

TC = 0.49 * TB (i)

5.4. Change of Carbon Stock in Absence of Program

A consultation was held with environmental committee representatives from various communities within the program boundary to discuss likely land-use changes in connection with land resources use.

The first phase involved discussing the environmental history of the area from the perspective of participants over the course of their lives to establish a sense of the time frame of this technical specification. The testimonies of community elders reiterated the devastating impacts of the "Green Revolution" on the local economy and environment. While vegetation was able to recover somewhat from the destruction by cotton monocrops, elders noted that the forest cover has been in steady decline since the 1990s, which is consistent with published literature on the history of the region.[18]

The second phase of the consultation involved discussing and identifying the various factors that lead to land-use change in terms of intensity and area. Using a pair-wise ranking method, the main threats and respective intensities were compared to determine the relative importance of each. The two most important factors identified were the expansion of agricultural land and pastureland.

The third phase involved assessing the communities' expectations regarding the future evolution of each land-use relative to the present over the program lifetime. It was clear that communities expected the trend of deforestation and forest degradation to continue. Consultation with an outside expert validated the likeliness of the presented scenario. This confirmation letter can be found in Appendix 6 and the minutes of this consultation are available upon request.

5.5. Baseline Results

Due to environmental and socio-economic conditions in the municipality of San Juan de Limay and Somoto, land-use commonly cycles from agriculture, to cattle pasture, to fallow fields where bushy vegetation regenerates.

Satellite imagery was used to determine the composition of vegetation cover within the program area at a given point in time. Although the location of each vegetation type changes over time, the ratio of different vegetation cover is maintained over time. Through the use of this technical specification, the relative proportion of agricultural land is likely to remain constant and the relative proportion of pastureland and woody vegetation is likely to diminish due to gains in efficiency brought about by the reforestation program.

At the time of this baseline study, the predominant vegetation cover was bushy vegetation. However, the majority of participants chose to establish this technical specification in open fields, where the baseline would be close to zero. Since woody vegetation will likely be cleared elsewhere as part of the normal land-use cycle, the program chose to take a more conservative approach and integrate the carbon stock present in the other vegetation covers. Due to the land-use and the cycle of land-use change, the two eligible categories of vegetation cover have been considered as one land-use stratum for the baseline.

The carbon stock baseline is an area-weighted average of the following two land-use types: (i) agriculture and pasture, and (ii) bushy vegetation. These areas were included in the average scenario because each will be directly or indirectly affected by the program intervention. Despite evidence of a probable decline in carbon stocks over time in the absence of the program (a relative increase in low carbon stock vegetation covers), the program recognizes the difficulty in accurately quantifying the decline of the baseline over time. Therefore, the baseline will be conservatively assumed to stay constant, which is consistent with simplified baseline and monitoring methodologies for small-scale A/R CDM program activities.

The results of the initial carbon stock are presented in Table 6 and Table 6 below:

Table 6 – Baseline results in San Juan de Limay

	Area (ha)	Above ground woody biomass (tC/ha)	Below ground woody biomass (tC/ha)	Total (tC/ha)
Agriculture and pasture	14,588	0	0	0.00
Bushy vegetation	11,871	5.79	1.67	7.46
Area weighted total	26,459	2.60	0.75	**3.35**

Table 7 – Baseline results in Somoto

	Eligible Area (ha)	Eligible Area (%)	Average Carbon per Class	Total Average Weighted Carbon (tC/ha)
Agriculture and pasture	6,645	54.2	1.17	-
Bushy vegetation	5,624	45.8	5.34	-
Area weighted total	12,269	100	-	3.08

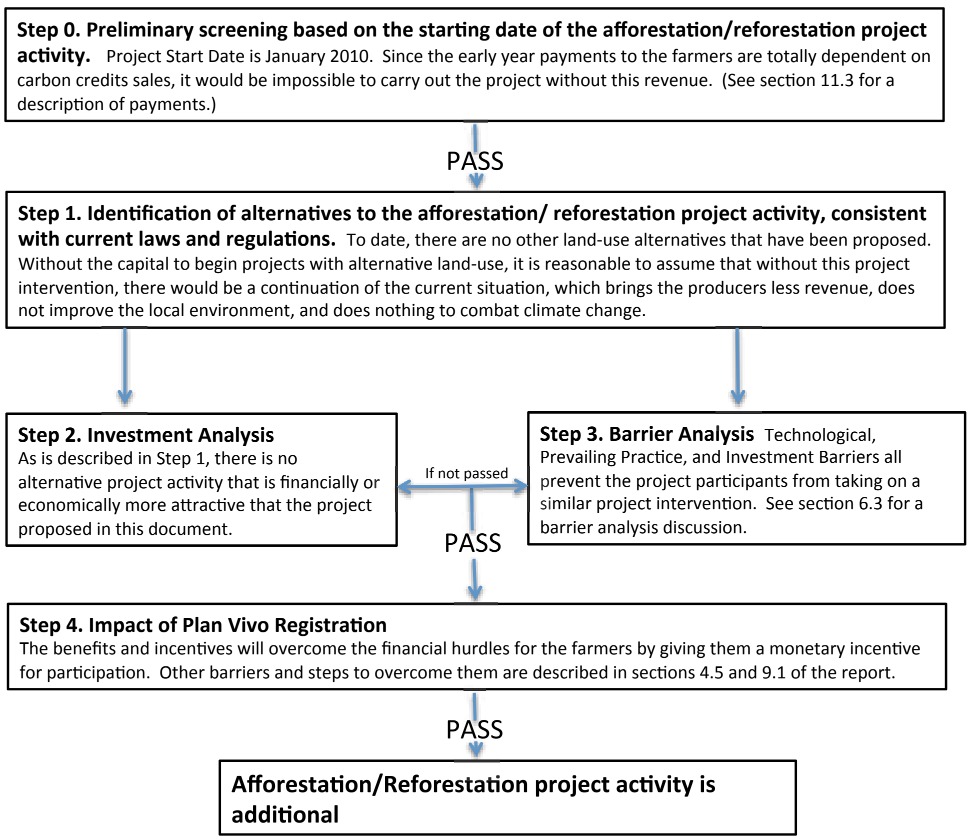
Although the program area in Somoto has a lower baseline, in order to be conservative, Taking Root uses the higher value for the two program areas, 3.35 (tC/ha) from San Juan de Limay to calculate the carbon benefits of this technical specification.

6. Additionality

Taking Root Nicaragua is a non-profit organisation with no ties to any government whether contractual or financial. All of its activities are designed independently and the scale of these reforestation programs is limited by available funding. The primary objective of adopting the Plan Vivo Standard is to increase the marketability of the carbon sequestered. Without this type of finance, this program would not take place.

Figure 14 displays the results from a step-wise tool to test the additionally of prospective program activities.[19] The results of the tool indicate that the program intervention is additional.

Figure 14 – Step Wise Test for Additionality



In Section 6.3 of this document, a barrier analysis is carried out. This is a rapid assessment tool used in community development programs to identify behavioural determinants associated with a particular behaviour so that effective change can be developed.[20] Since the Technical Specification is designed to be beneficial to the community, a barrier analysis is an important tool to help understand what prevents these activities from taking place in the absence of this program, and therefore ensures additionality.

6.1. Comparison to Normal Practice

To ensure additionality, it is important to understand the land-use processes before the program intervention. In the community of San Juan de Limay and Somoto, traditional means of subsistence farming are normal practice, notably through the expansion of the agricultural frontier. New land is continuously cleared for agriculture as the soil in previous sites loses fertility. Degraded land is then used for cattle grazing, which prevents natural regeneration. Forested lands in the area are also degraded through the harvest and sale of fuelwood and timber. Through this expansion, natural resources become increasingly scarce.

6.2. Risk of Loss of Ecosystem Services

As a consequence of normal land-use practices, vegetation is lost at a continuous rate. Without vegetation cover, the soil looses its ability to retain water for long periods of time during the rainy season. The overexploited soil then becomes barren and dry. Consequently, wildlife habitat, agricultural productivity and water security declines,. The loss of these ecosystem services, leads to a decline in the quality of life for the residents of the area.

6.3. Barrier Analysis

The predominant barriers to the successful long-term implementation of forest programs are summarized in Table 8 below.

Table 8 – Barrier analysis

Barrier	Why Barrier Exists	Action
Lack of technical expertise	Due to the inaccessibility and unaffordability of education in the region, many people are unable to get formal training in forestry and other necessary fields.	This program utilizes the expertise of experienced foresters and brings such expertise into the community.
Lack of funding	The region is poor and many of the residents do not have adequate sources of income.	The sale of Plan Vivo certificates will enable funding for seeds, nurseries, labour, equipment, and other needs of the program.
Lack of reforestation program examples in this region of Nicaragua; Globally, similar ecosystem services programs are fledgling	This method of sustainable ecological and economic development is a new field. No program of this type has been attempted in the region.	As the program grows and brings together experts from a wide range of fields, more successful examples to learn from will become available. The science and methodology of this type of sustainable development program will also advance.
Difficult for smallholders to register their plantations with the government making legal management of the plantations impossible	In an attempt to protect the remaining forests, it is now illegal to harvest trees without the land being registered as a plantation. This law is geared towards large plantations and not smallholders, as the process requires technical expertise and bureaucratic processes in the capital.	All programs will have their forestry plan registered by Taking Root with the Nicaraguan government forestry authorities, INAFOR.
Not a part of cultural heritage	No program of this type has ever been developed in the region.	As the program grows within the community, it will slowly gain importance in the community's way of life. The benefits from the program will provide incentives for participation and will become a greater part of the culture of the region.

7. Leakage

The Plan Vivo Standard defines leakage as "the unintended loss of carbon stocks outside the boundaries of a program resulting directly from the program activity."

There are three broad categories of leakage to be considered:

Activity Shifting

This is the loss of vegetation cover outside the program boundary as a direct result of the program intervention. i.e. Clearing new agricultural land elsewhere if the reforested area replaces needed agricultural land.

Market Effect

Although unlikely to have much of an impact from small-scale reforestation programs, market effect leakage occurs when changes in supply and demand cause the loss of forest cover outside the program boundary. i.e. Preventing large-scale logging activity creates a gap in supply, leading to the felling of trees elsewhere.

Super-Acceptance

This takes place when alternative livelihood activities are so successful that people from the surrounding regions move into the area to take part in the activity. Note that this can have a positive or a negative effect on leakage.

7.1. Assessing the Risk of Leakage

The first step in assessing the risk of leakage involves defining and understanding the processes that lead to deforestation and forest degradation in the area. In San Juan de Limay and Somoto, the harvest of fuelwood and timber, as well as the clearance of pastoral and agricultural land, fuel the local community. These economically important activities also cause deforestation. If a program intervention conflicts with the aforementioned activities, the risk of leakage is considered high.

7.2. Minimizing the Risk of Leakage

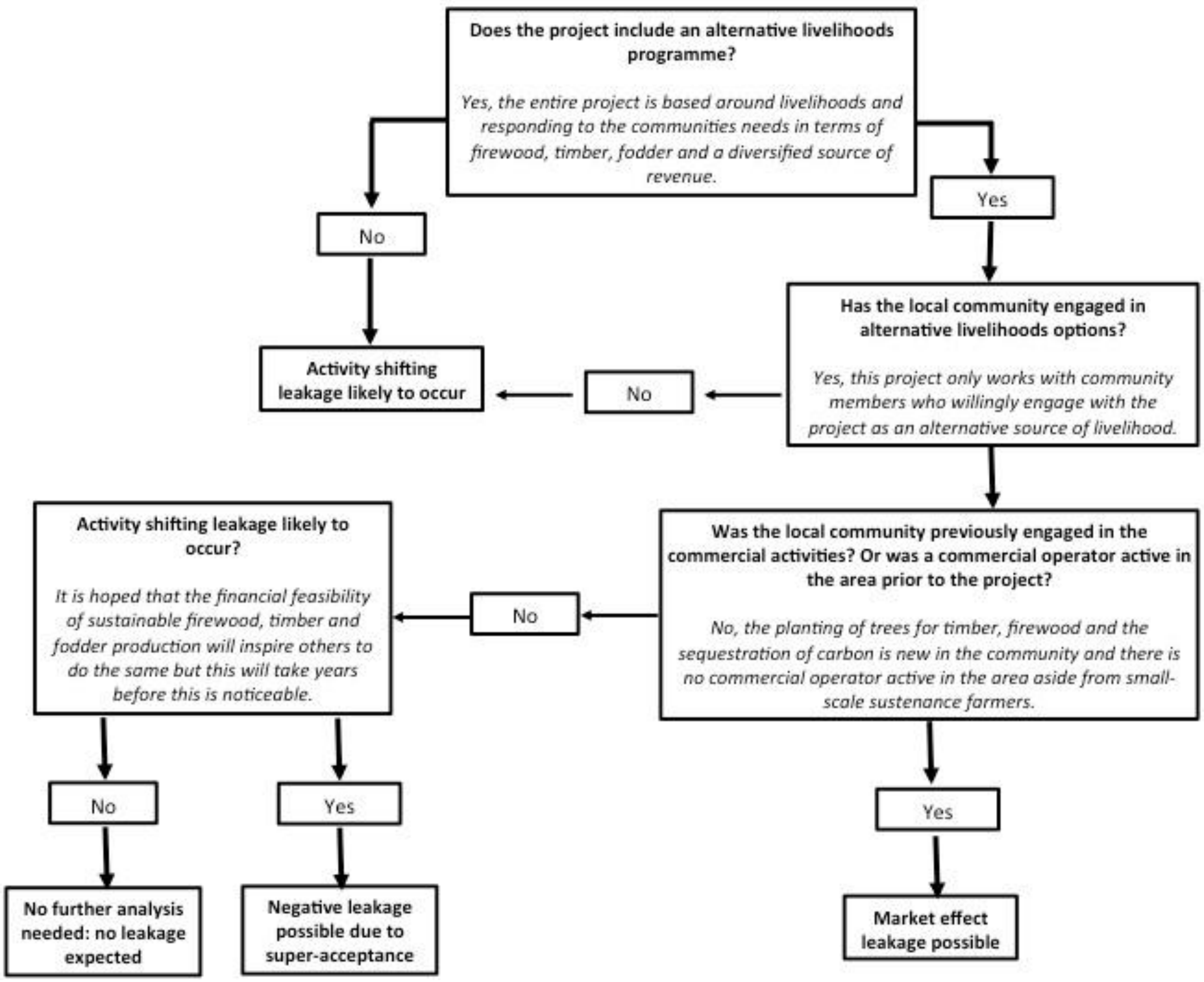
Since a significant portion of the land within the program boundary is either not being utilized, or minimally utilized, for any economic activity (i.e. for occasional fuelwood collection), leakage is relatively easy to minimize as long as appropriate land-use planning is employed. Every participant that uses a technical specification is required to demonstrate through the creation of a plan vivo that they have sufficient additional land to provide for their agricultural and pasture needs and adequate space for reforestation activities.

7.3. Quantification of Leakage

Activities of the Mixed Species Forest Plantation technical specification are designed to reduce the need for further forest clearing. Notably, the integration of fuelwood production within the forest plantation will reduce the need to harvest unsustainably produced firewood. Additionally, the fuelwood species in the program produce a source of high protein foliage that makes excellent fodder for cattle, thus reducing the amount of land needed to sustain cows, particularly in the dry season. It is also hoped that due to the increase in family income associated with sustainable fuelwood and forest plantations, surrounding communities will start using similar land-use strategies on the under-productive portions of their farms - a negative leakage scenario. However, for this to take place, the community will have to overcome cultural barriers (see Section 6.3).

Based on the decision tree, *Assessing the Potential for Leakage* (see Figure 15) from *Sourcebook for Land Use, Land-use Change and Forestry Projects* 10 the potential for leakage was evaluated. After conducting the analysis, the leakage potential is considered as negligible and therefore not calculated within the carbon benefit.

Figure 15 – Assessing the Potential for Leakage



7.4. Activities to Minimize Risk of Leakage

Although it is suspected that leakage will not affect the program, it is still necessary to be proactive in preventing it currently and in the future. Both positive and negative leakage needs to be considered as results of this program. The principal economic activities that could be responsible for leakage are the increase of pasture and agricultural land outside the program boundary.

The following Table 9 outlines these and other factors that could lead to leakage, assesses the associated risk level and outlines appropriate management measures. These risks will be monitored at regular intervals and adjusted if necessary.

Table 9 - Activities to minimize risk of leakage

Leakage Risks	Level of risk (low/medium/high)	Management Measures
Displacement of agricultural activity	Low	– Technical support in the development of the Plan Vivos – Periodic longitudinal land cover analysis through remotely sensed aerial surveying using GIS and Landsat images to monitor land-use changes inside and outside of the program area
Displacement of pastureland	Low	– Technical support in the development of the Plan Vivos – Periodic longitudinal land cover analysis through remotely sensed aerial surveying using GIS and Landsat images in and around program area to monitor land use changes inside and outside of the program area – Use of high protein fodder species to provide source of food during dry season and thus reduce the area need for pastureland
Increased harvesting to meet demand for timber and posts	Low	– Establishment of forest plantations on participant land to provide a sustainable source of timber and posts
Increased fuelwood collection	Low	– Establishment of forest plantations on participant land to provide a sustainable source of firewood – Distribution of fuel-efficient cook stoves

8. Permanence

Programs will only succeed if land-use practices are viable over the long-term and provide sustainable economic benefits to communities over and above the carbon payments. The program intervention has a lifespan of 50 years and therefore must incorporate long-term risk management. Considering the lifespan, assuring the permanence of the program through risk management is an essential and intricate task. First, the participation of the participant, and in some cases their successors, throughout the program lifetime is crucial. Second, it is necessary to mitigate external risks unrelated to participation in the program. A discussion of how to manage these risks follows.

8.1. Activities to Minimise Risk of Non-Permanence

Participation

The most important factors in guaranteeing permanence is ensuring continual participation by the smallholder farmers. To do so, participants must genuinely want to participate. For this program, participation is voluntary and the yearly payments to the participants are not exceptionally high. Consequently, participants do not only participate for the money but rather for the long-term benefits of the program. Furthermore, there is no aggressive recruitment strategy but rather a series of community consultations. Through these consultations, each Plan Vivo is designed by the participants and are therefore in line with their needs, resources and capabilities. Additionally, the species used have been selected and are desired by the community. These species are chosen to provide multiple benefits to the participants beyond the carbon payments that they receive. As a result, smallholders participate only if they wish to reforest sections of their farm to gain the benefits of reforestation, and if they lack the means to do so independently.

Establishing a Risk Buffer for Externalities

Even if participants are committed to the program through its lifespan, there are many other risks that can halt the program. In order to prevent such externalities, a risk buffer is calculated. With the buffer in place, the Plan Vivo system can insure the program against such risks.

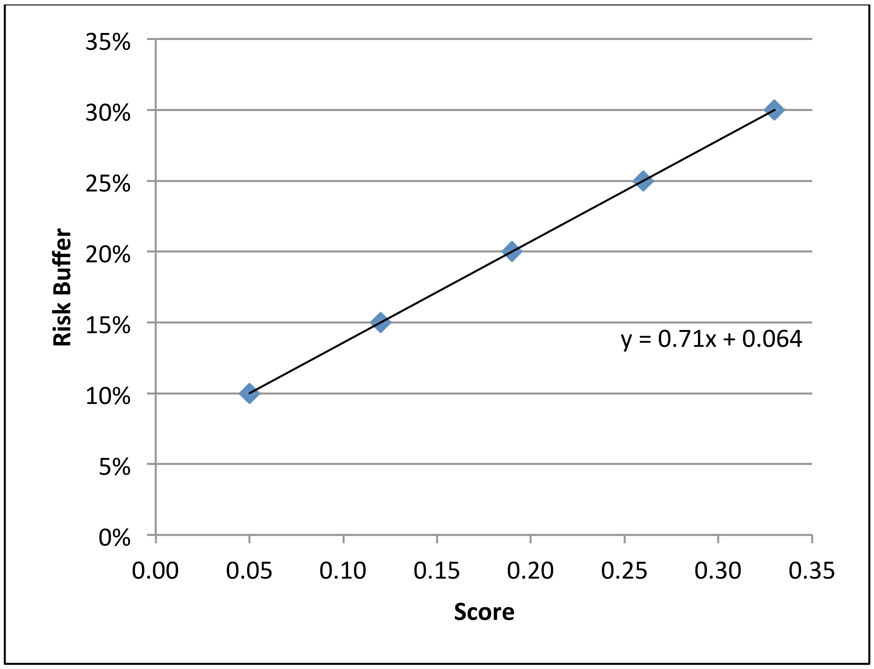
In accordance with the Plan Vivo Standard, this technical specification uses a risk buffer approach that resembles an insurance policy for the buyer of the Plan Vivo certificates. A risk buffer can be defined as a stock of unsold and non-saleable carbon held from each Plan Vivo, which is generated by deducting a specified percentage from each participant’s carbon sequestration potential according to the risk level determined for the program as a whole.[21] If the carbon sequestered is lower than anticipated, the amount of CO_2 purchased is still sequestered because of the carbon reserve in the unsold risk buffer.

Risk Identification

There are various risks to be considered for a program lasting 50 years. The community itself identified these risks during a series of community meetings. A pair-wise ranking system was created to identify and measure the risks. The methodology was taken from the BR&D document: *Community mapping: Baseline & threat assessment*. Pair-wise ranking can be used to help reach consensus about the relative importance of a list of identified threats of land-use change to land-uses with lower biomass stocks.

The buffer percentage is established using the Managing Risks for Non-Sustainability Tool.[22] This method evaluates each risk and designates values to the program's control over the risk, the risk's estimated timeframe, the probability of the risk after mitigation, and the impact of the risk. The score is then associated with an appropriate risk buffer according the following graph by BioClimate (see Figure 16).

Figure 16 - Risk Buffer and Corresponding Score[*]



Risk Buffer Results

After performing the analysis, the final risk buffer score was determined to be 13.65%. In order to be conservative and to take into account unidentified risks, the buffer was rounded up to 15%. This further guarantees the stability of the program. Appendix 4 outlines various risk factors to permanence and outlines the mitigation strategy for each.

[*] In the "Managing risks for non-sustainability" tool, "minimal risk" occurs when all probabilities of risk and all impacts of risk are low (score 0.05). "Higher risk" occurs when all probabilities of risk and all impacts of risk are high (score 0.35). A score of 0.05 is associated with a recommended risk buffer of 10%, and a score of 0.35 is associated with a recommended risk buffer of 60%. A linear relationship between these two points is used to arrive at a recommended risk buffer for each score.

9. Carbon Modeling and Accounting

In order to calculate the benefits of carbon sequestration over the program lifetime, a carbon model for 50 years of tree and stand growth is created. Using a variety of quantitative methodologies and allometric equations derived from relevant journals and datasets, the model estimates the average carbon sequestration over the program period. To do so, the model predicts the growth of the trees in the first 25 years and then of the stand in the last 25 years. Included in this timeframe is the decay of a selection of the harvested trees. To ensure the program's carbon obligations, a technique called adaptive management guarantees that the actual sequestration of carbon reflects the predicted sequestration in the model.

9.1. Carbon Periods

Crediting Period

The crediting period is for 50 years from each participant's starting year. For example, the program period for the participants that join the program in 2012 will last until the beginning of the planting cycle in 2062 and a participant that joins the program in 2013 will have a program period that ends in 2063. This time period was selected to allow sufficient time for transition from a non-forested landscape, to plantation forestry, to sustainable forest management. This demonstrates the program's intent to generate a permanent land-use change and allow for the variability of carbon stocks over the harvest and re-growth period to be averaged out. This crediting period also allows sufficient time to transition towards financially viable sustainable forestry practices.

Program Period

Activities related to the maintenance of the program interventions take place over the entire crediting period. However, the bulk of the work takes place in the first three years, as establishment, planting, and clearing the property requires a significant labour investment. From years 4 to 8, occasional silvicultural activities are required but to a much smaller extent. For all future years, plantation activities are largely dominated by harvesting.

Payment Period

Ecosystem service payments are made during the first ten years (see Section 11.3 for more details). Like most afforestation/reforestation programs, the payment period is shorter than the crediting period as payments are made when carbon finance is needed to incentivise the establishment of a new land-use system. Larger payments are made in the early years to help farmers get through the costly stage of the plantation before the first saleable forest products are generated. Afterwards, the majority of participants will continue with their land-use system and benefit from the selective cutting and sale of wood products. From that point on, both the forest itself and Taking Root's assistance with the commercialization of their timber products are the incentives to ensure the perpetual use of sustainable forestry as a viable land-use option.

Training is given over this period to guarantee that the benefits involved in maintaining the land-use system are understood. Furthermore, when the forest stands approach merchantable sizes, Taking Root intends to play an active role in facilitating the marketing, logistics, and sale of the forest products so that participants receive a fair price, which will keep the incentive system in place.

9.2. Adaptive Carbon Management

The carbon benefit is calculated using the *ex-ante* forecasted average carbon stock of the system over the crediting period minus the baseline and risk buffer of 15%. Section 4 describes the schedule of activities, including the planned harvest schedules, which has a direct impact on the carbon benefit of this land-use system. This technical specification uses multiple tree species managed for multiple objectives, notably carbon sequestration, ecosystem restoration, and commercial fuelwood and timber production.

The forecasted carbon benefit is based on the best information available; however results are likely to vary from one stand to another. Therefore, a dynamic approach to forest management is applied in which the effects of treatments, natural regeneration, and decisions are continually monitored and, along with research results, are used to modify management on a continual basis to ensure that carbon sequestration objectives are being met. In order to conservatively account for this variability, a distinction is made between forecasted *ex-ante* stand growth and monitored *ex-post* stand growth.

Forecasted stand growth: The forecasted carbon benefit per hectare only takes into account the carbon benefit of the longer rotation species (*Swietenia humilis, Bombacopsis*, and *Albizia saman*). The other species are excluded to actively manage the carbon sequestration of the system based on adaptive management. If the longer rotation species grow at a lower rate than is forecasted in this report, the program can delay or remove fewer of the species scheduled for shorter rotations (*Gliricidia* and *Caesalpinia velutina*) so that on a stand level the carbon requirements are being met. For example, if one species of timber is not growing to expectation, more *Caesalpinia velutina* can be left uncut to ensure a wider growth until it must be removed to make room for longer-lived and valuable species, all the while guaranteeing the carbon obligations for that year. This also ensures that participants can meet their growth milestones since the number of trees planted is approximately double what is used for the carbon forecasting.

Monitored stand growth: Monitored stand growth accounts for all trees within the stand. If naturally regenerating trees take root, their growth will be encouraged and if they perform better than the plantation trees, they will be given priority. For a full description of the monitoring methodology, see Section 11.

9.3. Carbon Pool Choices

In order to calculate the total carbon benefit, the sources of carbon must be determined. Table 10 describes the choice and justification for the carbon pools included and excluded in the carbon modelling and accounting.

Table 10 - Carbon pools included in the calculation of the carbon benefit

Carbon Pool	Factors in calculation	Included (Source Given)	Excluded (Reason for Exclusion)
Above ground biomass (AGB)	Stem growth	In-house allometric equations for lesser known species plus published growth information for more common species of all non-firewood species	
	Biomass Expansion Factor (BEF), which is the ratio of above ground tree biomass in relationship to the tree's stem volume.	IPCC default values	
	Specific density	Published information	
	AGB allometric equations (when available)	Published information	
	Carbon fraction	IPCC default values	
Above ground non-woody biomass			Expected to increase as a result of program activities, but difficult and costly to measure with only a small increase in carbon benefit. Thus, conservatively excluded.
Below ground biomass (BGB)		IPCC default values for shoot to root ratios of all non-firewood species	
Litter			Expected to increase as a result of program activities, but difficult and costly to measure with only a small increase in carbon benefit.
Soil			Expected to increase as a result of program activities, but difficult and costly to measure.
Harvested wood products (HWP) (*Albizia saman, Swietenia humilis*, and *Bombacopsis*)	Decay rate	IPCC default values	
	Processing loss	Published information	
Caesalpina velutina* and *Gliricidia			Allows for more conservative carbon calculations, and is vital for the realisation of the adaptive carbon management plan.

9.4. Carbon Modelling

Given that ecosystem service payments are based on the growth of the proposed Mixed Species Forest Plantation technical specification, forecasting the mass of carbon sequestered by the proposed system is of great interest. The average carbon stock sequestered in the crediting period is calculated using the following equation:

$$C_{Avg} = \sum \left(C_{ABGB} + C_{AAGB} + C_{AHWP} \right) \quad \text{(j)}$$

Where C_{Avg} = Average mass of carbon sequestered over the crediting period; C_{AAGB} = Average carbon in above ground biomass of tree components for all species; C_{ABGB} = Average carbon in below ground biomass of tree components; C_{AHWP} = Average carbon stored in harvested wood products for all species

Average Above Ground Biomass of Tree Components (AAGB)

The carbon in the AAGB (C_{AAGB}) is calculated as follows:

$$C_{AAGB} = \frac{\sum_{t=1}^{n} \sum_{p=1}^{3} AGB_{t,p} \times D_p \times CF}{n} \quad \text{(k)}$$

Where $AGB_{t,p}$ = AGB for species p at time t; D_p = the specific density of the wood of species p; CF is assumed to be constant representing the carbon fraction of dry biomass for tropical forests and is equal to 0.4928.[17]

Below is a list of equations used to calculate AGB for the various species employed.

Bombacopsis quinata

Above ground biomass in tonnes was estimated for *Bombacopsis* using the following equation:

$$AGB_{Bombacopsis_t} = V_t \times BEF \times D_{Bombacopsis} \quad \text{(l)}$$

Where BEF is the biomass expansion factor, which was estimated using the following equation:[23]

$$BEF = 3.23983 \times DBH^{0.45162} \times ht^{-0.67457} \quad \text{(m)}$$

Where DBH = the diameter of breast height in cm and ht = the height of the tree in m.

Published growth equations for *Bombacopsis quinata* from Costa Rican plantations exist however, they proved to be overly optimistic based on our experience in the region. As such, the standard Chapman-Richards growth and yield model for both DBH and ht was used but calibrated to local conditions where $yield = b_0 \times (1 - e^{-b_1 \times t})^{b_2}$. With this functional form, b_1 and b_2 determine the shape of the curve whereas the b_0 coefficient determines the asymptote of the growth curve (the maximum obtainable yield value). As long as realistic and conservative values are used for the asymptote, the yield modeling will always remain constrained to realistic values over a sufficiently long time period. To conservatively calibrate the asymptote, data well below maximum plantation values were used from a recent study on *Bombacopsis quinata*[24] so that DBH was caped at 42 cm and height was caped at 26 m. For the shape of the curve, the model was calibrated to intersect observed datasets from the region. As such, the DBH equation is as follows:

$$DBH_t = 42 \times (1 - e^{-0.16 \times t})^{4.2} \quad \text{(n)}$$

Where t = age in years; and e is a constant representing the base of the natural logarithm.

The height equation is as follows:

$$ht_t = 26 \times (1 - e^{-0.17 \times t})^{1.6} \quad \text{(o)}$$

Where ht = the height in metres and t = the age in years.

The maximum height (b_1) of 26 metres was taken from this study's dataset.

Stem volume (V) was estimated using the following model:[25]

$$\ln(v) = -8.0758 + 1.2678 \times \ln(DBH) + 0.9729 \times \ln(ht) \quad \text{(p)}$$

Where *v* represents volume in m^3.

Caesalpinia velutina

C. velutina is the species planted at the highest density is this technical specification and is scheduled to be harvested at an early age to provide a merchantable source of firewood. As such, its carbon sequestration is excluded from the carbon modeling. However, the species can grow considerably larger and given the high density of its wood, has the potential to sequester considerable quantities of carbon. Through our system of adaptive management, should stand growth not meet expectations, individuals of *C. velutina* trees will not be removed to ensure that carbon obligations are met.

Above ground biomass in kg can be estimated for *Caesalpinia velutina* using the following equation:[26]

$$\ln(AGB_{Caesalpinia_t}) = -2.708 + 1.6155 \times \ln(DBH) + 1.1209 \times \ln(ht) \quad \text{(q)}$$

Where AGB = above ground biomass in kilograms, DBH = the diameter at breast height in centimeters and ht = the height in metres.

The stem volume in m^3 can be estimated using the following equation: [26]

$$\ln(V) = -9.0215 + 1.4263 \times \ln(DBH) + 1.1431 \times \ln(Ht) \quad \text{(r)}$$

Where V = the stem volume in metres cubed, DBH = the diameter at breast height in centimeters = Ht is the height of the tree in metres.

In order to forecast growth and yield, an in house stand level height equation was built using easily obtainable environmental and climatic variables as well as an allometric relationship between height and DBH. The dataset used for building these equations originated from 68 permanent sampling plots (PSP) that were made available to the general public as part of the CATIE technical series[27]. The PSPs originated from Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica and Panama, representing a wide range of environmental and climatic growing conditions. Several years later, a newer version of the same dataset with older trees was published in a graduate thesis, 26 of which was added to the dataset.

The equation for height is as follows:

$$\ln(ht) = -2.0144 + 0.9862 \times \ln(t) - 0.00179 \times elev + 0.000187 \times precip + 0.005728 \times slope \quad \text{(s)}$$

Where ht = the height in m; t = the age of the trees in months; elev = the average elevation above sea level in m; precip = the average annual rainfall in mm; and slope = the average slope of the stand.

$$DBH = 2.22982 + 0.74529 \times ht - 0.00032 \times TPH - 0.000555 \times precip \quad \text{(t)}$$

Where TPH = the number of trees per hectare in the stand.

Above Ground Biomass for Swietenia humilis, Albizia saman and Gliricidia sepium

Above ground biomass (AGB) for these three species was estimated using the following equation:

$$AGB_{t,p} = (BA_{t,p} \times ht_{t,p} \times FF_{t,p}) \times BEF_p \times D_p \qquad \text{(u)}$$

Where FF is form factor, which is assumed to be a constant equal to 0.5*; BEF is the biomass expansion factor, which is also assumed to be a constant equal to 1.5 times the stem biomass for tropical dry forests;[26] t is time measured in years; p represents the species; and basal area (BA) in m^2 is:

$$BA_t = \left(\frac{DBH_t}{200}\right)^2 \times \pi \qquad \text{(v)}$$

Where π = the mathematical constant Pi whose value is equal to the ratio of any circle's circumference to its diameter; and FF = form factor, which is assumed to be a constant equal to 0.5

Where BEF = biomass expansion factor, which is also assumed to be a constant for tropical dry forests;[28] and t = time measured in years

Swietenia humilis

Using data from an in-house study, the Chapman-Richards model was fitted and calibrated using height and DBH measurements from different years (for more details on this method, see the growth section for Bombacopsis quinata). The maximum DBH was set at 40 cm and the maximum height was set at 20 m (again, well below the species potential). As such, the DBH equation was determined to be as follows:

$$DBH_t = 40 \times (1 - e^{-0.16 \times t})^{4.2} \qquad \text{(w)}$$

The height equation was determined to be as follows:

$$ht_t = 20 \times (1 - e^{-0.17 \times t})^{1.6} \qquad \text{(x)}$$

Albizia saman

Albizia saman is rarely grown in plantations thus reliable growth information was difficult to obtain. Consequently, site-specific allometric equations were derived for height and DBH based on measurements taken from temporary sample plots within the community of San Juan de Limay using a full range of ages used in this forecasting exercise. Unfortunately, the trees measured were commonly open grown with no effect of stand density taken into account resulting in bias results. Individuals grown in the plantation will likely grow taller and narrower than forecasted.

$$DBH_t = 0.0311 \times \mathrm{t} \qquad \text{(y)}$$

$$Ht_t = 2.0344 \times \mathrm{t}^{0.6601} \qquad \text{(z)}$$

Gliricidia sepium

Like *C. velutina, G. sepium* is scheduled for harvest at a young age so its carbon sequestration is excluded from the carbon modeling. The height prediction model for *Gliricidia sepium* is as follows:[29]

$$\ln(Ht) = 0.1671 + \frac{-14.684}{t} + 0.9538 \times \ln(SI) \qquad \text{(aa)}$$

---

* Default form factor suggested in a professional consultation by Henriette Duda, Doctor of Biometrics at PrimaKlima -weltweit- e.V. and also inspired by various publications, notably: Malik, A. (2002). Untersuchungen über waldmess- und waldwachstumskundliche Grundlagen zur Bewirtschaftung der Baumart Diospyros celebica Bakh. (Ebenholz.)

Where SI = site index with a base year of 5 measured in m and t = age in months.

Since this planting design will take place in an area with no prior experience growing the species, the site index was assumed to be 5, which represents medium growth.[29]

Although there is much literature on the benefits of *Gliricidia sepium*, we were unable to find information on actual growth of DBH. Therefore, 80% of the DBH growth rate of *Leucaena leucocephala* was used, which is a conservative estimate. This is based on literature stating that *Gliricidia sepium* and *Leucaena leucocephala* are two of the most productive native biomass trees in dry zones of Central America.[30] Internal field trials of *Gliricidia sepium* show the species growing just as tall as *Leucaena leucocephala* after one year of growth.

$$DBH_t = 1.825 \times t \times 0.8 \quad \text{(bb)}$$

Where t =age of the tree in years; 0.8 is the conservative DBH growth rate modifier.

Below Ground Biomass

Average carbon in the belowground biomass (BGB) is calculated as follows:

$$C_{ABGB} = \frac{\sum_{t=1}^{n}\sum_{p=1}^{3} AGB_{t,p} \times D_p \times CF \times R}{n} \quad \text{(cc)}$$

Since species-specific BGB equations were not available, IPCC default values were used where R is the ratio of BGB to above-ground biomass (AGB) for tropical dry forests, equal to 0.56 when AGB_t is less than 20 and equal to 0.28 when AGB_t is greater than 20.[28]

Calculations for Harvested Wood Products

Wood products contribute to mitigating climate change through forming a storage pool of wood-based carbon, which can last longer than the lifespan of the tree when used in long-lived products. In this program, some of the trees will provide carbon storage benefits long after they are cut down. The average carbon in the harvested wood products (HWP) is calculated as follows:

$$C_{HWP_{avg}} = \frac{\sum_{p=1}^{3}\sum_{i=1}^{n} (C_{HWP_{tp}} + (C_{HWP_{t-1}p} \times k_p))}{n} \quad \text{(dd)}$$

Where k = decay rate of species p.

$$C_{HWP_{tp}} = HWP_{tp} \times D_p \times CF \quad \text{(ee)}$$

and

$$HWP_{pt} = V_{merchantable_{pt}} \times V_{harvested_{pt}} \times PF_p \quad \text{(ff)}$$

Where $V_{merchantable}$ = standing volume per tree of merchantable timber of species p at year t; $V_{harvested}$ is the volume harvested from species p at year t; and PF is a constant processing factor (the remaining volume after processing) of species p.

For *Caesalpinia velutina*, the following equation for merchantable standing volume was used.[31]

$$\ln(V_{merchantable_{Caesalpinia}})_t = -9.0215 + 1.4263 \times \ln(DBH) + 1.143 \times \ln(Ht) \quad \text{(gg)}$$

For *Bombacopsis*, merchantable volume was estimated using the following model.[32]

$$\ln(V_{merchantable_{Bombacopsis}})_t = -8.0758 + 1.2678 \times \ln(DBH) + 0.9729 \times \ln(ht)$$

(hh)

For *Swietenia humilis*, *Gliricidia sepium* and *Albizia* saman the following equation was used for merchantable standing volume:

$$V_{merchantable} = BA_t \times H_t \times FF \quad \text{(ii)}$$

Values for Timber Processing Factors

When the trees are processed, only a minority of the stem is processed into long-lived timber products. For this program, a processing factor of 80% of the stem is used for posts, and 35% is used when larger stems are processed into sawnwood.[32] This factor is taken from a study done in Costa Rica where trees with a DBH of 19 centimeters had a processing factor of 35% and those with a larger DBH had a higher factor. Although trees used for sawnwood in this program all have a DBH much larger than 19 centimeters at harvest, to be conservative, a constant factor of 35% is being used.

Values for Decay Rates of Harvested Wood Products

The rate of decay of harvested wood products is taken into consideration at a constant rate of 2.3% per year,[33] which is consistent with decay rates used in other publications for tropical agroforestry environments.[31] The default value is appropriate because the majority of the sawnwood products use highly valued species with international markets under the trade names Honduran Mahogany and Spiny Cedar. These species are traditionally used for furniture and cabinetry. The projected merchantable volumes of harvested timber for each species are shown in Table 2..This is wood that is decayed in the form of harvested wood products in the carbon modelling. As with carbon sequestration, the carbon stored in HWP of *C. velutina* and *G. sepium* are excluded from the carbon modelling.

9.5. Mortality Considerations

This technical specification requires that all trees that die be replanted in the first few years, when tree mortality is highest. However, modelling mortality can be challenging and complex due to the lack of data. Consequently, the carbon modelling is done considering only 90% of the trees planted. If mortality dips below 90%, adaptive management ensures that the carbon obligations are met.

9.6. From Plantation Forestry to Sustainable Forest Management

When the plantation approaches maturity near year 25, the management regime will progressively shift towards sustainable forest management. The larger trees will be selectively harvested while natural regeneration will be encouraged and, when needed, new trees will be planted. From this point on, the carbon modelling shifts from a tree level model to a stand level model. A conservative growth rate of 9 m^3 per hectare[*] per year is assumed with a harvest regime of 45 m^3 every 5 years. The average density of the stand is assumed to be the average of the last species left in the stand, which is 0.57 g/cm^3.

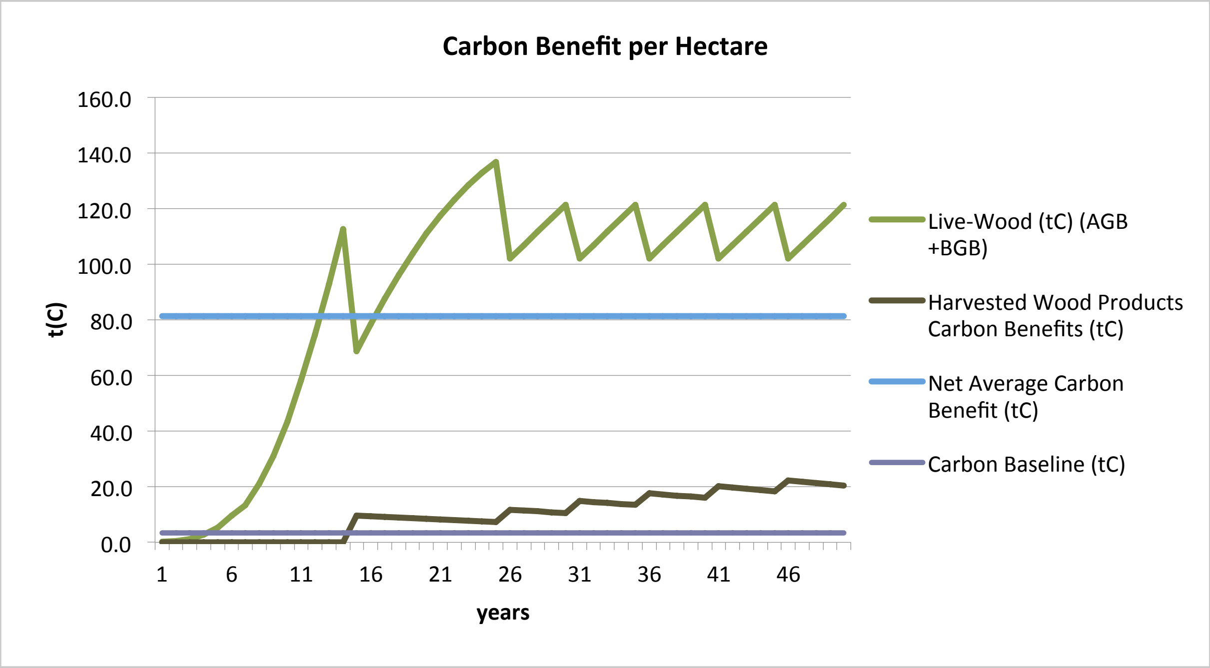
[*] This is based on local professional knowledge and is a common figure for timber stand growth.

9.7. Carbon Benefit

According to the calculations based on this methodology, the average total carbon per hectare for the timber trees over the program period, after subtracting the baseline, leakage, and the risk buffer, is of 81.7 tC. See the Appendix 2 for specific species growth information and further calculations.

The following Figure 17 and Appendix 3 describe the total calculated carbon benefits:

Figure 17 – Forecasted carbon benefit per hectare



The net carbon benefit is then converted to CO_2 by multiplying the ratio of the molecular weight of CO_2 (molecular weight: 44) by the molecular weight of carbon (molecular weight 12). Therefore the average total CO_2 sequestration per hectare is 299.7 tCO_2. The results are within the range cited in the following literature results:

"An average of various non-managed 20 year old teak monocultures in Panama had 440tC/ha, of which 120t were in the trees." [34]

"One hectare of tropical forest in the neo-tropics is assumed to store 181 tC above ground" [35]

It is also important to note that mixed forest plantations can produce more biomass per unit area because competition among individuals is reduced and the site is used integrally.[36]

10. Ecosystem Impacts

The CommuniTree Carbon program takes a holistic approach to land-use management in an area that has suffered from intense environmental degradation for several decades. As a result, the community must cope with heavy soil erosion, water shortages and flooding, as well as drastic declines in wildlife and tree species. Although carbon sequestration funds the program, its scope integrates watershed management, sustainable resource use and land-use planning. Table 11 provides a summary of the expected impacts:

Table 11 – Summary of expected impacts on key environmental services

Title of technical specification	Biodiversity impacts	Water availability impacts	Soil conservation impacts	Air quality impacts
Mixed Species Forest Plantation, Silvopastoral, Boundary Planting	**Positive impact:** Increase forest cover and wildlife habitat through the use of rare native tree species	**Positive impact:** Increase water security by prioritizing critical watersheds reducing the probability of flooding in the wet season and increasing water retention in the dry season	**Positive impact:** Forest cycle and use of nitrogen fixing trees nourishes the soil while increased forest cover reduces erosion	**Positive impact:** Retain humidity and reduce particulate matter in the air, particularly in the dry season; Sequester CO_2 and produce oxygen

10.1. Biodiversity Impacts

Factors that increase biodiversity:
The establishment of mixed species forest plantations on underutilized lands with minimal biodiversity.

Emphasis is placed on collecting tree seeds from around the community, instead of buying from one supplier, to promote variation within species.

A more diverse tree stock will ensure the long-term biodiversity preservation and growth as external environmental and human pressures are progressively placed on the ecosystem.

Increase in forest cover increases wildlife habitat and therefore biodiversity.

10.2. Soil Impacts

Factors that increase soil quality:
Increased forest cover

Use of nitrogen fixing species

10.3. Water Impacts

Factors that increase water benefits:
Increased forest cover (increased water retention and decreased evaporation)

Planting within the vicinity rivers and streams

Planting within strategic watersheds

10.4. Air Quality Impacts

Factors that increase air quality benefits:
Planting trees that sequester carbon and remove particulate matter

11. Monitoring Plan

Monitoring objectives

The objectives of the monitoring plan are is to obtain a reliable overview of each parcel from each participating smallholder by tracking indicators to:

- Estimate the delivery of ecosystem services, notably carbon sequestration
- Estimate the size and composition of forest inventory to inform appropriate management interventions.
- Determined if each Plan Vivo has reached a payment target
- Estimate long-term timber supply
- To develop a rich data set on plantation performance and interactions to inform continuously improved decisions based on adaptive management.

Each technical specification includes a monitoring plan, which is used as a basis to assess the progress of each Plan Vivo. It also sets forth a series of milestones that must be reached in order for payments to be received (see Table 13).

Table 12 describes the variables being monitored as part of the monitoring plan as well as the instruments being used and the justification. Each participating smallholder's Plan Vivo is verified at various points of the year by the community technicians for a set of indicators (see Table 12 below for a list of indicators).

Organizational annual reports are the basis by which Taking Root reports the monitoring work and progress. Annual reports will be submitted and reviewed by the Plan Vivo Foundation, and by on-site third party verification every five years. Taking Root management staff reviews the quality of the community technician's assessments before compiling annual reports.

11.1. Annual Monitoring Methodology

Summary

Sampling method: Systematic with random start
Sampling unit: 7 metre radius circular sample plots
Plot Types: Temporary sample plots (TSP) for monitoring (M1) and permanent sample plots (PSP) for scientific research (S2).
Number of samples: M1: Minimum of 10% of technical specification or 6.5 PSPs per hectare. S2: one per parcel.
Population: All trees of this technical specification on participant's Plan Vivo
Frequency of sampling: Annual

Overview

The CommuniTree Carbon Program uses its proprietary Smallholder Carbon Project Information Management System (SCPIMS) to monitor the performance of every parcel reforested with every participating smallholder.

As illustrated in Figure 18, each parcel of land that is integrated into the project is geo-referenced and a systematic series of monitoring points with a random start is overlaid onto the parcel using a GIS. Annually, every monitoring point of every parcel in visited by a team of monitoring technicians. After locating the points with a GPS, the technicians attach a 7-metre rope to the monitoring point and walk in a circle measuring information on every tree within that circle. Through this system, 10% of the entire area planted is monitored. The information is entered into

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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 8. A larger update to this technical specification is expected later in 2021.

a tablet and when they get back to the office, the information is synched to the SCPIMS providing analytics is almost real time.

Resources needed: Handheld GPS, 7 metre plot cord, monitoring tablet, measuring tape, spray paint, clinometer, DBH tape, and calliper for trees with DBH < 5 cm.

Personnel: A community technician is responsible for completing an annual internal monitoring report for each participant according to this technical specification. Although it is the responsibility of the community technician to head the internal monitoring, it is performed with the participating smallholder so that all parties have a clear understanding of the process.

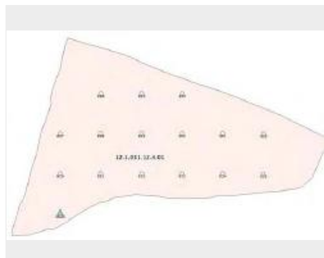
Figure 18 – Monitoring with the SCPIMS

Hoja de muestro para la verificacion interno

Taking Root
www.takingroot.org

Nombre del verificator : ______________________________

Fecha (dd/mm/yy): ______________________________



Communidad	Casco Urbano
Plan Vivo #:	12.1.031
Nombre del Productor:	Maritza de Jesus Morales Davila
Especificacion tecnica:	Mixed Species (High Density)
Ano de Grupo:	2012
Ano de Sembrar:	2012
Numero Parcela Unica:	12.1.031.12.4.01

Puntos a verificar:

Punto Unico	Este	Norte	S2 (S/N)
12.1.031.12.4.01.888	544006	1456049	No
12.1.031.12.4.01.889	544036	1456049	No
12.1.031.12.4.01.890	544066	1456049	No
12.1.031.12.4.01.897	543976	1456019	No
12.1.031.12.4.01.898	544006	1456019	No
12.1.031.12.4.01.899	544036	1456019	No
12.1.031.12.4.01.900	544066	1456019	No
12.1.031.12.4.01.901	544096	1456019	No
12.1.031.12.4.01.902	544126	1456019	No
12.1.031.12.4.01.910	543976	1455989	No
12.1.031.12.4.01.911	544006	1455989	No
12.1.031.12.4.01.912	544036	1455989	No
12.1.031.12.4.01.913	544066	1455989	No
12.1.031.12.4.01.914	544096	1455989	No
12.1.031.12.4.01.915	544126	1455989	No
12.1.031.12.4.01.927	543976	1455959	Yes

Plot selection and characteristics: The sampling procedure uses 7 metre radius PSPs systematically located on each plan vivo with the centre of the first PSP point placement randomly generated through a GIS upon plan vivo registration. The area of each PSP is 153.9 m^2 or 1.54% of a hectare implying that in order to sample 10% of a hectare, a minimum of 6.5 PSPs need to be established.

For the establishment of these plots, the plot location is identified using a hand held GPS and a high-density, thick wooden stake that is inserted into the ground. Approximately 20 centimeters of it should protrude above ground, be painted with a bright colour and a have a large nail hammered into the top of it. The paint is used to facilitate locating it visually and the nail can be used to attach the plot cord. Should the stake not be replaced before entirely rotting, a metal detector can be used to detect the nail and pinpoint the plot's exact location for replacement.

Since the plot centres will be visible, it is possible that the trees within that area receive a different treatment, which would bias the results. However, since the stands and plots are relatively small, it will be easy to notice this bias should it take place.

When trees surpass breast height, a line demarking 1.3 metres of height (or slightly higher if that height happens to not be representative of the tree's diameter at that point) should be marked on each tree within each plot to ensure that annual measurements are always taken at the same spot.

Figure 19 is an illustration of the monitoring sheet that is used.

11.2. Specifics of Monitoring Metrics

Table 12 describes the variables being monitored as part of the monitoring plan as well as the instruments being used and the justification. Figure 19 gives an example of the monitoring work being done by community technicians to record the monitoring criteria.

Table 12 – Details on metrics and their measurement

Variable	Instrument	**Plot type**	Justification
Height	Measuring tape or clinometer	S2.	Commonly used variable for growth and yield information. When appropriate, a measuring tape is used because it is precise and efficient. When the trees are too tall, a clinometer is used.
DBH	Caliper or DBH tape	M1, S2	Commonly used variable for growth and yield information. Two caliper measurements are used for seedlings and very thin trees and geometric mean is calculated. Calipers are used because they are easier to use on small diameter trees. However, a DBH tape will be used on trees with a diameter greater than 5 cm because it is faster, accounts for the tree's ecliptic shape, and the same tool can be used on small and large trees.
Point of measurement (POM)	Measuring tape/DBH tape	S2	Used to specify where measurement was taken, which is typically at DBH. However, if the tree is too short, diameter at base is measured. Furthermore, if DBH is not a representative diameter of that region of the tree due to a point of branching or an irregular growth, the diameter just above that point should be used.
# of trees	N/A	M1, S2	Used to estimate stand density, estimate the number of new trees needed from the nursery and is necessary for estimating stand yield.
Species	N/A	M1, S2	Used for growth and yield information, used to know which species are needed from nursery for the following planting season and used to compare between species.
Location of tree	Measuring tape, compass	S2	To track location of tree relative to other trees in order to track location species-specific interactions.
Condition: Dead or Alive	N/A	M1, S2	Used for carbon yield estimations.
Requires Clearing	N/A	M1, S2	Used to verify milestone completion.
Requires pruning	N/A	M1, S2	Used to verify milestone completion.
Crown diameter	Measuring tape	S2	To establish relationship between tree attributes and canopy size

Figure 19 –Community technicians monitor smallholder plantation and enter data into SCPIMS tablet

11.3. Basis of Payments

Each year, differing metrics determine the participant's payments. Table 13 describes the targets that match up to the modelled carbon forecasting. Table 14 describes the participant's payment percentage when meeting the threshold versus the target.

Table 13 – Payment Breakdown

Year	Basis of payment	Threshold	Target	Percent of total payment received per hectare
1	Tree planting Fences placed around properties		Minimum density of 375 trees per hectare* Fence complete	25%
2	Areas cleared Trees replanted	50% of the plots cleared	80% of the plots cleared Minimum density of 375 trees per hectare	20%
3	Areas cleared Survival Rate	75% of the plots cleared	90% of the plots cleared Minimum density of 375 trees per hectare	15%
4	Growth milestone	Basal area no less than .65 m^2/ha	Basal area no less than .86 m^2/ha	10%
5	No payment			0%
6	Pruning and	75% of trees show evidence	90% of trees show evidence of	10%

* The density requirements reflect the needed number of trees for those species included in the carbon accounting.

	clearing	of clearing and timber trees are pruned.	clearing and timber trees are pruned.	
7	Growth milestone	Basal area no less than 2.99 m^2/ha	Basal area no less than 3.99 m^2/ha	10%
8	Harvest		Harvest of *Gliricidia sepium* and *Caesalpinia velutina*	0%
9	No payment			0%
10	Pruning and clearing	75% of trees show evidence of clearing and timber trees are pruned.	90% of trees show evidence of clearing and timber trees are pruned.	10%

In the first years of planting, there are three payments given to provide the capital that the participants need to plant. In May, a payment is given for planting or replanting in which the participants receive 50% of their annual payment. The second and third payments, each 25% of the annual payment, made in July and September respectively, are for cleaning and weeding the area around the plants.

After participants reach close to 100% the technical specifications density target, and after the internal annual monitoring of each Plan Vivo, payments are issued to the participant according to a predetermined schedule based on the different program targets over the program lifetime. Targets are validated by a combination of on the ground technician judgement and in office data analysis. If both the technicians and the data suggest that the participant has met his target, full payment is received. If the target has not been met but the threshold is achieved, partial payment is made and corrective actions are implemented. If the threshold is not met, payments are withheld until the following year when the objectives have been reached. In accordance with the carbon accounting model, the majority of the participants will reach 100% planting by first year. If they miss the target, they will replant to 100% capacity by the following year.

Corrective Actions

When participants do not meet their targets, a predetermined amount of pay is withheld from their annual payment until the milestone has been reached (details are in Table 14). Corrective actions must be taken to ensure that milestones will be met the following year. Corrective actions are established on a case-by-case basis. For example, if a participant fails to reach the required planting density, their corrective action would be to replant new trees.

Table 14 – Basis of payments when planting density is reached

Performance	Payment
Meets target	100% of payment
Meets threshold	50 % of payment withheld and corrective actions taken
Fails to meet threshold	100% of payment withheld and corrective actions taken

11.4. Quality Assessment and Quality Control

Various steps are taken to ensure quality control. The operations manager reviews all of the monitoring data, cleans it, and enters it into the program database. The database calculates if the participant has reached their target for the year. The results of the monitoring are brought to the community technicians in Nicaragua for review. They verify if the monitoring results conform to their field experience. The results of the monitoring from both the database and the community technicians are analysed by Taking Root and published in its annual reports. Furthermore, every participating smallholder is assigned to a specific community technician so that the performance of each technician’s group of participants can be compared to each other to identify needs for additional capacity building.

11.5. Monitoring Leakage

In order to ensure that the program does not cause leakage, periodic longitudinal land cover analyses are performed using Landsat imagery. The target for these surveys is to ensure that the change in the proportion of agriculture and pasture is comparable inside and outside the program boundaries. If a change is detected, a more detailed review will be done and corrective actions will be undertaken.

Appendix 1: Species Growth Modelling and Carbon Accounting (First 25 Years)

Constants Used in the Carbon Accounting Section

Carbon Accounting Constants	Value	Source or *Notes*
Carbon Fraction of Dry Matter	0.4928	*Agriculture, Forestry and Other Land Use, in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, IPCC, Editor 2006, Institute for Global Environmental Strategies. p. 1-83*
Ratio of Below-Ground Biomass to above-ground Biomass - Tropical Dry Forest	1.56 1.28	When above ground biomass is smaller than 20 t/ha When above ground biomass is larger than 20 t/ha *Agriculture, Forestry and Other Land Use, in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, IPCC, Editor 2006, Institute for Global Environmental Strategies. p. 1-83*
Biomass Expansion Factor	*1.5*	*Good Practice Guidance for Land Use, Land Use Change and Forestry, IPCC, Editor 2003. p. 151-186. Table 3A.1.10 Default values of biomass Expansion Factors (BEFs)*
Rate of Decay (k)	*0.023*	*Agriculture, Forestry and Other Land Use, in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, IPCC, Editor 2006, Institute for Global Environmental Strategies. p. 1-83*
Rate of Decay for Fence Posts (kp)	0.15	Based on Local Knowledge, Decay rate at 15% per year means that posts need to be replaced once every 6 years.
Form Factor	0.5	Default form factor suggested in a professional consultation by Henriette Duda, Doctor of Biometrics at PrimaKlima -weltweit- e.V. and also inspired by various publications, notably*: Malik, A. (2002). Untersuchungen über waldmess- und waldwachstumskundliche Grundlagen zur Bewirtschaftung der Baumart Diospyros celebica Bakh. (Ebenholz.)*

Wood Densities

Wood Density		Source
Swietenia humilis	0.718	*Maluenda, J., et al., Guia de Especies Forestales de Nicaragua. 1 ed2002, Managua: Editora de Arte, S.A. 304.*
Bombacopsis quinata	0.428	“”
Caesalpinia velutina	0.722	“”
Albizia saman	0.53	“”
Gliricidia sepium	0.67	“”
Average of *Swietenia humilis* and *Bombacopsis quinata*	0.573	The average of the two species is used in the stand management phase since they will be the primary species in the stand.

Site Index Variables

Variable	Value	Source
Annual Precipitation	1394 mm	*Resumen Meteorologico Annual De San Juan De Limay*, M.o.S.J.d. Limay, Editor.
Slope	2 degrees	Based on currently established plantations within the program.

Length of Dry Season	6 months	Ficha Municipal, Municipality of San Juan De Limay. Given to Taking Root by the municipality of San Juan de Limay in 2010.
Elevation	400 m	

Appendix 2: Specific Species Information

Swietenia humilis

Spanish Name: Caoba		**Type: Sawnwood**	
Processing factor	0.35	Quirós, R., O. Chinchilla, and M. Gómez, *Rendimiento en aserrio y procesamiento primario de madera proveniente de plantaciones forestales.* Agronomía Costarricense, 2005. **29**: p. 7-15.	
Dbh Equation	$dbht = 40*(1-e^{(-0.16*t)})^{4.2}$		In-house modeling using Chapman-Richards model and in-house allometric equation
Height Equation	$htt = 20*(1-e^{(-0.17*t)})^{1.6}$		In-house modeling using Chapman-Richards model and in-house allometric equation

Predicted Growth for *Swietenia Humilis*

Age (years)	Count of Trees per Hectare with Mortality	Tree DBH (cm)	Tree Height (m)	Stem Volume per Hectare (m^3)	Basal Area per Hectare (m^2)	Above Ground Biomass per Hectare (t)	Below Ground Biomass per Hectare (t)	Total Biomass per Tree (t)	Total Biomass per Hectare (t)	Carbon per Hectare (tC)
1	125	0.01	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	125	0.17	2.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	125	0.70	4.61	0.01	0.00	0.01	0.01	0.00	0.02	0.01
4	125	1.72	6.46	0.09	0.03	0.10	0.06	0.00	0.16	0.08
5	125	3.26	8.20	0.43	0.10	0.46	0.26	0.01	0.72	0.35
6	125	5.27	9.78	1.33	0.27	1.43	0.80	0.02	2.24	1.10
7	125	7.62	11.19	3.19	0.57	3.43	0.96	0.04	4.39	2.16
8	125	10.18	12.44	6.33	1.02	6.82	1.91	0.07	8.73	4.30
9	125	12.85	13.54	10.97	1.62	11.81	3.31	0.12	15.12	7.45
10	125	15.51	14.48	17.11	2.36	18.43	5.16	0.19	23.59	11.62
11	125	18.10	15.30	24.61	3.22	26.50	7.42	0.27	33.92	16.72
12	125	20.55	16.00	33.19	4.15	35.74	10.01	0.37	45.75	22.55
13	125	22.84	16.61	42.51	5.12	45.79	12.82	0.47	58.61	28.88
14	125	24.93	17.12	52.24	6.10	56.26	15.75	0.58	72.02	35.49
15	125	26.83	17.56	62.04	7.07	66.82	18.71	0.68	85.53	42.15
16	125	28.53	17.93	71.66	7.99	77.17	21.61	0.79	98.78	48.68
17	125	30.04	18.25	80.87	8.86	87.10	24.39	0.89	111.48	54.94
18	125	31.38	18.52	89.54	9.67	96.43	27.00	0.99	123.43	60.83
19	125	32.56	18.75	97.56	10.41	105.07	29.42	1.08	134.49	66.28
20	125	33.59	18.94	104.89	11.07	112.96	31.63	1.16	144.59	71.25
21	125	34.48	19.11	111.51	11.67	120.09	33.63	1.23	153.72	75.75
22	125	35.26	19.25	117.44	12.20	126.48	35.41	1.30	161.89	79.78
23	125	35.93	19.36	122.70	12.67	132.15	37.00	1.35	169.15	83.36
24	125	36.51	19.46	127.35	13.09	137.16	38.40	1.40	175.56	86.52
25	125	37.01	19.55	131.43	13.45	141.55	39.63	1.45	181.19	89.29

Bombacopsis quinata

Spanish Name: Pochote		Type: Sawnwood
Processing factor	0.35	Quirós, R., O. Chinchilla, and M. Gómez, Rendimiento en aserrio y procesamiento primario de madera proveniente de plantaciones forestales. Agronomía Costarricense, 2005. 29: p. 7-15.
DBH:	dbht = 42*(1-e(-0.16*t))4.2	In-house modeling using Chapman-Richards model,; Kanninen, M., et al., Stand growth scenarios for Bombacopsis quinata plantations in Costa Rica. Forest Ecology and Management, 2003. 174: p. 345-352.
Height (m)	htt = 26*(1-e(-0.17*t))1.6	In-house modeling using Chapman-Richards model; Kanninen, M., et al., Stand growth scenarios for Bombacopsis quinata plantations in Costa Rica. Forest Ecology and Management, 2003. 174: p. 345-352.
Biomass Expansion Factor	3.23983*dbh.45162*ht-.67457	Avendaño, R., Modelos Genéricos de Biomasa Aérea para Especies Forestales en Función de la Arquitectura y la Ocupación del Rodal, 2008, Centro Agronómico Tropical de Investigación y Enseñanza.
Stem Volume per Tree	ln(v)= -8.0758 + 1.2678 * ln(dbh) + .9729 * ln(height)	Kanninen, M., et al., Stand growth scenarios for Bombacopsis quinata plantations in Costa Rica. Forest Ecology and Management, 2003. 174: p. 345-352.
Site Index	8.5565+0.0015* precip+1.5969* monthsdry-0.0839*slope	Navarro, C., Evaluación del crecimiento y rendimiento de Bombacopsis quinatum (Jacq) Dugand en 14 sitios en Costa Rica. Indices de sitio y algunos aspectos financieros de la especie., 1987, Tesis Mag. Se. Turrialba, CR, Programa Universidad de Costa Rica/CATIE. p. 1-151.

Bombacopsis quinata is one of the more commonly used native timber plantation species in Central America due to its highly prized wood and fast performance in arid regions.

Predicted Growth for *Bombacopsis quinata*

Count of Trees per Hectare with Mortality	Tree DBH (cm)	Tree Height (m)	Stem Volume per Hectare (m^3)	Basal Area per Hectare (m^2)	Above Ground Biomass per Hectare (t)	Below Ground Biomass per Hectare (t)	Total Biomass per Hectare (t)	Carbon per Hectare (tC)
125	0.01	1.33	0.00	0.00	0.00	0.00	0.00	0.00
125	0.18	3.55	0.02	0.00	0.00	0.00	0.01	0.00
125	0.73	5.99	0.15	0.01	0.05	0.03	0.08	0.04
125	1.81	8.40	0.65	0.03	0.28	0.16	0.44	0.22
125	3.43	10.65	1.85	0.12	0.91	0.51	1.42	0.70
125	5.53	12.71	4.03	0.30	2.18	1.22	3.40	1.67
125	8.00	14.55	7.34	0.63	4.28	1.20	5.47	2.70
125	10.69	16.18	11.76	1.12	7.27	2.04	9.31	4.59
125	13.49	17.60	17.14	1.79	11.12	3.11	14.23	7.01
125	16.29	18.83	23.25	2.60	15.69	4.39	20.09	9.90
125	19.01	19.89	29.82	3.55	20.80	5.82	26.62	13.12
125	21.58	20.81	36.60	4.57	26.22	7.34	33.57	16.54
125	23.98	21.59	43.36	5.64	31.78	8.90	40.68	20.05
125	26.18	22.26	49.92	6.73	37.29	10.44	47.73	23.52
125	28.17	22.83	56.15	7.79	42.62	11.93	54.56	26.89
125	29.96	23.31	61.96	8.81	47.68	13.35	61.03	30.07
125	31.55	23.73	67.29	9.77	52.38	14.67	67.05	33.04
125	32.95	24.08	72.14	10.66	56.71	15.88	72.58	35.77
125	34.19	24.37	76.49	11.47	60.63	16.98	77.60	38.24
125	35.26	24.63	80.36	12.21	64.15	17.96	82.12	42.45
125	36.20	24.84	83.78	12.87	67.29	18.84	86.14	44.20
125	37.02	25.02	86.79	13.46	70.07	19.62	89.70	44.20
125	37.73	25.17	89.42	13.97	72.52	20.31	92.83	45.74
125	38.34	25.30	91.72	14.43	74.66	20.91	95.57	47.10
125	38.86	25.41	93.70	14.83	76.53	21.43	97.96	48.27

Caesalpinia velutina (excluded from carbon modelling)

Spanish Name: Mandagual		Type: Firewood
Processing factor	1	Entire biomass assumed to be instantly returned to the atmosphere at time of harvest.
Rate of decay	N/A	
DBH	2.22982+0.74529*ht-0.00032*tph-0900555*precip	In house allometric equations developed using datasets published in CATIE. (1986). *Crecimiento y rendimiento de especies para lena en areas secas y humedas de America Central, 1986: Centro Agronómico Tropical de Investigación y Enseñanza.; and* Hurtarte, E.O., *Comportamiento en Plantacion de Mangium (Acacia mangium willd) y Aripin (Caesalpinia velutina (B y R) Standl) en America Central*, 1990, Turrialba (Costa Rica). p. 117.
Height	ln(ht) = -2.0144 + .9862*ln(t) - 0.00179 * ele + 0.000187*precip + 0.005728*slope	In house allometric equations developed using datasets published in CATIE. *Crecimiento y rendimiento de especies para lena en areas secas y humedas de America Central*, 1986: Centro Agronómico Tropical de Investigación y Enseñanza.
Above Ground Biomass	ln(agb)= -2.708 + 1,6155 * ln(dbh) + 1.1209 * ln(ht)	Hurtarte, E.O., *Comportamiento en Plantacion de Mangium (Acacia mangium willd) y Aripin (Caesalpinia velutina (B y R) Standl) en America Central*, 1990, Turrialba (Costa Rica). p. 117.
Stem Volume	ln(v) = -9.0215 + 1.4263 * ln(dbh) + 1.1431 * ln(ht)	Hurtarte, E.O., *Comportamiento en Plantacion de Mangium (Acacia mangium willd) y Aripin (Caesalpinia velutina (B y R) Standl) en America Central*, 1990, Turrialba (Costa Rica). p. 117.

Predicted Growth for *Caesalpinia velutina*

Age (years)	Count of Trees per Hectare with Mortality	Tree DBH (cm)	Tree Height (m)	Stem Volume per Hectare (m^3)	Basal Area per Hectare (m^2)	Above Ground Biomass per Hectare (t)	Below Ground Biomass per Hectare (t)	Total Biomass per Hectare (t)	Carbon per Hectare (tC)
1	944	1.72	0.99	0.26	0.23	0.00	0.00	0.00	0.00
2	944	2.44	1.97	0.93	0.47	0.60	0.34	0.94	0.46
3	944	3.16	2.93	2.13	0.78	1.43	0.80	2.23	1.10
4	944	3.88	3.89	3.95	1.18	2.73	1.53	4.26	2.10
5	944	4.59	4.85	6.46	1.66	4.59	2.57	7.17	3.53
6	944	5.31	5.81	9.74	2.21	7.09	3.97	11.06	5.45
7	944	6.02	6.76	13.87	2.84	10.30	2.89	13.19	6.50

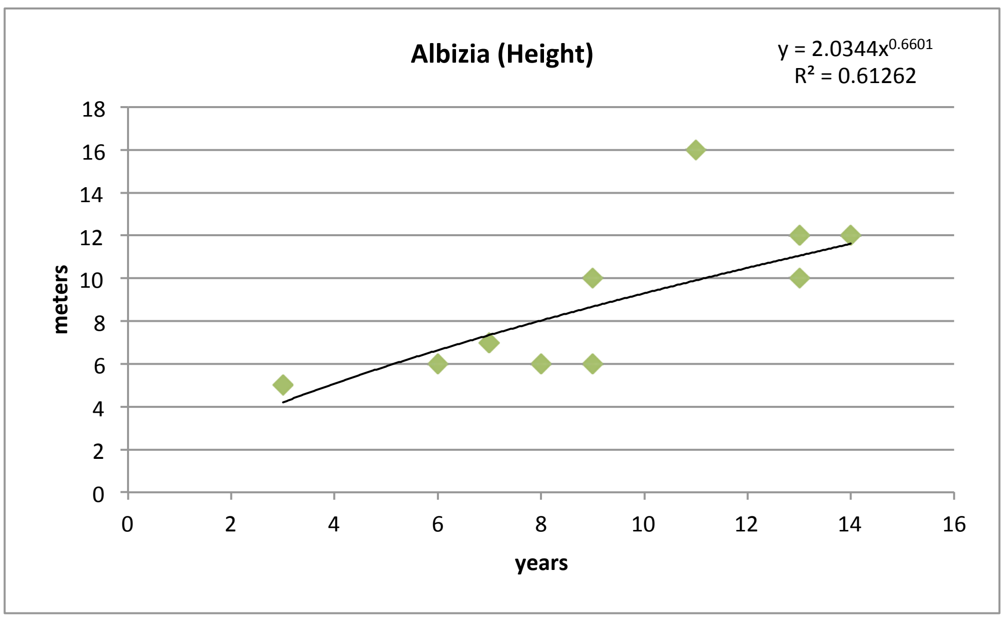
Albizia saman

Spanish Name: Genizero		Type: Sawnwood
Processing factor	0.35	Quirós, R., O. Chinchilla, and M. Gómez, Rendimiento en aserrio y procesamiento primario de madera proveniente de plantaciones forestales. Agronomía Costarricense, 2005. 29: p. 7-15.
DBH (m)	.0311(Age)	In House Allometric Equation
Height (m)	$2.0344(Age)^{0.6601}$	In House Allometric Equation
Rate of decay	0.023	Agriculture, Forestry and Other Land Use, in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, IPCC, Editor 2006, Institute for Global Environmental Strategies. p. 1-83.

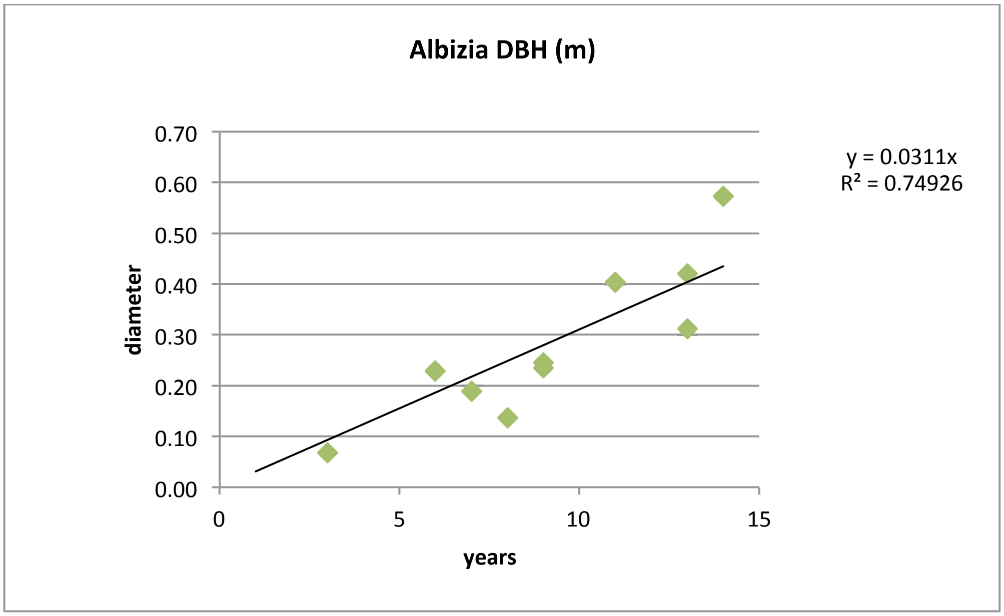
Predicted Growth for *Albizia saman*

Age (years)	Count of Trees per Hectare with Mortality	Tree DBH (cm)	Tree Height (m)	Stem Volume per Hectare (m3)	Basal Area per Hectare (m2)	Above Ground Biomass per Hectare (t)	Below Ground Biomass per Hectare (t)	Total Biomass per Hectare (t)	Carbon per Hectare (tC)
1	125	3.11	2.03	0.10	0.09	0.08	0.04	0.12	0.06
2	125	6.22	3.21	0.61	0.38	0.49	0.27	0.76	0.37
3	125	9.33	4.20	1.80	0.85	1.43	0.80	2.23	1.10
4	125	12.44	5.08	3.86	1.52	3.07	1.72	4.79	2.36
5	125	15.55	5.89	6.99	2.37	5.55	3.11	8.66	4.27
6	125	18.66	6.64	11.35	3.42	9.02	5.05	14.07	6.94
7	125	21.77	7.35	17.10	4.65	13.59	3.81	17.40	8.57
8	125	24.88	8.03	24.39	6.08	19.39	5.43	24.82	12.23
9	125	27.99	8.68	33.37	7.69	26.53	7.43	33.95	16.73
10	125	31.10	9.30	44.16	9.50	35.11	9.83	44.94	22.14
11	125	34.21	9.91	56.90	11.49	45.24	12.67	57.90	28.54
12	125	37.32	10.49	71.72	13.67	57.02	15.97	72.99	35.97
13	125	40.43	11.06	88.74	16.05	70.55	19.75	90.30	44.50
14	125	43.54	11.61	108.08	18.61	85.92	24.06	109.98	54.20

Growth of *Albizia saman* (Height)



Growth of *Albizia saman* (DBH)



Gliricidia sepium (Polewood Species, excluded from carbon modelling)

Spanish Name: Madero Negro		Type: Firewood
DBH	1.825(Age) * .8	Although there is much in the literature on the benefits of *Gliricidia Sepium*, we were unable to find actual DBH growth information. Therefore, we used 80% of the DBH growth rate of *Leucaena leucocephala*. This is based on literature stating that *Gliricidia Sepium* and *Leucaena leucocephala* are two of the most productive native biomass tree, which was initiated in 1984 to test 27 non-industrial species from the dry zone of Central America on a wide range of sites throughout the semiarid and sub humid tropics.[30] Internal field trials of *Gliricidia Sepium* show the species growing just as tall as *Leucaena leucocephala* after one year of growth.
Height	Ln(h) = 0.1671 + (-14.684 / Age) + 0.9538 * ln(SI)	Hughell, D., *Modelos para la predicción del crecimiento y rendimiento de: Eucalyptus camaldulensis, Gliricidia sepium, Guazuma ulmifolia y Leuraena leucocephala en América Central.* 1990.
Rate of decay	15% per year	Based on Local Knowledge, Decay rate at 15% per year means that posts need to be replaced once every 6 years.
Processing Factor	0.8	Educated guess based on local experience

Predicted Growth for *Gliricidia sepium*

Count of Trees per Hectare with Mortality	Tree DBH (cm)	Tree Height (m)	Stem Volume per Hectare (m3)	Basal Area per Hectare (m2)	Above Ground Biomass per Hectare (t)	Below Ground Biomass per Hectare (t)	Total Biomass per Hectare (t)	Carbon per Hectare (tC)
125	1.46	1.61	0.02	0.02	0.02	0.01	0.03	0.01
125	2.92	2.98	0.12	0.08	0.13	0.07	0.20	0.10
125	4.38	3.65	0.34	0.19	0.35	0.19	0.54	0.27
125	5.84	4.04	0.68	0.33	0.68	0.38	1.06	0.52
125	7.30	4.29	1.12	0.52	1.13	0.63	1.76	0.87
125	8.76	4.47	1.69	0.75	1.69	0.95	2.64	1.30
125	10.22	4.61	2.36	1.03	2.37	0.66	3.04	1.50

Appendix 3: Stand Growth Modelling (Years 26-50)

Assumptions	Quantity	Source
Growth rate under forest management (m^3/ha/yr)	9	This is based on local professional knowledge, and is a common figure for timber stand growth.
Density of stand	0.573 (g/cm^3)	Average density of *Swietenia humilis* and Bombacopsis

The following gives the carbon benefit per hectare of the fifty years of the program intervention. It also describes the harvesting in the stand management period.

Predicted carbon sequestered throughout crediting period per hectare

Year	Count of Trees with Mortality	Above Ground Carbon (tC)	Below Ground Carbon (tC)	Live-Wood (tC) (AGB+BGB)	Harvested Wood Products Carbon Benefits (tC)	Total Carbon Benefit (tC)	Net Average Carbon Benefit (tC)
1	375	0.0	0.0	0.1	0.0	0.1	81.7
2	375	0.2	0.1	0.4	0.0	0.4	81.7
3	375	0.7	0.4	1.1	0.0	1.1	81.7
4	375	1.7	1.0	2.7	0.0	2.7	81.7
5	375	3.4	1.9	5.3	0.0	5.3	81.7
6	375	6.2	3.5	9.7	0.0	9.7	81.7
7	375	10.5	2.9	13.4	0.0	13.4	81.7
8	375	16.5	4.6	21.1	0.0	21.1	81.7
9	375	24.4	6.8	31.2	0.0	31.2	81.7
10	375	34.1	9.6	43.7	0.0	43.7	81.7
11	375	45.6	12.8	58.4	0.0	58.4	81.7
12	375	58.6	16.4	75.1	0.0	75.1	81.7
13	375	73.0	20.4	93.4	0.0	93.4	81.7
14	375	88.4	24.8	113.2	0.0	113.2	81.7
15	250	53.9	15.1	69.0	9.7	78.7	81.7
16	250	61.5	17.2	78.8	9.4	88.2	81.7
17	250	68.7	19.2	88.0	9.2	97.2	81.7
18	250	75.5	21.1	96.6	9.0	105.6	81.7
19	250	81.7	22.9	104.5	8.8	113.3	81.7
20	250	87.3	24.4	111.7	8.5	120.3	81.7

21	250	92.3	25.9	118.2	8.3	126.5	81.7
22	250	96.9	27.1	124.0	8.1	132.1	81.7
23	250	100.9	28.2	129.1	7.9	137.0	81.7
24	250	104.4	29.2	133.6	7.7	141.3	81.7
25	250	107.5	30.1	137.6	7.4	145.0	81.7
26	N/A	80.1	22.4	102.5	11.7	114.3	81.7
27	N/A	83.9	23.5	107.4	11.4	118.9	81.7
28	N/A	87.7	24.6	112.3	11.2	123.5	81.7
29	N/A	91.5	25.6	117.2	10.9	128.1	81.7
30	N/A	95.4	26.7	122.1	10.7	132.7	81.7
31	N/A	80.1	22.4	102.5	14.9	117.4	81.7
32	N/A	83.9	23.5	107.4	14.5	121.9	81.7
33	N/A	87.7	24.6	112.3	14.2	126.5	81.7
34	N/A	91.5	25.6	117.2	13.9	131.0	81.7
35	N/A	95.4	26.7	122.1	13.5	135.6	81.7
36	N/A	80.1	22.4	102.5	17.7	120.2	81.7
37	N/A	83.9	23.5	107.4	17.3	124.7	81.7
38	N/A	87.7	24.6	112.3	16.9	129.2	81.7
39	N/A	91.5	25.6	117.2	16.5	133.7	81.7
40	N/A	95.4	26.7	122.1	16.1	138.2	81.7
41	N/A	80.1	22.4	102.5	20.2	122.7	81.7
42	N/A	83.9	23.5	107.4	19.7	127.1	81.7
43	N/A	87.7	24.6	112.3	19.3	131.6	81.7
44	N/A	91.5	25.6	117.2	18.8	136.0	81.7
45	N/A	95.4	26.7	122.1	18.4	140.5	81.7
46	N/A	80.1	22.4	102.5	22.4	125.0	81.7
47	N/A	83.9	23.5	107.4	21.9	129.3	81.7
48	N/A	87.7	24.6	112.3	21.4	133.7	81.7
49	N/A	91.5	25.6	117.2	20.9	138.1	81.7

50	N/A	95.4	26.7	122.1	20.4	142.5	81.7

Appendix 4: Non-Permanence – Risks and Mitigation Strategies

	Risk type	Program's control over risk	Initial situation	Mitigation measure	Risk estimate time-frame	Probability (After management)	P	Impact (After management)	I	Score
A	Unclear land tenure and potential for disputes									0.1375
A.1	Land tenure	High	Privately owned land but often not registered nationally	Ownership and individual is verified with the municipality	Medium	Medium	0.1	Medium	2	0.2
A.2	Potential for disputes with landless individuals	Medium	Some individuals do not own land	Involve landless individuals in group activities (e.g. Nursery building) and seasonal work on neighbor's land.	Long	Low	0.05	Low	1	0.05
A.3	Disputes caused by conflicting land-use interests	High	A significant potion of land is underutilized but cattle often roam all over the place,	All programs are fenced in	Short	Medium	0.1	Medium	2	0.2

			which can destroy young trees							
A.4	With inheritance to land, new land owner decides to not participate in program	Medium	Privately owned land usually by the patriarch or matriarch of the family	Education to current and future inheritors on medium and long-term benefits of program. Continually education on importance of program on environment.	Medium	Low	0.05	Medium	2	0.1
B	Financial failure									0.175
B.1	Program financial plan	High	Financial strategy in place with backing and support from the Community Economic Development Corporation + future payments to participants kept in separate	Development of business plans (reviewed periodically) for economically viable management	Medium	Medium	0.1	High	3	0.3

			guaranteed fund							
B.2	Decrease in timber value	Low	Fuel-wood and timber have high relative value	Diversification of chosen species	Long	Low	0.05	Low	1	0.05
C	Technical failure									0.075
C.1	Technical capability of program implementer	High	Proven capacity to design and implement activities	Only hire highly qualified staff	Short	Low	0.05	Medium	2	0.1
C.2	Poor choice of trees	High	Use of species well adapted to region	Evaluation of species based on experience	Short	Low	0.05	Low	1	0.05
D	Management failure									0.05
D.1	Management activities not carried out effectively	High	Organization has experience carrying out program activities	Program managers and staff adequately trained	Short	Low	0.05	Low	1	0.05
D.2	Double-counting due to poor or bad faith record keeping	High	Proper record keeping system in place	Transparent record-keeping procedures written in program design document and quality mapping	Short	Low	0.05	Low	1	0.05

				of program activities and area; up-to-date database maintained with records of all carbon monitored and sold						
D.3	Staff with relevant skills and expertise	High	Staff highly qualified	Careful selection of program staff and training	Short	Low	0.05	Low	1	0.05
E	Rising land opportunity costs that cause reversal of sequestration and/or protection									0.1
E.1	Returns to participant and implementer stakeholders	High	Opportunity cost of land very low	Financial analysis of program interventions. In addition of the payments for ecological services, the programs are designed to provide	Long	Low	0.05	High	3	0.15

				high valued products in the form of fuel wood and timber.						
E. 2	Introduction of new cash crop in region	Low	Tabaco production, the latest cash cop in region, is banned in municipality	Appropriate land use planning through Plan Vivos	Short	Low	0. 05	Low	1	0.05
F	Political instability									0.07 5
F. 1	Land reform removes property rights	Low	Government currently in process of legalizing property	N/A	Short	Low	0. 05	Low	1	0.05
F. 2	Social unrest	Low	Very peaceful community. Economic hardship is generally dealt with by searching for employment in cities of other countries	Continuous process of community consultations	Long	Low	0. 05	Medium	2	0.1
G	Social instability									0.05

G.1	Disputes caused by conflict of program aims or activities with local communities or organizations	High	Program was build in consultation with other NGOs, community and government consultation	Participatory planning and continued stakeholder consultation over program lifetime	Medium	Low	0.05	Low	1	0.05
G.2	Participants lose interest in program	High	High degree of desired participation by community	Program aims aligned with participants' needs	Short	Low	0.05	Low	1	0.05
H	Devastating fire									0.1
H.1	Forest fire	Medium	Forest cover in the area is minimal and isolated making it difficult for fires to spread.	Removal of fuel wood from program areas	Long	Low	0.05	High	3	0.15
H.2	Intentional burning of agricultural land	Medium	The local government has recently imposed heavy restrictions on the use of fire to clear land.	Ongoing involvement and dialogue with participants	Short	Low	0.05	Low	1	0.05
I	Pests and diseases									0.05

I.1	Incidence of tree crop failure from pests or disease	Medium	Mahogany is the only chosen species subject to insect attack by the shoot borer, *Hypsipyla grandella*. These attacks are common and effect apical growth but rarely kill the tree when grown in polycultures.	Assessment of tree species, careful selection of tree species, strong diversification	Long	Low	0.05	Low	1	0.05
J	Extreme weather events									0.25
J.1	Drought	Low	Frequent (<1 in 10 years)	Replanting of trees as required, planting at the very beginning of wet season, selection of drought resistant species	Short	High	0.25	Medium	2	0.5
J.2	Hurricane	Low	Hurricanes occasionally hit the region, notably	Replanting of trees as required	Long	Medium	0.1	Medium	2	0.2

			hurricane Mitch in 1998.							
J. 3	Floods	Low	Infrequent (<1 in 10 years)	Replanting of trees as required in new areas	Short	Low	0. 05	Low	1	0.05
K	Geological risk									0.05
K. 1	Earthquakes	Low			Short	Low	0. 05	Low	1	0.05
K. 2	Landslides	Medium	Land slides haven't cause much damage in the past	Programs don't take place in really steep areas	Short	Low	0. 05	Low	1	0.05
	Overall Score (average of risk categories)									0.10
	Suggested risk buffer									13.65%

Appendix 5: Tree Count and Species Harvesting Schedule

The following table describes the number of expected trees in year 1, not taking into account mortality.

Expected # of Trees in Year 1

Trees Calculation	Type of Tree
1667	Trees per hectare
1,111	Firewood
556	Sawnwood

The following table describes the harvesting of the different species in the program intervention.

Harvesting Schedule

Beginning of Year	Description of Harvest
1	Planting of all species
2	Replanting to take into account mortality of year 1
8	*Caesalpinia velutina* is harvested for firewood. *Glircidia sepium* are harvested and processed into posts.
15	*Albizia saman* is harvested and processed.
26	*Swietenia humilis* and *Bombacopsis quinata* are selectively harvested and processed.

Appendix 6: Baseline Approval Letter

Gobierno de Reconciliación y Unidad Nacional
El Pueblo, Presidente!

2009: AÑO 30 DE LA REVOLUCIÓN
Viva Nicaragua Libre!

Diciembre del 2009
Somoto Madriz - Nicaragua

La degradación de los recursos naturales en el departamento de Madriz en los últimos años es una realidad, la causa principal de esta degradación es la reducción del recursos forestal causada por el avance de la frontera agrícola (cambio de uso de suelo forestal a agrícola), y el uso de el recurso forestal para leña y madera; esta tendencia continuará sino se toman medidas urgente para frenar la reducción de los bosques en el departamento, medidas como por ejemplo: uso de suelo de acuerdo a su vocación (ordenamiento territorial), el aumento de la masa forestal mediante la reforestación, manejo de la regeneración natural y la protección del bosque existente actualmente.

La situación de los recursos naturales en el departamento de Madriz no es muy diferente a lo encontrado en la microcuenca Platanares, por lo que los resultados de la consulta realizadas a los miembros de las comunidades de esta microcuenca (aumento de tierras agrícolas y pastos y reducción de las tierras en descanso), no me parece poco realista.

Atentamente,

MSc Douglas Benavidez
Delegado Territorial MARENA - Madriz

PODER CIUDADANO
Nicaragua Gana con Vos!

Ministerio del Ambiente y los Recursos Naturales - DT Madriz
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Appendix 7: Technical Validation Report

Available through the Plan Vivo web site at:
http://www.planvivo.org/wp-content/uploads/Limay_Carbon_Project_Final_PlanVivoVal-_Report.pdf

Appendix 8: 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 2014, 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 13 on p. 50 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 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 13).

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 13 (p.50), 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 8.1. 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 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 13 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 13 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 2014 to the original version of the technical specifications published in 2010.

To fix this issue, the technical specifications need to be updated. Specifically, Section 11 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 8.1 - 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.

References

1. *Nicaragua's Environment: Why Should We Care?* [cited 2012 12-04-2012]; Available from: *http://www.nicanet.org/?p=38.*

2. *Ficha Municipal*, Municipality of San Juan De Limay.

3. Resumen Meteorologico Annual De San Juan De Limay, M.o.S.J.d. Limay, Editor.

4. Programa de Desarrollo de Area - Limay, 2009: San Juan de Limay.

5. *Diagnostico Municipal*, 2008, Municipality of San Juan de Limay.

6. Baker, A.K., D. Baumann, and S. Gervais, *Plan Vivo project Design Document (PDD) - CommuniTree Carbon Project*, 2011, Taking Root: Montreal. p. 1-36.

7. Montero, M. and E. Viquez, *Manejo silvicultural y rendimiento de Bombacopsis quinata.* Oxford Tropical Forestry Papers, 2003. **39**: p. 97-111.

8. Maluenda, J., et al., *Guia de Especies Forestales de Nicaragua*. 1 ed2002, Managua: Editora de Arte, S.A. 304.

9. Species Information, in Agroforestry Tree Database, W.A. Centre, Editor.

10. Pearson, T. and S. Walker, Sourcebook for land use, land-use change and forestry projects., B.F. Winrock, Editor 2005.

11. Survey, U.S.G., USGS Global Visualization Viewer.

12. Martinuzzi, S. and W. Gould, Creating cloud-free Landsat ETM+ data sets in tropical landscapes: cloud and cloud-shadow removal, I.I.o.T. Forestry, Editor 2007.

13. Tou, J.T. and R.C. Gonzalez, *Pattern recognition principles.* Image Rochester NY, 1974: p. xxii, 377 p.

14. Ball, G.H. and D.J. Hall, ISODATA, a novel method of data analysis and pattern classification. Analysis, 1965: p. 1-79.

15. Conese, C., et al., *Forest classification by principal component analyses of TM data.* International Journal of Remote Sensing, 1988. **9**: p. 1597-1612.

16. Brown, S., *Estimating biomass and biomass change of tropical forests: a primer*, in *FAO Forestry Paper*1997, Food and Agriculture Organization of the United Nations. p. 55.

17. Agriculture, Forestry and Other Land Use, in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, IPCC, Editor 2006, Institute for Global Environmental Strategies. p. 1-83.

18. *Nicaragua - Agriculture*. 1993; Available from: *http://countrystudies.us/nicaragua/38.htm.*

19. Step-wise Tool to Test for Additionality., in From Executive Board 21st Meeting, Annex I6., CDM Executive Board.

20. Davis Jr., T.P. Barrier Analysis Facilitator’s Guide: A Tool for Improving Behavior Change Communication in Child Survival and Community Development Programs. 2004. Washington, D.C.

21. The Plan Vivo Manual : Guidance for Developing Projects, T.P.V. Foundation, Editor 2008.

22. Limited, B.R.a.D., Managing risks for non-sustainability: A method to identify risks of non-sustainability, mitigation measures, and overall risk of non-sustainability., 2012.

23. Avendaño, R., Modelos Genéricos de Biomasa Aérea para Especies Forestales en Función de la Arquitectura y la Ocupación del Rodal, 2008, Centro Agronómico Tropical de Investigación y Enseñanza.

24. Kanninen, M., et al., *Stand growth scenarios for Bombacopsis quinata plantations in Costa Rica.* Forest Ecology and Management, 2003. **174**: p. 345-352.

25. Hughell, D., Modelo Preliminar De Rendimiento Para Pochote (Bombacopsis quinata (Jacq) Dugand) En Costa Rica y Panama. Silvoenergía, 1991: p. 4.

26. Hurtarte, E.O., Comportamiento en Plantacion de Mangium (Acacia mangium willd) y Aripin (Caesalpinia velutina (B y R) Standl) en America Central, 1990, Turrialba (Costa Rica). p. 117.

27. Crecimiento y rendimiento de especies para lena en areas secas y humedas de America Central, 1986: Centro Agronómico Tropical de Investigación y Enseñanza.

28. Good Practice Guidance for Land Use, Land Use Change and Forestry, IPCC, Editor 2003. p. 151-186.

29. Hughell, D., Modelos para la predicción del crecimiento y rendimiento de: Eucalyptus camaldulensis, Gliricidia sepium, Guazuma ulmifolia y Leuraena leucocephala en América Central. 1990.

30. Stewart, J.L. and A.J. Dunsdon, Performance of 25 Central American dry zone hardwoods in a pantropical series of species elimination trials. Forest Ecology and Management, 1994. **65**: p. 183-193.

31. Kursten, E. and P. Burschel, *CO2-mitigation by agroforestry.* Water, Air, and Soil Pollution, 1993. **70**.

32. Quirós, R., O. Chinchilla, and M. Gómez, Rendimiento en aserrio y procesamiento primario de madera proveniente de plantaciones forestales. Agronomía Costarricense, 2005. **29**: p. 7-15.

33. IPCC. IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4 Agriculture, Forestry and Other Land Use. in Agriculture, Forestry and Other Land Use. 2006.

34. Kraenzel, M., et al., *Carbon storage of harvest-age teak (Tectona grandis) plantations, Panama.* Forest Ecology and Management, 2003. **173**: p. 213-225.

35. Kirby, K., Land-use change in the Neotropics: regional-scale predictors of deforestation and local effects on carbon storage and tree-species diversity. 2004: p. 117.

36. Montagnini, F., et al., Mixed and pure forest plantations in the humid neotropics : a comparison of early growth , pest damage and establishment costs. Commonwealth Forestry Review, 1995. **74**: p. 306-314.