Empowering Mayan Mothers through Agroforestry

Growing security for families, food, and the environment

GUATEMALA program

Plan Vivo Project Design Document

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Date:

December 2nd 2014

USAID
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Executive Summary

This Project Design Document (PDD) outlines the Plan Vivo project Empowering Mayan Mothers through Agroforestry (EMMA) in western Guatemala. This project was initiated in 2014 as the carbon-offset initiative of the larger Catholic Relief Services (CRS) led Guatemala Food Security Focused on the First 1,000 Days (SEGAMIL) project. EMMA is designed to tackle food security, chronic poverty, and environmental degradation for Mayan women who are pregnant and/or have small children. The implementation of agroforestry systems aims to provide the capacity for mothers and families to take control of improving their health and wellbeing.

CRS Guatemala and local operational partners are coordinating project activities. As of 2018, CRS will hand over all aspects of the project to the local operational partners. Training for implementation, maintenance and monitoring of project activities will be provided by CRS-run field schools.

The project activities include a dispersed agroforestry and barrier planting systems. The dispersed agroforestry systems will use a mix of native fruit trees and fast growing nitrogen fixing species. This intervention will be implemented on existing agricultural land, improving soil fertility and stability as well as diversifying food sources, improving household income while reducing expenditures. The barrier planting system will use a mix of native species and will be implemented along edges of agricultural land. This intervention will provide natural weather breaks and improve soil stability.

The project has a crediting period of 25-years. Funding for project establishment and training is provided by CRS through the SEGAMIL project and tree planting activities are funded through the sale of carbon offsets. Payments will be made to participants after successfully reaching defined establishment and growth goals. The estimated carbon benefit of the project ranges from 39.2 tCO_2e/ha to 86.2 tCO_2e/km.

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A Aims and Objectives

The Empowering Mayan Mothers through Agroforestry (EMMA) project is the carbon offset component of the Catholic Relief Services (CRS) Guatemala Food Security Focused on the First 1,000 Days (SEGAMIL) project. The SEGAMIL project aims to work with Mayan families to improve food availability, increase sources of household income, and empower women to improve their health and the health of their children. The objective of the EMMA project is to implement agroforestry systems with Mayan mothers to address child malnutrition, food insecurity, chronic poverty, and environmental degradation. The project will achieve these objectives through:

- A diversification and improvement of livelihoods
  - Increased and diversified food production
  - Sale of fruit
  - Sale of carbon offsets
  - A reduction of household expenditures on firewood
- The sequestration of carbon dioxide (CO_2)
- Improvement of soil fertility and stability
  - Improved yields

B Site Information

B.1 Project location and boundaries

The location of participating municipalities within Guatemala and their Holdridge Life Zones classifications (see Section B.2 for more on Holdridge Life Zones) are presented in Figure B-1. The project takes place in the municipalities of San Lorenzo and Comitancillo in the department of San Marcos, and in the municipality of Santa Maria Chiquimula in the department of Totonicopan.

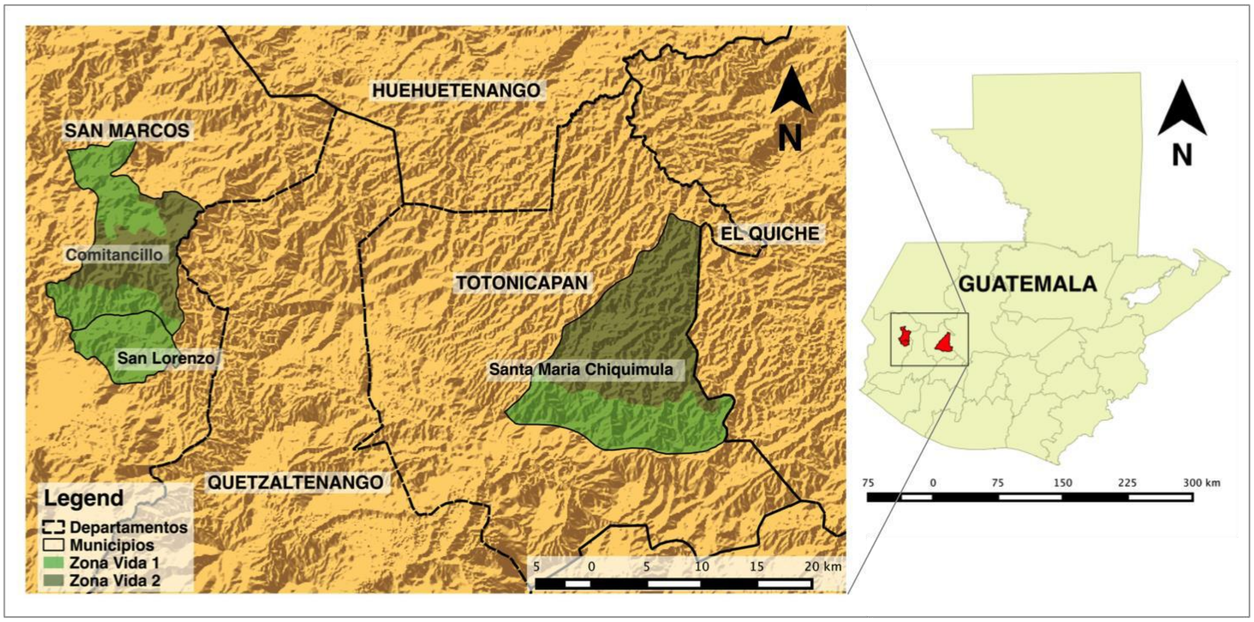

Figure B-1 Project location within Guatemala. The three participating municipalities of Santa Maria Chiquimula, Comitancillo and San Lorenzo are classified into Holdridge Life Zones.

B.2 Description of the project area

The project interventions will take place in three municipalities in two departments in the Western Highlands of Guatemala (Table B-1). Both departments are in the Western Highlands of Guatemala and are disproportionally affected by poor socio-economic conditions, marginalized health, and natural disaster factors.

Table B-1 – Geographic information for participating municipalities

Department	Municipality	Elevation (m)	Area (km^2)	Population
San Marcos	Comitancillo	2,280	113	46,371
San Marcos	San Lorenzo	1,620	25	9,714
Totonicapán	Santa María Chiquimula	2130	237	35,759

The Western Highlands are made up of a series of upland valleys surrounded by mountains. The climate of the region is dictated by elevation with a cold highland climate at higher elevations and a temperate subtropical climate at lower elevations. There are two distinct seasons in the region, dry (December – April) and wet (May – November). The project area across the three municipalities encompasses two distinct Holdridge Life Zones: subtropical montane wet forest (elevations of 2400 – 3000 masl), and subtropical lower montane wet forest (2000 to 2400 masl). The dominant species are Elderberry (*Sambucus mexicana*), Coral trees (*Erythrina spp.*), Pine (*Pinus spp.*), White Cedar (*Cupressus lucitanica*), and Alder (*Alnus jorullensis*) with Nettle (*Bohemia spp.*) at lower eleveations.

According to the IUNC Red List of Threatened Species, there are multiple tree species within the project area that are listed as vulnerable due to expanding agriculture and overexploitation[1]. Guatemalan fir (*Abies guatemalensis*), once plentiful in the Western Highlands, is listed as endangered due to over exploitation for timber. Additionally, habitat destruction in the department of San Marcos has led to the critically endangered status of the Robber Frog (*Craugastor lineatus*).

Other critical factors that affect the project management are extreme weather events such as torrential rainfall, causing flooding and landslides, and prolonged frosts that damage crops.

B.3 Recent changes in land use and environment conditions

The main land use practice in all three municipalities is the "*milpa*". The *milpa* is a traditional crop system of maize grown with beans and squash based on ancient Mayan agricultural methods. These are the staple crops of the region. Fruit trees such as peach, apple, plum, and cherry are occasionally planted throughout the landscape and avocado and matasano are sometimes grown at lower elevations. The traditional *milpas* practice followed a process of slash and burn; a cycle of clearing, cultivation, fallow, and forest regeneration was followed. In modern day *milpas*, small land size results in smallholders skipping the secondary regeneration phase causing a decrease in soil productivity and crop yield, and reducing diversity focusing primarily on the production of maize.

B.4 Drivers of degradation

Over cultivation and increasing variability of precipitation due to climate change over the last decade has repeatedly devastated staple crops. An increase in extreme weather events such as hurricanes, torrential rain, flooding, droughts, and cold waves/frosts is also to blame (Table B-2).

Table B-2 – Drivers of degradation

Drivers of degradation	Description	Livelihoods	Ecosystem services
Extreme weather events	Hurricanes, torrential rains, frosts, and droughts	Soil erosion and low fertility, crop damage	Disrupts watershed flow, decreases soil productivity
Over cultivation/small	Unsustainable	Decreasing crop	Decreases soil

[1] Vivero J.L., Szejner M., Gordon J., Magin G. (2006) The Red List of Trees of Guatemala. Flora and Fauna International.

plot sizes	cultivation	yields	productivity

C Community Livelihoods Information

C.1 Participating communities/groups

CRS SEGAMIL conducted a baseline study of participating municipalities from January to June 2013. The baseline includes 75 communities from the departments of San Marcos and Totonicapán.

C.1.1 Population, culture, ethnicity and social groups

The majority of the population in both San Marcos and Totonicapán is indigenous of Mayan descent. Citizens of San Marcos speak Mam and Totonicapán speak Quiché. Due to unemployment and income pressures, migration greatly shapes the makeup of communities. Household characteristics of the two departments are summarized in Table C-1.

Table C-1 – Household characteristics	
Average inhabitants per household	6.5
Households with children 0-59 months (%)	60.5
Households with a child 6-23 months (%)	27.7
Households with a child 0-5 months (%)	10.6
Household headship (% male)	82.9
Education level of head of household (%)	
No formal education	40.4
Pre-primary	0.2
Primary	53.9
Lower secondary	2.3
Upper secondary	2.7
Higher	0.5
Gendered household type (%)	
Adult female no Adult Male	9.9
Adult Male no Adult Female	1.4
Male and Female Adults	88.6
Child no Adults	0.1
Number of responding households	**3,074**

C.2 Socio-economic context

The primary sources of income in the project area are small-scale agriculture, casual and opportunistic labor, masonry, and work acquired through internal and external migration. Men are the primary breadwinners of families although women do provide income mainly from keeping and selling of livestock, washing clothes for neighbors, and selling textiles, handmade clothing and crafts.

Overall, men perform the majority of agricultural crop production, however women are in charge of post-harvest activities and other duties such as applying fertilizer. In some areas where there have been advances in women's rights, women take on greater roles in crop production and men aid in the rearing of animals. Women also take on greater responsibilities out of necessity in communities where there has been large-scale migration of men to the United States and Mexico.

Challenges to the agricultural success of respondents include a lack of financial resources, technical assistance, and reliable water sources. Additionally, respondents reported a lack of access to adequate land, low levels of organization, and little cooperation among farmers.

Poverty is a significant challenge in the project area. The baseline study revealed that nearly half (43.8%) of the population in San Marcos and Totonicapán live in extreme poverty living on less than USD $1.25/day. Daily per capita expenditures for the two departments are USD $1.90/day. Household's primary expenditure is on Maize for subsistence followed by the purchase of firewood to cook food (14% of household expenditures).

C.3 Land tenure & ownership of carbon rights

In Guatemala, there are no laws granting government ownership of carbon rights. Consultation with national level government indicates that carbon sequestered by trees on private land belongs to the landowner (see Appendix 1).

Land ownership in the project area is a result of historical family settlement. As the population has grown, less and less land is available for small-scale producers. A custom of subdividing land for offspring over several generations has resulted in families owning parcels less than 0.5 ha in size. Gender inequalities and discriminatory socio-cultural norms severely limit women's ownership and control of resources as well as productive potential. Although women play a central role in agriculture only 17% of farms are owned by women.

C.3.1 EMMA approach to land tenure

The project signs payments for ecosystem services (PES) agreements with Savings and Internal Lending Communities (SILC) rather than individuals. SILCs are financial cooperatives of self-selected individuals from the adult population of the communities supported by CRS. The purpose of SILCs is to communally save money to create a safety net for vulnerable families. SILCs also provide financial services to communities who have limited access to formal financial services or where access is complicated by high transaction costs and other entry barriers. This approach is used because individual smallholder land areas are very small making the carbon benefit per individual very minimal. As such, the administrative costs of registering families individually, administrating payments and verifying land tenure on such small farm sizes would be prohibitive. An additional reason for this approach is to ensure that land tenure is demonstrated in accordance with Mayan values and customs, which require decisions to be made communally.

As part of this PES agreement, the SILC must demonstrate land ownership of each individual participating farmer through written statements provided by a Community Council for Urban and Rural Development (COCODE). COCODEs are community political organizations designed to decentralize power and promote local economic, social as well as cultural development within communities. COCODEs are written into the Guatemalan constitution and provide local governance.

CRS office staff is responsible for the management of PES agreements with participants (for an example, see Appendix 2), sale contracts with buyers, the preparation of annual reports and general administration.

D Project Interventions & Activities

D.1 Project interventions

The project will generate ecosystem service benefits through improved land use management. Project activities include the implementation of agroforestry systems to address food insecurity, diversify income, improve soil productivity and stability, and sequester carbon. There are two technical specifications applied across the project area, a dispersed planting design, which will be incorporated into existing *milpas* in the lower montane life zone, and a barrier planting design planted on *milpa* boundaries in both the lower montane and montane life zones.

D.2 Project activities for each intervention

A summary of project activities is presented in Table D-1.

Table D-1 – Description of activities

Intervention type	Project activity	Description	Target group	Ecosystem services contracted (yes/no)
Improved land management	Dispersed planting	Dispersed planting of nitrogen fixing and fruit trees in *milpas*	Mayan women who are pregnant and/or have small children that are members of a SILC	Yes
Improved land management	Barrier planting	Linear planting of trees along property boundaries	Mayan women who are pregnant and/or have small children that are members of a SILC	Yes

D.3 Effects of activities on biodiversity and the environment

The project activities will increase the biodiversity of the ecosystem by incorporating native tree species into existing *milpas*. The planting of trees will also provide natural soil fertilization and improve soil stability reducing erosion and runoff. The project activities will provide a positive environmental impact and generate ecosystem services.

E Community Participation

E.1 Participatory project design

E.1.1 Planning process

All projects activities were developed and designed by stakeholders through community and expert consultations. Lead farmers and nutritionists of local field schools *Escuelas de Campo para el Desarrollo Integral* (ECADI) in each municipality were consulted on the project design and implementation. ECADIs are the primary delivery mechanism of the project interventions to communities through comprehensive experiential agricultural training and education. They are local, autonomous organizations that are based on a philosophy of learning by doing. The goal of an ECADI is to generate a change in behaviors and attitudes to improve the livelihoods of families by demonstrating the intrinsic links between agriculture, nutrition, natural resources, and gender roles

E.1.2 Target groups and governance

This project targets Mayan women who are pregnant and/or have small children who are participating in SILCs. SILCs are governed through internal governing committees consisting of a chairperson, secretary, treasurer and two money counters. Governing committees are self-selected and members develop and agree to a set of rules, by-laws or constitution.

E.1.3 Barriers

A detailed description of barriers is presented in Table G-1.

E.2 Community-led implementation

E.2.1 Preparation and registration

The project activities are carried out on land owned by smallholder farming families, who are members of both a SILC and an ECADI. This project area will be managed under an agreement made between SILCs and CRS. Plan vivos are prepared by individuals in collaboration with the local ECADI to best suit their land and needs. Individual plan vivos are then registered as part of the SILC.

E.2.2 Assessment system

Assessment, to ensure implementation of project activities does not undermine livelihoods or increase food security, is an ongoing process carried out by three levels of project management. Local ECADI technicians perform the first assessment to ensure that participating farmers meet all criteria for participation including the review of Plan Vivos and geospatial information. Local CRS project coordinators then review the data quality of each SILC to ensure that no errors have been made. Finally, CRS Guatemala management confirms that funding is available to support all that the newly registered participants.

E.2.3 Mapping, recording, storing

Each participating smallholder is responsible for creating a current and future map of their land to visualize, record, and store their individual plan vivo (Figure E-1). Project coordinators and field staff create geo-referenced shapefiles of each plan vivo and the information is stored in a Smallholder Carbon Project Information Management System (SCPIMS), which is described in more detail in Section I4.2.

Figure E-1 Example of a *plan vivo* demonstrating the current and future land-use scenarios.

E.3 Community-level project governance

E.3.1 Decision-making and project management

Participating smallholder farmers will be involved in decision-making and project management through involvement in their local ECADI.

E.3.2 Grievance recording

Farmers are invited to bring grievances to local technicians who then report to the CRS Guatemala office. Additionally, in local offices, the telephone number of the CRS Guatemala office will be provided in the case of grievances with local technicians.

F Ecosystem Services & Other Project Benefits

F.1 Carbon benefits

The carbon benefits of the project are summarized in Table F-1.

Table F-1 – Carbon benefits

Intervention		Baseline carbon uptake (tCO_2e/ha)	Carbon uptake/emissions reduction (tCO_2e/ha)	Expected losses from leakage (tCO_2e/ha)	Deduction of risk buffer (tCO_2e/ha)	Net carbon benefit (tCO_2e/ha)
Dispersed agroforestry						
Zone 1	Alder-cherry	3.63	55.1	0	11.0	40.5
	Alder-avocado	3.63	53.5	0	10.7	39.2
Zone 2	Alder-cherry	3.63	58.5	0	11.7	43.2
Barrier planting						
Zone 1	Alder-pine	3.63	112.2	0	22.4	86.2
Zone 2	Alder-pine	3.63	112.2	0	22.4	86.1

F.2 Livelihoods benefits

Livelihood benefits are summarized in Table F-2.

Table F-2 – Livelihoods benefits

Food and Agricultural	Financial	Environmental	Social and cultural
The incorporation of an agroforestry system will provide a food source and diversify crops. The barrier planting system will create weather breaks protecting crops from extreme weather events.	Fruit trees diversify income and food production. Improved land management will increase crop yields and household income. Reduced household expenditure on firewood. Increased income through carbon payments.	Increased tree cover will increase biodiversity, improve soil quality (nutrients) and stability, and reduce vulnerability to flooding and drought. Sustainably produced firewood will reduce pressure on surrounding forest resources.	Increased resilience to extreme weather events. Improved food and income source. SILCs can improve community building and trust.

F.3 Ecosystem & biodiversity benefits

Ecosystem and biodiversity benefits are summarized in Table F-3.

Table F-3 – Ecosystem benefits

Intervention	Biodiversity impacts	Watershed impacts	Soil productivity/ conservation impacts	Other impacts
Dispersed agroforestry	Increase tree cover of native species.	Reduced probability of flooding in the wet season and increasing water infiltration and retention. Protects water springs	Nitrogen fixing species provide nutrients to the soil. Leaf litter to increase soil organic matter. Root systems facilitate the cycling of nutrients from deeper layers to the surface. Roots systems reduce erosion and nutrient leaching.	Create a temperature stabilizing microclimate to guard against extreme weather. Form natural wind and rain breaks. Sequesters CO_2.
Barrier planting	Increases tree cover of native species.	Reduced probability of flooding in the wet season and increasing water retention in the dry season.	Reduces erosion and soil nutrients. Maintains natural forest cycles.	Create a temperature stabilizing microclimate to guard against extreme weather. Form natural wind and rain breaks. Sequesters CO_2.

G Technical Specifications

G.1 Project activities

The common objectives of all project activities are to address food insecurity, diversify income, improve soil productivity, and sequester carbon. To achieve these objectives, the following two distinct planting activities are proposed and further described below: 1) a dispersed inter-planting design, and 2) a barrier planting design.

G.1.1 Dispersed inter-planting

The dispersed inter-planting design uses a combination of nitrogen fixing alder (*Alnus jorullensis*) and fruit trees (cherry: *Prunus serotina* subsp. *Capuli*, or avocado: *Persea americana*) (Figure G-1). Species are planted at low density throughout cultivated fields. The nitrogen-fixing alder will improve soil nutrients enhancing the productivity of cultivated fields, the fruit trees will provide an additional food source and income and the sustainably produced firewood from pruning will reduce household expenditures. The trees will also increase farm diversity, enhance soil stability and litter will provide an organic fertilizer. For the fruit trees, smallholders can choose to plant cherry, avocado or both provided that the total density of both species combined is 24 trees per hectare.

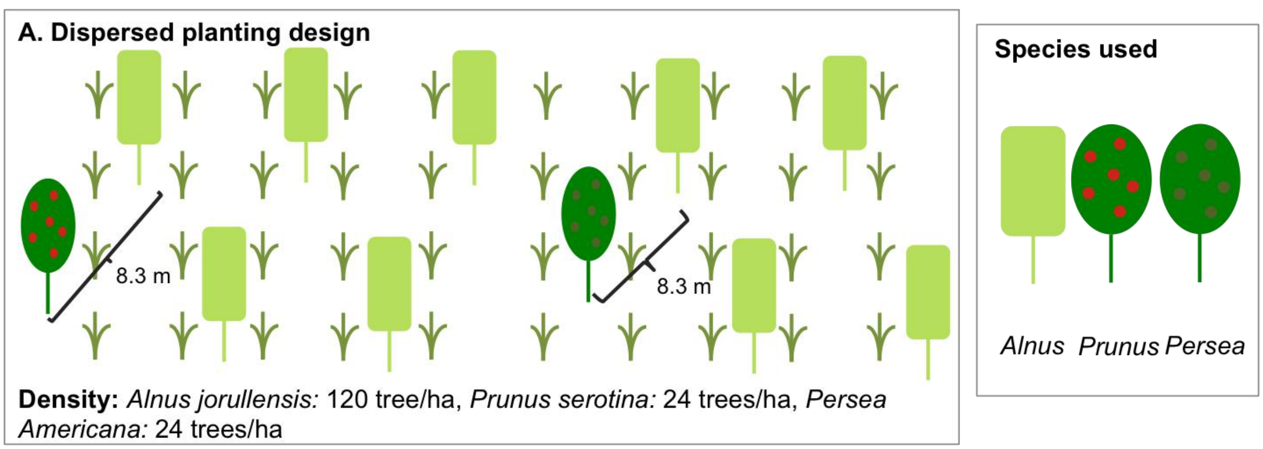

Figure G-1 Dispersed agroforestry design.

G.1.2 Barrier planting

The barrier planting design uses a combination of pine (*Pinus spp.*) and alder (*Alnus jorullensis*) (Figure G-2). Multiple pine species (*P. ayacahuite, P. pseudestrolus, P. oocarpa*) native to Guatemala are used. Trees will be planted in a linear, alternating fashion along agricultural field boundaries at a spacing of 5 m alternating between pine and alder.

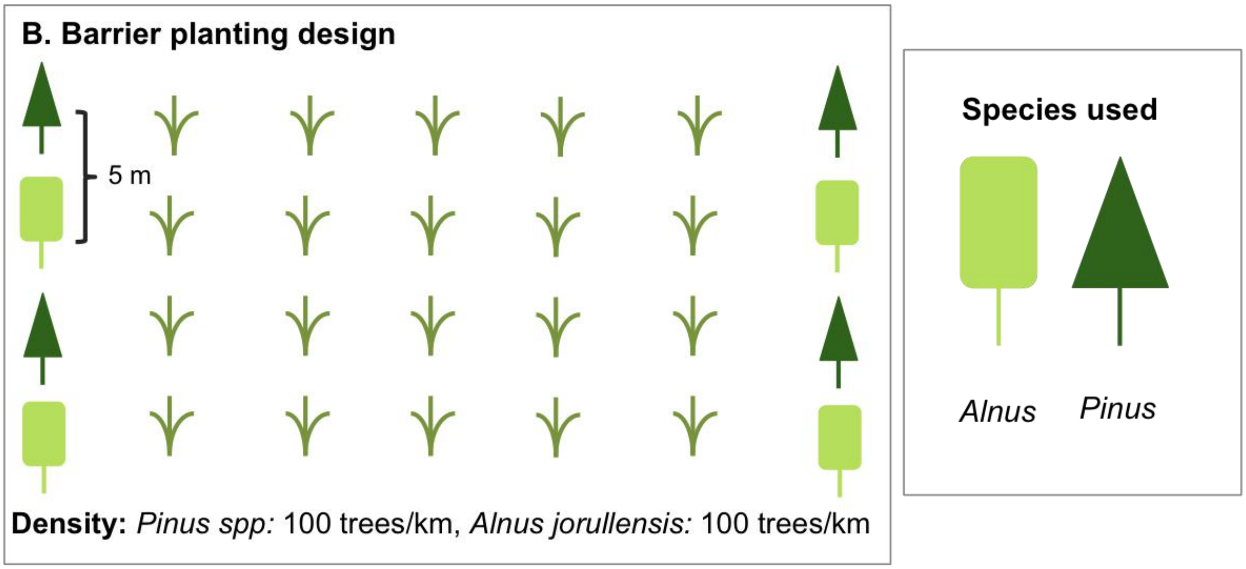

Figure G-2 Barrier planting design.

G.2 Additionality and environmental integrity

The carbon benefits proposed by the project interventions are all additional to current practices in the project area. The additionality of the project was assessed using the methodology set out by the Clean Development Mechanism (CDM) Rules[2]. Additionality, and barriers to implementation are summarized in Table G-1.

[2] CDM A/R Methodological tool. "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities" (Version 01). 2007.

Table G-1– Additionality Test		
Additionality Test	**Initial Scenario**	**Action**
Regulatory Surplus	There are no existing laws and regulations that require or mandate land-use practices in the project area.	Improve local livelihoods and food security through agroforestry and PES incentives.
Common Practice	Declining productivity and yields in *milpa* land-use practices.	Sustainable land management. Implement agroforestry (native species intercropping and barrier planting) activities.
Implementation barriers		
Financial	• No money to develop the project. No PES system currently in place. • Small land size making transaction costs of participation prohibitively expensive	• Funding has been secured through CRS. • Membership of SILCs reduces transactional costs making participation possible.
Technical	• Inaccessibility and unaffordability of education in the region creates a deficit in formal training in forestry and other necessary fields • No project of this type has been attempted in the region. This method of sustainable ecological and economic development is a new field.	• This program utilizes the expertise of experienced foresters and brings such expertise into the community and leaves it there through a farmer-to-farmer methodology. • 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.
Institutional	• Land interventions from outside the community are a very delicate and contentious topic for Mayan communities as proof of land title requested by outsiders is	• The project will ensure that demonstration of long-term land-use rights is done according to local values and customs, which require decisions to be made communally.

	commonly perceived as an attempt of stealing ancestral lands due to a long history of persecution, land grabs and social conflict.	
	• In the region, trees are not traditionally a part of *milpas,* although this was not historically the case. Current land-use practices do not include a fallow and regeneration phase of the traditional agricultural cycle. Farmers regrow their *milpa* on the same permanent piece of land due to limited available land and small farm sizes. Without the inclusion of trees the land suffers from declining fertility.	• The concept will be presented with great cultural sensitivity and phrased as a form of targeted incentive to support tree-planting activities. Project activities will be promoted in a way that builds upon existing Mayan values while exploring lost or forgotten practices or approaches to family agriculture.

G.2.1 Avoidance of double-counting

To ensure no double counting, PES agreements can only be entered into and signed by farmers not already participating in existing Guatemalan national forest incentives.

Two national level forest incentive programs currently exist in Guatemala. The first is the Program of Forestry Incentives (PINFOR), which was established in 1996 under the Forest Law to promote reforestation through plantations and the protection and regeneration of natural forests. This program will not be relevant in the program area as full ownership of the land and a minimum of 2 ha is required to participate in the program.

The second is the Program of Incentives to small landowners with forestry or agro-forestry resources (PINPEP). Established in 2007, this forest incentive is geared directly to smallholder farmers without clear land titles. The minimum land required for an individual to participate is 0.1 ha and the maximum is 15 ha. Organized groups of landholders can participate with more than 15 ha as long as no individual in the group hold more than 15 ha. In the region this national program will likely not be undertaken for the following reasons:

- Monetary incentives are very low for small land sizes
- Non-reliable longevity of government payments
- Local mistrust of government

- Lack of organization and leadership necessary to engage with government and successfully follow through with registration requirements

G.3 Crediting period

The project has a crediting period of 25 years.

G.4 Baseline scenario

G.4.1 Carbon pools

In order to calculate the total carbon baseline, it must be determined what sources of carbon are to be considered. describes the choice and justification for the carbon pools included and excluded in the carbon baseline and the carbon modeling.

Table G-2 – Carbon Pools

Carbon Pool		Includes	Included	Excluded with Reasoning
Above & below ground non-woody biomass	Aboveground	Grasses, Musaceae etc.	No	Carbon pool is expected to be very small and it is difficult and costly to measure.
	Belowground	Roots	No	
Above & below ground woody biomass (DBH >= 5 cm)	Aboveground	Stems, branches, bark	Yes	
	Belowground	Tree roots	Yes	
Above & Below ground woody biomass (DBH < 5 cm)	Aboveground	Shrubs, small trees etc.	No	Carbon pool is expected to be very small and it is costly to measure.
	Belowground	Roots of shrubs, small trees etc.	No	
Soil		Organic material	No	Carbon pool is expected to be small.
Litter & Lying dead-wood		Leaves, small fallen branches, lying dead wood	No	Carbon pool is expected to be very small.

G.4.2 Methodology

The first phase of conducting the baseline was determining the initial carbon stock present in above and below ground woody biomass. To do so, the project boundary was stratified into one eligible vegetation cover class using satellite imagery. Field teams sampled the eligible stratum and measured then woody biomass to estimate the initial carbon stock. See Appendix 4 for a complete description of the methodology used.

G.5 Ecosystem service benefits

G.5.1 Methodology

Ex-ante carbon stocks are estimated by modeling tree growth and stand development for carbon stock in tree biomass. The Gold Standard afforestation/reforestation (A/R) Requirements[3] were used. Under this method existing data are used in combination with tree growth models to predict the growth of trees and the development of the tree stand over time for each strata. In this case, the strata are the different technical specifications modeling on a per hectare or per kilometer basis. See Appendix 3 for a full description of the methodology used and detailed results.

G.6 Leakage & uncertainty

In this project leakage is not anticipated to be an issue as project interventions are added into existing agricultural systems rather than in addition to agricultural activities.

Uncertainty is inherent in any model, the goodness of fit and key assumptions for each model are presented in more detail in Appendix 3.

[3] Gold Standard Foundation (2014). The Gold Standard Afforestation/Reforestation (A/R) Requirements V.0.9 available at: http://www.goldstandard.org/wp-content/uploads/2014/01/AR-Requirements_v0-9.pdf

H Risk Management

H.1 Identification of risk areas

Risk factors associated with the project and mitigation strategies are presented in Table H-1.

Table H-1 – Risk factors and strategies

Risk Factor	Mitigation Strategy
Legal/Social	
Disputes caused by conflict of program aims/activities with local communities/organisations	Participatory planning and continued stakeholder consultation over program life span. Organization of stakeholders into SILC groups which include formal roles and leadership.
Land tenure and carbon ownership disputes	Close collaboration with participating SILC members. Written declaration of tenure by COCODEs.
Project Organisation	
Management of activities not carried out effectively	Adequate training of project managers and staff.
Double-counting due to poor record keeping	Transparent record-keeping procedures written in project design document and quality mapping of program activities and area; up-to-date database with records of all carbon monitored and sold.
Project not practically viable in long-term due to lack of resources/skills/expertise	Careful selection of program staff and training. Training and staff development of local partner who will continue working in the project region post-project.
Economic	
Financial failure	Funding secured to cover project development costs in order to test project processes.
Natural	
Pests and diseases	Careful selection of tree species. Most species used are native or naturalized.
Extreme climatic events	Site selection criteria; takes into account of slope of land and proximity to shifting riverbeds.

H.2 Risk buffer

A 20% risk buffer is used in the calculation of the carbon benefit.

I Project Coordination and Management

I.1 Project organizational structure

I.1.1 Project coordinator and legal status

CRS Guatemala is overseeing the implementation of the project and the marketing and sale of carbon offsets. Local partners in each department are responsible for all project coordination and operations. CARITAS is responsible for San Marcos and ADIPO is responsible for Santa Maria de Chiquimula.

CRS is a faith-based 501(c)(3) charity registered in the United States.

Caritas San Marcos is a faith-based foundation, charitable, non-political and non-profit registered in Guatemala. Caritas has 17 years of experience, a permanent and dedicated staff with experience implementing education, micro-credit, health, water and sanitation, agriculture, livelihoods and emergency response interventions.

ADIPO is a private, non-governmental, non-political, non-profit organization registered in Guatemala. ADIPO has a team of qualified and experienced staff implementing projects in health, agriculture, environment, livelihoods and education since 1992.

I.1.2 Organizational structure

The organizational structure is summarized Figure I-1.

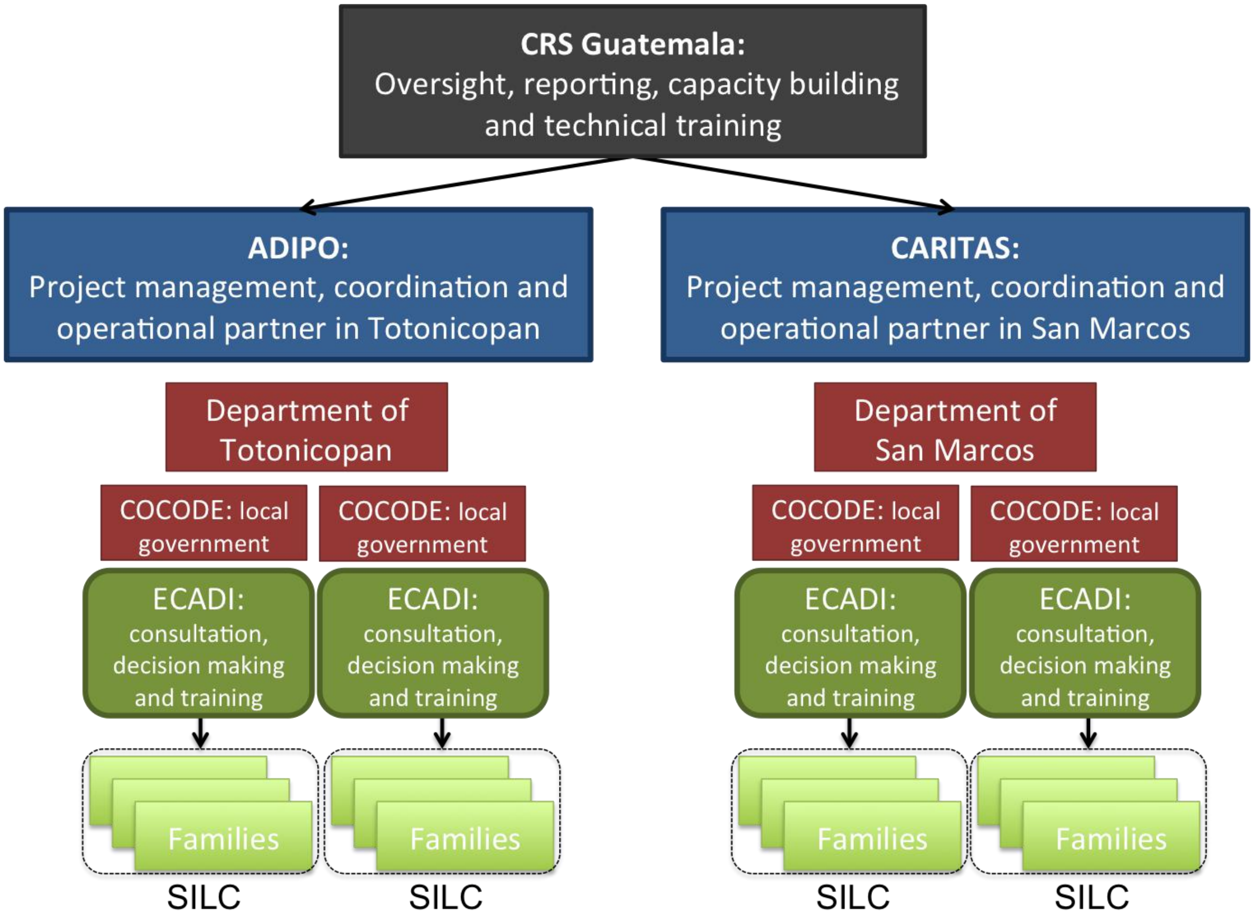

Figure I-1 Organizational structure flowchart.

I.2 Relationships to national organizations

There is no coordination at the national level with government or organizations.

I.3 Legal compliance

All project activities are in compliance with Guatemalan laws and regulations. The Ministry of Natural Resources (MNR) confirmed that the government of Guatemala does not currently regulate the issuance of carbon credits (Appendix 1).

I.4 Project management

I.4.1 Timeline

An approximate project timeline is outlined in Table I-1- Timeline.

Table I-1- Timeline		
Milestone		**Timeline**
Project Registration with Plan Vivo		Early 2015
Piloting	Planting	Spring 2015
	Monitoring	Fall 2015
	Validation	Winter 2015
Scaling-up		2016 onward

I.4.2 Record Keeping

The EMMA project will manage all project information using a Smallholder Carbon Project Information Management System (SCPIMS), developed by Taking Root. The SCPIMS is an indispensable, highly customized tool for managing smallholder carbon projects. It provides the basic needs of data management of the technical and financial information from the program as well as communicating it with the entities and people that depend on that information. These entities and people include: the Plan Vivo Foundation for annual reporting, CRS Guatemala, the third party program validators and verifiers, the program management team and the ECADIs.

The SCPIMS tracks and records participating smallholder farmer names, Plan Vivos, copies of identification cards, verification of land tenure by local SILCs and the area dedicated to the prospective technical specification. The SCPIMS also tracks the sale of Plan Vivo Certificates. It records the purchaser, the quantity purchased, the date purchased, the planting season associated with the purchase, the price and the proportionate amount of money directed towards the Plan Vivo Trust Fund.

The SCPIMS also provides analytics from annual monitoring listed by year, participant, and parcel (e.g. tree species, density, height, diameter, survival) and exports annual reports prepared to Plan Vivo requirements. Since the SCPIMS is linked to a mobile data collection application, the program technicians can enter data directly into the SCPIMS system, ensuring efficiency and accuracy in the data-entry process. Using collected monitoring data the system automatically calculates payment amounts to be disbursed to SILCs. By automating and streamlining this process, errors in data entry and analysis are greatly reduced. Furthermore, this automation allows for large cost savings in labor by reducing what would otherwise take months to complete to a matter of minutes.

I.5 Project financial management

I.5.1 Mechanism of disbursement of PES funds

The monetization and disbursement of PES will follow standard CRS procedure. The sale of carbon offsets takes place at CRS headquarters in the United States and funds are channelled to the country office. Funds are then transferred to farmers upon successfully meeting monitoring milestones.

I.5.2 Project budget

The EMMA project is part of a broader SEGAMIL project funded by USAID. The total budget of the SEGAMIL project is US$43,174,117 from July 1, 2012 to June 30, 2018. However, tree planting activities and the sale of carbon offsets is an additional funding component to the program that funds planting activities and expands based on sales and local demand.

I.6 Marketing

The marketing and sales of Plan Vivo certificates are facilitated through CRS headquarters. CRS headquarters integrates this into their fundraising and markets the offsets to the different CRS partners.

I.7 Technical support

External consultants Taking Root will provide technical support and capacity building through continued training, project design, and online support.

I.7.1 Tree nurseries

Caritas and ADIPO professionals provide guidance for the central tree nurseries while ECADI members execute on-site supervision. Most of the labour is done by the participating smallholders who are responsible for doing their proportional share of the work depending on the size of their individual farm. This helps build local capacity while ensuring quality guidelines are met.

I.7.2 Agroforestry management

ECADIs will provide training for participating smallholders on how to establish and manage agroforestry systems at the various stages of development. Under the guidance of ECADIs, each smallholder is responsible for the management of their own Plan Vivo. However, it is not uncommon for various participants to form work parties and take turns working on each other’s properties.

J Benefit Sharing

J.1 PES agreements

A PES agreement template is provided in Appendix 2. Whenever a PES agreement is signed with a SILC, CRS will either have a buyer identified for the carbon offset or the CRS head office will fund the PES. The agreements are in Spanish and the technician will go through each aspect of the agreement in great detail. The technician will translate the agreement to the participant's local language when relevant.

J.2 Payments & benefit sharing

The disbursement of payments is illustrated in Figure J-1. SILCs receive a bulk payment for their collective carbon offsets and choose how the money is spent within the group.

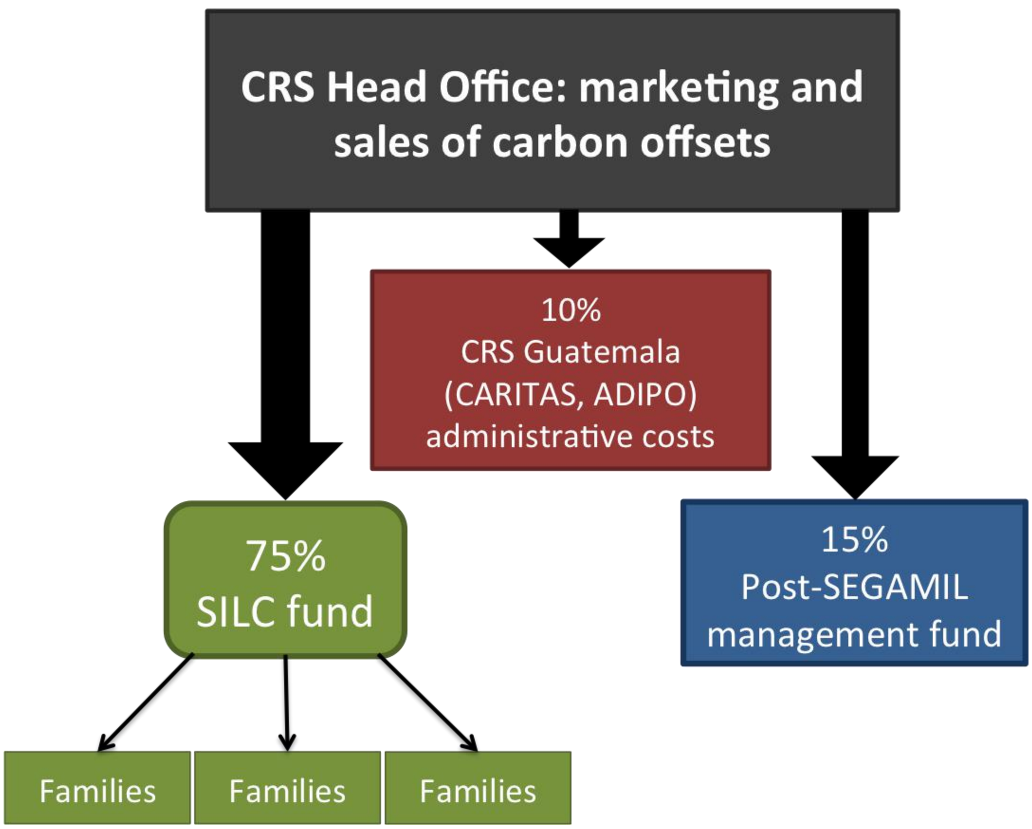

Figure J-1 Payment disbursement schematic.

K Monitoring

K.1 Monitoring of ecosystem services benefits

K.1.1 Monitoring plan

A total of 10% of farms within in a participating SILC, with a minimum of 2 farms per SILC, are randomly selected for monitoring. Annually, community technicians from CARITAS or ADIPO visit the selected farms and measure every tree planted. The information is entered into tablets and synched to the SCPIMS once back in the office.

K.1.2 Community involvement

Though the responsible parties for monitoring are technicians from CARITAS and ADIPO, participating farmers will be involved in the monitoring activities. When technicians arrive at participating farms to complete monitoring procedures farmers are briefed and technicians receive verbal consent. Farmers are requested to join in monitoring so they can understand how monitoring is being conducted and see that their farms are in no way damaged by the procedures.

K.1.3 Monitoring indicators

Monitoring indicators as well as the instruments being used and the justification are summarized in Table K-1.

Table K-1 – Monitoring indicators.

Variable	Instrument	Justification
DBH	Caliper or DBH tape	Measured for all trees with a height > 1.3 meters. DBH is a very easily measured tree attribute which is highly correlated with trees biomass.
Height	Measuring tape	Measured for all trees with a height < 1.3 meters since these trees are not tall enough to have a DBH.
Species	N/A	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.
Condition: dead or alive	N/A	Used for carbon yield estimates
Requires clearing	N/A	Used to verify milestone completion
Require pruning	N/A	Used to verify milestone completion

K.1.5 Performance indicators

Performance indicators and payment plan are summarized in Table K-2 and Table K-3.

Table K-2 – Performance indicators for dispersed planting design				
Year	**Basis of payment**	**Threshold**	**Target**	**% Of total payment received**
1	Planting trees at specified density, weeding	Minimum density of 100 trees/ha	Density of 114 trees/ha	25%
2	Re-planting, weeding	Minimum density of 100 trees/ha	Minimum density of 114 trees/ha	20%
3	Weeding	Minimum density of 100 trees/ha and 75% of plots well weeded	Minimum density of 114 trees/ha. 100% of plots cleared	15%
4	Weeding, pruning	75% of plots well weeded and pruned	100% of plots well weeded and pruned	10%
5	Weeding		No payment	0%
6	Basal area	Basal are no less than 75% of target	**Basal area no less than:** Lower Zone: A-C 1.95 m^2/ha A-A 2.01 m^2/ha Upper Zone: A-C 1.61 m^2/ha	10%
7	Weeding		No payment	0%
8	Weeding, pruning	Basal are no less than 75% of target	**Basal area no less than:** Lower Zone: A-C 3.24 m^2 A-A 3.38 m^2 Upper Zone: A-C 2.67 m^2	10%
9			No payment	0%
10	Basal area	Basal are no less than 75% of target	**Basal area no less than:** Lower Zone: A-C 3.32 m^2 A-A 3.50 m^2 Upper Zone: A-C 2.80 m^2	10%

*A-C: alder-cherry, A-A: alder-avocado,

Table K-3 – Performance indicators for barrier planting design				
Year	**Basis of payment**	**Threshold**	**Target**	**% Of total payment received**
1	Planting trees at specified density, weeding	Minimum density of 180 trees/km	Density of 220 trees/km	25%
2	Re-planting, weeding	Minimum density of 180 trees/km	Density of 220 trees/km	20%
3	Weeding	Minimum density of 220 trees/km and 75% of plots well weeded	Minimum density of 220 trees/km. 100% of plots cleared	15%
4	Weeding, pruning	75% of plots well weeded and pruned	100% of plots well weeded and pruned	10%
5	Weeding		No payment	0%
6	Basal area	Basal are no less than 75% of target	**Basal area no less than:** Lower Zone: 2.97 m^2/km Upper Zone: 2.51 m^2/km	10%
7	Weeding		No payment	0%
8	Weeding, pruning	Basal are no less than 75% of target	**Basal area no less than:** Lower Zone: 4.62 m^2/km Upper Zone: 4.10 m^2/km	10%
9			No payment	0%
10	Basal area	Basal are no less than 75% of target	**Basal area no less than:** Lower Zone: 5.54 m^2/km Upper Zone: 5.18 m^2/km	10%

K.2 Socio-economic impacts

Socio-economic impacts will be monitored by the larger SEGAMIL project.

L Appendix 1: MARN Communications

L.1 Notificacion al MARN – Plan Vivo

CATHOLIC RELIEF SERVICES

Guatemala, 20 de agosto de 2013.

Estimado
XXXXXXXXX
Ministerio de Ambiente y Recursos Naturales

Respetable Señor:

Reciba un atento saludo en nombre de nuestra organización, con el empeño compartido de alcanzar mejores condiciones para la población y el medio ambiente de nuestro país.

Esta carta sirve como notificación que el organización sin fines de lucres Catholic Relief Services, con sede en Baltimore, Maryland, EEUU, tiene el intención de implementar un programa voluntario de Pagos por Servicios Ambientales (Créditos de Carbonos) en los Departamentos de San Marcos y Totonicapán. Este programa seria en cumplimiento completo con las leyes del Gobierno de Guatemala.

Con referencia a la solicitud 2403, con fecha del 7 de Marzo, 2013, dirigido, a la Unidad de Información Publica del Ministerio de Ambiente y Recursos Naturales recibimos la respuesta siguiente: **Form-MARN-UIP-2394, Oficio No. UIP-201-213/JPM/mcf “Por lo anterior, lo comunico que en Guatemala no está regulada la emisión de bonos de captura de CO2.”**

Gracias por confirmar la recepción de esta carta.

Agradeciendo la atención a la presente,

Anne Elizabeth Bousquet
Directora CRS Guatemala
Catholic Relief Services CRS Guatemala
Diagonal 6, 11-97 Zona 10, Oficina 201, Edificio Internaciones,
Guatemala, C.A. Teléfono oficina PBX (502) 23622173

L.2 Respuesta oficial MARN

Gobierno de Guatemala
Ministerio de Ambiente y Recursos Naturales

Oficio No. ONDL-10-2013/RECI/mmc
Guatemala, 8 de marzo de 2013

Señora
María del Carmen Fonseca
Coordinadora a.i.
Unidad de Información Pública
Presente

Estimada Señora Fonseca:

Por este medio me dirijo a usted para hacer referencia a su solicitud **Expediente: Form-MARN-UIP-2394, Oficio No. UIP-201-2013/JPM/mcf,** con fecha 7 de marzo del presente.

Por lo anterior, le comunico que en Guatemala no está regulada la emisión de bonos de captura CO_2.

Sin otro particular, me suscribo.

Atentamente,

Ing. Raul Castañeda Illescas
COORDINADOR
OFICINA NACIONAL DE DESARROLLO LIMPIO
MINISTERIO DE AMBIENTE Y RECURSOS NATURALES

Ministerio de Ambiente y Recursos Naturales
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20 calle 28-58 zona 10, 01010 PBX (502) 2423-0500 Ciudad Guatemala
www.guatemala.gob.gt | www.marn.gob.gt

M Appendix 2: Sales Agreements

M.1 Sales Agreement ADIPO

Guatemala
Carbon Agreement

Name of SILC:
Plan Vivo #:
Year:

Section I: Preamble
We the **Developer**: *Catholic Relief Services at 228 W. Lexington St, Baltimore, Maryland, USA,* ADIPO Guatemala at 8 Calle, 8-89, zona 2 de San Marcos, Guatemala and SILC: *Full Name,* ID: *ID Number.* All parties have decided to sign this agreement under the following terms:

This agreement aims to provide the terms and conditions agreed by the parties listed below for the sale of ecosystem services under the Plan Vivo system framework applied through an agroforestry project and detailed in the forestry management plans attached to this agreement in Tables *A, B, and C*.

Whereas Developer agrees to purchase the SILC's ecosystem services under the Plan Vivo brand, the price and the conditions set forth below:

Whereas the SILC is the owner of the land described in Section *A* of this agreement, of which the Plan Vivo number is related to the same land, and that the rules of the Plan Vivo system have been evaluated and approved by Developer.

Section II:
1. This agreement will run for *fifty (25) years* starting from the signing of this agreement and ending the *(DATE)*.

CONDITIONS
The Developer agrees to:
2. Carry out technical monitoring of the SILC's Plan Vivo designated land during the period of the agreement with respect to the objectives set out in Tables *A, B, and C* and in accordance with its procedures, as specified in the project manual.

3. Pay SILC the incentive established in Table A, where the monitoring results show that the corresponding targets are met, records of these transactions are kept by Developer official receipts.

4. If monitoring results comply only with the threshold, *50%* of the payment shall be paid to the SILC and the other *50%* the following year when goals set in the project are met.

5. In cases where advanced payments are given to the SILC to carry out their Plan Vivo, the debt will be deducted from the payment according to the project specifications. Records of these transactions are kept by the Developer as official receipts.

The SILC agrees to:

6. Perform the activities summarized in *Tables A, B, and C*, specifically management actions established in this agreement and implement corrective actions prescribed during the monitoring process. Failure to perform these activities is considered a Breach of agreement (see section III).

7. Identify a Guarantor for this Agreement.

M.2 Sales Agreement CARITAS

CRS CATHOLIC RELIEF SERVICES	**Guatemala Carbon Agreement**	**Name of SILC:** **Plan Vivo #:** **Year:**

Section I: Preamble
We the **Developer**: *Catholic Relief Services at 228 W. Lexington St, Baltimore, Maryland, USA,* CARITAS Guatemala at km. 15 Carretera Roosevelt, 4-54, zona 3 de Mixco, Guatemala and SILC: *Full Name,* ID: *ID Number.* All parties have decided to sign this agreement under the following terms:

This agreement aims to provide the terms and conditions agreed by the parties listed below for the sale of ecosystem services under the Plan Vivo system framework applied through an agroforestry project and detailed in the forestry management plans attached to this agreement in Tables *A, B, and C.*

Whereas Developer agrees to purchase the SILC's ecosystem services under the Plan Vivo brand, the price and the conditions set forth below:

Whereas the SILC is the owner of the land described in Section *A* of this agreement, of which the Plan Vivo number is related to the same land, and that the rules of the Plan Vivo system have been evaluated and approved by Developer.

Section II:
1. This agreement will run for *fifty (25) years* starting from the signing of this agreement and ending the *(DATE)*.

CONDITIONS
The Developer agrees to:
2. Carry out technical monitoring of the SILC's Plan Vivo designated land during the period of the agreement with respect to the objectives set out in Tables *A, B, and C* and in accordance with its procedures, as specified in the project manual.

3. Pay SILC the incentive established in Table A, where the monitoring results show that the corresponding targets are met, records of these transactions are kept by Developer official receipts.

4. If monitoring results comply only with the threshold, *50%* of the payment shall be paid to the SILC and the other *50%* the following year when goals set in the project are met.

5. In cases where advanced payments are given to the SILC to carry out their Plan Vivo, the debt will be deducted from the payment according to the project specifications. Records of these transactions are kept by the Developer as official receipts.

The SILC agrees to:

6. Perform the activities summarized in *Tables A, B, and C*, specifically management actions established in this agreement and implement corrective actions prescribed during the monitoring process. Failure to perform these activities is considered a Breach of agreement (see section III).

7. Identify a Guarantor for this Agreement.

N Appendix 3: Carbon Modeling

N.1 Methodology

Ex-ante carbon stocks were estimated using the Gold Standard afforestation/reforestation (A/R) Requirements[4]. Under this method, existing data are used in combination with tree growth models to predict the growth of trees and the development of the tree stands over time for each strata. In this case, the strata are the different technical specifications modeled on a per hectare or per kilometer basis. The carbon pools included and excluded are described and justified in below.

Appendix Table 1 – Carbon Pools

Carbon Pool		Includes	Included	Excluded with Reasoning
Above & below ground non-woody biomass	Aboveground	Corn, beans, squash	No	Carbon pool is expected to be very small and unchanged since agricultural land-use remains unchanged
	Belowground	Roots	No	
Above & below ground woody biomass	Aboveground	Stems, branches, bark	Yes	
	Belowground	Tree roots	Yes	
Soil		Organic material	No	Carbon pool is expected to be very small and it is difficult and costly to measure.
Litter & Lying dead-wood		Leaves, small fallen branches, lying dead wood	No	Carbon pool is expected to be very small and it is difficult and costly to measure.

N.1.1 Carbon stock

The carbon stock in tree biomass was modeled based on tree growth and stand development as follows:

$$C_{TREE} = \sum_{s=1}^{S} \sum_{n=1}^{N} C_{tree_{n,s}}$$

[4] Gold Standard Foundation (2014). The Gold Standard Afforestation/Reforestation (A/R) Requirements V.0.9 available at: http://www.goldstandard.org/wp-content/uploads/2014/01/AR-Requirements_v0-9.pdf

$$C_{tree} = (AGB + BGB) \times \frac{44}{12} \times CF_{Tree}$$

$$BGB = AGB \times R_s$$

Where:

C_{TREE} = Carbon stock in trees in the tree biomass estimation strata (tCO_2e);

$CF_{tree_{n,s}}$ = Carbon stock of tree *n* of species *s* (tC). A default value of 0.49 was used for tropical tree species[5]

BGB = Below ground biomass (t d.m.)

R_s = Shoot to root ratio (dimensionless). A default value of 0.24 was used for tropical tree species[2].

AGB= Above ground biomass (t d.m.)

AGB = Above ground biomass (t d.m.) determined by the following species specific biomass equations:

For pine, a general equation for tropical pine species[6] such that:

$$AGB = 0.1354(DBH)^{2.3033}$$

Where:

DBH = diameter of tree at breast height (cm)

H = height (m)

For cherry (*Prunus serotina*) a species specific equation[7] such that:

$$AGB = -2.67 + 0.03(DBH^2 \times H)$$

For Alder (*Alnus jorullensis*) a species specific equation[8] such that:

---

[5] IPCC (2006). default value - Guidelines for National Greenhouse Gas Inventories. Volume 4 Agriculture, Forestry and Other Land Use. p.73.

[6] Návar, J. (2009). Allometric equations for tree species and carbon stocks for forests of northwestern Mexico. Forest Ecology and Management, 257(2), 427–434. doi:10.1016/j.foreco.2008.09.028

[7] Annighöfer, P., Mölder, I., Zerbe, S., Kawaletz, H., Terwei, A., & Ammer, C. (2012). Biomass functions for the two alien tree species Prunus serotina Ehrh. and Robinia pseudoacacia L. in floodplain forests of Northern Italy. European Journal of Forest Research, 131(5), 1619–1635. doi:10.1007/s10342-012-0629-2

[8] Mireles, M. A. (2011). Estimación de biomasa y carbono en dos especies de bosque mesófilo de montaña. *Revista Mexicana de Ciencias Agrícolas*, *2*(4), 529–543.

$AGB = 0.1649 \times \text{DBH}^{2.2755}$

For avocado, a general equation for total biomass for moist tropical forests[9] was such that:

$$AGB_{Avocado} = \frac{0.059 \times \rho DBH^2 H}{1{,}000}$$

where

ρ = density of the over dried wood using a constant for avocado of 590 kg/m^3.

N.2 Growth and yield

The growth and yield was based on a DBH driven model from which height was derived. The models were developed in house according to the following methodology:

N.2.1 Data Collection

In the months of August and September 2014, 291 trees of the species used in this technical specification were purposively sampled. Trees were sampled in 122 plots at similar densities (measured in trees per hectare) as proposed in these technical specifications located on farms across the municipalities of San Marcos and Santa Maria de Totonicopan. At each sample location, a 7 m radius plot was used and all trees within the plot were measured. The diameter at breast height (DBH) was measured at 1.3 meters above ground using a DBH tape. Total height of each tree was measured using a clinometer and farmers whose land the tree was on estimated age. Efforts were made to sample stands with the full variety of ages and densities used for the proposed modeling exercise. Summary statistics for the trees measured are presented in Appendix Table 2 – 5 below.

[9] Chave, J., Andalo, C., Brown, S., Cairns, M. a, Chambers, J. Q., Eamus, D., … Yamakura, T. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia, 145(1), 87–99. doi:10.1007/s00442-005-0100-x

Appendix Table 2 – Avocado					
Variable	**n**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
DBH (cm)	45	21.27	12.40	0.5	60
Height (m)	45	8.95	4.07	0.6	18
Trees per plot (TPP)	45	2.02	1.12	1	4
Age (years)	45	11.20	6.86	1	25

Appendix Table 3 – Alder					
Variable	**n**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
DBH (cm)	87	11.84	8.06	1	35
Height (m)	87	8.67	5.89	1	26
Trees per plot (TPP)	87	3.31	0.69	2	4
Age (years)	86	6.29	4.51	1	18

Appendix Table 4 – Cherry					
Variable	**n**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
DBH (cm)	71	10.53	6.61	0.9	30
Height (m)	71	6.61	3.56	1.2	19
Trees per plot (TPP)	71	3.03	0.72	1	4
Age (years)	71	5.49	2.97	1	19

Appendix Table 5 – Pine					
Variable	**n**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
DBH (cm)	88	16.76	11.87	1	80
Height (m)	88	10.51	7.77	0.8	35
Trees per plot (TPP)	88	3.34	0.69	1	4
Age (years)	88	8.56	7.29	0.5	50

N.2.2 Trees per hectare

To calculate the number of trees per hectare (TPH) in each plot, the number of trees measured in each plot was multiplied by the appropriate expansion factor:

$$EF = \frac{10{,}000}{\pi \times r^2}$$

$$EF = 64.96$$

Where EF= Expansion factor; π = 3.14159; and r = radius of the plot equal to 153.938.

To correct for the slope of the land, a slope correction formula was used such that:

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

Where L = the true horizontal plot area; L_s = the standard plot area measured in the field along the steepest slope; S = the slope in degrees; Cos = the cosine of the angle.

Basal Area per Hectare was calculated as follows:
$BAHA = \sum_{i=1}^{p} \pi(\frac{DBH}{200})^2 \times EF$

Where p = plot; i = i^{th} tree per plot; DBH = diameter at breast height (cm); and $BAHA$ = basal area per hectare (m^2/ha)

N.2.3 Growth and Yield

The models were fitted using PROC REG of SAS version 9.4 and variables were tested for statistical significance using α =0.05.

DBH was modeled using a nonlinear Chapman-Richard functional form such that:

$$DBH_{t,s} = \alpha \times [1 - EXP(-\beta_{1_s} \times t)]^{\beta_{2s}} + \varepsilon$$

Where α = upper DBH value of the data range; t = time; s = species;

It is important to note that this analysis was performed using cross-sectional data to make time-series inferences, thus biasing the results[10]. This is due to a lack of information on factors that affected the growth trajectory of a particular stand. To minimize this bias, samples were taken at the density, elevation and same climactic conditions where the growth and yield models are applied. This analysis provides the best estimate available for modeling growth and yield curves given the paucity of available time series data.

All models were visually inspected to confirm that the models fit the data and the coefficients of determination are presented.

N.2.4 Modeling height

Height prediction models were developed for each species using the following methodology. Height and DBH were plotted and visually inspected for a linear relationship. If the relationship was linear, a simple linear regression model was:

$$Height = \alpha + \beta_1 \times DBH + \varepsilon$$

[10] Schabenberger, O., & Pierce, F. J. (2002). Contemporary Statistical Models for the Plant and Soil Sciences (p. 139). Taylor & Francis, New York.

If there was a non-linear relationship, the following model[11] was used:

$$Height = 1.3 + \gamma_1\left(1 - e^{\gamma_2 \times DBH^{\gamma_3}}\right) + \varepsilon$$

Predicted values were plotted against actual values to assure that the model fit the data.

N.2.5 Results

The coefficients of the DBH growth models are presented in Appendix Table 6.

Appendix Table 6 – Coefficients for DBH growth models					
Tree species	**Coefficient (α)**	**Coefficient (β_1)**	**Coefficient (β_2)**	**Coefficient (β_3)**	**Coefficient of determination (R^2)**
Cherry (both Life zones)	30	0.122124	1.383906	0	0.6485
Alder Life Zone 1	35	0.108669	1.310901	0	0.7967
Alder Life Zone 2	35	0.089243	1.226977	0	0.8552
Pine Life Zone 1	50	0.033531	0.740584	0	0.7800
Pine Life Zone 2	50	0.051177	0.99287	0	0.8153
Avocado	30	0.159386	1.58528	0	0.5785

[11] Yang, R. C., Kozak, A., & Smith, J. H. G. (1978). The potential of Weibull-type functions as flexible growth curves. Canadian Journal of Forest Research, 8(4), 424–431. doi:10.1139/x78-062

N.2.6 Height models

There was a linear relationship between height and DBH for all of the species measured except for avocado trees therefore a linear model was well suited for this dataset. Results for the estimated coefficients are presented in Appendix Table 7 below.

Appendix Table 7 – Coefficients for height prediction models

Tree species	Intercept (α)	Coefficient (β_1)	Coefficient (γ_1)	Coefficient (γ_2)	Coefficient (γ_3)	Coefficient of determination (R^2)
Cherry	1.86040	0.45091	N/A	N/A	N/A	0.7030
Alder	0.56774	0.6838	N/A	N/A	N/A	0.8761
Pine	0.74406	0.58294	N/A	N/A	N/A	0.7927
Avocado	N/A	N/A	15.64879	-0.03188	1.037068	0.5761

N.3 Harvesting schedule

Harvesting schedules vary according to each strata and each life zone as follows:

N.3.1 Dispersed Planting (Alder-Cherry): Life Zone 1

Cherry trees are used for fruit and are therefore not harvested. Alder trees are coppiced progressively starting in year 8 and maximum size is when DBH > 27 cm. The wood is used as fuelwood.

N.3.2 Dispersed Planting (Alder-Cherry): Life Zone 2

Cherry trees are used for fruit and are therefore not harvested. Alder trees are coppiced progressively starting in year 8 and maximum size is when DBH > 27 cm. The wood is used as fuelwood.

N.3.3 Dispersed Planting (Alder-Avocado): Life Zone 1

Avocado trees are used for fruit and are therefore not harvested. Alder trees are coppiced progressively starting in year 8 and maximum size is when DBH > 27 cm. The wood is used as fuelwood.

N.3.4 Barrier Planting (Pine-Alder): Life Zone 1

Alder trees are coppiced progressively starting in year 8 and maximum size is when DBH > 25 cm. The wood is used as fuelwood. Pine is progressively when basal area per kilometer surpasses 8 m^2/km to a basal area of 6.5 m^2/km. Harvested is estimated to start in year 25.

N.3.5 Barrier Planting (Pine-Alder): Life Zone 2

Alder trees are coppiced progressively starting in year 8 and maximum size is when DBH > 25 cm. The wood is used as fuelwood. Pine is progressively when basal area per kilometer surpasses 8 m^2/km to a basal area of 6.5 m^2/km. Harvested is estimated to start in year 25.

N.4 Calculation of Plan Vivo Certificates

The carbon benefit is determined by the biomass in the trees when they reach their long-term equilibrium. In this case, this is estimated to take place by year 25 and the equilibrium is calculated as the average value over the next 25-year period. As such, Plan Vivo certificates (PVC) are calculated as follows:

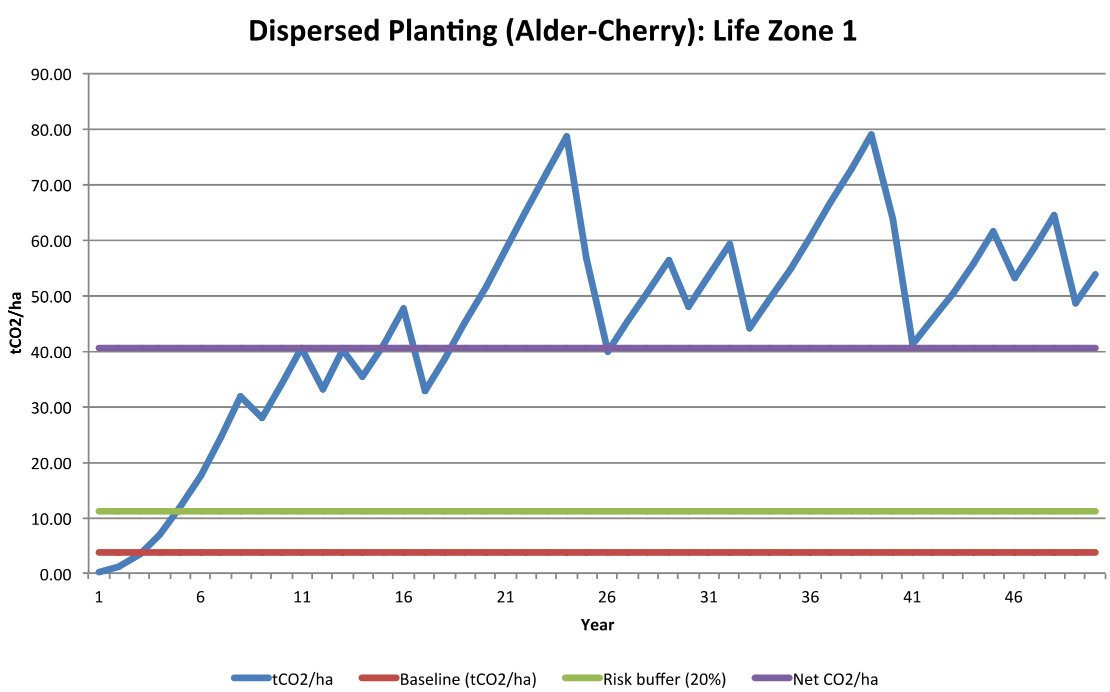
$$PVC = \frac{\sum_{t=25}^{T=50} C_{TREE_t}}{25} - Baseline - Risk\ Buffer - Leakage$$

N.5 Dispersed planting

There are three variants to the dispersed planting: Alder-Cherry in lower Holtridge life zone; Alder-Cherry in upper Holtridge life zone; Alder-Avocado in lower Holtridge life zone.

N.5.1 Alder-Cherry in lower Holtridge life zone

Results of the carbon modeling for the alder-cherry dispersed planting design are presented in Appendix Figure 1 and Appendix Table 8.



Appendix Figure 1 Cherry-alder carbon benefit in the lower Holdridge life zone.

Appendix Table 8 – Alder-cherry carbon benefit model								
Age (year)	Trees per hectare (TPH)	BAHA (m^2)	Above ground biomass (t/ha)	Below ground biomass (t/ha)	tCO_2/ha	Baseline (tCO_2/ha)	Risk buffer (20%)	Net CO_2/ha
1	144	0.03	0.01	0.00	0.03	3.63	10.10	40.5
2	144	0.18	0.46	0.11	1.03	3.63	10.10	40.5
3	144	0.47	1.47	0.35	3.27	3.63	10.10	40.5
4	144	0.87	3.07	0.74	6.84	3.63	10.10	40.5
5	144	1.38	5.24	1.26	11.67	3.63	10.10	40.5
6	144	1.95	7.89	1.89	17.59	3.63	10.10	40.5
7	144	2.58	10.94	2.62	24.36	3.63	10.10	40.5
8	144	3.24	14.26	3.42	31.77	3.63	10.10	40.5
9	144	2.80	12.52	3.01	27.90	3.63	10.10	40.5
10	144	3.32	15.23	3.65	33.92	3.63	10.10	40.5
11	144	3.86	18.12	4.35	40.36	3.63	10.10	40.5
12	144	3.17	14.90	3.58	33.20	3.63	10.10	40.5
13	144	3.80	18.00	4.32	40.10	3.63	10.10	40.5
14	144	3.35	15.80	3.79	35.19	3.63	10.10	40.5
15	144	3.86	18.51	4.44	41.25	3.63	10.10	40.5
16	144	4.40	21.40	5.14	47.67	3.63	10.10	40.5
17	144	3.12	14.73	3.54	32.82	3.63	10.10	40.5
18	144	3.61	17.37	4.17	38.70	3.63	10.10	40.5
19	144	4.13	20.17	4.84	44.94	3.63	10.10	40.5
20	144	3.84	18.95	4.55	42.21	3.63	10.10	40.5
21	144	4.33	21.56	5.17	48.03	3.63	10.10	40.5
22	144	4.84	24.31	5.84	54.17	3.63	10.10	40.5
23	144	3.85	19.45	4.67	43.34	3.63	10.10	40.5
24	144	4.30	21.79	5.23	48.54	3.63	10.10	40.5
25	144	4.77	24.30	5.83	54.13	3.63	10.10	40.5

N.5.2 Alder-Avocado in lower Holdridge life zone

Results of the carbon modeling for the alder-avocado dispersed planting design are presented in Appendix Figure 2 and

Appendix Table 9 – Alder-avocado carbon benefit model

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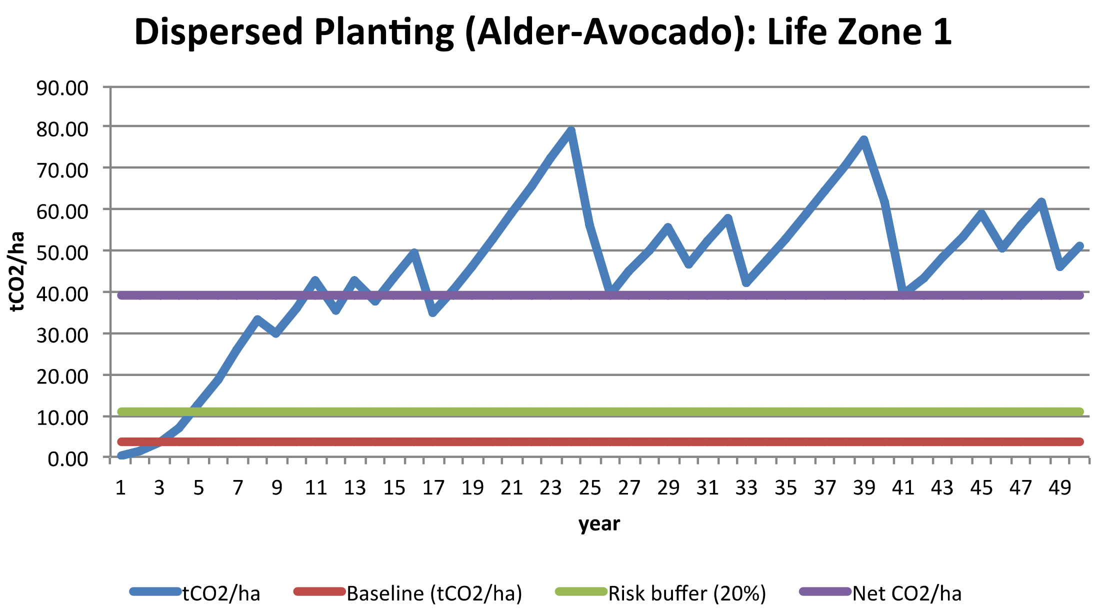
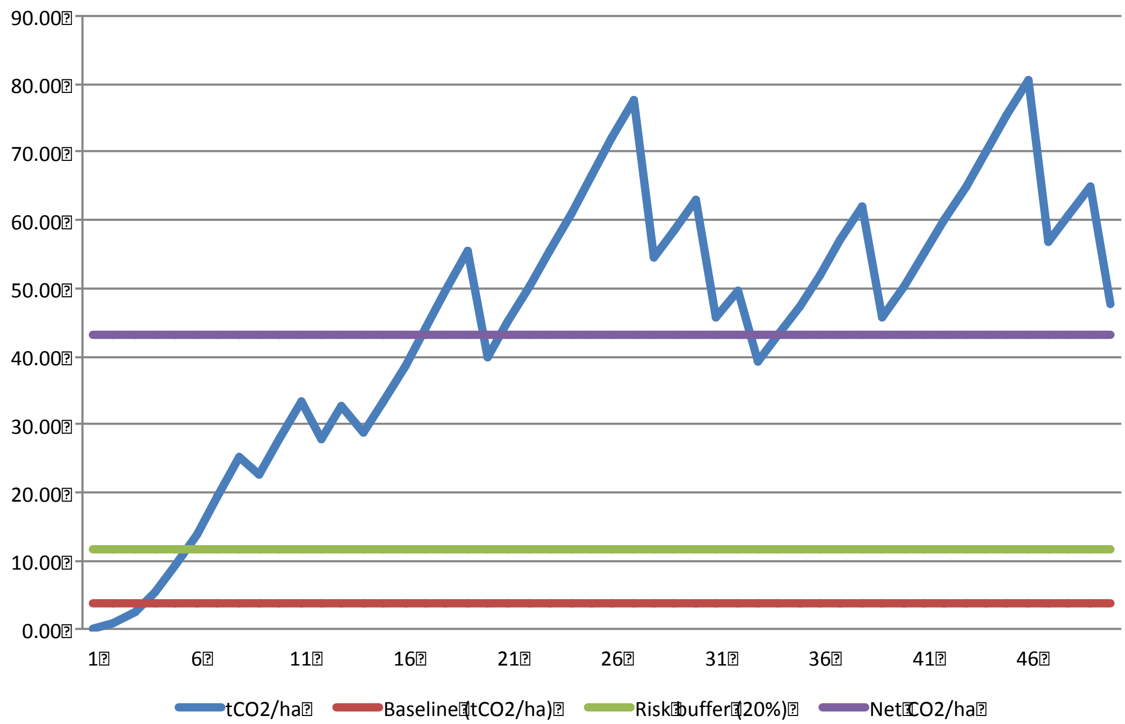


Appendix Figure 2 Alder-avocado carbon benefit in the lower Holdridge life zone.

Appendix Table 9 – Alder-avocado carbon benefit model								
Age (year)	Trees per hectare (TPH)	BAHA (m^2)	Above ground biomass (t/ha)	Below ground biomass (t/ha)	tCO_2/ ha	Baseline (tCO_2/ha)	Risk buffer (20%)	Net CO_2/ha
1	144	0.03	0.08	0.02	53.50	3.63	10.70	39.2
2	144	0.19	0.53	0.13	53.50	3.63	10.70	39.2
3	144	0.48	1.57	0.38	53.50	3.63	10.70	39.2
4	144	0.91	3.26	0.78	53.50	3.63	10.70	39.2
5	144	1.44	5.56	1.33	53.50	3.63	10.70	39.2
6	144	2.04	8.37	2.01	53.50	3.63	10.70	39.2
7	144	2.70	11.58	2.78	53.50	3.63	10.70	39.2
8	144	3.38	15.06	3.61	53.50	3.63	10.70	39.2
9	144	2.96	13.46	3.23	53.50	3.63	10.70	39.2
10	144	3.50	16.27	3.90	53.50	3.63	10.70	39.2
11	144	4.05	19.22	4.61	53.50	3.63	10.70	39.2
12	144	3.38	16.04	3.85	53.50	3.63	10.70	39.2
13	144	4.00	19.13	4.59	53.50	3.63	10.70	39.2
14	144	3.56	16.89	4.05	53.50	3.63	10.70	39.2
15	144	4.06	19.55	4.69	53.50	3.63	10.70	39.2
16	144	4.60	22.35	5.36	53.50	3.63	10.70	39.2
17	144	3.31	15.61	3.75	53.50	3.63	10.70	39.2
18	144	3.79	18.13	4.35	53.50	3.63	10.70	39.2
19	144	4.31	20.82	5.00	53.50	3.63	10.70	39.2
20	144	4.84	23.65	5.68	53.50	3.63	10.70	39.2
21	144	5.38	26.57	6.38	53.50	3.63	10.70	39.2
22	144	5.92	29.53	7.09	53.50	3.63	10.70	39.2
23	144	6.46	32.49	7.80	53.50	3.63	10.70	39.2
24	144	6.97	35.40	8.50	53.50	3.63	10.70	39.2
25	144	5.02	25.36	6.09	53.50	3.63	10.70	39.2

N.5.3 Alder-Cherry in upper Holdridge life zone

Results of the carbon modeling for the alder-avocado dispersed planting design are presented in Appendix Figure 3 and Appendix Table 10.

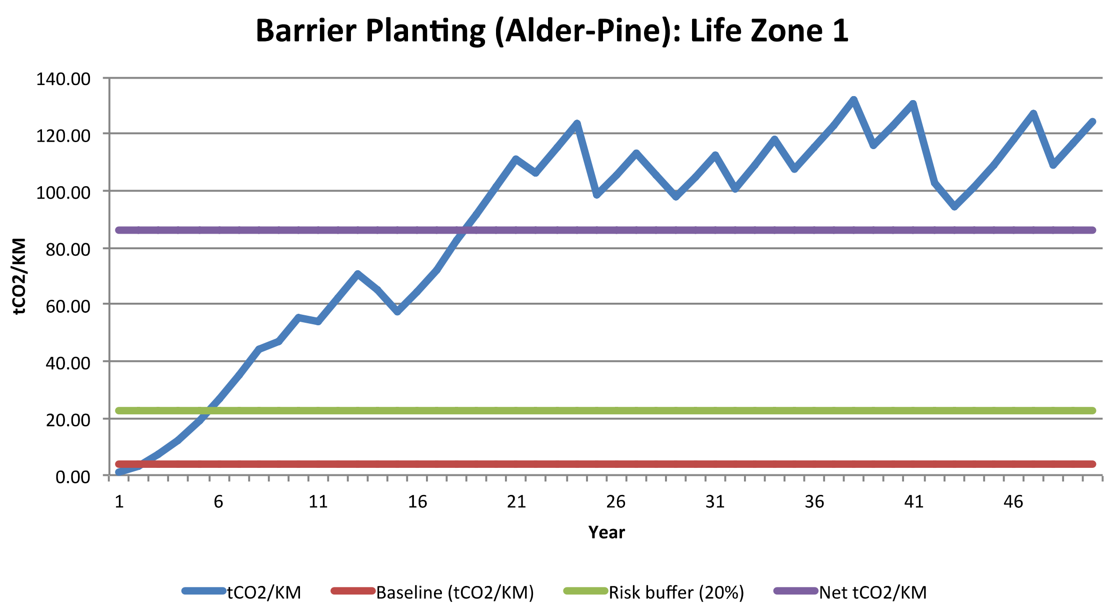


Appendix Figure 3 Alder-cherry carbon benefit in the upper Holdridge life zone

Appendix Table 10 – Alder-avocado carbon benefit model								
Age (year)	Trees per hectare (TPH)	BAHA (m^2)	Above ground biomass (t/ha)	Below ground biomass (t/ha)	tCO_2/ha	Baseline (tCO_2/ha)	Risk buffer (20%)	Net CO_2/ha
1	144	0.03	0.01	0.00	0.02	3.63	11.70	43.2
2	144	0.16	0.38	0.09	0.85	3.63	11.70	43.2
3	144	0.39	1.18	0.28	2.62	3.63	11.70	43.2
4	144	0.72	2.44	0.58	5.43	3.63	11.70	43.2
5	144	1.13	4.14	0.99	9.22	3.63	11.70	43.2
6	144	1.61	6.24	1.50	13.89	3.63	11.70	43.2
7	144	2.13	8.67	2.08	19.31	3.63	11.70	43.2
8	144	2.67	11.36	2.73	25.31	3.63	11.70	43.2
9	144	2.35	10.18	2.44	22.67	3.63	11.70	43.2
10	144	2.80	12.47	2.99	27.77	3.63	11.70	43.2
11	144	3.28	14.93	3.58	33.27	3.63	11.70	43.2
12	144	2.75	12.56	3.02	27.99	3.63	11.70	43.2
13	144	3.16	14.73	3.53	32.81	3.63	11.70	43.2
14	144	2.77	12.88	3.09	28.69	3.63	11.70	43.2
15	144	3.17	14.99	3.60	33.40	3.63	11.70	43.2
16	144	3.61	17.29	4.15	38.51	3.63	11.70	43.2
17	144	4.07	19.73	4.74	43.96	3.63	11.70	43.2
18	144	4.54	22.28	5.35	49.64	3.63	11.70	43.2
19	144	5.02	24.90	5.98	55.47	3.63	11.70	43.2
20	144	3.67	17.91	4.30	39.89	3.63	11.70	43.2
21	144	4.08	20.17	4.84	44.94	3.63	11.70	43.2
22	144	4.52	22.53	5.41	50.19	3.63	11.70	43.2
23	144	4.96	24.96	5.99	55.61	3.63	11.70	43.2
24	144	5.41	27.44	6.59	61.13	3.63	11.70	43.2
25	144	5.86	29.94	7.19	66.70	3.63	11.70	43.2

N.5.4 Barrier in lower holdridge life zone

Results of the carbon modeling for the alder-avocado dispersed planting design are presented in Appendix Figure 4 and Appendix Table 11.

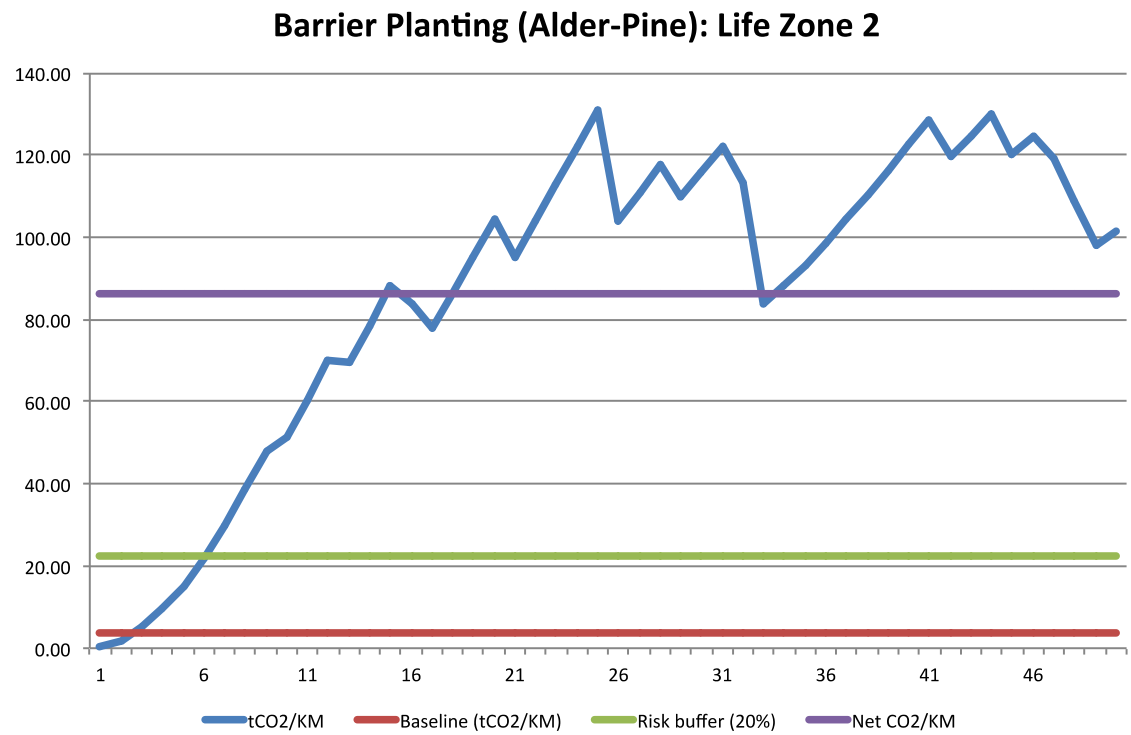


Appendix Figure 4 Barrier carbon benefit in the lower Holdridge life zone.

Appendix Table 11 – Barrier carbon benefit model								
Age (year)	Trees per KM (TPKM)	Basal Area (m^2/KM)	Above ground biomass (t/ha)	Below ground biomass (t/ha)	tCO_2/KM	Baseline (tCO_2/KM)	Risk buffer (20%)	Net CO_2/KM
1	200	0.15	0.39	0.09	0.87	3.63	22.45	86.2
2	200	0.47	1.46	0.35	3.24	3.63	22.45	86.2
3	200	0.94	3.21	0.77	7.15	3.63	22.45	86.2
4	200	1.53	5.62	1.35	12.51	3.63	22.45	86.2
5	200	2.22	8.60	2.06	19.16	3.63	22.45	86.2
6	200	2.97	12.06	2.90	26.88	3.63	22.45	86.2
7	200	3.78	15.91	3.82	35.44	3.63	22.45	86.2
8	200	4.62	20.03	4.81	44.63	3.63	22.45	86.2
9	200	4.78	21.07	5.06	46.95	3.63	22.45	86.2
10	200	5.54	24.95	5.99	55.58	3.63	22.45	86.2
11	200	5.40	24.40	5.86	54.37	3.63	22.45	86.2
12	200	6.11	28.00	6.72	62.39	3.63	22.45	86.2
13	200	6.85	31.80	7.63	70.85	3.63	22.45	86.2
14	200	6.36	29.32	7.04	65.32	3.63	22.45	86.2
15	200	5.71	25.84	6.20	57.56	3.63	22.45	86.2
16	200	6.39	29.02	6.96	64.64	3.63	22.45	86.2
17	200	7.11	32.39	7.77	72.17	3.63	22.45	86.2
18	200	7.88	36.94	8.87	82.31	3.63	22.45	86.2
19	200	8.67	41.10	9.86	91.57	3.63	22.45	86.2
20	200	9.47	45.40	10.90	101.15	3.63	22.45	86.2
21	200	10.28	49.78	11.95	110.91	3.63	22.45	86.2
22	200	9.82	47.75	11.46	106.38	3.63	22.45	86.2
23	200	10.54	51.65	12.40	115.06	3.63	22.45	86.2
24	200	11.26	55.61	13.35	123.90	3.63	22.45	86.2
25	200	8.93	44.19	10.61	98.44	3.63	22.45	86.2

N.5.5 Barrier in upper Holdridge life zone

Results of the carbon modeling for the alder-avocado dispersed planting design are presented in Appendix Figure 5 and Appendix Table 12.



Appendix Figure 5 Barrier carbon benefit in the upper Holdridge life zone.

Appendix Table 12– Barrier carbon benefit model								
Age (year)	Trees per KM (TPKM)	Basal Area (m^2/KM)	Above ground biomass (t/ha)	Below ground biomass (t/ha)	tCO_2/KM	Baseline (tCO_2/KM)	Risk buffer (20%)	Net CO_2/KM
1	200	0.07	0.17	0.04	0.38	3.63	22.44	86.1
2	200	0.31	0.88	0.21	1.96	3.63	22.44	86.1
3	200	0.68	2.23	0.53	4.96	3.63	22.44	86.1
4	200	1.19	4.21	1.01	9.38	3.63	22.44	86.1
5	200	1.81	6.79	1.63	15.13	3.63	22.44	86.1
6	200	2.51	9.90	2.38	22.05	3.63	22.44	86.1
7	200	3.28	13.45	3.23	29.97	3.63	22.44	86.1
8	200	4.10	17.37	4.17	38.71	3.63	22.44	86.1
9	200	4.95	21.59	5.18	48.11	3.63	22.44	86.1
10	200	5.18	22.96	5.51	51.15	3.63	22.44	86.1
11	200	5.99	27.10	6.50	60.37	3.63	22.44	86.1
12	200	6.83	31.41	7.54	69.98	3.63	22.44	86.1
13	200	6.73	31.18	7.48	69.45	3.63	22.44	86.1
14	200	7.51	35.27	8.47	78.58	3.63	22.44	86.1
15	200	8.32	39.52	9.48	88.05	3.63	22.44	86.1
16	200	7.91	37.65	9.04	83.87	3.63	22.44	86.1
17	200	7.37	34.97	8.39	77.90	3.63	22.44	86.1
18	200	8.10	38.77	9.30	86.37	3.63	22.44	86.1
19	200	8.86	42.78	10.27	95.31	3.63	22.44	86.1
20	200	9.65	46.98	11.28	104.67	3.63	22.44	86.1
21	200	8.75	42.79	10.27	95.33	3.63	22.44	86.1
22	200	9.47	46.71	11.21	104.07	3.63	22.44	86.1
23	200	10.20	50.70	12.17	112.95	3.63	22.44	86.1
24	200	10.92	54.70	13.13	121.87	3.63	22.44	86.1
25	200	11.62	58.70	14.09	130.77	3.63	22.44	86.1

O Appendix 4: Determining the Carbon Baseline

O.1 Initial Carbon Stock

The first phase of conducting the baseline was of determining the initial carbon stock present in aboveground and belowground woody biomass with a precision of plus or minus 20% of the mean with a 90% confidence level (two-tailed). To do so, the project boundary was stratified into non-eligible and eligible vegetation cover class using satellite imagery. The eligible stratum was then sampled in the field to estimate the initial carbon stock. The methodology in the section is based on the Winrock International Sourcebook for Land Use, Land-Use Change and Forestry Projects. (Pearson & Walker, 2005).

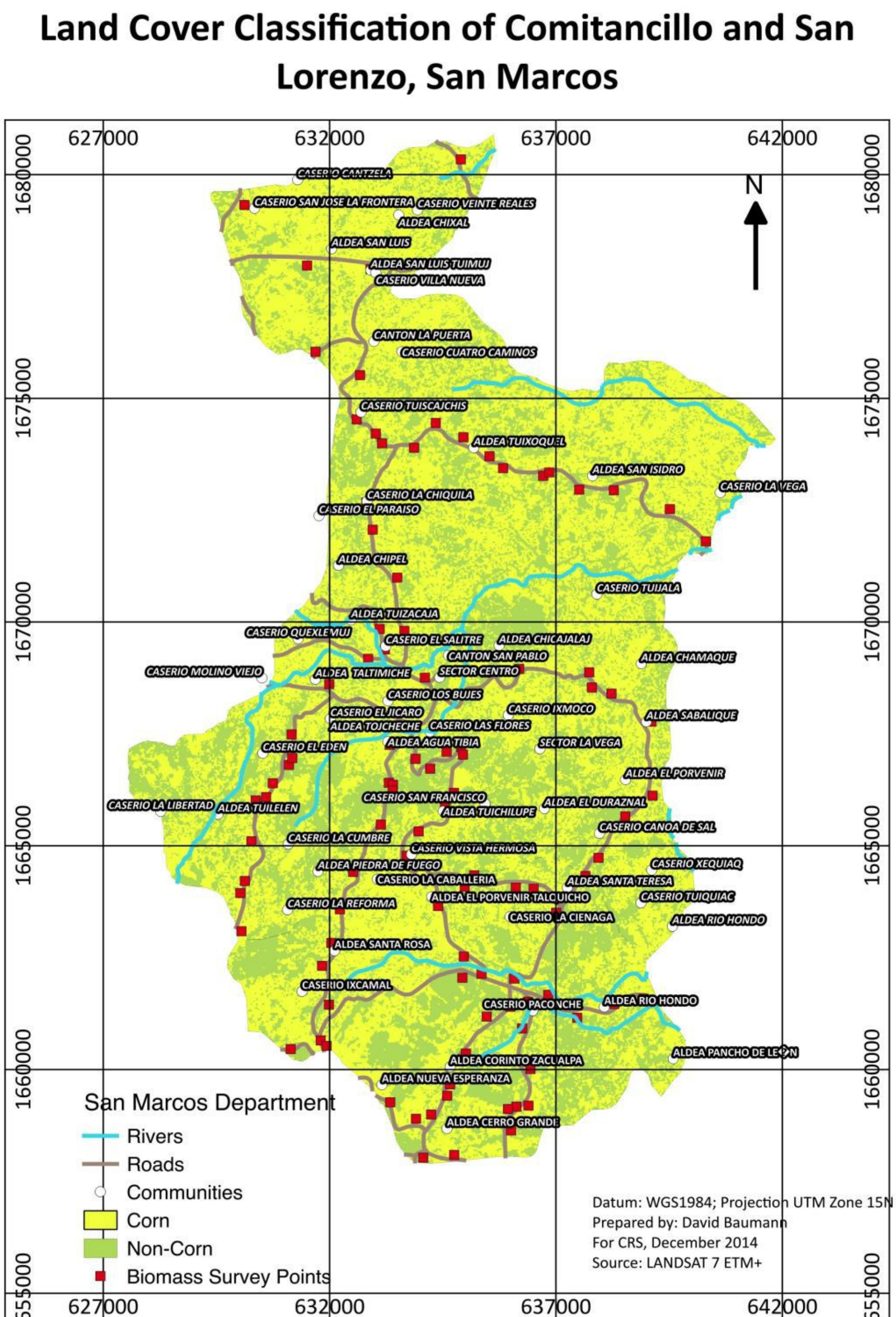
O.1.1 Stratification

Two images, Landsat 5 TM+ (September 7th 2014) and Landsat 7 EMT+ (September 13th 2014) were acquired from the United State Geological Survey (USGS) website along with a digital elevation model (DEM). These two 30-meter spatial resolution images were selected based on the limited amount of atmospheric contamination (clouds and cloud shadows) and seasonality. Seasonality was an important consideration in choosing the images due to the significant atmospheric contamination over the humid and tropical latitudes, especially during the rainy season. For the project area, clouds and cloud-shadows proved to be a significant problem that required image manipulation by removing and overlaying the two Landsat images to create one cloud free image.

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

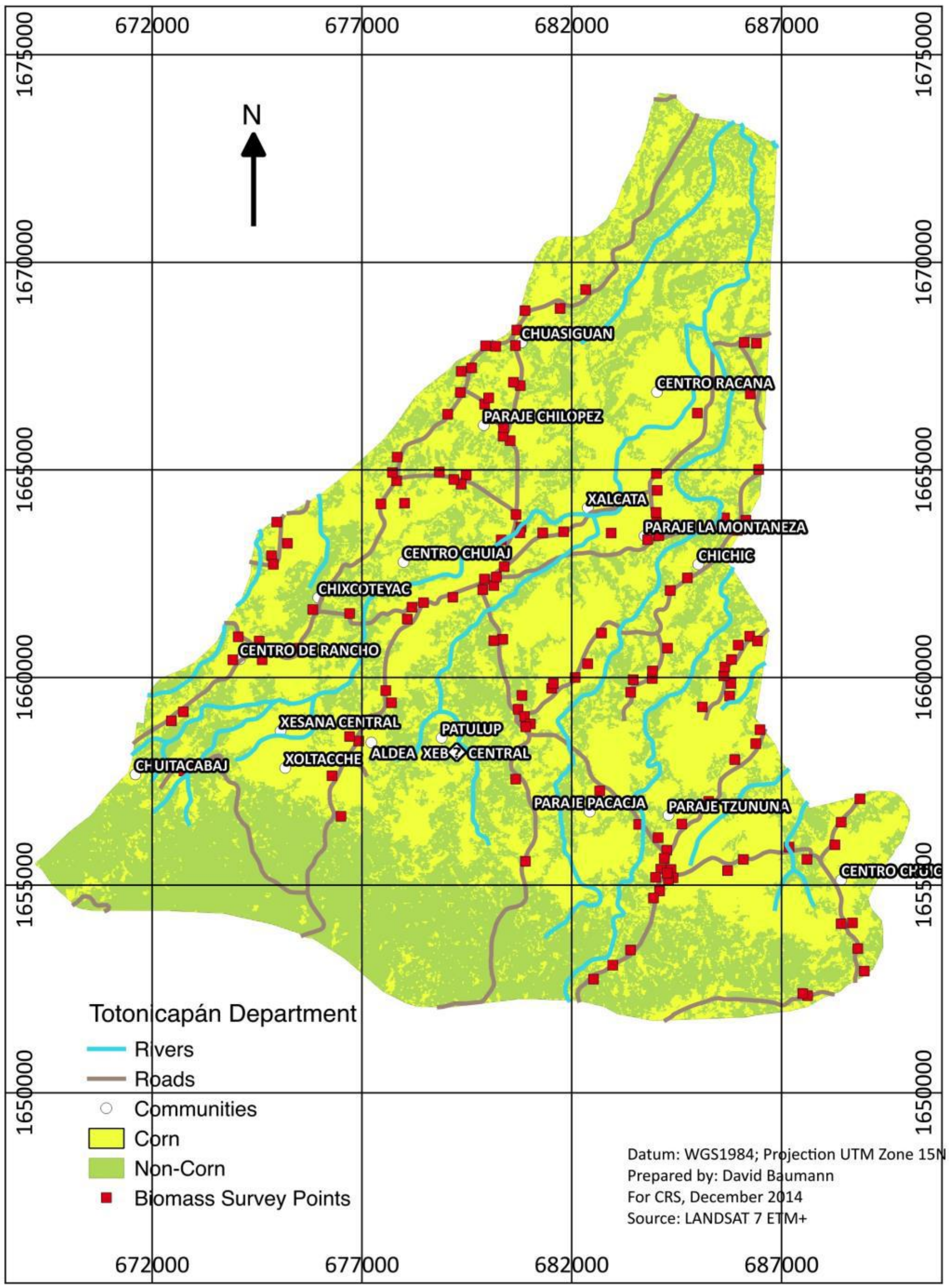
An unsupervised classification was then performed on the new image using a Region of Interest (ROI) technique. ROIs are selected areas of a raster that are identified for a particular purpose (urban, river, corn, partially corn). Using ROI, five classes were generated and then merged into two classes: corn and non-corn.

The merging of the five classes into two classes was based on imagery from Google earth and ground truthing of 50 randomly generated points throughout the project area. With the completed classification map, a total of 414 biomass survey points were randomly generated and placed within the corn classification. Finally, the accuracy of the ROI classification was evaluated after ground truthing by comparing the number of randomly generated points that were actually corn relative to the total number of points generated. In total, 254 of the survey points fell within the corn classification, leading to 61% classification accuracy. The land cover classification maps are presented in Appendix Figure 6 and Appendix Figure 7.



Appendix Figure 6 Land cover classification for the municipality of San Marcos.

Land Cover Classification of Santa Maria Chiquimula, Totonicapán



Appendix Figure 7 Land cover classification for the municipality of Totonicapan.

As mentioned above, the reason for the low classification accuracy was scale. The Landsat imagery has a pixel size of 30 m while the cornfields to be used for project activities are often smaller than 30 m. As a result, the accuracy of the classification was low. We do see this as a major limitation and source of error in our classification and carbon estimates. However, the baseline biomass sampling indicates very minimal amounts of carbon are present in the cornfields and our method ensures the estimate remains conservative.

O.1.2 Sampling

A biomass pilot survey was executed in August 2014 (n=23) using a non-stratified random sampling approach in the corn land-use classification.

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

$$\bar{Y} = \frac{\Sigma(y_i)}{n}$$

Where $\bar{Y}$ = Estimate of the overall mean; y_i= carbon value in metric tons of sample *i*; *n* = sample size

2) The required sample size was calculated as follows:

$$n = \frac{(N \times s)^2}{\frac{N^2 \times E^2}{t^2} + N \times s^2}$$

Where E = allowable error, t = t-value at 95% confidence level, N_h=number of sampling units for stratum *h*, *n*=number of sampling units in the population, and s_h= standard deviation of stratum *h*.

The results of the pilot survey suggest a sample size of over 2000 was needed to acquire the desired precision and confidence intervals. Sampling that many plots is both temporally and monetarily prohibitive. As such, we adjusted the precision of our baseline calculation to reflect a 90% confidence that the baseline is less than a critical t-value scaled to the mean. This was calculated using the following equation.

$$t_{0.1,253} = \frac{\bar{x} - m}{\frac{s}{\sqrt{N}}}$$

Where t is the critical t-value using a 90% confidence and degrees of freedom of 253, $\bar{x}$ is the population mean, m is the calculated sample mean, s = standard deviation of the sample, N= the sample size.

O.1.3 Biomass Survey Methodology

A biomass survey was carried out at each sample plot to estimate the quantity of woody biomass within the corn class. 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 below.

Appendix Table 13 – Size of sampling plots, sub-plots and trees measured			
Sub-plot	**Square**	**Area**	**Trees**
Small	20 m	0.04 ha	>5 cm DBH
Medium	40 m	0.16 ha	>20 cm DBH
Large	60 m	0.36 ha	>50 cm DBH

In order to calculate the total carbon baseline, the carbon sources that are included must be determined. describes the choice and justification for the carbon pools included and excluded in the carbon baseline.

Appendix Table 14 – Carbon Pools				
Carbon Pool		**Includes**	**Included**	**Excluded with Reasoning**
Above & below ground non-woody biomass	Aboveground	Grasses, Musaceae etc.	Yes	
	Belowground	Roots	Yes	
Above & below ground woody biomass (DBH >= 5 cm)	Aboveground	Stems, branches, bark	Yes	
	Belowground	Tree roots	Yes	
Above & Below ground woody biomass (DBH < 5 cm)	Aboveground	Shrubs, small trees etc.	No	Carbon pool is expected to be very small and it is difficult and costly to measure.
	Belowground	Roots of shrubs, small trees etc.	No	
Soil		Organic material	No	Carbon pool is expected to be very small and it is difficult and costly to measure.
Litter & Lying dead-wood		Leaves, small fallen branches, lying dead wood	No	Carbon pool is expected to be very small and it is difficult and costly to measure.

O.1.4 Field Measurements

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

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

O.1.5 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:

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

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

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

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

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

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

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

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: (IPCC, 2006)

$$TC = 0.49 * TB$$

O.2 Change of Carbon Stock in Absence of Project

The baseline will be assumed to stay constant, which is consistent with simplified baseline and monitoring methodologies for small-scale A/R CDM project activities (UNFCCC, 2010).

O.3 Baseline Results

The carbon stock baseline is presented as a critical t-value scaled to the mean with 90% confidence. In other words, we are 90% confident that the mean falls below the given values in . The biomass data collected for the baseline was not normally distributed due to the zero-heavy nature of the data as a result of the sampling design. However, given the sample size we believe the baseline calculations used represent a conservative estimate.

Appendix Table 15 – Baseline results

	Area (ha)	Aboveground woody biomass (t CO_2/ha)	Belowground woody biomass (t CO_2/ha)	Total (t CO_2/ha)
Cornfields	25,830	1.82	1.01	3.63

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