Evaluation of agroforestry systems in the

Toledo district, Belize.

This study aims to provide data for the promotion and the improvement of agroforestry systems as an alternative for slash-and-burn and cattle ranching practices. A second goal is to determine if some of the farms visited could be used as a model farm to provide training for the farmers from Toledo.

The costs inherent to the location or the purchase of a terrain will not be considered here. All the results are expressed over a period of one year.. All information about the crop yields comes from farmers' estimates, and only applies to these parts of the farm that are currently bearing. None of the farmers use chemical fertilizers or pesticides.

The price of cacao used in these estimates is based on dry and fermented cacao sold on the local market for international export.

Methods:

- **Semi-structured interview:**

  Opinions about agroforestry ?

  Good results ?

  Opinion about Ya'axché study of the farm ?

- **Inventory of cultivated species**

- **GPS coordinates of the parcel**

- **Questionaire:** yield and hours of work

- **Office work**

Results

Farm 1:

Surface area of the farm : 2.46 acres

Crops:

Culture	Units	Yield/crop (lbs, bundle or unit)	Yield/acre (lbs, bundle or unit)	Yield of the farm (lbs, bundle or unit)	Price (BZ$)	Yield/crop (BZ$)	Yield/acre (BZ$)	Yield of the farm (BZ$)
Cacao	405	1.52	203.25	500	2.50/lbs	3.8	508	1250
Palm tree	37	10	162.60	400	0.50/leaf	5	81.3	200
Coffee	91	0.66	24.39	60	3.5/lbs	2.31	85.36	210
Coconut	18	83	610	1500	0.25/unit	20.75	152.5	375
Golden plum	3	133	162.60	400	1.00/lbs	133	162.6	400
Custard apple	5	0	0	0	2.00/lbs	0	0	0
Balam	5	0.45	0.91	2.25	3.00/lbs	1.35	2.73	6.75
Breadfruit	4	125	203.25	500	0.50/lbs	62.5	101.62	250
Mango	4	75	121.95	300	1.00/lbs	75	121.95	300
Orange	1	50	20.32	50	0.50/lbs	25	10.16	25
Lime	3	50	60.97	150	0.50/lbs	25	30.485	75
Rollina	5	40	81.30	200	1.00/lbs	40	81.30	200
Bribri	1	200	81.30	200	0.50/lbs	100	40.65	100
Canistal	1	20	8.13	20	1.00/lbs	20	8.13	20
Jipijapa	/	/	60.97	150	1.00/lbs	/	60.97	150
Cocoyam	/	/	20.32	50	0.50/lbs	/	10.16	25
Cassava	/	/	121.95	300	0.50/lbs	/	60.97	150
TOTAL	**583**	/	/	/	/	/	1518.88	3736.75

- Bread fruit are not counted in the total because the fruit is used as a fertilizer and because there is no opportunity to sell it on the market.
- Density of cacao trees : **165 trees/acre**

Timber trees :

Culture	trees	Yield/tree (ft²)	Yield/acre (ft²)	Yield of the farm (ft²)	Price (BZ$)	Yield/tree (BZ$)	Yield/acre (BZ$)	Yield of the farm (BZ$)
Black cabbage bark	1	1000	406.5	1000	2.00/ft²	2000	93	2000
Guanacaste	1	700	284.55	700	2.50/ft²	1750	711.37	1750
Cedar	4	1000	1626	4000	3.50/ft²	3500	5691	14000
salmwood	1	600	243.9	600	2.50/ft²	1500	609.75	1500
Ya'axché	1	1500	609.75	1500	0.50/ft²	750	304.87	750
Mahogany	7	1000	2845.53	7000	3.00/ft²	3000	8536.59	21000

Bay cedar	1	10	4.06	10	1.00/ft²	10	4.06	10
TOTAL	**16**	/	/	/	/	/	**15950.64**	**41010**

This informations are based on an estimated 25 years maturation period of the tree. All the measurements are in boardfeet (ft²).

- The average annual production of timber trees per acre : **667 BZ$**
- The average annual production of timber trees for the farm : **1640.4 BZ$**

The farm :

- Average annual production : **5377.15 BZ$**
- Average annual production per acre : **2185.88 BZ$**
- Density : **243 trees/acre**

Start-up costs of the system (per acre) :

didn't pay anybody to do this work and doesn't use any pesticides or chemical fertilizers.

Items	Unit cost (BZ$)	Units	Cost (BZ$)
Poly bags	0.10	405	40.5
Cacao seeds	0.20	405	81
Timber seeds	0.25	16	4
Other seeds	0.35	178	62.3

--> Which totals **657.3 BZ$** to establish the system (267.2 BZ$/acre)

Hours of work per year (just to maintain the field) :

3 weeks or **120 hours**

Farm 2 :

Surface area of the farm : 1.35 acreCrops:

Culture	Units	Yield/crop (lbs, bundle or unit)	Yield/acre (lbs or unit)	Yield of the farm (lbs, bundle, unit)	Price (BZ$)	Yield/crop (BZ$)	Yield/acre (BZ$)	Yield of the farm (BZ$)
Cacao	294	1	222.22	300	2.50/lbs	2.50	555.55	750
Coffee	83	0.84	51.85	70	3.00/lbs	2.53	155.55	210
Coconut	10	50	370.37	500	0.25/unit	12.5	92.59	125
Golden plum	1	500	370.37	500	1.00/lbs	500	370.37	500
Jackfruit	4	6	18.52	25	10.00/unit	60	185.2	250
Craboo	1	100	74.07	100	1.00/lbs	100	74.07	100
Avocado	2	25	37.04	50	0.30/unit	7.5	11.112	15
Mami apple	1	N.B	N.B	N.B	N.B	N.B	N.B	N.B
Soursop	1	100	74.07	100	1.00/unit	100	74.07	100
Guava	2	60	88.88	120	1.00/lbs	60	88.88	120
Balam	1	N.B	N.B	N.B	N.B	N.B	N.B	N.B
Lime	1	N.B	N.B	N.B	N.B	N.B	N.B	N.B
Bribri *	7	28.6	148.15	200	0.50/lbs	14.3	74.07	100
Banana	6	8	37.04	50	5.00/bundle	40	185.2	250
Yellow ginger	/	N.H	N.H	N.H	N.H	N.H	N.H	N.H
Jipijapa	/	/	14.81	20	1.00/lbs	/	14.81	20
TOTAL	**415**	/	/	/	/	/	**1881.72**	**2540**

* Only two young trees are bearing
(N.B : Not Bearing, N.H : Not Harvesting)

- Density of cacao trees : **218 trees/acre**

Timber trees :

Culture	trees	Yield/tree (ft²)	Yield/acre (ft²)	Yield of the farm (ft²)	Price (BZ$)	Yield/tree (BZ$)	Yield/acre (BZ$)	Yield of the farm (BZ$)
Black cabbage bark	6	1000	4444.44	6000	2.00/ft²	2000	8888.88	12000
Leucina*	2	/	/	/	/	/	/	/
Bitterwood	18	/	/	/	50/tree	50	666.66	900
TOTAL	**26**	/	/	/	/	/	**9555.54**	**12900**

* Leucina is a fabaceae tree with no commercial value
This information is based on an estimated 25 years maturation period of the tree.Exception : Bitterwood - is based on 15 years

- The average annual production of timber trees per acre : **400 BZ$**
- The average annual production of timber trees for the farm : **540 BZ$**

The farm :

- Average annual production : **3080 BZ$**
- Average annual production per acre : **2281.48 BZ$**
- Density : **327 trees/acre**

Start-up costs of the system (per acre) :

didn't pay anybody to do this work and doesn't use any pesticides or chemical fertilizers.

Items	Unit cost (BZ$)	Units	Cost (BZ$)
Poly bags	0.10	294	29.4
Cacao seeds	0.20	294	58.8
Timber seeds	0.25	26	6.5
Other seeds	0.35	121	42.35

--> Which totals **137.05 BZ$** to establish the system (101.51 BZ$/acre)

Hours of work per year (just to maintain the field) :

2 weeks or **80 hours**

Farm 3 :

Surface area of the farm : 2.37 acresCrops:

Culture	Units	Yield/crop (lbs, unit, bundle)	Yield/acre (lbs, unit, bundle)	Yield of the farm (lbs, unit, bundle)	Price (BZ$)	Yield/crop (BZ$)	Yield/acre (BZ$)	Yield of the farm (BZ$)
Cacao	619	0.97	253.16	600	2.50/lbs	2.23	632.9	1500
Mango	7	300	886.07	2100	1.00/lbs	300	886.07	2100
Palm tree	6	N.H	N.H	N.H	0.50/leaf	N.H	N.H	N.H
Coconut	5	N.H	N.H	N.H	0.25/unit	N.H	N..H	N.H
Golden plum	5	N.H	N.H	N.H	1.00/lbs	N.H	N.H	N.H
Soursop	3	N.H	N.H	N.H	1.00/unit	N.H	N.H	N.H
Lime	3	N.H	N.H	N.H	0.50/lbs	N.H	N.H	N.H
Banana	10	1.5	6.33	15	5.00/bundle	7.5	31.64	75
Avocado	3	N.H	N.H	N.H	0.30/unit	N.H	N.H	N.H
Bribri	5	N.H	N.H	N.H	0.50/lbs	N.H	N.H	N.H
TOTAL	**666**	/	/	/	/	/	**1550.61**	**3675**

Density of cacao trees : **261 trees/acre**

Timber trees :

10 timber trees from the original forest --> No value in the market but source of wood for the farmer

The farm :

- Average annual production : **3675 BZ$**
- Average annual production per acre : **1550.61 BZ$**
- Density : **285 trees/acre**

Start-up costs of the system (per acre) :

didn't pay anybody to do this work and doesn't use any pesticides or chemical fertilizers.

Items	Unit cost (BZ$)	Units	Cost (BZ$)
Poly bags	0.10	619	61.9
Cacao seeds	0.20	619	123.8
Timber seeds	0.25	/	/
Other seeds	0.35	47	16.45

--> Which totals 202.15 to establish the system (82.29 BZ$/acre)

Hours of work per year (just to maintain the field) :

6 days or **48 hours**

Farm 4 :

Surfce area of the farm : 2.10 acre Crops:

Culture	Units	Yield/crop (lbs or unit)	Yield/acre (lbs or unit)	Yield of the farm (lbs, bundle, unit)	Price (BZ$)	Yield/crop (BZ$)	Yield/acre (BZ$)	Yield of the farm (BZ$)
Cacao	892	0.53	226.19	475	2.50/lbs	1.22	565.48	1187.5
Golden plum	2	N.B	N.B	N.B	1.00/lbs	N.B	N.B	N.B
Avocado	1	200	95.23	200	0.30/unit	60	28.57	60
Bribri	20	N.H	N.H	200	0.50/lbs	N.H	N.H	N.H
Banana	20	0.65	6.19	13	5.00/bundle	3.25	30.95	65
Jipijapa	/	/	/	/	1.00/lbs	/	/	/
TOTAL	**935**	/	/	/	/	/	**625**	**1312.5**

(N.B : Not Bearing, N.H : Not Harvesting)

Density of cacao trees : **425 trees/acre**

Timber trees :

Culture	trees	Yield/tree (ft²)	Yield/acre (ft²)	Yield of the farm (ft²)	Price (BZ$)	Yield/tree (BZ$)	Yield/acre (BZ$)	Yield of the farm (BZ$)
Mahogany	2	1000	952.38	2000	3.00/ft²	3000	2857.14	6000

This informations are linked to an estimation of a 25 years maturation period of the tree. All the mesures are in ft².

- A lot of forest trees (no value but source of wood)
- The average annual production of timber trees per acre : **114.28 BZ$**
- The average annual production of timber trees for the farm : **240 BZ$**

The farm :

- Average annual production : **1552.5 BZ$**
- Average annual production per acre : **739.28 BZ$**
- Density : **446 trees/acre**

Cost of implantation of the system (per acre) :

didn't pay anybody to do this work and doesn't use any pesticides or chimical fertilizers.

Items	Unit cost (BZ$)	Units	Cost (BZ$)
Poly bags	0.10	892	89.2
Cacao seeds	0.20	892	178.4
Timber seeds	0.25	2	0.50
Other seeds	0.35	43	15.05

--> Which totals **283.5 BZ$** to establish the system (135.04 BZ$/acre)

Hours of work per year (just to maintain the field) :

3 men 2 weeks per year or **240 hours**

Farm 5 :

Surface area of the farm : 5 acres

Crops :

Culture	Units	Yield/crop (lbs or unit)	Yield/acre (lbs or unit)	Yield of the farm (lbs, bundle, unit)	Price (BZ$)	Yield/crop (BZ$)	Yield/acre (BZ$)	Yield of the farm (BZ$)
Cacao	1620	0.74	240	1200	2.50/lbs	1.85	600	3000
Balam	150	/	/	/	3.00/lbs	/	/	/
TOTAL	**1770**	/	/	/	/	/	**600**	**3000**

(N.B : Not Bearing, N.H : Not Harvesting)

Density of cacao trees : **324 trees/acre**

Timber trees :

- A lot of forest trees (no value, but source of wood)
- The average annual production of timber trees per acre : **0 BZ$**
- The average annual production of timber trees for the farm : **0 BZ$**

The farm :

- Average annual production : **3000 BZ$**
- Average annual production per acre : **600 BZ$**

Start-up costs of the system (per acre) :

didn't pay anybody to do this work and doesn't use any pesticides or chemical fertilizers.

Items	Unit cost (BZ$)	Units	Cost (BZ$)
Poly bags	0.10	1620	162
Cacao seeds	0.20	1620	324
Balam	0.10	150	15

--> Which totals **501 BZ$** to establish the system (**100** BZ$/acre)

Hours of work per year (just to maintain the field) :

0 hours

Farm 6 :

Surface area of the farm : **1.28 acre** Crops:

Culture	Units	Yield/crop (lbs or unit)	Yield/acre (lbs or unit)	Yield of the farm (lbs, bundle, unit)	Price (BZ$)	Yield/crop (BZ$)	Yield/acre (BZ$)	Yield of the farm (BZ$)
Cacao	500	1	390.62	500	2.50/lbs	2.5	976.55	1250
Craboo	10	20	156.25	200	1.00/lbs	20	156.25	200
Mami apple	1	N.B	N.B	N.B	0.30/unit	N.B	N.B	N.B

Bribri	12	N.H	N.H	N.H	0.50/lbs	N.H	N.H	N.H
Pacaya	/	/	234.37	300	1.00/lbs	/	234.37	300
TOTAL	**523**	**/**	**/**	**/**	**/**	**/**	**1367.17**	**1750**

(N.B : Not Bearing, N.H : Not Harvesting)

Density of cacao trees : **390 trees/acre**

Timber trees :

- A lot of forest trees (no value, but source of wood) + 1 Bayleaf and 1 Sapodilla (value unknown)
- The average annual production of timber trees per acre : **0 BZ$**
- The average annual production of timber trees for the farm : **0 BZ$**

The farm :

- Average annual production : **1750 BZ$**
- Average annual production per acre : **1367.17 BZ$**

Start-up costs of the system (per acre) :

didn't pay anybody to do this work and doesn't use any pesticides or chemical fertilizers.

Items	Unit cost (BZ$)	Units	Cost (BZ$)
Poly bags	0.10	500	50
Cacao seeds	0.20	500	100
Timber seeds	0.25	/	/
Other seeds	0.35	23	8.05

--> Which totals **158.05 BZ$** to establish the system (123.47 BZ$/acre)

Hours of work per year (just to maintain the field) :

20 days or **180 hours**

Notes and observations :

Farm 1

- No pruning of shade trees
- Important pruning of the cacao trees
- Gaps with light allowing cocoyam, jipijapa and cassava cultures on the system
- Healthy farm
- Rich ecosystem
- Farm = extension of the forest

Farm 2

- Age: 11 years
- Chicken
- Important pruning of the cacao trees
- Jipijapa at the edges of the system
- Less shade (30% --> dryer), too much light ---> small cacao trees
- A lot of defoliation by leaf-cutter ants

Farm 3

- – Farm deep in the forest
- – Fruit trees not harvested
- – No parasitism

Farm 4

- – Jipijapa only for home consumption
- – Very few pods affected by birds
- – A lot of borers and leafeminers
- – A lot of pods affected by squirrels
- – Shade only provided by forest trees
- – A lot of pods

Farm 5

- – High density
- – A lot of interbranching
- – A lot of parasitism (black pod, birds)
- – Not harvested last year
- – Fire from slash-and-burn practice burned a part of the farm
- – Farm deep in the forest
- – Almost no fruit trees

Farm 6

- – Farm deep in the forest
- – No fruit trees, no timber trees
- – Tall cacao trees due to the shade provided by the mountain
- – Little parasitism (birds, rodents)

Agronomical characteristics of the farms :

Farm		1	2	3	4	5	6
Acrage		2.46	1.35	2.37	2.1	5	1.28
Type of soil							
Origin		Forest	Forest	Forest	Forest	Forest	Forest
Altitude							
Age		16	11	15	7	12	9
Hours of work/acre		49	59	20	114	0	140
Density of cacao trees		165	218	261	425	324	390
Density of trees		243	327	285	446	/	/
Shade	**25%**		x	x			
	50%				x		
	75%	x				x	x
Number of cultivated species	**Low**	x				x	
	Medium		x				x
	High			x	x		
Number of Fabaceae	**Low**	x		x		x	
	Medium		x				
	High				x		x
Air	**Low**			x		x	

circulation	Medium	x					x
	High		x		x		
Parasitism	Low	x		x			x
	Medium		x		x		
	High					x	
Animal farming		x	x	/	/	/	/
Compost		/	/	/	/	/	/
Yield/cacao tree (lbs)		1.52	1.00	0.97	0.53	0.74	1
Cacao yield/acre (lbs)		**203.25**	**222.22**	**253.16**	**226.19**	**240**	**390**

Interpretation:

Context and ways of intensification

The average density of cacao trees in an agroforestry systems in familial exploitation around the world is 444 trees per acre. The majority of the plantations we visited are far below this density of cacao trees. This means that the farmers of the district of Toledo practice an extensive agriculture that could be intensified.

<u>Density of cacao trees per acre of the visited farms</u>

<u>(Source for 'Recommended' : Memento de l'agronome, 2012 – figure for conventional cacao farming)</u>
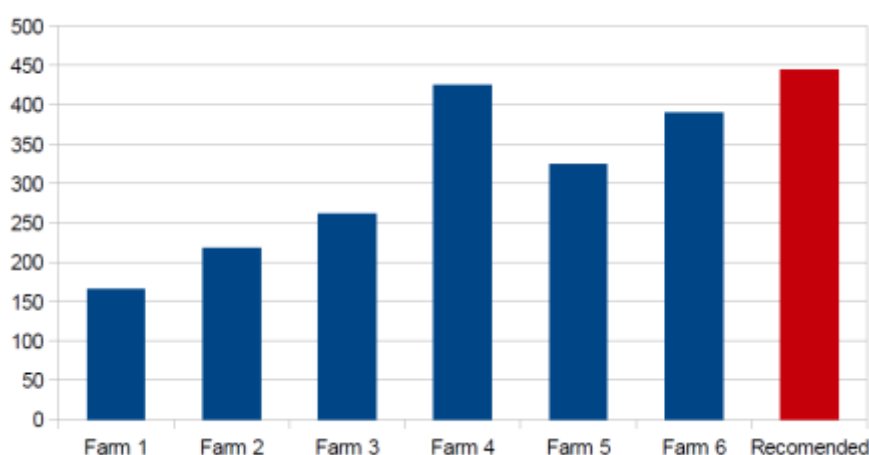
According to our observations and the research conducted, we consider a distance of 10 by 12 feet between cacao trees an optimum for intensifying cacao -based agroforestry in the District of Toledo, Belize. As a result, we can calculate that 378 cacao trees fit within one acre. This cacao density combined with 36 other trees represent an optimal

productivity in a context where farmers don't use any fertilizers or pesticides.

We also would like to highlight that, as opposed to extensification which just needs extra effort and land, intensification can only be achieved through increasing knowledge and capacity, by means of farmer exchange visits, peer to peer learning, farming technique training in model farm, etc.

Hours of work per acre

Agroforestry systems generally constitute a secondary activity for the farmers from Toledo. They don't spent a lot of time on their farms to maintain the field at optimum levels of productivity (e.g. by weeding, pruning, sucker removal).

Hours of work in the field (only maintaining)

(source for 'Recommended': Memento de l'agronome, 2012 – figure for conventional cacao farming)
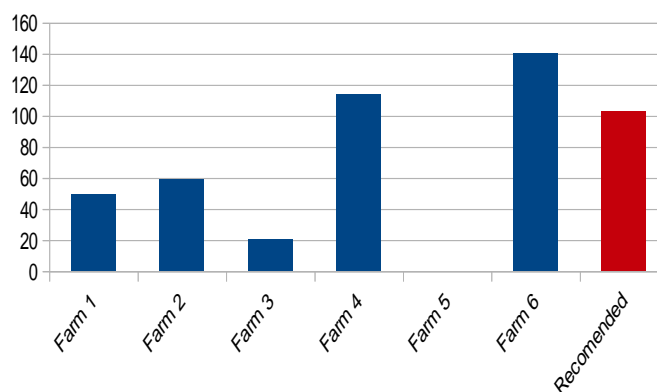
Trees of agro-economic importance

Intensification can be achieved by combining the right tree species and numbers for different uses. The table below outlines the uses of different tree species, and is based on our research findings and field observations, with the exception of 'High level of associated biodiversity', which is based on anecdotal observations and assumptions.

Crops	Nitrogen fixation crop	High comercial value	Good shade for cacao trees	Important organic restitution	Wind-break	Temporary culture	High level of associated bio-diversity	Ornemental value
Copna	x				x		x	x
Black cabbage bark	x	x	x					
Guanacaste	x	x	x					
Bribri	x		x	x				
Madre cacao	x		x					

Ya'axché		x	x				x	x
Mahogany		x	x					
Cedar		x	x					
Mango		x			x		x	
Breadfruit		x		x	x			
Salmwood		x	x		x		x	
Golden plum		x			x		x	
Jackfruit		x			x		x	
Soursop		x	x				x	
Craboo		x	x				x	
Banana		x	x			x		
Pineapple		x				x		
Cocoyam		x				x		
Cassava		x				x		
Pacaya		x				x		

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Suggested agroforestry package

In case of transformation of existing farmland to agroforestry, the year before the establishment of this package,

temporary crops should be planted to provide shade for the future plantation and to reduce the cost of establishment.

These temporary crops can stay until their decay.

The package instructions are based on the following parameters:

- the optimal cacao tree density

- the overall diversity of cultivated species

- The optimal amount of shade provided for cacao trees

- The windbreak effect

- The organic restitutions

- The optimum number of leguminous trees

- The market value of the crops

Package content:

The major part of the package should be trainings in different farming practices. These trainings should cover

- different uses of tree species

- Compost training

- Crop health

– pruning

– Interesting trees to keep when beginning the agroforestry system from forested land

– Diversification of products (e.g. small livestock, bee keeping, ..)

– Fallow land management training

The second part of the package are the actual numbers and species of trees:

– 378 cacao trees

– 9 leguminous trees (e.g. 3 black cabbage bark, 3 guanacaste and 3 bribri)

– 6 windbreak trees (e.g. 2 Mango, 2 jackfruit and 2 golden plum)

– 2 timber trees (e.g Mahogany, Rosewood)

– 19 fruit trees (at least 10 different species)

Keeping in mind that is only an estimate, during the years of full production one acre of a such system could provide to the farmer :

Trees	Number of trees	Average yield in BZ$ per year
Cacao	378	950
Black cabbage bark	3	129
Guanacaste	3	84
Bribri	3	300
Mango	2	600
Golden plum	2	600
Jackfruit	2	120
Mahogany	2	240
Rollina	3	180 (?)
Canistal	3	180 (?)

Avocado	3	180
Custard apple	4	400 (?)
Soursop	4	400
Craboo	4	400
TOTAL	**412**	**4754**

Diversity in the cultivated species

Due to our observations, we think that a high level of diversity in the cultivated species plays an important role in an agroforestry system!

Diversity

- reduces the risk of failing crops (due to climate, parasitism, etc)

- facilitates the selling of the products locally sold

- regulates pest populations

- creates a rich ecosystem, attractive for pollinator species (e.g. bees) and for species important for conservation (birds, insects, mammals,...)

However, to allow an accurate vision of the impacts of diversity in cultivated species in an agroforestry system, these parameters need to be studied in more detail.

Proximity of the farms to the village

Due to large distances between farms and villages, timber trees and fruit trees are rarely cultivated in some farms situated deep in the forest. This represents a limiting factor in the improvement of the agroforestry systems of Toledo, Belize.

Compost

None of the farmers of Toledo uses compost when establishing an agroforestry system! This represents an important loss of productivity for the future cacao trees.

Conclusion

We believe that agroforestry presents a lot of advantages in terms of economy, social and environmental benefits in comparison to slash-and-burn and cattle ranching practices. However, the practice of agroforestry in Toledo is recent and the systems could be improved. We believe that this improvement can be achieved by providing farmers with technical support and agroforestry training, to which the presented results could contribute.

We believe that the establishment of one or more model farms would be instrumental for the advancement of cacao-based agroforestry in Toledo. The farms would help to improve the agronomic, economic, environmental and social qualities of other farms and would provide an opportunity for Ya'axché to learn from experiments and teach best agroforestry practices to the farmers of Toledo. Farms 4 and 6 provide good starting points to be developed in model farms (optimal tree density and farmer involvement), but unfortunately are both located deep in the forest, which makes them less suitable for exchange visits and peer-to-peer learning. Thus, we haven't found the ideal spot for the model farms.