Forest Succession and Fruit Availability in Planted and Natural Regenerated Areas of Cloudbridge Reserve, Costa Rica

Technical report of a third-year internship for the minor Tropical forestry at Van Hall Larenstein university of applied sciences done at Cloudbridge reserve in Costa Rica.

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Foreword

For my third-year internship of Forestry and Nature Management with a major in Tropical Forestry at Van Hall Larenstein, University of Applied Science I carried out research at Cloudbridge Nature Reserve in Costa Rica.

I was asked by the Reserve Manager, Frank Spooner, and Scientific Coordinator, Jennifer Powell, to conduct a habitat assessment and gain forestry related information about the different forest types that Cloudbridge has within their boundaries. In addition, I was asked to set up a method for a mast count that will be done monthly in the future. All this vegetational information can be used and combined with other research data that has been done at Cloudbridge.

I would like to thank Jennifer Powell, Scientific Coordinator of Cloudbridge for her great help with my research. Also, Tom Gode, Reserve Director, for sharing his knowledge about the local plants and the history of the reserve. And of course, all the volunteers that helped me with the data collection.

Abstract

The purpose of this study was to compare the planted forest areas in Cloudbridge Nature Reserve with the naturally regenerated areas. For this research, 24 pre-existing plots were used within these forest types and all the trees above 10 cm DBH in these plots where measured. Also, the fruit availability was measured for the months May and June, 2016. The data was combined and it was found that the planted areas were slightly behind in succession towards primary forest compared to the naturally regenerated areas. The planted areas consist of more trees per hectare with a lower diameter and height. It was remarkable that there were no dead trees found in the planted areas. The fruits found on trees in the planted areas were slightly above average comparing to the other forest types, but the fruits on shrubs were found to be very low.

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Introduction

The Costa Rican mountain cloud forest is a unique habitat for many species and has a very high diversity. In the 1950s and after, these areas were heavily degraded and fragmented, but have been recovering in recent years. The main cause for this was agricultural pressure and expansion, as well as governmental laws that allowed farmers to claim land if they used it for cattle pasturing in the mid 60’s. Cloudbridge is located at the food of mount Chirripó in the Talamanca range and was purchased in 2002 by Ian and Genevieve Giddy. By then, Cloudbridge mainly consisted of cattle pasture separating two large areas of cloud forest. On the east side of the Cloudbridge valley, there is the Chirripó National Park, and on the west, there is the Talamanca Reserve. Cloudbridge is actively reforesting to reconnect these two forested areas, helping to create a wildlife corridor and make animal migration between the two areas possible again (Figure 1).

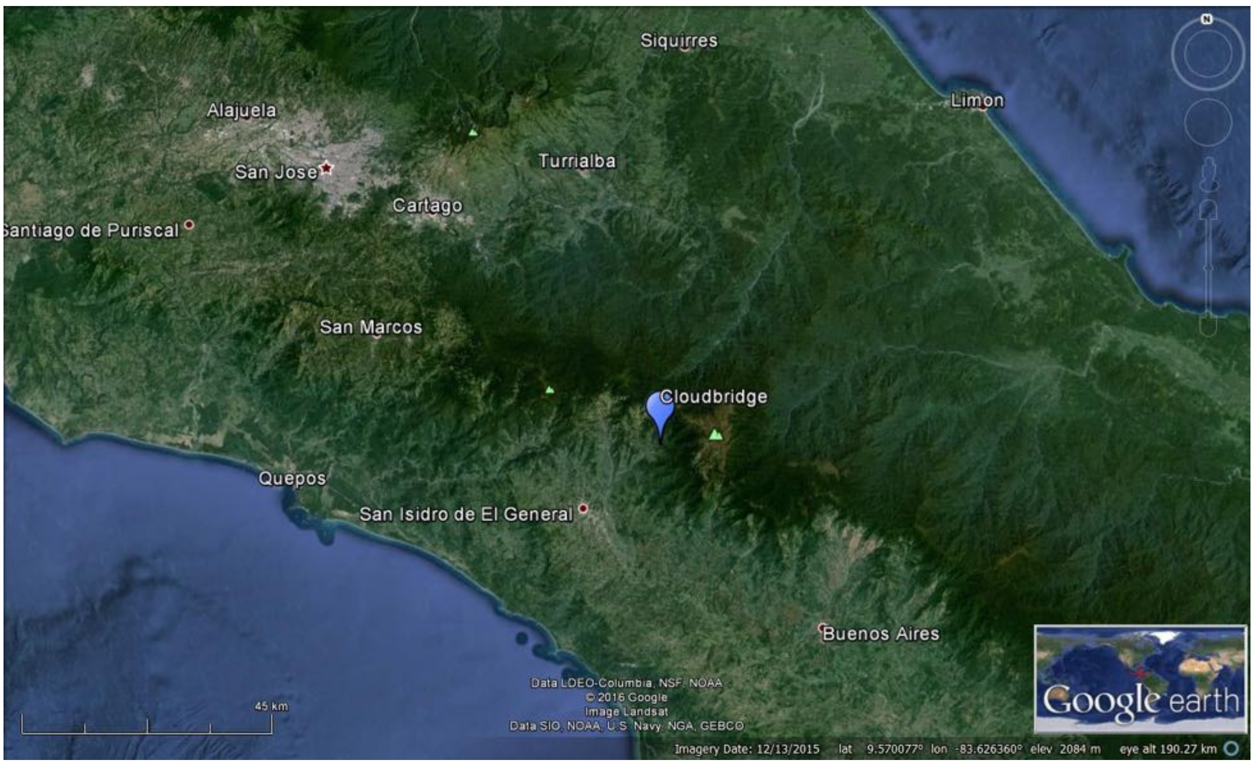

Figure 1 Map of Costa Rica with the location of Cloudbridge reserve

Problem statement and goals

Cloudbridge has been reforesting since 2002 and the habitats have changed significantly in the past 14 years. Walking through Cloudbridge, you can notice a difference between areas (Cloudbridge, 2016). These are mostly vegetational differences in forest structure, species composition, age of the forest, number of gaps, and light intensity. The main reason for this is that some parts have been reforested by planting and managed by weed clearing and vine cutting, and other areas are left to naturally regenerate. Also, there are areas of old growth (or primary) forest left within the reserve that have not been cut down or managed in the past (Appendix 1). Cloudbridge is carrying out studies to monitor the effect of reforestation on plants and animals. Most studies are to inventory the species in the area or to compare the planted with the naturally regenerated areas. The most prominent studies that are carried out throughout the year are bird counts and frog identification. There is still a lack of knowledge about the vegetation and the effects of reforestation.

This research is conducted to evaluate the effects of the reforestation efforts by comparing the planted areas with the naturally regenerated areas in terms of tree diameter, tree height, tree volume, species composition, canopy cover and fruit availability.

Research question and hypothesis

- Is there a significant difference in vegetation structure between the planted forest areas and the naturally regenerated areas?

It is expected to find a difference in the two forest types because the planted areas have actively been replanted with well growing pioneer species and kept clear of overgrowing ferns and grasses. Therefore, the planted areas should have been better developed.

- Is there a difference in fruit availability in the over- and understory between the planted forest and the naturally regenerated forest?

As a part of the reforestation, species were selected for their pioneer features or because they have an ecological benefit. For example, fruiting trees and shrubs that provide food for all kinds of different animals. Therefore, the planted areas should have richer fruit availability in the over story. The old growth forest is expected to have a lower understory score because of its enclosed crown.

- Is there a difference in the estimated standing deadwood volume between the planted forest, naturally regenerated forest, and the old-growth?

Deadwood is a feature that represents a healthy forest. It should not be too high nor too low. It is assumed that 10 to 15% is average for a healthy forest. Since the naturally regenerated forest areas are more dynamic than the planted forest areas, it is expected that the naturally regenerated areas have a higher amount of deadwood per hectare (Humphrey and Bailey, 2012), and the old growth should be in the healthy forest range, around 12,5%.

- Is there a difference in the estimated number of small trees per hectare between the planted forest, naturally regenerated forest, and the old-growth?

The planted areas have had some management in the past, to help ensure the survival of the planted trees. Before the trees were planted, small unwanted trees, thick vegetation and grasses were cut to make room for the planted species. Also, after planting most areas were maintained by periodic weeding. The pioneer species that have been planted are fast growing to help establish some shade in these areas. All this would result in less trees per hectare in the planted areas, but the trees that you can find will be better developed in terms of DBH and height.

Methodology tree measurements

Plots

The plot locations were based on previously established bird point count stations and evenly cover the whole area of Cloudbridge (Figure 2). They were all located on trails for accessibility reasons. All plots were circles with a radius of 12.5m and an area of 490.87 m^2. The center of a plot was marked with the bird point count sign that shows the plot ID number (Figure 3). From this center, the edges of the plot were determined with a 12.5m long measuring tape and marked with flagging tape.

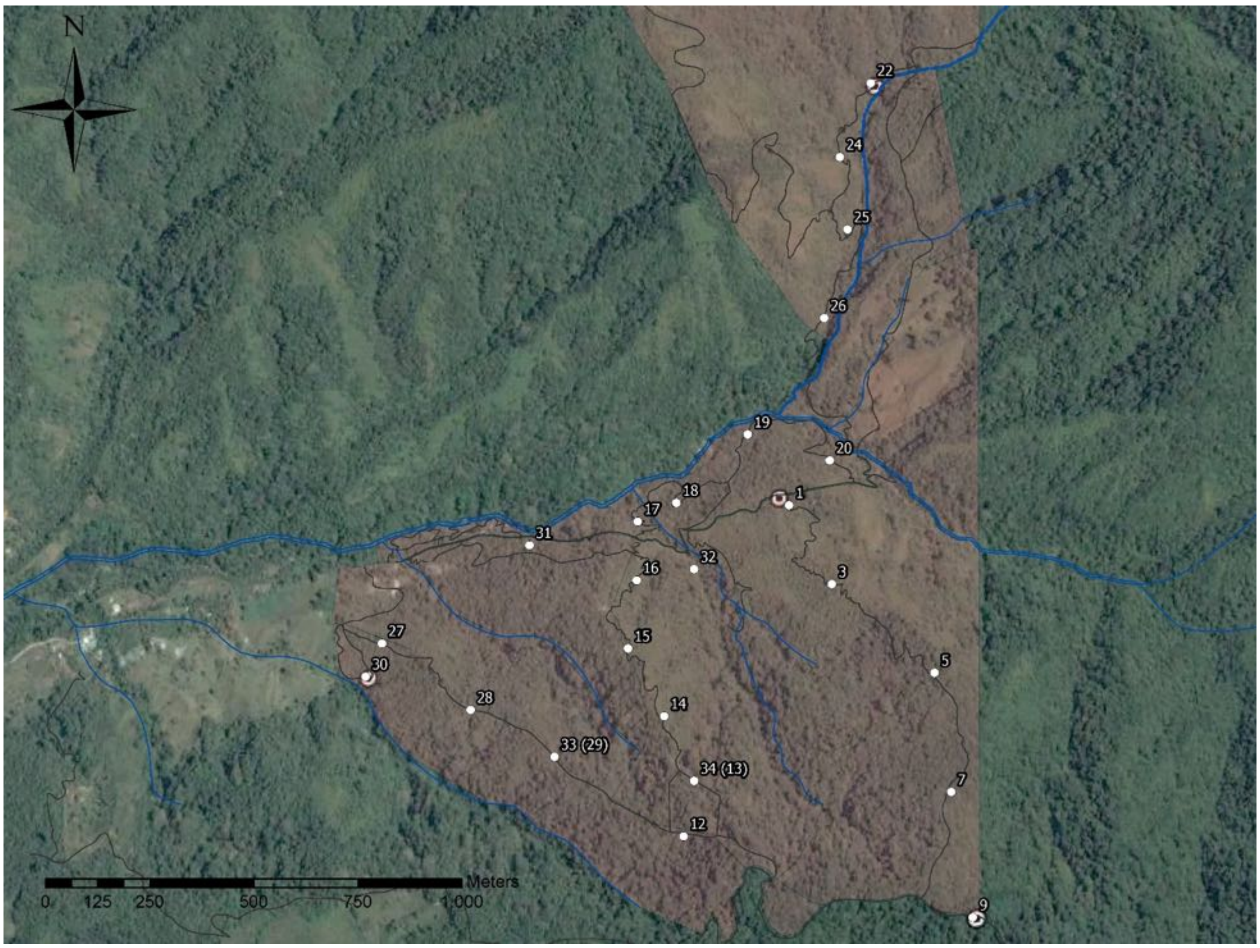

Figure 2 Plot locations

Figure 3 Bird point count sign with the plot id number

DBH measurements

In each plot, the DBH (diameter at breast height) for each tree was measured and trees that were 10 cm or greater were noted. Each tree was measured at 1.35m above the ground with a DBH measuring tape (Figure 4). Trees that forked before, or at this height, were each measured separately, or at a different height. The height where the DBH was measured was then also noted (Avery and Burkhart, 2012).

Figure 4 DBH measuring tape

Tagging

Figure 5 Tree tag with tree number

Trees greater than 10 cm DBH were tagged with a metal plate giving the tree a unique number. The number was used in the database to link the tree data to the tree in the field (Figure 5).

Height measurements

For the height measurements, two methods were used. One was with a rangefinder. A rangefinder is an electronic device that needs to be pointed directly at the tree for distance measurement, one measurement for the top of the tree and one for the base. The rangefinder then calculates the exact height of the tree. The downside of this is that you need a clear view of the tree with no shrubs in the way.

The other method was with inclinometer triangulation. The inclinometer shows you the angle in which you are holding it in degrees and percentage. The distance to the tree was measured with a measuring tape and then the angles to the top and the base of the tree read from the inclinometer. For slope corrections, the angle to the tree at eye height was also measured. In Figure 6, an example of this tangent triangulation method is shown. With this information, the total tree height was calculated through this formula (Husch et al., 2003)**:**

Total tree height=((((a-b)/100) x D) + B) x Cos(Angle to eye height on tree)

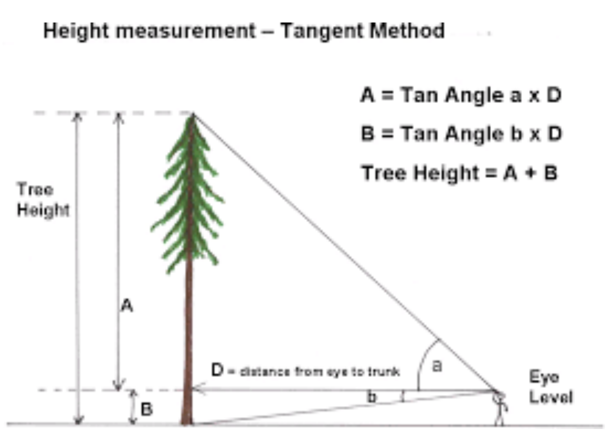

Figure 6 Example of Tangent triangulation method

Slope

The slope was measured by pointing the inclinometer at a tree at eye height on the downhill and uphill sides of the plot and the angles are noted. Then the average of the two numbers was taken which determined the angle of the slope, which was noted in percentage.

Canopy cover

For this a densitometer was used. The densitometer is a device with a convex mirror pointing upwards with a small grid of squares on it (Figure 7). To determine the canopy cover, the corners of each square that show open sky (open canopy) are counted. As there are a total of 96 corners, the results were multiplied by 1.04, giving you the amount of open canopy expressed as a percentage (Forestry Suppliers Inc., 2008). This measurement was carried out in each plot at 5 different locations. At each location, all four cardinal directions were measured. The average of all 20 measurements in the plot was taken to get the average canopy cover percentage for the plot.

Figure 7 Densitometer

Small tree count

A fast count of the small trees (trees with a DBH of <10cm) in each plot were counted by dividing the plot into 4 quarters. In each quarter, all the small trees that you could see from the center were counted. The number from all quarters was then added up. This was done with 2 observers independently, and the average taken from both tallies.

Volume

Tree volume calculations can be very complicated. To get a good estimation of the volume you must know the tree species to look up the tree allometric equations, or you must cut some trees down and measure the volume and dry weight. Since cutting down trees is not an option in Cloudbridge, and I was able to identify only 20% of all tree species, we choose to use a more general calculation method. To get an idea of the volume of a tree it is assumed that the tree trunk has the shape of a cylinder. With the known height and the DBH the cylindrical volume of the tree can be calculated. This volume number is not accurate, but can be compared with volume numbers from other plots.

Data sheets for the measurements

Before going in to the field there were 2 different sheets that need to be prepared for each plot. One sheet for collecting the tree measurements per tree, and the other for the plots general information, canopy measurements, and small tree counts (Appendix 7).

Methodology - mast count

Understory fruit availability

The understory fruit availability assessment was conducted by counting understory fruits along 2 transects in every plot. Every transect was 12.5m long and 1m wide. Along the transect, all the fruits that were found on shrubs and lower plants were collected and put in zip locks labelled with the date, plot number, zip lock serial number, transect number, weight of the bag itself, weight of the bag with fruits, and number of fruits in it (Figure 8).

Figure 8 Collected fruits

Overstory fruit availability

For the fruit availability of the overstory, every tree within the plot with a diameter of <10cm was assessed whether it had fruits or not. The tree was then assigned a fruit score depending on the abundance of the fruit: 0 for no fruits, 1 for very few fruits, 2 for few fruits, 3 for many fruits, and 4 for of an abundance of fruits.

Datasheet mast count

For collecting the mast count data, a well-prepared data sheet was needed that showed all the tree ID numbers of each plot in sequential order and the information from previous mast counts, which helps to check every tree systematically.

Results

After measuring 515 trees during a period of 4 months from March until July, 2016, the data was combined into two large databases: one for the tree measurements (Table 2), and one for the mast count (Table 4). The results are presented separately.

Measurements

The results show that the planted areas in general have lower numbers in terms of average DBH, percentage of standing dead wood, average height, and number of large and small trees per hectare (Table 1, Appendix 2). The light availability was similar in the planted (9.8% open canopy) and naturally regenerated areas (9.1% open canopy) (Table 1). The old-growth canopy seems to be better enclosed than the other forest types (4.1% open canopy).

It is remarkable that in the planted areas, no standing dead wood was found, whereas the naturally regenerated areas seem to have a relatively high tree mortality with a standing dead wood percentage of 11%.

The number of stems per hectare for the old growth and the planted areas is close to the same, but the old-growth consist mainly of trees with a diameter of 10cm and higher with an average DBH of 25.6cm (Figure 9). In the planted areas, the trees of 10cm and higher have an average DBH of 16.7cm, the lowest of the habitat types, but has 3 times as many small trees than the old-growth. The naturally regenerated areas have the highest numbers in terms of large and small trees with an average DBH of 21.2cm (Appendix 3).

For a better comparison, some of the plots were taken out of the analysis because the conditions at the plots varied too much from the other plots under comparison. Reasons for removal included plots: that had a poor canopy closure overall, were on too high a slope, too low a tree count per plot (Plot 32 only had 2 trees), or not enough tall trees (Plot 3 had no trees higher than 7 meters). After removing these plots, the results for the naturally regenerated and planted plots were much more similar, showing the two habitats were not very different (Table 3). The average DBH was 10% higher in the naturally regenerated areas, and the height about 5%, but the number of trees per plot was higher in the planted areas.

Table 1 Forest types results

Habitats	Number of plots	Area (m^2)	Average DBH (cm)	Average height (m)	Trees/ha	Small trees/ha^2	Volume/ha	Standing dead wood %	Canopy % open
Planted	7	3,434	16.69	9.40	349	278,071	170.30	0%	9.8%
Natural regen	14	6,869	21.22	10.65	441	434,867	367.96	11%	9.1%
Old growth	3	1,472	25.63	11.41	605	80,758	946.76	2%	4.1%

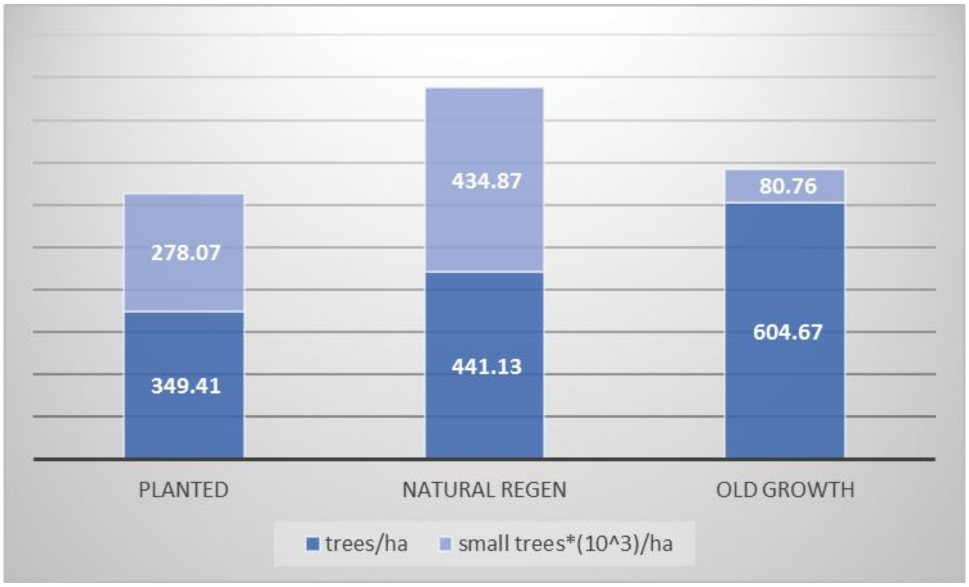

Figure 9 Number of trees per forest type

Table 2 Plot measurement summary

Plot number	Trail name	Forest type	Forest age (years)	Slope %	Canopy % open	Dead wood volume (m^3)	Average DBH (cm)	Average height (m)	Volume (m^3)	Number of large trees measured	Number of small trees
1	Montana	Planted	14	20%	18%	-	16.04	8.75	8.75	24	73
3	Montana	Planted	14	23%	52%	-	11.70	6.88	0.94	5	68
5	Montana	Natural regen	14		5%	0.20	22.03	11.00	29.65	30	86
7	Montana	Natural regen	14	15%	4%	3.86	21.85	12.14	35.92	45	79
9	Chirripo	Old growth	70	44%	5%	0.23	26.17	13.26	41.60	23	70
12	El Jilguero	Old growth	70		7%	1.97	27.24	10.91	65.62	36	71
14	Gavilan	Natural regen	30		18%	2.86	22.89	10.08	16.68	24	71
15	Gavilan	Planted	10		13%	-	17.18	9.43	8.01	19	81
16	Gavilan	Planted	10		18%	-	17.94	10.23	8.33	21	56
17	Rio	Natural regen	14		16%	0.78	15.83	15.40	8.33	12	59
18	Rio	Natural regen	14		4%	-	20.96	13.82	10.26	14	56
19	Rio	Natural regen	14		9%	17.25	23.03	13.68	35.19	20	63
20	Rio	Natural regen	14		12%	2.65	29.33	13.73	41.72	12	56
22	Don Victor	Natural regen	14	25%	14%	-	18.17	6.39	3.26	9	59
24	Don Victor	Natural regen	14	40%	15%	0.04	20.74	8.62	11.61	24	72
25	Don Victor	Natural regen	14	20%	7%	-	20.59	8.15	9.42	16	70
26	Don Victor	Natural regen	14	44%	13%	-	17.50	7.59	4.50	11	65
27	El Jilguero	Planted	8		9%	-	21.44	8.61	16.04	28	56
28	El Jilguero	Natural regen	8		37%	0.54	24.10	9.76	13.56	19	56
30	El Jilguero	Planted	8		10%	-	20.90	11.68	16.18	21	73
31	Principal	Natural regen	25	34%	7%	-	22.08	9.44	7.72	13	62
32	Sentinel	Planted	6		24%	-	11.60	10.25	0.23	2	57
33 (29)	El Jilguero	Natural regen	8		7%	0.52	18.05	9.35	24.93	54	69
34 (13)	Gavilan	Old growth	70		6%	-	23.48	10.05	32.13	30	66

Table 3 Forest type results with select plots

Forest type	Canopy open %	Avg. DBH (cm)	Avg. height (m)	Avg. volume (m^3)	Trees/plot	Small trees/plot
Natural regen	14%	20.82	10.30	16.26	19.67	63.22
Planted	13%	18.70	9.74	11.11	22.60	67.80
Difference:	**-1%**	**-10%**	**-5%**	**-32%**	**15%**	**7%**

Mast count

June seems to be a month with a higher fruit availability in the over- and understory, when compared to May (Table 4, Appendix 5). It was found that fruit availability was concentrated in some areas over others. Around the trails of Rio and Gavilan in the river area, the fruit availability for over- and understory in May and in June were above general average (Table 5).

There were lots of shrubs with small berries, and medium trees with aguacatillos (*Persea spp.*), some oaks (*Quercus spp.)* and limoncitas (*Siparuna sp*.). The Chirripó and El Jilguero trails scored poorly in terms of fruit score with around 20 points below the general average. On the Chirripó trail there were many oak trees that had already lost their fruits and without many shrubs or other trees around there was not a lot of fruit left at the time of the survey. The Don Victor trail had a poor understory score, but the over story seems to be doing well with a large number of fruiting oaks (Appendix 6).

Table 4 Mast count score over- and understory per plot

Plot	Trail	Forest type	May over story	June over story	May understory	June understory
1	Montana	Planted	0.00	0.00	0.00	0.00
3	Montana	Planted	0.00	1.64	0.00	0.00
5	Montana	Natural regen	0.59	27.77	1.63	56.80
7	Montana	Natural regen	8.54	0.00	11.86	28.03
9	Chirripo	Old growth	5.84	0.00	0.00	0.00
12	El Jilguero	Old growth	13.94	4.56	0.46	0.00
14	Gavilan	Natural regen	0.00	0.00	0.00	110.20
15	Gavilan	Planted	0.00	0.00	0.00	0.00
16	Gavilan	Planted	45.69	44.52	3.61	0.00
17	Rio	Natural regen	0.00	0.00	3.70	1.70
18	Rio	Natural regen	17.18	5.84	0.40	56.10
19	Rio	Natural regen	6.99	6.99	2.93	156.50
20	Rio	Natural regen	2.57	27.75	14.77	0.00
22	Don Victor	Natural regen	7.97	27.22	5.86	5.20
24	Don Victor	Natural regen	23.34	66.36	0.00	0.60
25	Don Victor	Natural regen	11.71	5.86	14.33	0.00
26	Don Victor	Natural regen	1.45	0.00	0.00	0.00
27	El Jilguero	Planted	27.46	15.53	0.00	0.00
28	El Jilguero	Natural regen	0.00	0.00	0.00	0.00
30	El Jilguero	Planted	1.17	1.17	0.42	0.00
31	Principal	Natural regen	0.00	0.00	0.00	0.00
32	Sentinel	Planted	0.00	0.00	2.71	18.20
33(29)	El Jilguero	Natural regen	4.74	2.71	0.00	0.10
34(13)	Gavilan	Old growth	0.00	0.00	0.00	19.30
Grand total:			**179.16**	**237.90**	**62.66**	**452.73**

Table 5 compare average fruit scores of different areas

Trail	Avg. fruit score overall
Rio	18.96
Gavilan	13.96
Don Victor	10.62
Montana	8.55
El Jilguero	3.61

Table 6 Mast count score over- and understory per forest type

Habitat	Average of May over story	Average of May understory	Average of June over story	Average of June understory
Planted	10.62	0.96	8.98	2.60
Old growth	6.59	0.15	1.52	6.43
Natural regen	6.08	3.96	12.18	29.66
Grand Total	**7.47**	**2.61**	**9.91**	**18.86**

Discussion

Collecting data in the old growth forest was a challenge because the trees are all very large, making height measurements difficult because it was almost impossible to see the canopy. This also made tree identification and the mast count very hard. Therefore, the old growth data is functioning as a background comparison.

The planted areas in Cloudbridge are mostly “problem areas.” Areas where natural regeneration was slow in the first-place, therefore trees were planted to help the succession. This is especially true of the planted area on Montaña, which is very grassy with many ferns that prevent trees from sprouting (Fröling, 2012). Even the oak trees that were planted 14 years ago are not proportionally sized compared to planted oaks of the same age in the Rio area. This could mean that other influences are causing this area to have a poor succession. For the Montaña area, this could be the steep slope or the lack of moisture throughout the dry season (Smith, 2016).

The plots that have been used for this research were originally set up for bird point counts and not for vegetation research. The same plots were used for this research in order to combine vegetation information with the bird information. To make the results of the planted and natural regenerated areas more comparable, the plot locations should be chosen by looking at more specific features such as: average temperature, slope, and soil moisture and texture.

The mast count that has been done is part of a greater study that should give information about the fruit availability throughout one year. Because of the limited time in the study area this report covers only two months.

Conclusion

Is there a difference in vegetation structure between the planted forest areas and the natural regenerated areas?

The research shows that the planted areas are slightly behind in its successional state when compared to the naturally regenerated areas, with a lower average DBH and height. However, the planted areas differ greatly in quality compared to each other, and even the better developed ones seem to be just about under the average of the naturally regenerated areas. The number of trees per hectare seems to be the highest in the planted areas which could mean a high future potential for these areas. Also, the over story fruit availability seems to very good, but the understory seems to be lacking for the months of May and June.

Answering the research questions

- Is there a difference in fruit availability in the over- and understory between the planted forest and the naturally regenerated forest?

The planted areas have a very poor understory score (Figure 10). For that, more data needs to be collected over other months to get a full year picture. The over story score is about the same as the naturally regenerated areas, so it is good to see that the planted trees are producing fruits.

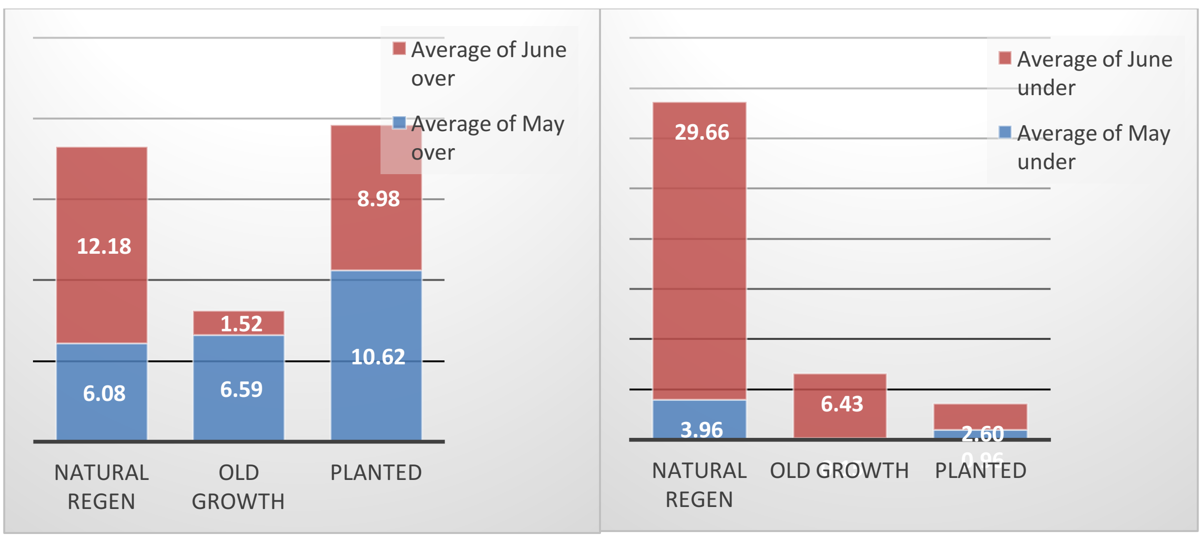

Figure 10 Compare average fruit score per forest type

- Is there a difference in average DBH, height, and volume between the planted forest, naturally regenerated forest, and the old-growth?

Yes, the old-growth is the highest in volume, height and DBH followed by the naturally regenerated areas. The planted areas are a little bit behind with diameters 5% smaller than the naturally regenerated areas

- Is there a difference in the estimated standing deadwood volume between the planted forest, naturally regenerated forest, and the old-growth?

In the planted areas, there was no standing dead wood found. The naturally regenerated areas had very high numbers. This is probably because the naturally regenerated areas are very dynamic and still in their pioneer state. With high number of small trees and quite a closed canopy, it is expected to have a high mortality. The old-growth has a healthy standing dead wood of about 10%.

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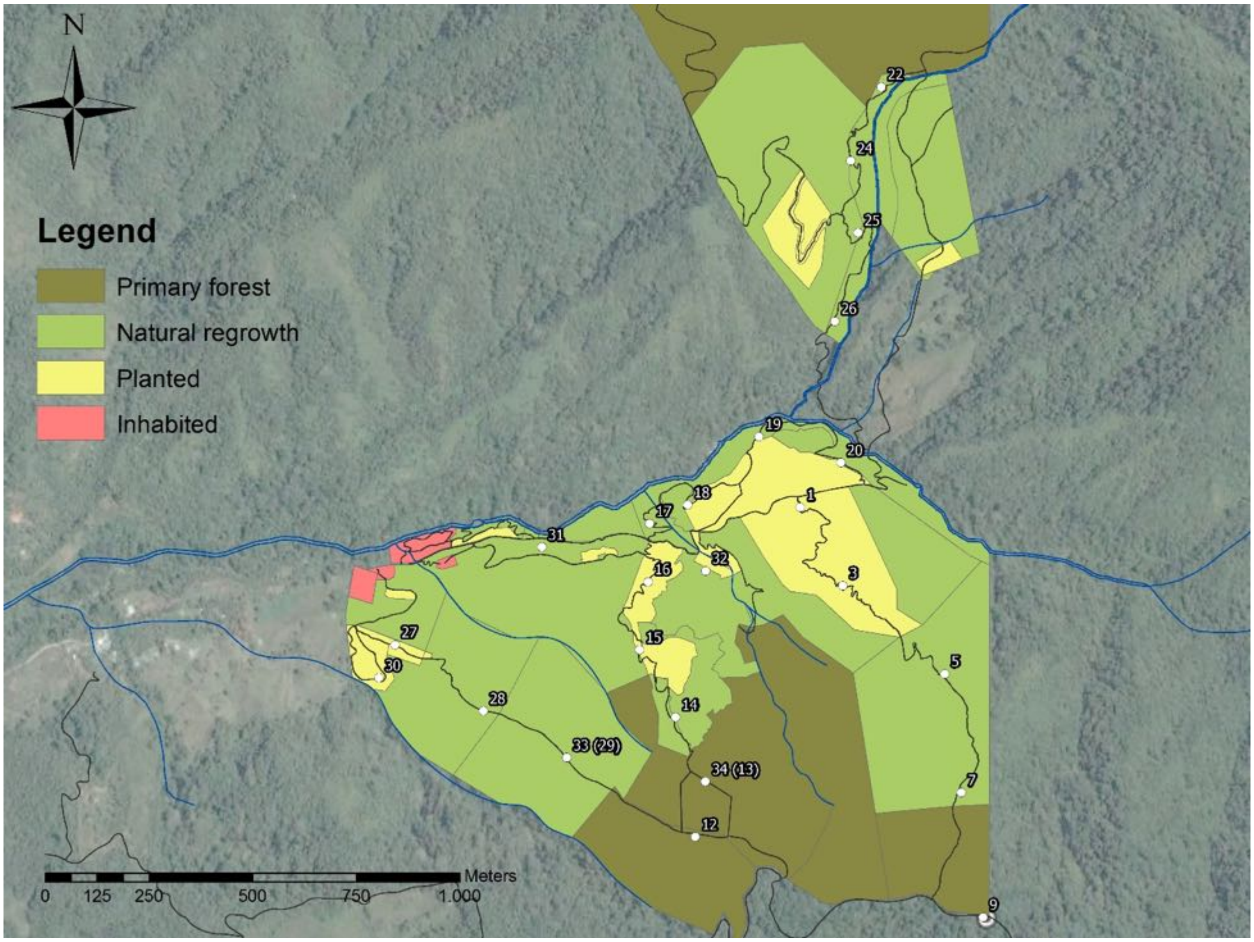
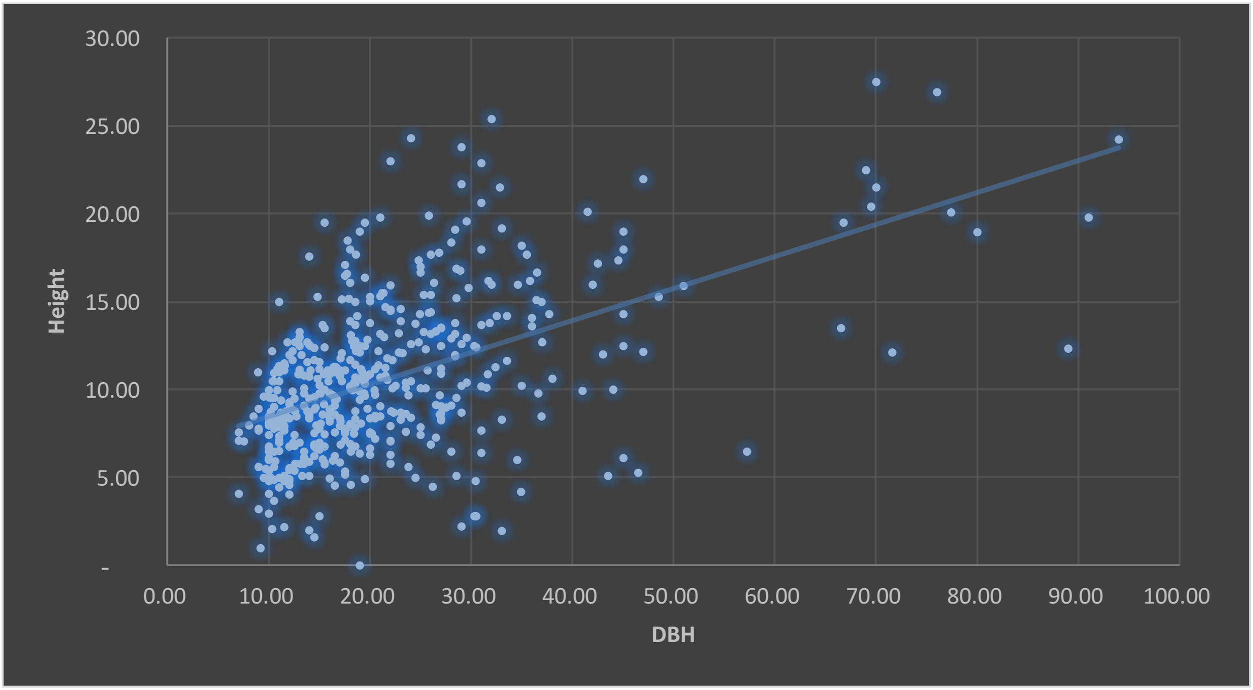
Appendices

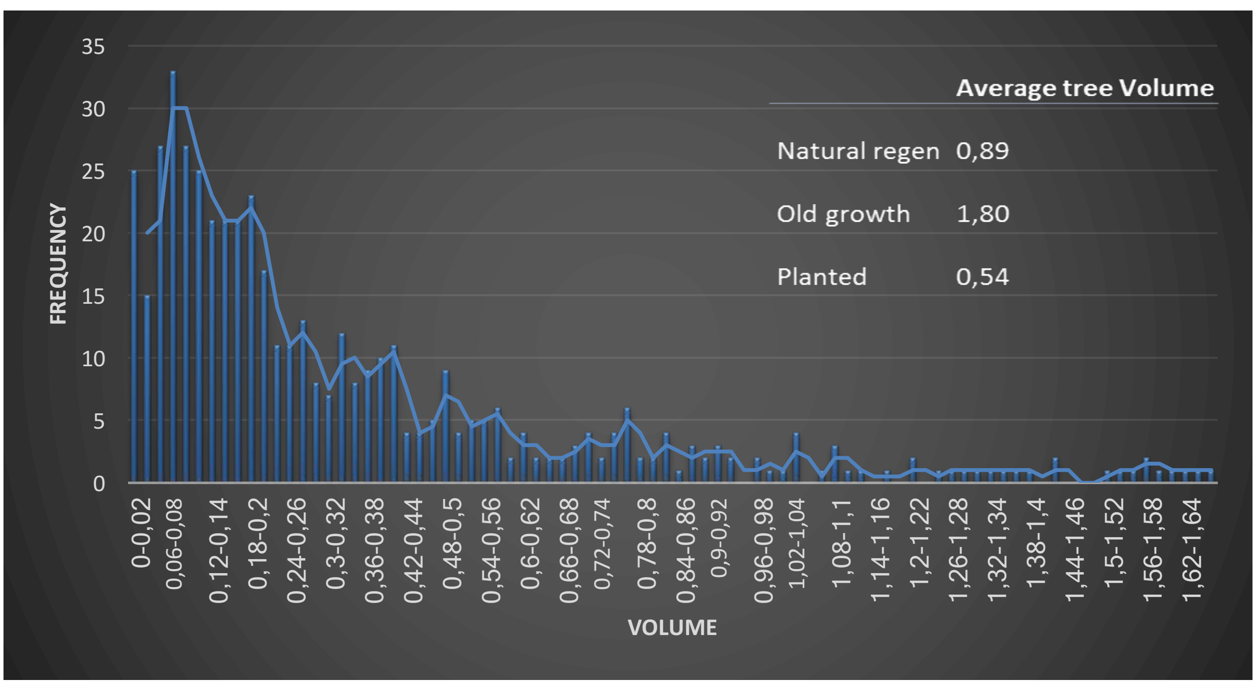
Appendix 1 Cloudbridge map with plot numbers and forest types



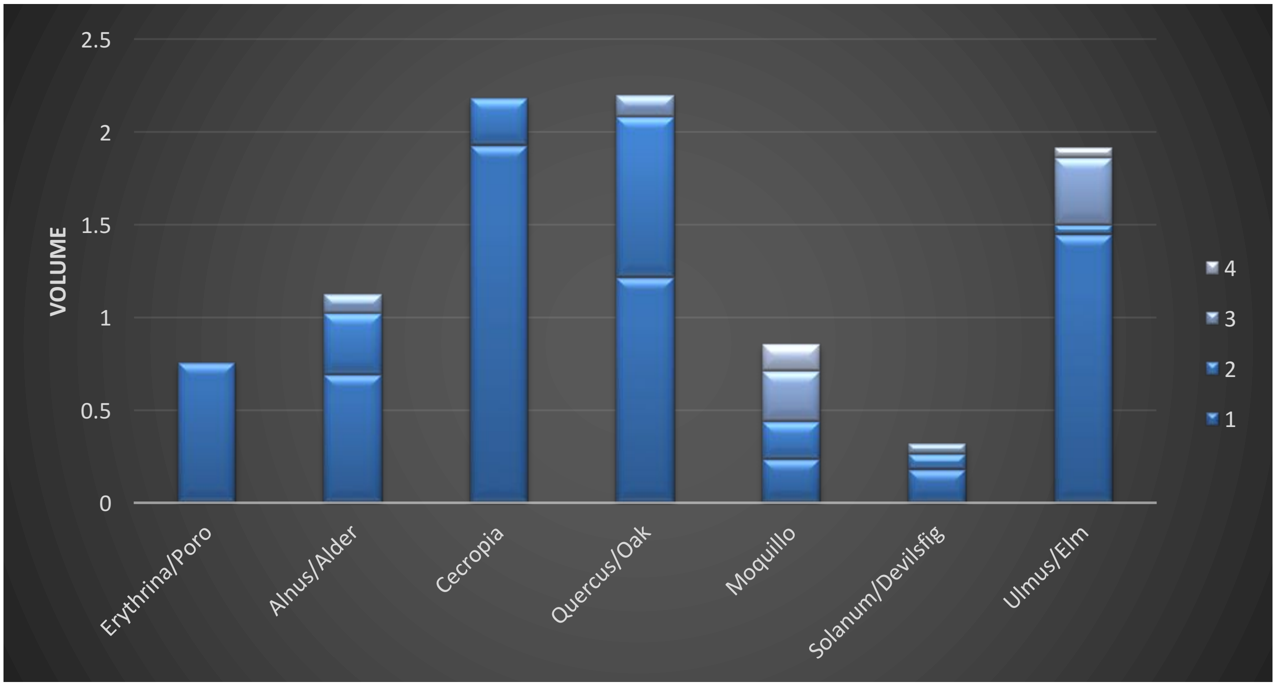
Appendix 2 All trees DBH-Height relationship



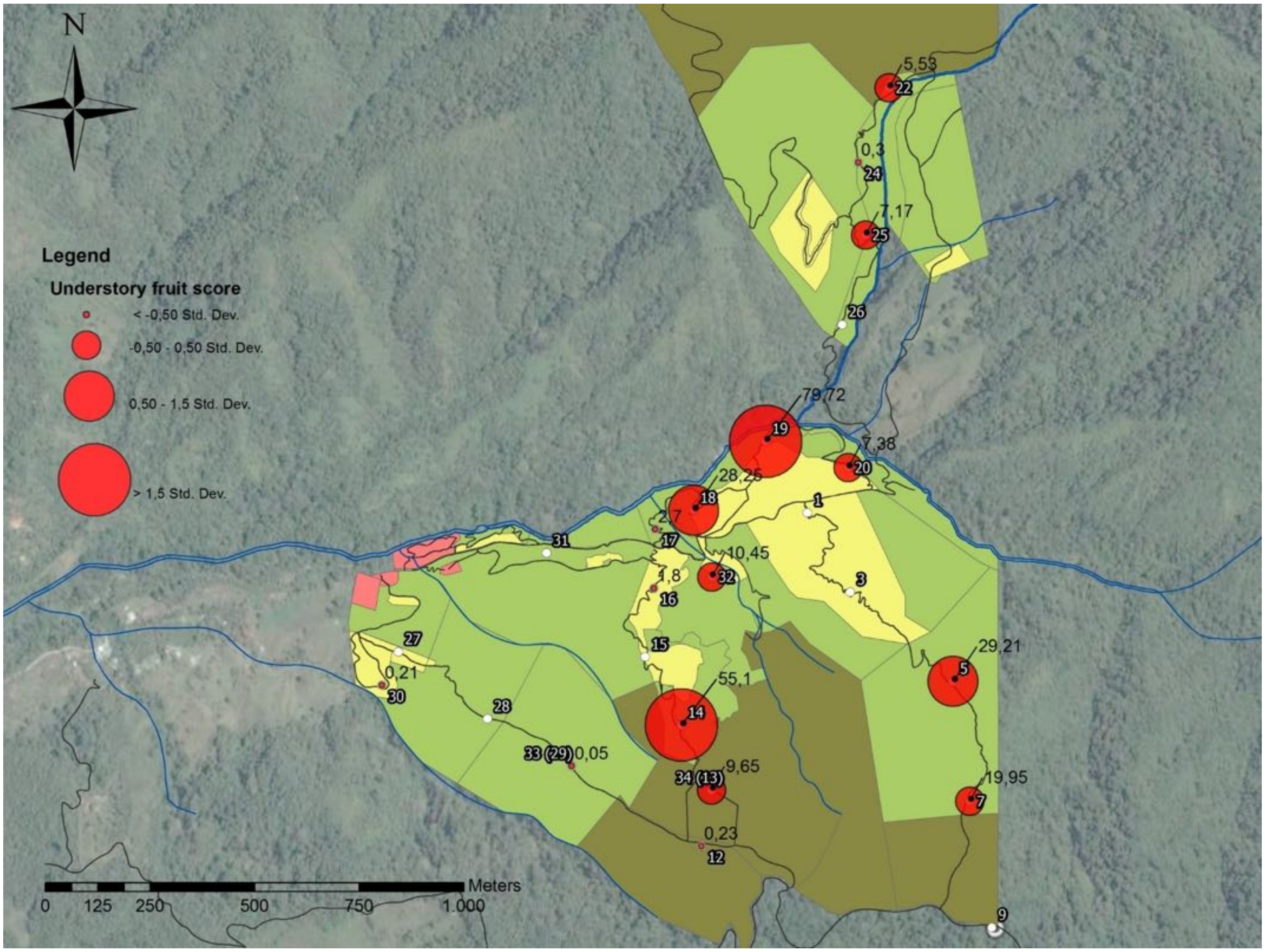
Appendix 3 All trees Volume-Frequency distribution

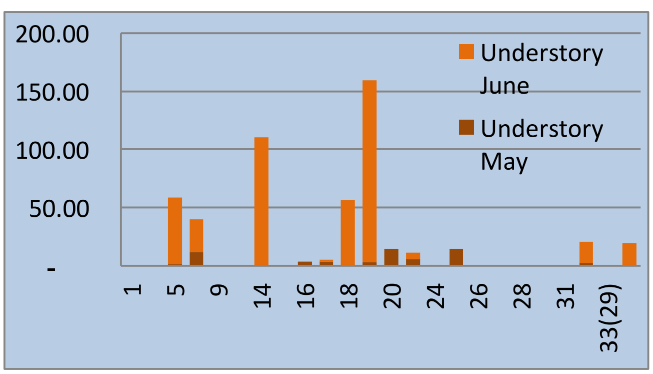


Appendix 4 Tree species volume per canopy class

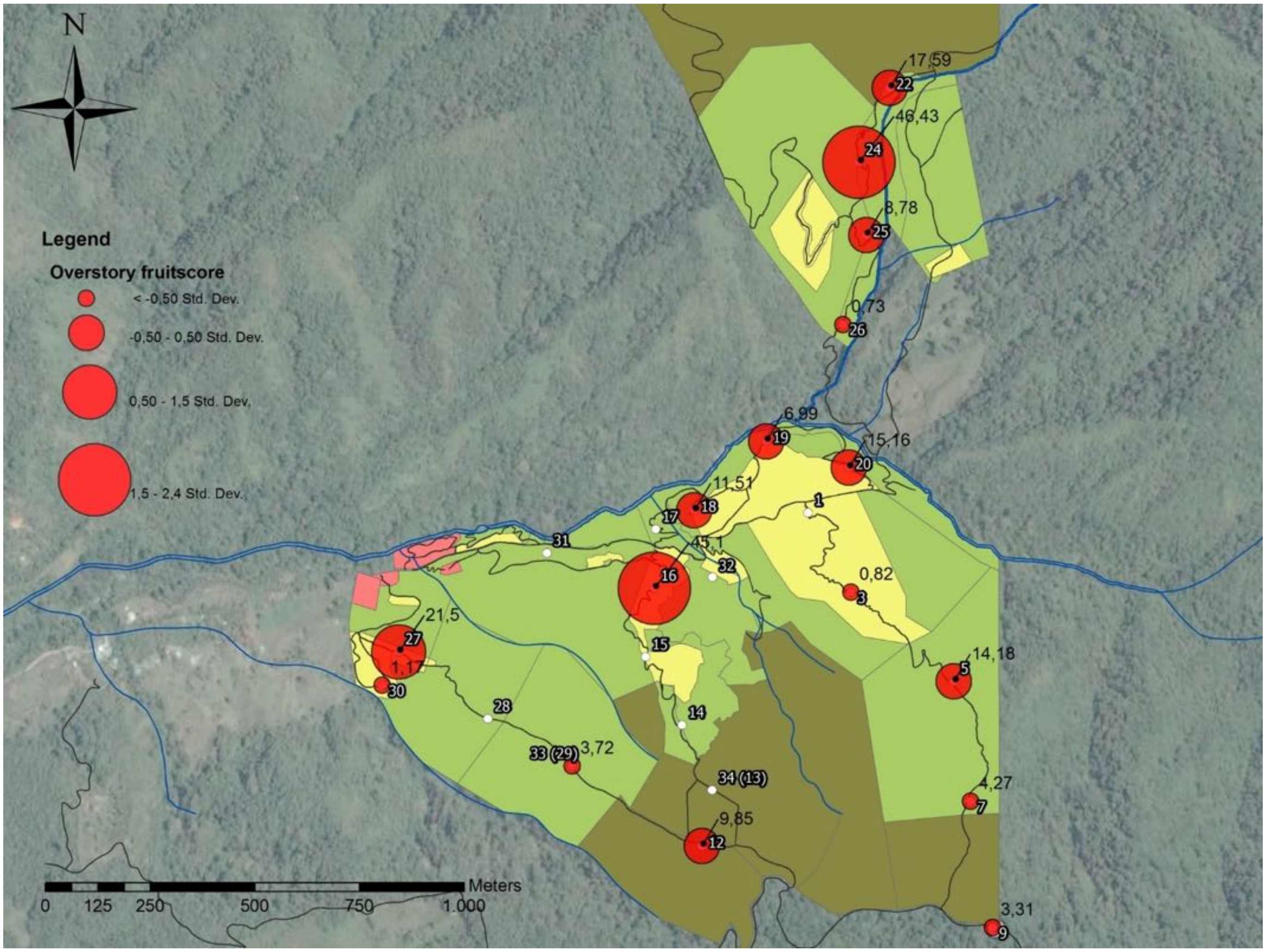


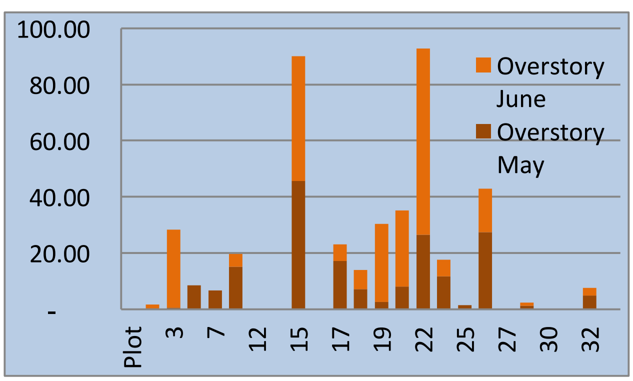
Appendix 5 Map of the understory fruit score per plot





Appendix 6 Map of the over story fruit score per plot





Appendix 7 Example tree measurement field sheet

Plot	Measurements	Eye height	Dead wood volume	Average DBH (cm)	Average height (m)	Volume single trees m3)	Total volume	Small trees	Number of trees
34	2016	1.58	0.00	23.48	10.05	32.05	32.13	66	30
				Median DBH	**Median height**			19	
				19.75	8.97			20	
				Mode DBH	**Mode height**			17	
				10.50	#N/A			10	

IDplot	Measurement	IDtree	IDspecies	Name	DBH (cm)	Height (m)	Volume (m^3)	Canopy class	Tree status	Notification	Distance to tree (m)	Eye height on tree	Base%	Apex%
34	1	326		-	42.00	15.99	2.95	1	1		9.5	38	-62	135
34	2	327		-	19.00	9.42	0.36	2	1		8	40	-72	62
34	3	328		-	19.50	10.36	0.41	2	1		10.3	36	-63	46
34	4	329		-	10.50	8.25	0.10	2	1		9.65	-35	-65	23
34	5	330		-	38.00	10.63	1.61	1	1		10.75	35	-64	42
34	6	331		-	20.00	7.50	0.31	2	1	2 stem 20.0-12.0	5.05	31	-42	100
34	7	332		-	41.50	20.15	3.63	1	1		11.6	31	-59	130
34	8	333		-	23.50	7.63	0.44	4	1	lay down stem	10	46	-90	4
34	9	334		-	13.50	10.81	0.21	1	1		7.6	32	-62	85
34	10	335		-	17.50	7.73	0.25	3	1		8.1	37	-60	40