Tree species comparison in planted, naturally regenerated and old growth cloud forests

A habitat assessment study of the Cloudbridge nature reserve in Costa Rica.

Max Hoving
Van Hall Larenstein university of applied sciences
May 25, 2019

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Practical placement research project

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Author: Max Hoving

Supervisors: Jennifer Powell, Cloudbridge nature reserve
Anko Stilma Van hall Larenstein university of applied sciences

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San Gerardo de Rivas

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Summary

After years of unsustainable practices in the 60’s and after deforested much of Costa Rica, in 2002, Ian Giddy and Genevieve Giddy purchased 255 hectares of degraded cloud forest in and founded Cloudbridge Nature Reserve with the main goal of reforesting it. This research is done to help determine whether this is best done by replanting the area or letting it naturally regrow without much interference. The tree species composition of planted and naturally regenerated plots are compared to the already present old growth plots. The research question is: “In what ways does the tree species composition in planted, naturally regenerated, and primary forests in Cloudbridge differ?”

Trees were found with maps of the area and tree tags. Samples were then collected with a slingshot, slinging rock, and pole saw and, using literature and the help of the herbarium, most of the species were determined. Canopy closure was measured with the help of a densiometer.

After analyzing the data, significant differences between the forest types were found in species richness, species diversity, and canopy closure, with suggestive results in species composition and pioneer-climax composition. Due to time constraints old growth data was very limited or absent, but most of the data suggests that naturally regenerated forests are, in their current state, more similar to the old growth forests than planted forests are. With this knowledge, Cloudbridge can make management decisions accordingly.

1 Introduction

Worldwide, about 1.6 billion people rely on the forests to secure their livelihoods (UNEP, 2011). Not only are forests vital for people living of them directly, but also to the rest of the world as forests produce oxygen and have the capacity to sequester carbon. Over 650 billion tons of carbon are stored In forests (FAO, 2010). Of course, forests do not only benefit people, but provide a habitat for animals as well. It may seem that contributing to the preservation of the forests is in everyone's benefit, yet every year about 13 million hectares of forest cover is cleared, mainly for the ever growing demand for agricultural land (FAO, 2010).

In Costa Rica, deforestation remains a problem. Starting in the 1960's the government promoted increasing the value of virgin lands due to the growing demand of beef for the fast food industry of North America. Farmers were given the piece of land they wanted to live and work on if they cleared and built a house on it themselves. Many of these pieces of land were used, became degraded, and were subsequently abandoned, leaving the forests fragmented and vulnerable to erosion (Evans, 1999) (Buschbacher, 1986).

One type of forest affected in Costa Rica are the montane cloud forests. Cloud forests are one of the most threatened and fragile ecosystems in the world, which is a shame as they are also among the most biodiverse ecosystems in the world (Bellingham, 2016). In 2002, Ian Giddy and Genevieve Giddy purchased 255 hectares of degraded cloud forest in Costa Rica and founded Cloudbridge Nature Reserve with the main goal of reforesting it.

2 Area description

This chapter gives a general description of the study area with a summary on location, climate, Ecological zones, and anthropology.

Location

Cloudbridge is located in the Talamanca mountains of Costa Rica at an elevation ranging from 1550 to 2600 meters. Such a high difference in altitude over a relatively small area makes most of the reserve very steep. The large Chirripó Pacifico river flows through the area, which is an important source of water for the wildlife and local communities (Figure 1).

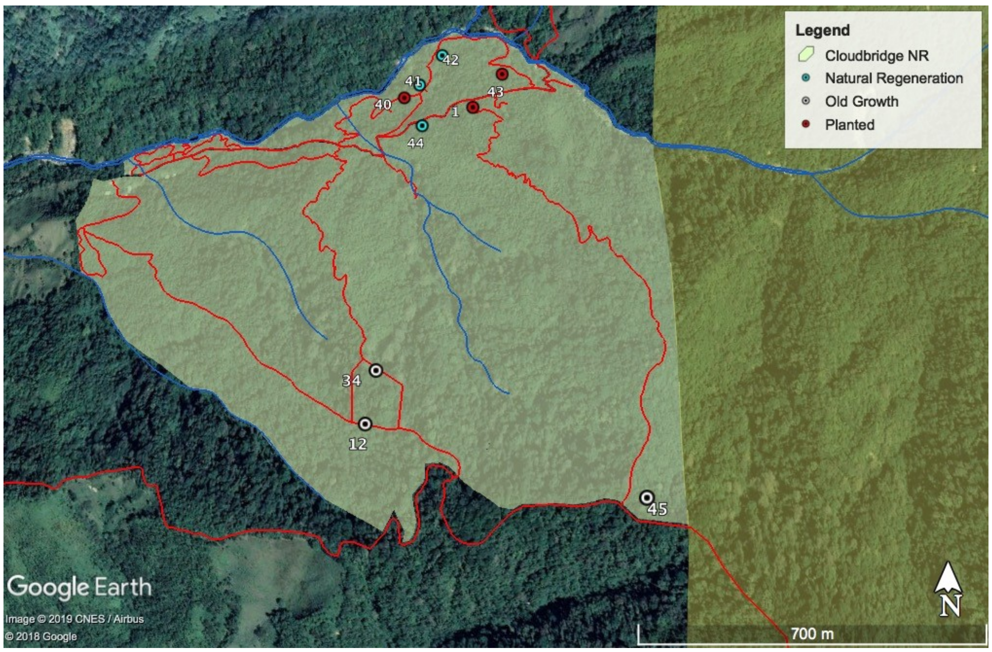


Figure 1: Map research area

Climate

Unlike other forests in subtropical climates, cloud forests are moist throughout the whole year because the forest is shrouded in mist every day. Because of this, the leaves and ground are almost always moist, even in the dry season. The rainy season lasts from April to November and the dry season from December to March. Temperatures range from 15 to 30 degrees Celsius depending on the time of the year and hour of the day.

Ecological zones

For this particular research, the reserve is best divided into three ecological zones: planted forests, naturally regenerated forests, and old growth forests, and the forest plots are differentiated as such. The old growth forests are at least 100 years old. Compared to the planted and naturally regenerated areas, old growth forest is composed of older and taller trees, and has a higher biodiversity. The planted areas have been planted with a number of different species, but mainly Cecropia *(Cecropia angustifolia)*. The naturally regenerated forests have been left undisturbed. These two ecological zones share many similarities in appearance and structure.

Three study plots were set up in each forest type (Figure 1). For the planted and naturally regenerated plots, areas of secondary forest of the same age were selected (started regenerating in 2002-2003).

Anthropology

The nearest village in the area is San Gerardo de Rivas, which is about a 40 minute walk away, downhill from the reserve. San Gerado has about 300 villagers, many of whom visit the reserve, mainly to relax and hike. Besides the village, a lot of foreign tourists visit the reserve. Visitors are not allowed to hunt or leave the trails and there have been no reports of poachers or any other major anthropological disturbances.

3 Problem statement

One of the main goals of Cloudbridge is to reforest the degraded areas in the reserve to one day make them similar to the old growth forests present elsewhere within the reserve. Because reforesting by hand is a costly and time consuming activity, it is important to assess the planted and naturally regenerated areas periodically and compare the data to the old growth forests to determine the success of the practices. An important factor for the assessment is tree species composition, which this report focuses on. The research question is: “In what ways does the tree species composition in planted, naturally regenerated, and primary forests in Cloudbridge differ?”

This question can be divided in the following sub-questions:

- What is the difference in species richness between the forest types?
- What is the difference in tree species composition between the forest types?
- What is the difference in species diversity between the forest types?
- What is the difference in canopy closure between the forest types?
- Are there any significant relationships between canopy closure and tree species within the forest types?
- What is the difference in pioneer/climax composition between the forest types?

4 Methodology

This chapter describes the setup and variables of the forest inventory and the methodology; choice of plots, plot design, methods used for collecting the data for this research, including the materials used, and finally the data analysis method.

4.1 Variables

As described earlier, the aim of the forest inventory is to learn what the most effective practices are for reforesting the area. A lot of data has already been collected in these forests, but to answer the research questions, tree species need to be identified in the three different forest types.

Variables to measure were: species, but also canopy closure, pioneer/climax classification and age. Using existing literature about the identified species, it was determined for each species whether they were pioneer, climax, or intermediate species. Though classifying the species like this is not a very reliable method as it is not this simple, this the best that could be done given the limited time. Age class data of the individual trees has already been collected by Cloudbridge and was used for data analysis.

4.2 Choice of plot and plot design

Cloudbridge uses a number of plots to monitor their reforestation practices. Out of these, 9 plots were chosen, the locations are shown in the map in Figure 1. The plots are circular with a 25 meter diameter, the edges are marked with flagging tape. In these plots all trees above 10 cm DBH were tagged with a metal plate with a number on it. A list of all the trees in the plot was used to find the appropriate trees for sampling.

- Plots 1, 40, and 43 are in planted forests,
- Plots 41, 42, and 44 are in naturally regenerated forests, and
- Plots 12, 34, and 45 are in old growth forests.

Within planted forests, tree species in plot 40 and 43 were identified. Within naturally regenerated forests, tree species in plots 41 and 42 were identified. Tree species in the old growth plots could not be identified due to time constraints. Canopy closure was measured in all plots.

4.3 Forest inventory

The forest inventory included sampling trees, preserving the samples, and subsequently identifying the species with the help of literature. Canopy closure percentage was also measured during field work.

4.3.1 Sampling trees

The trees within the plots had never before been identified so samples were collected to aid in identification. The most import things to sample were the leaves and, if present, flowers and fruits. Any remarkable features were also written down. In some cases the leaves were low enough to plucked off by hand, but In most cases they needed to be collected with the help of one or more of the following items:

- Pole saw: A 6-7 meter long bamboo stick with a saw and pruning shear at the end. This was the easiest and fastest to use out of the three, but could only reach so high.

- Slinging rock: This was a simply put together rock attached to a string wound up around a straight stick. The string was unwound and the rock thrown by hand up and over a branch. Leaves were then sheared off using the string, or the branch was broken off by pulling both ends of the string if necessary. Branches up to 15-20 meters high could be reached through this method, but a downside was that it took a lot of time.
- Slingshot: A 2 meter high metal pole with an elastic slingshot at the end. One person would hold it straight while the other pulled and released the slinging rock from the elastic. The slinging rock could reach up to 30-40 meters, but the downside is that 2 people are needed to operate it and it was very hard to aim so it can take a lot of time. It was also less effective in denser forests.

Which equipment was used depended on the height of the lowest hanging leaves and whether a second person was available for helping. Trees from which samples could not be collected because of the height of the tree were left blank in the database list. After collecting, a sample it was put in a Ziplock bag, tagged with the corresponding tree number, and taken back to the research center.

4.3.2 Identifying trees

Pictures of the samples were taken for later reference and they were pressed in a botanic press to preserve it. When a sample was completely dry it was taken out, photographed again, and stored. Photos were always taken with a monotone background and next to measuring tape. The dry and fresh samples were identified with the help of literature research, mainly ‘A Field Guide to the Families and Genera of Woody Plants of North west South America’(ISBN 978-0226289441) and ‘An Introduction to Cloud Forest Trees: Monteverde, Costa Rica’ (ISBN 978-9968759038) were particularly useful (Gentry, 1993) (Haber, Zuchowski, & Bello, 1996). In cases where identification could not be confirmed using the reference books, the national herbarium (specifically Joaquin Sanchez) helped to identify it. Species were always identified down to the most specific taxonomic group that could be identified with confidence, in some cases this was only the family name. If even the family name was unclear, trees were recorded as separate morpho species (ex. Species A-, Species B, etc.). Afterwards, the scientific names of the trees were written down on the database list. Trees that could not be found or were dead, were left blank or noted ‘DEAD’, respectively.

4.3.3 Canopy closure

Canopy closure measurements were done in all 9 plots with the use of a densiometer (see Figure 2 on how to read the densiometer) at 5 points per plot, one in the center and four at eight meters from the center in each of the four main wind directions (Figure 3). The canopy closure of each plot point was measured in four directions and averaged. This number is then multiplied by 1.04 to get an estimation of the canopy closure for that point (Lemmon, 2005).

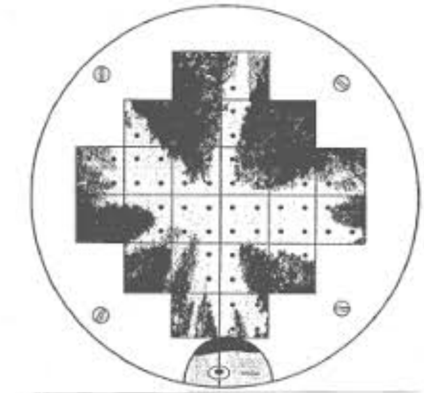


Figure 2: Densiometer. Imagine four dots in every square and count the dots covered by the canopy

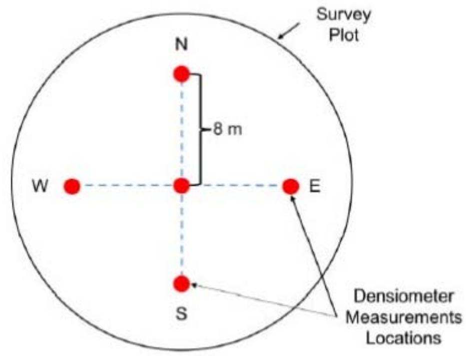


Figure 3: Densiometer measurement locations

4.4 Data analysis methods

After data was collected, the following methods were used for analysis:

- *What is the difference in species richness between the forest types?*
  In terms of absolute numbers of different species per plot. Chi-squared tests were used to see if the results are significant.
- *What is the difference in tree species composition between the forest types?*
  The species composition of planted and naturally regenerated forests was compared by calculating the Bray-Curtis dissimilarity of the species list per forest type, as well by counting numbers for clarifying dominance of specific species
- *What is the difference in species diversity between the forest types?*
  The average Shannon-Wiener index was calculated for the forest types and tested on significance with a t-test.
- *What is the difference in canopy closure between the forest types?*
  The canopy closure percentages were averaged and a Kruskall-Wallis test was used to see if there was a significant difference within the three compared forest types. If so, three Man-Whitney U-tests were used to find which forest types were significantly different.
- *Are there any significant relationships between canopy closure and tree species within the forest types?*
  Canopy closure percentages were correlated with abundance of the most common tree species and total number of trees.
- *What is the difference in pioneer/climax composition between the forest types?*
  An outline is given comparing the pioneer/climax composition per age class per forest type.

5 Data analysis and results

These are the results of the data analysis categorized by each sub-question as explained in the Chapter 3 problem statement. As species identification in the old growth forests could not be done due to time constraints, this forest type is left out of the species richness, composition and diversity comparison If P=<0.005 the result can be called significant.

5.1 Species richness

The number of different species was 21 and 10 for the naturally regenerated plots (average of 15.5) and 8 and 10 for the planted plots (average of 9). Plot 41 seems much higher in species richness than the other plots are (Figure 4).

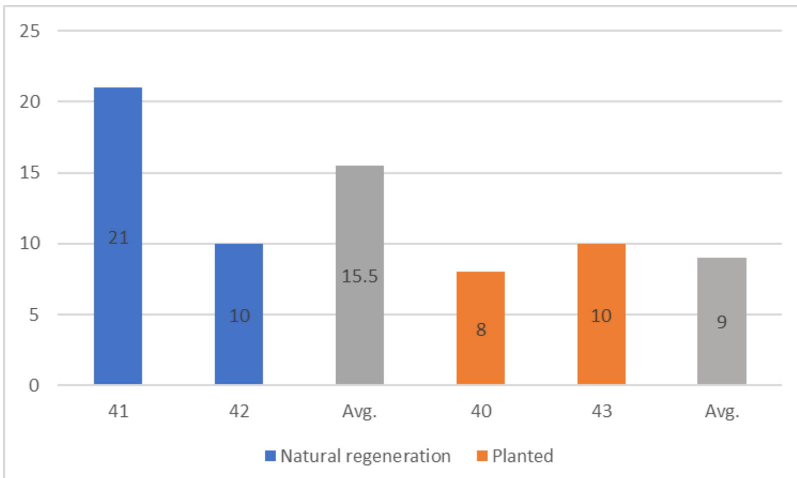


Figure 4: Species richness and averages per plot

A Chi-squared test showed a significant difference in species richness somewhere within the four compared plots. The chi-squared test was used in particular because it is the best test to use when comparing the counts of one variable in multiple groups. To find which of the plots are significant and which are not, more chi-squared tests were used to compare each plot separately with all other plots combined. A chi-squared index of 8.333 with a P-value of 0.0039 was found when plot 41 was compared with all the other plots, so that one is significantly richer. No other plots were found significantly different from each other. Comparing the two forest types together like this would give a false sense of data as 3 plots are similar while one is obviously much higher.

5.2 Species composition

There were three apparent observations when looking at species composition in the naturally regenerated and planted forests. Firstly, Cecropia *(Cecropia angustifolia)* was the most common species in the planted plots as most of them were planted purposefully there, only few were found in the naturally regenerated plots. Secondly, Leathery Colicwood *(Myrsine coriacea)* was very common in the naturally regenerated plots while only one individual was found in the planted plots. Lastly, Nightshade *(Solanum aphyodendron)* appeared almost equally as much in both forest types and was the most frequent species overall. Almost all other species appeared 1 to 5 times, about half of which exclusively in their respective forest type. The species composition of these two forest types was compared by calculating the Bray-Curtis dissimilarity of the species list per forest type. A Bray-Curtis dissimilarity of 0.5217 (and a similarity of 0.4783) was found. Knowing that a dissimilarity of 1 means that the composition is entirely different and that a dissimilarity of 0 means they are exactly the same, a dissimilarity of 0.52 indicates that about half of the species are the same.

5.3 Species diversity

Species diversity can be calculated with The Shannon-wiener index. The Shannon-wiener index for planted and naturally regenerated plots were 1.947 and 2.609, respectively. The diversity of naturally regenerated forests seems higher (Figure 5). Using a t-test, a P-value of <0.001 was found, signifying that the difference is significant.

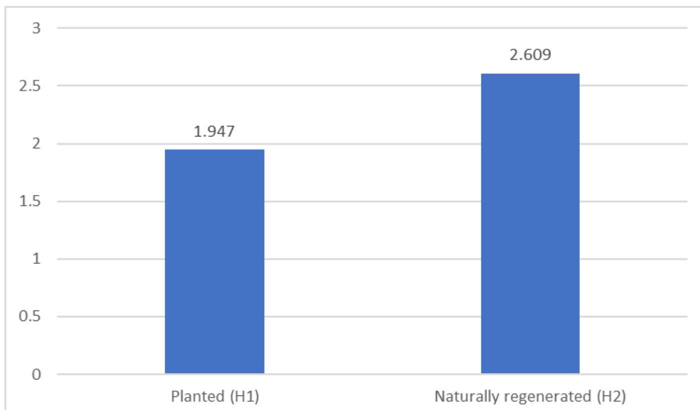
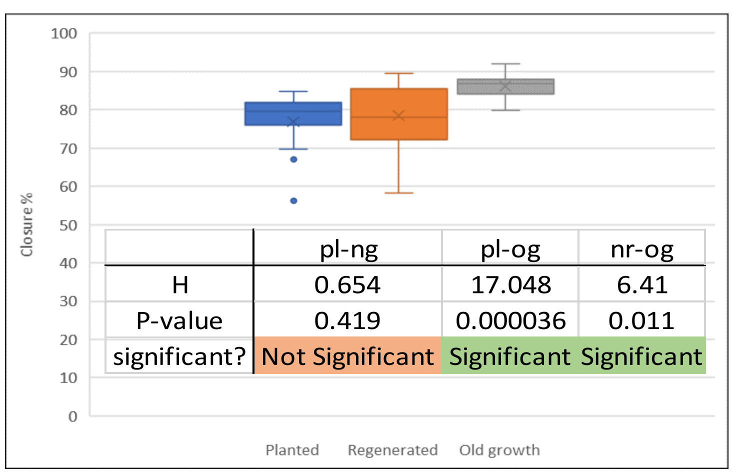


Figure 5: Species diversity per forest type

5.4 Canopy closure and forest types

The canopy closure percentages were highest in the old growth plots. The natural regeneration and planted plots have similar averages, though the data in the naturally regenerated plots is more spread out (Figure 6).



	pl-ng	pl-og	nr-og
H	0.654	17.048	6.41
P-value	0.419	0.000036	0.011
significant?	Not Significant	Significant	Significant

Figure 6: Canopy closure data distribution per forest type and test results

Comparing the canopy closure percentages for the three forest types in a Kruskall-Wallis test shows a significant difference somewhere within the three plots. Three Man-Whitney U-tests were used to compare each set of two forest types. This showed that there are significant differences between planted and old growth plots, and naturally regenerated and old growth plots.

5.5 Canopy closure and number of trees

To see if there are any correlations between canopy closure and any species, the following graphs showing the correlation (and P-value) between canopy closure and the number of individuals of the two most frequent species (*Cecropia angustifolia* and *Solanum aphyodendron*) as well as all species combined was created. Based on the data, no significant difference between canopy closure in the different areas could be found (Figures 7-9).

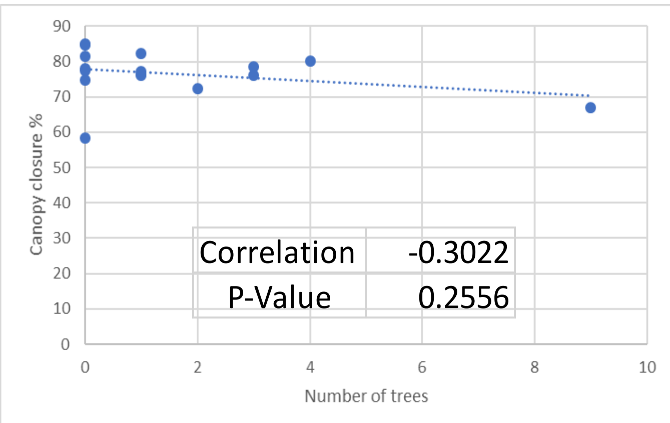


Figure 7: Correlation canopy closure and Cecropia angustifolia

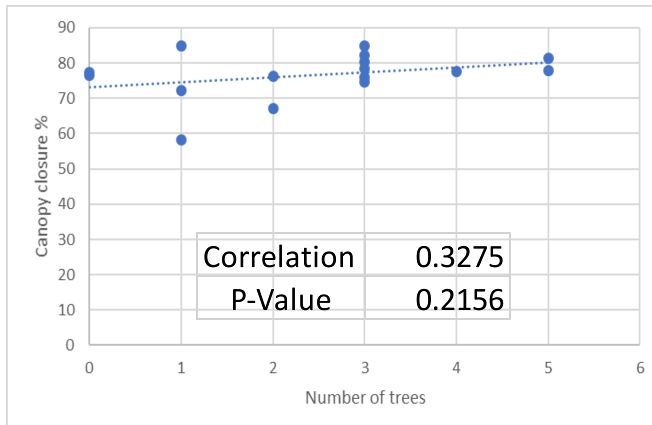


Figure 8: Correlation canopy closure and Solanum aphyodendron

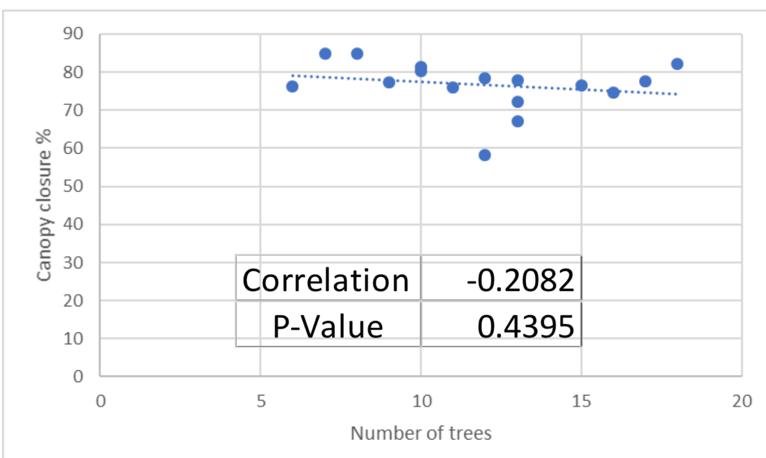


Figure 9: Correlation canopy closure and all species

5.6 Pioneer/climax composition

After determining for each species whether they are pioneer, climax or intermediate species with the help of literature (CABI, 2002) (Kapelle, 1993), the following graphs showing the composition of pioneers/intermediate/climax species per age class were created with the help of preexisting age class data from Cléa Lefebvre (see Figures 10-12) (Lefebvre, 2018). No data on species, and therefore pioneer/climax composition, was collected for old growth forests. There are more intermediate and climax species in the naturally regenerated plots than in the planted plots, though this is partly because the planted plots had pioneer species planted in them like Cecropia. The trees in the planted plots are also bigger on average, though again this is skewed because of the many Cecropias, which quickly grow very tall.

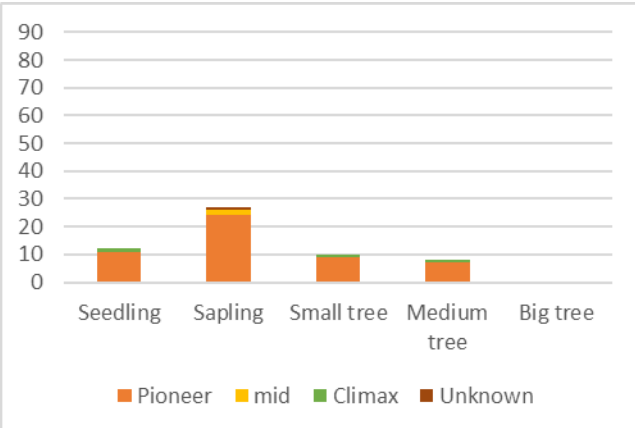


Figure 10: Pioneer/climax and age class composition planted plots.

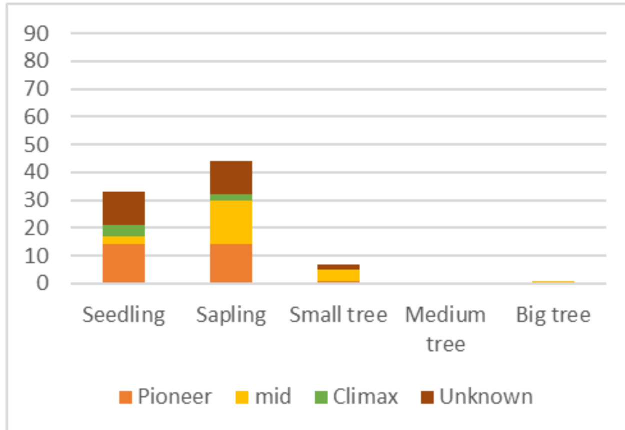


Figure 11: Pioneer/climax and age class composition naturally regenerated plots.

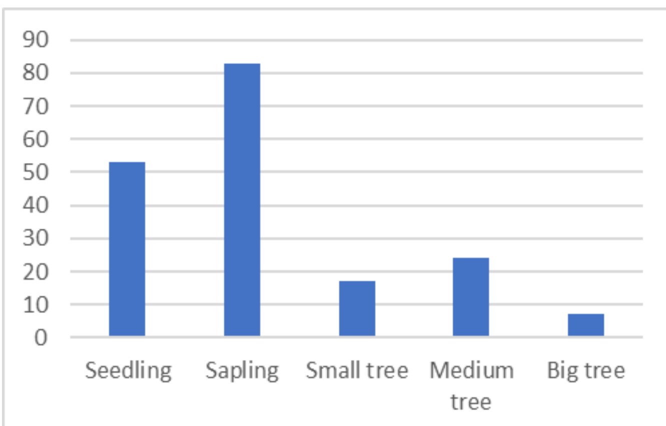


Figure 12: Age class composition old growth plots

6 Conclusion and discussion

Generally, naturally regenerated forests have a higher biodiversity, species richness, and a more diverse species composition as can be concluded from the significant differences and other suggestive results of some of the sub-questions. Species data for the old growth forests is missing so not much can be said about this. Canopy closure measurements show that both planted and naturally regenerated forests are still very different from old growth forests, but no real conclusions can be made on which type matches old growth forests the best. A very large sample size would likely be needed for any significant correlation between species types and canopy closure to show up and no correlations can be found in this research as such. Though no real definitive conclusion can be made for the pioneer/climax composition due to the small sample size, time constraint and skewed data, naturally regenerated forests seem to have more climax and intermediate species and match the differences in age class with old growth forests better.

To summarize and answer the main research question: *The data in this research suggests that the naturally regenerated forests resemble old growth forests more than the planted forests do, at the very least more decisively in species richness, biodiversity and species composition.*

This conclusion is backed up by previous similar reports on forest type differences in the area (Fleer, 2017) (Laan, 2018), though it is not completely conclusive for a number of reasons. The main reason being that the research questions and methods were initially designed and carried out with a larger sample size in mind. Originally, species in 9 plots (3 of each forest type) were supposed to be identified but unexpected circumstances resulted in the available research time being halved, so only species in 4 plots (2 planted and 2 naturally regenerated) could be identified and used for data-analysis.

Also, due to the difficulty of sampling and identifying, about 15% of the targeted trees are left unidentified and/or undistinguished from others. This can result in a false sense of overall species composition, as, for example, taller trees are harder to sample and are therefore more often left out of the analysis.

7 Recommendations

It is important to note that although the naturally regenerated forests seem to resemble the old growth forests more than planted forests do, this does not necessarily mean that they are closer to reaching climax stage, which is ultimately the goal Cloudbridge wants to achieve. The main theory driving the motivation to replant the area suggests that by planting fast growing, shading pioneers like Cecropia the natural succession will skip a few stages by growing more climax species quicker than by letting natural regeneration do the job. Because of this naturally regenerated forests could be higher in species richness and biodiversity, but be further away from reaching the climax stage.

As such, it is suggested to focus following research more on pioneer/climax composition of all forest types, but especially old growth and planted forests as old growth data is lacking and planted forest data seems to be skewed. For this to be possible, more species need to be identified. Next time a larger sample size should be used as well, I suggest at least 4 plots per forest type, if possible. Hopefully this report can at least serve as a baseline to go further from in that regard.

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