Forest Regeneration on previous pastureland in the Talamanca Mountain Range, Costa Rica

Research Report

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March 23, 2022

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Abstract

Fourteen years ago, research on forest regeneration was conducted by Matthijs Bol and Dennis Vroomen in Cloudbridge Nature Reserve Costa Rica. In this research the researchers investigated if the planting of trees can promote seed rain and the establishment of natural regeneration on abandoned pastures in the Cloudbridge reserve and which tree species are most effective in this respect (Bol et al., 2008). The most important finding of this research was the difference in species composition of the regenerating trees and the frequency of regenerating species. To continue this research fourteen years later, forest inventory studies have been carried out in both planted and naturally regenerated areas.

Data was collected using plots that were randomly placed using the Forest Types map of Cloudbridge. The factors that influenced the placement of the research plots were distance to primary forest, altitude and distance to streams and rivers. In total 22 plots were placed, of which 11 in planted areas and 11 in naturally regenerated areas. The plots had an area of 10x10m in which trees above 10 cm DBH were measured and identified. Within this plot, two subplots of 2.5x2.5m were placed for the inventory of trees and plants below 10 cm DBH.

In total 145 species have been identified. Within the planted areas 109 species were identified and within the naturally regenerated areas a total of 100 species. There is no significant difference in species diversity, but there is a difference in type of species and carbon storage. The planted area has a higher abundance of climax species in comparison to the naturally regenerated areas, which has mainly pioneer species that established. Furthermore, the planted areas have in terms of carbon sequestration roughly 100.000 tons C/ha more stored.

The problem stated in the problem description was the information gap in the effectiveness of planting trees for accelerated forest regeneration. The conclusions from this minor field study show that planting trees does actively assist in accelerated forest regeneration and that it can benefit the rehabilitation of natural forest while at the same time sequestering carbon rapidly.

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1. Introduction

Fourteen years ago, research on forest regeneration was conducted by Matthijs Bol and Dennis Vroomen in Cloudbridge Nature Reserve Costa Rica. In this research the researchers investigated if the planting of trees can promote seed rain and the establishment of natural regeneration on abandoned pastures in the Cloudbridge reserve and which tree species are most effective in this respect (Bol et al., 2008).

The most important finding of this research was the difference in species composition of the regenerating trees and the frequency of regenerating species. It showed that under planted trees a mixture of pioneer and climax species established, while in the subplot that was left to recover naturally only pioneer specialist species established.

At the time at which this research took place, the planted trees were only six years old. At this moment the planted trees are about twenty years old. The difference in time can provide for a broader understanding and provide data for the monitoring of forest development, comparing planted reforestation sites and natural regeneration.

To continue this research fourteen years later, forest inventory studies have been carried out in both planted and naturally regenerated areas. The data was compared by the data from previous inventories and current biodiversity was be tested. It is expected that planting of trees does have a significant impact on the speed of forest regeneration, but does it also positively influence biodiversity? The outcome of this study can help future reforestation efforts by explaining why it is or is not advisable to plant trees to accelerate forest succession rate.

2. Problem Analysis

The general view of the importance of natural forest for their intrinsic value, but also the value to humans through the so-called Ecosystem Services (ES) such as e.g., clean water, air purification and erosion prevention got exceedingly more attention in recent years. This shift in paradigm brings a lot of attention towards reforestation and overall rehabilitation of natural ecosystems. Natural forests have been struggling with fragmentation which prohibits animals from migrating through bigger areas. Numerous organizations are working with tree planting to combat climate change and protect species from extinction. But tree planting alone is not enough and research on the effect of tree planting is highly necessary to make a lasting impact for the good of the planet. The focus must lie in restoring natural ecosystems and bringing back natural forests. By bringing back natural forests it is possible to restore habitats, store more carbon and increase resilience of forests. But is planting trees the most effective strategy to combat these issues?

As mentioned in the introduction, this research is a continuation on research done in 2008 by Matthijs Bol and Dennis Vroomen (Bol et al., 2008). From their research insights on the effect of tree planting on the regeneration of cloud forests came forward. Their research was done when the planted trees were about six years old, this research will investigate similar questions, but now the planted trees are 20 years old. The goal is to understand forest regeneration better and thus also investigate the effect of tree planting on the establishment of natural forest.

There are a lot of factors at play when one wants to restore an ecosystem from degraded agricultural land. Seedbanks are non-existent, the soil is extremely degraded and poor in nutrients and naturally seed dispersing animals have been driven away. Should a former agricultural site be left to regenerate on its own, this will take years if not millennia for a forest to regrow to its former glory. Tree planting can help, but in what way and which species have the most impact? How do you attract animals to the site? How do you cope with the nutrient deficiency? These questions will not be answered by this research but need to be addressed by further research to build a better understanding for the accelerated rehabilitation of ecosystems.

This research will instead focus on the effect of planted trees on the recruitment of native species to the area and the effect on carbon storage. It is expected that this is the case due to the creation of microclimate and the attraction of forest animals to young growth forest. The objective is to assess whether the planting of trees can kickstart forest growth and increase carbon storage by skipping the first successional stages of grassland and shrubland.

The main question that will guide this research will be: *"Can planting of trees accelerate forest regeneration on abandoned pastures in Cloudbridge Nature Reserve?"*

Sub questions that can assist in answering the main question are:

- Does planting of trees increase or decrease potential biodiversity in 20 years?
- What is the difference in species between the two research areas?
- What type of trees are present in the two different study areas?
- Does tree planting have a significant effect on Carbon Storage?

Hypothesis

Planting of trees will positively impact the rate of tree establishment from later stages of succession and with that accelerate forest regeneration.

3. Literature review

Quite some research has been done on reforestation in recent years. One study by Taylor et al. (2017) explored the effect of Nitrogen fixating trees on the surrounding forest. It was thought that the planting of nitrogen fixating trees would positively impact forest regrowth on depleted soils, since plants need nitrogen to grow, and these trees bring nitrogen in the soil. However, Taylor et al. (2017) pointed out that due to the highly competitive ability of most N-fixating trees, the planting of these trees instead impacted the surrounding negatively. This research answers one of the questions Bol et al. (2008) stated in their report and since there have been N-fixating plants planted in the research area can be of use for this research.

The planting in Cloudbridge Nature Reserve consisted mainly of planting trees. However, a study done by Abbas et al. (2016) showed that the abundance of shrubs accelerates forest recovery faster than tree seedlings do. This can mean that the effect of tree planting is of less importance than the abundance of shrubs (e.g., ferns, etc.)

There are different approaches possible to reforestation an area. The main methods are natural regeneration, applied nucleation/island tree planting and plantation. One study found that recruit composition was least similar to the primary forest in naturally regenerated sites and most similar in plantation sites (Holl et al., 2016).

Another study states that intensive replanting in Kibale National Park, Uganda, can accelerate natural accumulation of biomass and biodiversity and facilitate the restoration of tropical forest communities. However, it also raised the question that the long-term financial costs and ecological benefits of planting and maintaining reforested areas need to be weighed against other potential restoration strategies (Omeja et al., 2010).

There is an active community of tree planting to counteract climate change and sequester carbon in forests. Depending on the objective of the plantation it is variable which strategy is most effective, but overall, the best way to sequester carbon is to protect old growth forests and rehabilitate degraded forest into lush natural forest. Tree planting can thus serve a purpose, if done correctly. Existing theories advocate of applied nucleation and enrichment planting, but does this assist the regrowth of natural forest? Otherwise stated, does planting of trees affect the succession rate of pastureland into natural forest positively or is it a waste of effort and money?

The outcome of this study may well give answers to some of these questions. Although it is a minor study with a small area being studied, it can provide insight into the effect of planted tree species, native or not, on the surrounding forest and bring to light if the planting done at Cloudbridge did accelerate natural regeneration in a sustainable way.

If the hypothesis is found to be true, it means that planting of the correct species can benefit the rehabilitation of natural forest. This can help in future reforestation efforts to make them as economically feasible and effective as possible.

4. Methods

4.1 Study Area

Cloudbridge Nature Reserve is located on the base of Parque Nacional Chirripó in the Talamanca Mountain range (figure 1).

It was started in 2001 by Ian and Genevieve Giddy with the plan to reforest the at that point highly degraded pasture lands. After the purchase of the land, small parts were reforested, and other parts were left to regenerate on their own. There is a difference between planting techniques, species planted and size of plantation.

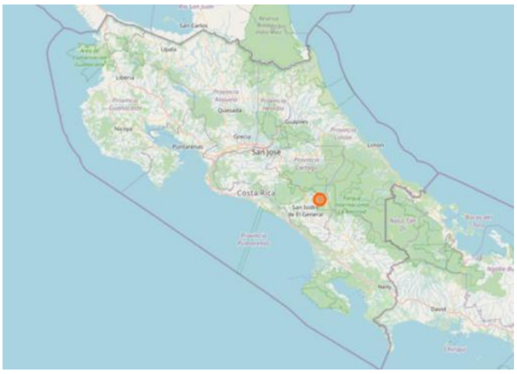

Figure 1 - Location of Cloudbridge (openstreetmap.org)

4.2 Research Design

This research is quantitative research on tree species present in the different research areas. Most data has been collected through fieldwork in the CNR and compared with data that previously has been collected. The results were analyzed using Microsoft Excel and Microsoft Access.

Biodiversity has been tested on alpha and beta diversity and analyzed using the Simpson- and Shannon-Wiener index.

This research was descriptive research of the current plant populations of the young forests of Cloudbridge Nature Reserve. Next to describing the plant population, biodiversity in both planted and naturally regenerated areas were compared to each other to illustrate whether natural regeneration or assisted regeneration is preferable. Finally, the amount of carbon storage in each forest type was calculated and compared.

4.3 Methodology

Data was collected using plots that were randomly placed using the Forest Types map of Cloudbridge. The factors that influenced the placement of the research plots were distance to primary forest, altitude and distance to streams and rivers. In total 22 plots were placed, of which 11 in planted areas and 11 in naturally regenerated areas. Figure 2 shows the location of the plots, the same map can be found in the appendix for a more readable scale.

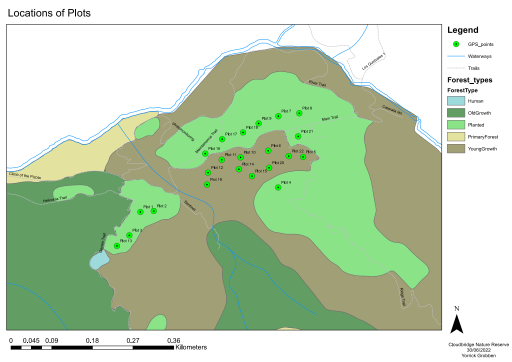

Figure 2 - Location of the plots

The plots had an area of 10x10m in which trees above 10 cm DBH were measured and identified. Within this plot, two subplots of 2.5x2.5m were placed for the inventory of trees and plants below 10 cm DBH (figure 3).

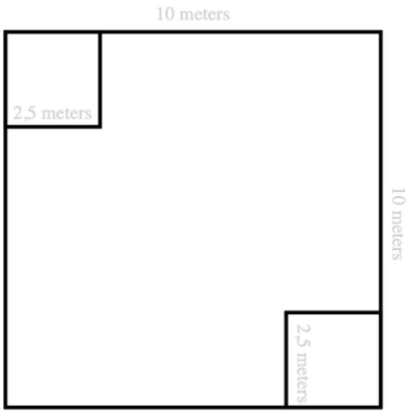

Figure 3 - Plot Design

The plots were identified on species, and of the tree species DBH, Height and Health were written down.

This method has been chosen to gather as much information on the state of the forest as possible. By identifying species, the species list of Cloudbridge can be updated. But more importantly this method gathered information on species present in both forest types which then were compared with each other to see what impact planting of trees has on the type of vegetation that establishes.

5. Results

5.1 Species Richness and Diversity

In terms of species diversity there is little to no difference between the two forest types. With 100 species in the naturally regenerated areas and 109 species in the planted areas there is a slightly higher number in the planted area, but it is not at all a significant difference (table 1).

Forest Type	*Amount of Species*
Natural	100
Planted	109

Table 1 - Alpha diversity

A two-sample t-test showed that with a p-value of 0,189 that there is a difference, but it is not below 0,05 and consequently not significant. (table 2)

With the Gamma Diversity being 145, the Beta diversity is 0,43, so the distribution of species is quite equal. It becomes more interesting in the abundance of species and type of species which the next paragraph explores.

Gamma Diversity	Total amount of species in all plots =	**145**
Beta Diversity	Regional and local species diversity ratio of all plots =	**0,43**

Two diversity indices were run to get an idea about the diversity in the forest of CNR. See figure 5 and figure 6 for the outcomes per forest type and for the entire area combined. It shows that although there is not a high difference in diversity between the two forest types, the overall diversity is very high.

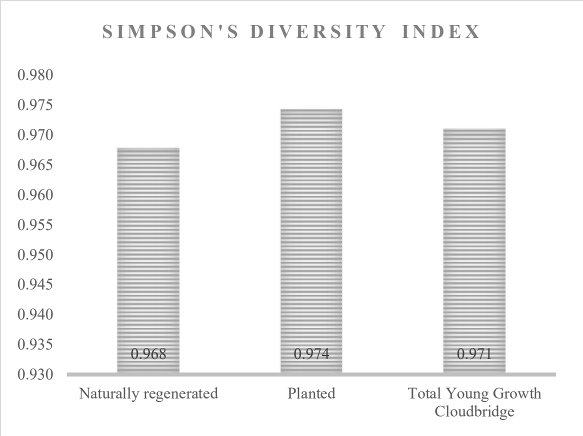

Figure 4 - Simpson's Diversity Index

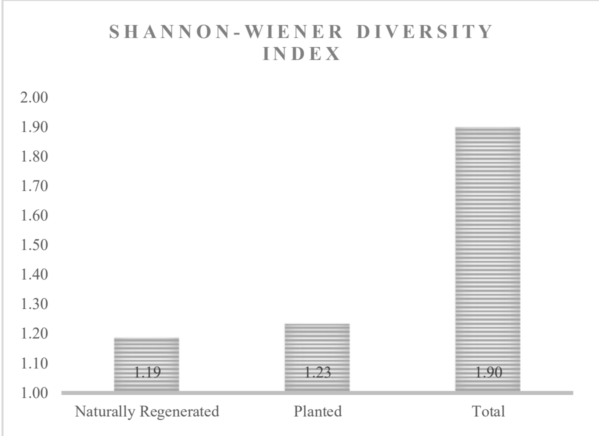

Figure 5 - Shannon-Wiener Diversity Index

F-Test Two-Sample for Variances			**t-Test: Two-Sample Assuming Equal Variances**		
	Variable 1	***Variable 2***		***Natural***	***Planted***
Mean	22,72727273	24,18181818	*Mean*	22,72727273	24,18181818
Variance	22,61818182	6,163636364	*Variance*	22,61818182	6,163636364
Observations	11	11	*Observations*	11	11
df	10	10	*Pooled Variance*	14,39090909	
F	3,669616519		*Hypothesized Mean Difference*	0	
P(F<=f) one-tail	0,026066658		*df*	20	
F Critical one-tail	2,978237016		*t Stat*	-0,899217039	
			P(T<=t) one-tail	0,189618218	
			t Critical one-tail	1,724718243	
			P(T<=t) two-tail	0,379236436	
			t Critical two-tail	2,085963447	

Table 2 - Two-sample t-Test

5.2 Most Abundant Tree Species & Types

The most abundant tree species and the type of species show an interesting difference (figure 6). Of the ten most abundant tree species in planted areas, 4 are pioneer species and 6 are climax species. For the naturally regenerated areas there are 7 pioneer species and 3 climax species. This is again for the most abundant of all trees and knowing a lot of climax tree species were planted in the planted areas, this might be expected (table 3). But if we then look to the most abundant tree species below 15 cm DBH (table 4) the difference becomes even higher. Here the planted area has 8 young climax tree species and only 2 pioneer species. The naturally regenerated areas have 5 climax species and 5 pioneer species.

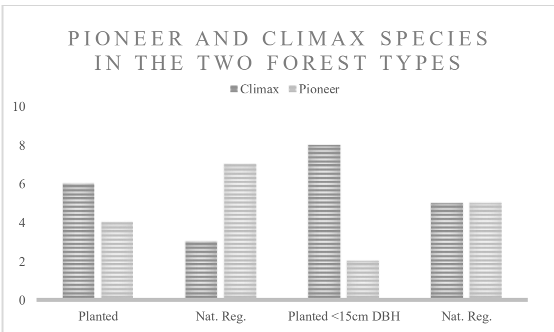

Figure 6 - Pioneer and Climax species in the two forest types

***Planted* Species**	**Number of Individuals**	**Type**	***Naturally Regenerated* Species**	**Number of Individuals**	**Type**
Myrsine coriacea	17	Pioneer	Myrsine coriacea	32	Pioneer
Saurauia pittieri	16	Climax	Heliocarpus appendiculatus	13	Pioneer
Heliocarpus appendiculatus	15	Pioneer	Saurauia pittieri	8	Climax
Telanthophora grandifolia	9	Pioneer	Hedyosmum mexicanum	7	Pioneer
Ulmus mexicana	9	Climax	Cyathea divergens	7	Pioneer
Sloanea ampla	8	Climax	Almendillo	7	Pioneer
Saurauia montana	8	Climax	Quercus benthamii	6	Climax
Cecropia angustifolia	5	Pioneer	Piper aduncum	5	Pioneer
Cestrum sp.	5	Climax	Cecropia angustifolia	5	Pioneer
Cedrela tonduzii	5	Climax	Palicourea padifolia	4	Climax
		4 Pioneer			***7 Pioneer***
		6 Climax			***3 Climax***

Table 3 - Most Abundant Tree Species

***Planted* Species**	**Type**	***Naturally Regenerated* Species**	**Type**
Cecropia angustifolia	Pioneer	Almendillo	Pioneer
Cedrela odorata	Climax	Alnus acuminata	Climax
Cedrela tonduzii	Climax	Cedrela tonduzii	Climax
Celtis trinervia	Climax	Celtis trinervia	Climax
Cestrum cristinae	Climax	Cestrum schlechtendalii	Climax
Cestrum nocturnum	Climax	Cestrum sp	Climax
Cestrum schlechtendalii	Climax	Cyathea divergens	Pioneer
Cestrum sp.	Climax	Guettarda crispiflors	Pioneer
Crossopetalum enervium	Climax	Hedyosmum mexicanum	Pioneer
Heliocarpus appendiculatus	Pioneer	Heliocarpus appendiculatus	Pioneer
	2 Pioneer		***5 Pioneer***
	8 Climax		***5 Climax***

Table 4 - Most Abundant trees between 1-15 cm DBH

5.3 Stage of succession

Next to type and size of species their health was also assessed. This happened on a scale of 1 to 3, with 1 being healthy and 3 being unhealthy. This showed that most trees where in very good condition, except for *Heliocarpus appendiculatus.* This species is highly abundant in both forest types and is an important pioneer species. Yet most of these individuals had badly damaged leaves. The reason for this damage could be a plague, or it is a sign that the forest is slowly moving into the next level of succession and the pioneer species are being pushed out.

5.4 Carbon Storage

In terms of the sequestering of carbon an even more impressive difference was found. The planted areas have with around 300.000 tons C/ha about 100.000 tons more carbon storage then naturally regenerating areas with about 200.000 tons C/ha. (figure 7)

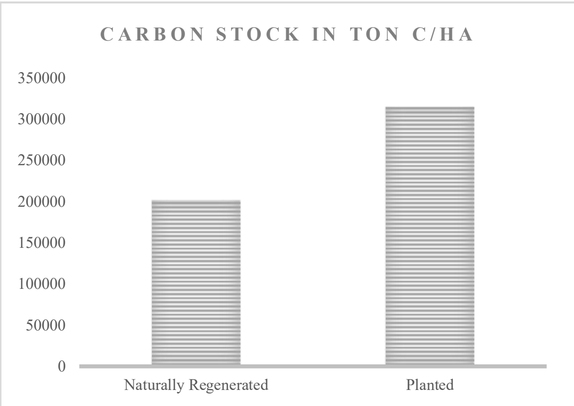

Figure 8 - Carbon Storage in both forest types

Figure 8 shows mainly an extremely high number in plot 10 of planted areas. A possible explanation of this difference can be that quite some areas of the naturally regenerating areas were dominated by Bracken fern *(Pteridium aquilinum)* and had because of this a very low number of trees compared to some of the planted areas where very big trees had grown. The biggest tree measured was a Ulmus mexicana with an DBH of 48,0 cm.

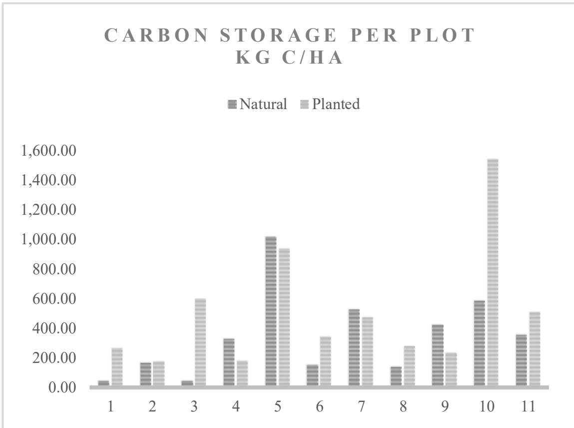

Figure 7 - Carbon Storage per plot

6. Discussion & Conclusions

The problem stated in the problem description was the information gap in the effectiveness of planting trees for accelerated forest regeneration. What can be concluded from this research is that planting of trees does actively accelerate forest regeneration. The main areas of acceleration are biomass and type of species of the newly establishing seedlings. According to this research is does not significantly influence potential diversity in 20 years, but it does influence the type of species that establish themselves. The results show that in the planted areas more climax species established in comparison to the naturally regenerated areas, where the number of young climax species was lower. Furthermore, tree planting has big impact on biomass by skipping the first stages of succession and in that way, it is possible to sequester carbon rapidly by planting trees.

With these conclusions a few side notes must be made. First, the most important obstacle was the identification of species. While there was a small amount of help with identification from others, most identification was done using identification books and applications like *Google lens* and *iNaturalist.* While a lot of species were identified, some were not or only until family. This might have caused inconsistency in the results, but only to a minor degree.

Furthermore, while conducting the research some plots seemed less natural than suspected. Bigger trees were found on areas that were supposed to be naturally regenerated. What could be the case is that the map is not fully accurate. Next to bigger trees, also some species found in naturally regenerated are equal to the planted species. Since these were mostly smaller trees, it could be the recruitment from the planted species that produce seeds quickly. Since the plantation sites are not that big and are quite scattered in between naturally regenerated areas, they might have influenced the regeneration in the non-planted areas positively by influencing the seed availability and micro habitat. This raises the question how big a reforestation area could be to influence the bordering areas enough and how many of these "reforestation islands" are optimal for the reforestation of an area. This could be an interesting objective for further research.

The collected data showed to be sufficient to answer the predefined research questions and left no information gaps for answering the main question. For further research it might be necessary to include more information. An interesting question for further research could be: "Does the size of a plantation site influence the speed o recruitment of new species?". For this the size of the reforested area and design the plots according to the different sizes could be incorporated. It could also be interesting to connect the tree species with seed dispensers and soil types. Finally, it could be interesting to study "reforestation islands". This research showed that there is almost no difference in diversity between planted and naturally regenerated areas in Cloudbridge and that species that were planted also regenerate in the bordering areas. If only a few of these islands have to be planted in a certain way to reforest a larger area, this could be more efficient in terms of time and money.

7. Acknowledgements

Most of all I would like to sincerely thank Greilin Fallas Rodríguez for all her help and support throughout this research. I would also like to thank Darío A. Cordero Mena and Edgar Madrigal for helping me identifying the trees, Tom Gode for inspiring me to do this research, Matthijs Bol for helping me start up, all volunteers at Cloudbridge Nature Reserve for helping me with my fieldwork and Peter van der Meer for assisting me from the Netherlands. Finally, I would like to thank Cloudbridge Nature Reserve for being my home for half a year and allowing me to study in their amazing forests.

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Appendix

1. Poster for the Cloud Forest festival (English version)
2. Poster for the Cloud Forest festival (Spanish version)
3. Species List Complete
4. Map: Location of the Plots

1. Poster for the Cloud Forest festival (English version)

FOREST REGENERATION

Differences between planted areas and natural regenerated area in species diversity, type of species and carbon storage

Yorrick Grobben
VAN HALL LARENSTEIN UNIVERSITY

INTRODUCTION

Fourteen years ago, research on forest regeneration was conducted where the researchers investigated if the planting of trees can promote seed rain and the establishment of natural regeneration on abandoned pastures in the Cloudbridge reserve and which tree species are most effective in this respect (Bol et al., 2008).

The most important finding of this research was the difference in species composition of the regenerating trees and the frequency of regenerating species. It showed that under planted trees a mixture of pioneer and climax species established, while in the subplot that was left to recover naturally only pioneer specialist species established.

At the time at which this research took place, the planted trees were only six years old. At this moment the planted trees are about twenty years old. The difference in time can provide for a broader understanding and provide data for the monitoring of forest development, comparing planted reforestation sites and natural regeneration.

To continue this research fourteen years later, it is planned to make an inventory of species present in the planted reforestation site and species present in the naturally regenerated site. The main question that will guide this research will be: "Does planting of trees have a significant impact on the speed of establishment of natural forest?"

Hypothesis
Expected is that planting of native trees does positively impact forest regeneration by acting on the absence of seed availability and microclimate.

METHODS

- Plots of 10 x 10 meters, with two subplots of 2,5 x 2,5 meters
- Main plots all trees above 10cm DBH are measured
- Subplots all trees below 10 cm and all other plants are measured
- During the inventories, data on DBH (Diameter at Breast Height) in cm, Height of the tree in M, and Health class is collected

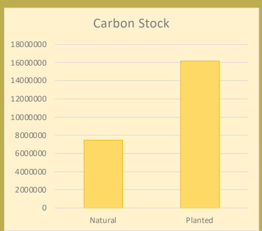
OBJECTIVES

Can planting of trees **promote the establishment of natural regeneration** on abandoned pastures in Cloudbridge Nature Reserve?

- Does planting of trees **increase or decrease potential biodiversity** in 20 years?
- What is the **difference in species** between the two research areas?
- In which **state of forest succession** are both research areas?
- What **type of trees** are present in the two different study areas?
- Is there a significant difference in **Carbon Storage** between planted and not-planted?

PRELIMINAIRY RESULTS

Below are two of the most important results, although it must be said that the study is not yet concluded and results can still change slightly over the coming weeks.



Amount of Carbon stored in both forest types

Species richness in both forest types

PRELIMINAIRY CONCLUSIONS

Planting of trees does increase potential biodiversity in 20 years

There is no significant difference in type of species, next to the planted species

Both forest types are in the same stage of succesioon: Young Inmature Forest

In both forest types, most species are pioneers species

There is a significant difference in carbon storage between the two forest types

Yorrick Grobben | Van Hall Larenstein University - The Netherlands | BSc Tropical Forestry

2. Poster for the Cloud Forest festival (Spanish version)

REGENERACIÓN FORESTAL

Diferencia en la diversidad de especies, tipo de especies y almacenamiento de carbono, entre áreas plantadas y zonas de regeneración natural

Yorrick Grobben
VAN HALL LARENSTEIN UNIVERSITY

INTRODUCCIÓN

Hace catorce años, se desarrolló una investigación donde se estudió si la plantación de árboles podría promover la lluvia de semillas y la regeneración natural del bosque en antiguas zonas de pastoreo dentro de la Reserva Cloudbridge y cuáles especies son más efectivas al respecto (Bol et al., 2008).

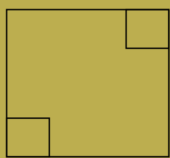
Como el hallazgo más importante de esta investigación, se encontró una diferencia en la composición de especies arbóreas y, así también, en la frecuencia de regeneración de especies al comparar zonas plantadas y zonas con regeneración natural. Esto mostró que bajo árboles plantados se establecía una mezcla de especies pioneras y especies comunidades clímax, mientras que en las subparcelas que se dejaron para regeneración natural, solo se establecieron especies pioneras especialistas..

En el tiempo que tuvo lugar esta investigación, los árboles plantados tenían solo seis años. Actualmente, tienen seis años, aproximadamente. Esta diferencia en tiempo puede proveer una comprensión más amplia y datos para el monitoreo del desarrollo del bosque, comparando sitios reforestados mediante plantación y sitios con regeneración natural.

Con el fin de retomar esta investigación realizada hace catorce años, se planea hacer un inventario de especies presentes en sitios donde se reforestó mediante plantación y especies presentes en sitios con regeneración natural. La pregunta principal que guía este estudio será: "¿La plantación de árboles puede promover el establecimiento de regeneración natural en pastizales abandonados en la Reserva Natural Cloudbridge?"

Hipótesis
Se espera que la plantación de árboles nativos sí impacte positivamente la regeneración del bosque al actuar ante la ausencia de disponibilidad de semillas y microclimas

MÉTODOS



- Parcelas de 10 x 10 metros, con subparcelas de 2,5 x 2 metros.
- El la parcelas principales se tomó datos de todos los árboles con un DAP (diámetro a la altura de pecho) mayor a 10 cm.
- Los datos considerados fueron: DAP, altura de los árboles en metros y estado de salud de los árboles.

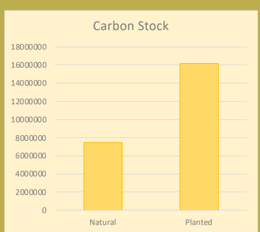
OTRAS PREGUNTAS

¿La plantación de árboles puede promover el establecimiento de regeneración natural en pastizales abandonados en la Reserva Natural Cloudbridge?

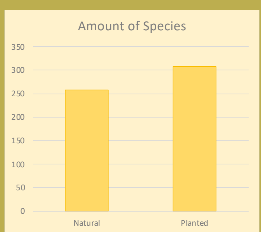
- ¿La plantación de árboles aumenta o disminuye la biodiversidad potencial en un lapso de 20 años?
- ¿Cuál es la diferencia en cuánto a especies entre estas dos áreas?
- ¿En qué estado de sucesión están estas dos áreas de bosque?
- ¿Qué tipo de árboles se encuentran en las dos áreas de estudio?
- ¿Hay una diferencia significative en almacenamiento de carbono entre áreas plantadas y no plantadas?

RESULTADOS PRELIMINARES

En los siguientes gráficos puede observar los resultados más importantes encontrados hasta el momento, es importante aclarar que esto podría variar ligeramente conforme se avance con el estudio.



Cantidad de carbono almacenado en ambos tipos de bosque



Riqueza de especies en ambos tipos de bosque

CONCLUSIONES PRELIMINARES

La plantación de árboles no incrementó la biodiversidad potencial en 20 años.

No hay diferencia significativa en el tipo de especies que crecen junto a especies plantadas.

Ambos tipos de bosque están en la misma etapa de sucesión: Bosque Joven Inmaduro.

Hay una diferencia significativa en el almacenamiento de carbono entre ambos tipos de bosque.

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3. Species List Complete

Species	N	Species	N	Species	N
?	5	Drymonia sp.	1	Peristeria elata	1
Alibertia edulis	2	Drymonia turrialvae	4	Persea / Ocotea sp.	1
Almendillo	7	Erythrina costaricensis	5	Persea sp.	2
Alnus acuminata	4	Gonzalagonia rosea	2	Phaseolus cf. lunatus	3
Amaranthaceae	1	Grass 1	8	Phaseolus sp	1
Anthurium microspadix	1	Grass sp. 1	6	Phaseolus sp.	1
Anthurium slechtendalii	1	Guettarda crispiflors	4	Piper aduncum	12
Anthurium sp	8	Hedyosmum mexicanum	11	Piper auritum	1
Anthurium sp.	1	Heliconia sp.	1	Piper sp	2
Arecaceae	1	Heliconia tortuosa	2	Piper sp.	1
Aspleniaceae	2	Heliocarpus appendiculatus	28	Piper sp. 1	2
Asplenium sp.	2	Hoffmania sp.	3	Piper sp. 2	1
Asteraceae	1	Inga mortoniana	1	Pipturus albidus	1
Begonia convallariodora	13	Inga oerstebiana	16	Polypodiaceae	6
Begonia sp.	5	Inga oerstediana	6	Polypodiaceae 2	1
Besleria solanoides	1	Iresine diffusa	3	Prunus mexicana	2
Blackea sp	1	Jessea multinervia	1	Psychotria sp	1
Blechnum occidentale	29	Lauraceae sp	1	Psychotria sp.	13
Blechnum sp.	1	Lauraceae sp.	2	Pteridium aquilinum	13
Buddleja sp.	1	Liabum asclepiadeum	7	Quercus benthamii	6
Calathea sp.	2	Liana sp.	1	Quercus insignis	4
Cecropia angustifolia	10	Marila pluricostata	1	Quercus salicifolia	3
Cedrela odorata	3	Melastomataceae	11	Renealmia sp.	18
Cedrela tonduzii	6	Mollinedia lanceolata	1	Rubus cf. urticifolius	9
Celtis trinervia	5	Mollinedia pallida	1	Rubus sp.	1
Centradenia paradoxa	2	Monstera deliciosa	5	Sabicea panamensis	2
Cestrum cristinae	3	Monstera sp.	2	Sanicula liberta	2
Cestrum nocturnum	4	Monstera tacanaensis	1	Saurauia ampla	1
Cestrum racemosum	3	Moussonia deppeana	8	Saurauia montana	13
Cestrum schlechtendalii	6	Myrsine coriacea	50	Saurauia pittieri	31
Cestrum sp	2	Ocotea sp.	1	Saurauia sp.	2
Cestrum sp.	9	Orchidaea	1	Saurauia veraguensis	1
Cinchona pubescens	1	Oreopanax xalapensis	6	Schefflera rodrigueziana	6
Cinnamomum brenesii	1	Palicourea padifolia	7	Siparuna sp	1
Columnea polyantha	1	Palicourea sp	1	Sloanea ampla	13
Commelina sp.	20	Palm sp.	2	Sommera donnell-smithii	5
Cordia alliodora	1	Pelargonium sidoides	1	Telanthophora grandifolia	13
Crossopetalum enervium	1	Peperomia hernandiifolia	1	Thelypteridaceae	5
Cyathea divergens	12	Peperomia longisetosa	1	Triumfetta bogotensis	20
Cyatheaceae	1	Peperomia sp.	4	Ulmus mexicana	10

4. Map: Location of the Plots