Research Project : Mammal and sapling trees interactions
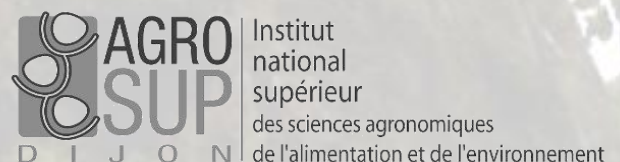

Project sponsor : Cloudbridge Nature Reserve

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CLOUD BRIDGE
NATURE RESERVE

AGRO SUP DIJON
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Summary

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I would like to express my appreciation to all the people who helped me in my project.

A special thanks goes to :

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Finally, I would like to thank all Cloudbridge staff for their welcome, and all the volunteers, interns, and researchers that I've met at the reserve, who spent more or less time there, but with whom I've shared, with pleasure, a part of my stay.

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Abstract

In the current context of global climate change and deforestation practices, studying the impact of animals on reforestation projects is very interesting. The reforestation project at Cloudbridge Nature Reserve is one of its main activities and, as there are some parts of the reserve which are still deforested, they need the reforestation practices to be efficient. As some animals have disturbed several planted areas of Cloudbridge, we wanted to know if their disturbance had a negative impact on the reforestation project. My study was focused on the monitoring sapling trees' health and growth. I choose 3 plots in the reserve with 15 trees in each one. After setting up an health index, I collected data every week for each tree and one of the plots was disturbed during my data collection. I statistically analyzed the impact of disturbance on tree health and tree growth and also looked at the potential effect of several environmental factors. We found that the disturbance had no significant impact on sapling health nor growth in the studied plots, but that soil humidity was positively correlated with tree health and increase in tree diameter.

Introduction

As a part of my second year engineering program in agronomy at AgroSupDijon, I did a 5 month internship at Cloudbridge Nature Reserve in Costa Rica. I had to lead my own research project and I wanted it to be useful for the reserve. As reforestation is one of the main activities at Cloudbridge, they asked me to study the impact of mammals on sapling trees because they had noticed mammal activities around the young trees may be affecting the sapling trees' growth.

Cloudbridge is in a tropical rain-forest situated in the Talamanca mountains between 1550 and 2600 meters of altitude, where the clouds condense right onto the forest so that it provides water to the trees. Most of the water provided to the trees come from the clouds and not from the rain. These forests, called cloudforests, are characterized by nearly 100% humidity throughout the year and cool temperatures.

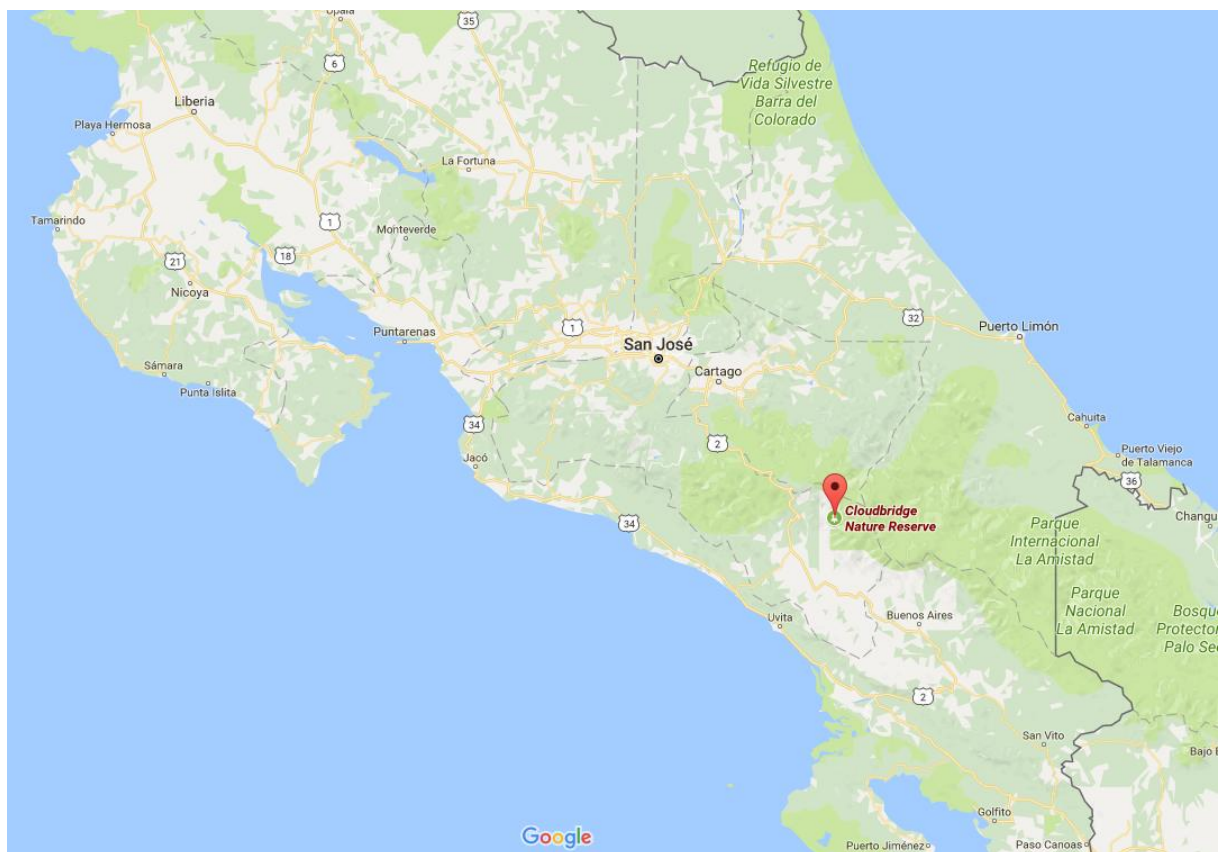Figure 1 : Map of Costa Rica with Cloudbridge location

The reforestation project began in 2002 when the reserve owners, Ian and Genevieve Giddy, bought their first land. Before that, it was pasture everywhere because in the 1950's the government gave away the lands for free provided that the farmers would raise cattle there. As a result, the farmers deforested most of the area converting the land to pasture. Now

the reserve includes 280 hectares, and thanks to the work of volunteers and researchers, the reforestation project is going really well with about 1000 trees planted each year.

The reforestation practices at Cloudbridge include putting cardboard around the base of each tree to prevent weed growth, hold in moisture, and increase soil biodiversity around the tree. While previous research at the reserve found the cardboard helped sapling survival, the cardboard also attracts animals, particularly insectivores, which dig up the cardboard and the soil around the base of the trees to get at the invertebrates beneath.

The potentials problem animals are White-nosed Coati (*Nasua narica*), Collared Peccary (*Pecari tajacu*), and pocket gophers (*Geomyidae sp.*). While Cloudbridge staff had noticed the disturbance of the cardboard around the trees and damage to the trees, they did not know which animal was responsible.

However, the animals could not be the only problem for sapling trees. The environmental conditions can affect their health too. The wind can break the trunk of the tree and take the cardboard away. The slope and the shade can affect tree health and growth too. So environmental factors such as slope, shade and humidity, has to be taken into account because they could explain some of the results too.

My research questions were:
1. Does mammal disturbance of the cardboard have an impact on tree health?
2. Does disturbance affect leaf damage or leaf colour?
3. Does disturbance affect the growth of the tree?
4. Is the health index, leaf damage or leaf colour correlated with tree growth?
5. Do environmental conditions have an effect on tree health or tree growth?

1. Materials and Methods

I chose three study sites in the reserve that had different environmental conditions (Table 1, Figure 1). The first plot (plot A) was on the sendero Rio. This plot is preliminary planting, which means that it has been planted just once so the trees are all the same age. It is situated at 1720 m altitude, the trees were planted two years ago, and the trees have a good height with most of them taller than 1 meter. This plot has a gentle slope and there is not a lot of shade. The second plot (plot B) was located near to the meditation garden on the main trail at 1625 m altitude. In plot B, the trees are secondary planting, which means that all the planted trees are not the same age because it is the second time they have planted trees in this plot. The sampled trees in Plot B are two years old as well. This plot is pretty flat with a lot of shade and the trees are around 1 meter tall. The third plot (plot C) was located near to the memorial garden at 1575 m altitude. The trees in the third plot were planted one year ago, are a preliminary planting, all the plot is really steep, and there is not a lot of shade around. The trees are small in plot C, they are smaller than 1 meter and sometimes only 30 cm.

Table 1 : Description of plots

Plot	Trail	Elevation	Preliminary or secondary planting	Age of the trees	GPS coordinates
A	Rio trail	1720 m	Preliminary	2 years	lat. 9.474572 lon. -83.568671
B	Main trail near to mediation garden	1625 m	Secondary	2 years	lat. 9.472838 lon. -83.575468
C	Near to memorial garden	1575 m	Preliminary	1 year	lat. 9.472279 lon. -83.577567

Figure 2 : Map of the plots

When I set up my project I choose to work only on one tree genus, the oaks (*Quercus spp.*), because it was the most common type of tree planted in the reserve. Oaks are native in Costa Rican forests. Cloudbridge plants a lot of oaks because they are a strong tree, are a common species in the primary forests in the area, and they provide food and shelter for wildlife. Oaks are slow growing, especially when they are surrounded by a lot of shade.

1.1. Baseline Data Collection

I selected 15 trees in each plot. Before beginning collecting my data, I put new cardboard around each tree. I went to each plot every week to collect data from each tree. The data I collected was basically the perimeter of the trunk at 2 cm from the ground and the height from the ground to the very top of the tree. For each tree, I counted the number of leaves and their color, except for big trees, which I sub-sampled. I also counted the number of damaged leaves at more than 50% and between 20 and 50%. This was done so I had data to monitor tree growth and data to calculate the tree health and monitor it. See Table 2 for an example of the data collected for two trees.

Table 2 : Example of data collection for two trees

Tree	Leaf color	Number of damaged leaves between 20 and 50%	Number of damages leaves at more than 50%	Perimeter (cm)	Height (cm)
A3	1B+12YG+23G	15	6	3,2	76
A8	36GY+25G	21	12	4,6	89

1.2. Health Index and Tree Growth

In order to assess the effect of cardboard disturbance and environmental factors on the health of the saplings, I set up a health index and monitored the growth of the studied trees. The health index included 2 components: the leaf colour, and amount of damaged leaves. For growth, the change in diameter and height of the saplings was monitored.

1.2.1. Health index

Leaves can have different colors, for example if a leaf is dying, it turns into brown whereas when it is healthy, it is green. So the leaf color can indicate if the tree is dying or in good health or if it needs more nutrients. So the aim was to count all the leaves on the tree and to assess what the leaf color was. Each colour was assigned a value between 0 (all brown leaves) and 100 (all green leaves) (Table 3). When two colours were present on the leaf, the value was assigned based on the dominant colour of the leaf.

Table 3: Leaf colour index

Leaf colour	Symbol	Assigned value out of 100
Brown	B	0
Brown Yellow	BY	14.3
Yellow Brown	YB	28.6
Yellow	Y	42.9
Yellow Green	YG	57.2
Green Brown	GB	71.5
Green Yellow	GY	85.8
Green	G	100

Sometimes I noticed more than one leaf color on a tree. To calculate the leaf colour value for the tree, I proceeded as followed:

$$\text{Leaf Colour Value} = \frac{N_a V_a + N_b V_b + N_c V_c}{N_t}$$

N_x = Number of leaves of colour X
V_x = Value of leaf colour X
a through c = Leaf colours present on tree
t = Total number of leaves

For big trees that had many leaves, I took a sub-sample of the tree, choosing random branches from the bottom to the top of the tree and counting the leaves on the chosen branches.

The leaves can be deteriorated by insects which reduces the surface area of leaves available for photosynthesis so it is an indicator of tree health. To calculate the percentage of undamaged leaves, I counted the total number of leaves on the tree, then I counted the leaves that were more than 50% deteriorated, and the leaves that were deteriorated between 20 and 50%. Each deterioration group was assigned a health value (Table 4). I calculated the percentage of undamaged leaves for the tree and proceeded as followed:

$$\text{Undamaged leaves percentage} = 100 - \frac{(N_{50} \times X_{50}) + (N_{20} \times X_{20})}{N_t}$$

N_{50} = Number of deteriorated leaves at more than 50%
N_{20} = Number of deteriorated leaves between 20 and 50%
X_{50} = 50% deterioration value
X_{20} = 20-50% deterioration value
N_t = Total number of leaves

Table 4 : Leaves deterioration index

Deterioration amount	Deterioration value out of 100 for non-deteriorated leaves
0-20%	100
20-50%	65
More than 50%	25

The overall health index value is the mean between the leaf color value and the undamaged leaf value for each tree.

1.2.2. Growth index

I measured the diameter and height of all the trees each week and calculated the percentage increase for each value, each week as followed:

$$\frac{(N_{W2} - N_{W1})}{N_{W1}}$$

N_{W2} = Diameter/Height week 2
N_{W1} = Diameter/Height week 1

1.2.3. Environmental conditions

Even in one plot the trees are in different conditions, with different slope, different amount of humidity retained in soil, and different canopy closure, which are all factors that could impact the health and growth of the saplings. In order to understand any changes in sapling health before and after disturbance with more precision, I measured the environmental conditions as well.

In order to measure the soil humidity, I took a 5 cm soil sample at a depth of 10 cm, 1 m away from each sapling. I always took all the sample of one plot on the same day. After that I weighed each sample and put them in an oven at 150°C for 4 hours and weighed it again. I measured the difference between the sample before and after putting it in the oven. I calculated the relative humidity in the ground proceeded as followed :

$$\frac{WB-DB}{WB} \times 100$$

WB = Wet bulk
DB = Dry bulk

I measured the slope next to each tree using an inclinometer application on a smartphone.

Canopy closure was measured around each tree with a spherical densitometer. For each tree, 4 measurements were taken, standing facing each of the cardinal directions (north, south, east, and west) to be more precise. The canopy closure value of a tree is a mean of the four values.

The densiometer is a mirror with a grid of 24 squares (Figure 3). Before taking a reading, you have to level the densiometer using the level in the corner of the unit. Then you imagine 4 dots in each corner of the squares, count the dots that are in shadow (Figure 4), and then multiply by 1.04 to have the percentage of canopy closure.

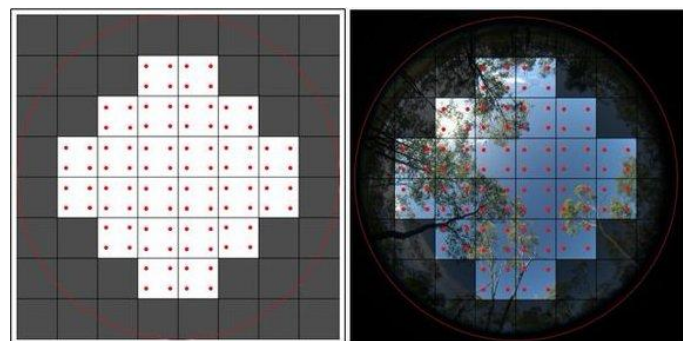**Figure 3 : Spherical densiometer**

Figure 4 : How to use a spherical densiometer

1.3. Data analysis

I used five statistical tests to analyse my data.

First I used The Shapiro-Wilk test to calculate whether a random sample comes from a normal distribution.

The W statistic is calculated as follows:

$$W = \frac{\left(\sum_{i=1}^{n} a_i x_{(i)}\right)^2}{\sum_{i=1}^{n} (x_i - x)^2}$$

where the $x_{(i)}$ are the ordered sample values and the a_i are constants generated from the means, variances and covariances of the order statistics of a sample of size n from a normal distribution.

As all my samples were normal, I could use the Student t-test.

The Student t-test tests the hypothesis that two population means are equal. The T statistic is calculated as follows:

$$T = \frac{\overline{x1} - \overline{x2}}{Sp \times \sqrt{\left(\frac{1}{n1} + \frac{1}{n2}\right)}}$$

Where Sp is the pooled standard deviation.

To see the correlation between two variable, I used the Pearson correlated coefficient that measures the linear correlation between two variables X and Y. The Pearson correlated coefficient is calculated as follows:

$$\rho_{X,Y} = \frac{\text{cov}(X,Y)}{\sigma_X \sigma_Y}$$

Where cov is the covariance and sigma is the standard deviation.

I also used a multiple regression that tests the effect of two or more independent variables on a dependent variable. The result of the multiple regression tells us if the independent variables can predict the dependant one. Multiple regression technique does not test whether data are linear. On the contrary, it proceeds by assuming that the relationship between the Y and each of Xi's is linear.

The Mann-Whitney U test is a non parametric test that can be use on non normal distribution to compare two samples means. The Mann-Whitney U coefficient can be calculated as follows:

$$U = n_1 n_2 + \frac{n_2 (n_2 + 1)}{2} - \sum_{i=n_1+1}^{n_2} R_i$$

Where : n_1 = sample size one

n_2 = Sample size two

R_i = Rank of the sample size

2. Results

In a total of 45 trees monitored during 12 weeks from the 17th of April, to the 9th of July, eleven trees were disturbed during week 21 between May 18th and May 25th, all of them in plot A.

In Table 5, you can find summary data for the health index and tree growth for each plot, where in Table 6 you can find the summary environmental data for each plot. I will use this data for my results analysis.

Table 5 : Summary of the tree health and growth data in each plot

Plot	Data (progression between first and last week)	Mean	Standard deviation	Minimum	Maximum
A	Health index	1.40	6.85	-8.96	12.44
	Tree height	25.83	16.20	-3.3	56.2
	Tree diameter	0.43	0.23	0	0.96
B	Health index	-5.70	8.34	-20.24	5.74
	Tree height	24.25	9.46	3.7	36.2
	Tree diameter	0.28	0.18	0.06	0.73
C	Health index	-9.29	10.13	-27.45	14.45
	Tree height	18.62	17.30	0.5	49.5
	Tree diameter	0.29	0.16	0.10	0.61

Plot	Environmental variable	Mean	Standard deviation	Minimum	Maximum
A	Relative humidity (%)	36.92	3.07	30.15	44.70
	Slope (°)	19.27	7.97	4.00	34.00
	Canopy closure (%)	62.66	15.11	34.32	87.88
B	Relative humidity (%)	35.32	4.05	26.91	40.44
	Slope (°)	9.00	5.92	1.00	21.00
	Canopy closure (%)	68.54	8.31	53.30	79.30
C	Relative humidity (%)	29.39	2.58	25.80	34.04
	Slope (°)	18.13	9.75	9.00	36.00
	Canopy closure (%)	65.76	10.49	45.76	85.28

2.1. Comparison of tree health index between disturbed and undisturbed trees

We compared the progression of the health index over time between the disturbed and undisturbed trees.

In Figure 5, you can see the difference in the health index measured between the beginning and the end of the study, with disturbed and undisturbed trees (in Figure 6) separated. The disturbed trees had a mean change in the health index of 1.43 (±2.3), while the undisturbed trees had a mean change of -7.69 (±1.7). The data was normally distributed so I was able to do a Student test (t-test). With a p-value of 0.005, we can state that the mean of the change in the disturbed trees' health index is significantly different from the mean of the change in the undisturbed trees' health index with a confidence level of 0.005.

Moreover, we can see that the mean of the disturbed trees health is 1.43 compared to -7.69 for the mean of the undisturbed trees' health. This means that the undisturbed trees' health index progression is worse than for the trees that have been disturbed. We expected that the trees' health index would decrease after the disturbance. As all the disturbed trees occurred in Plot A, we suspected the drop in the health index seen between the disturbed and undisturbed trees may have been due to differences in the environmental conditions of the plots rather than an effect of the disturbance.
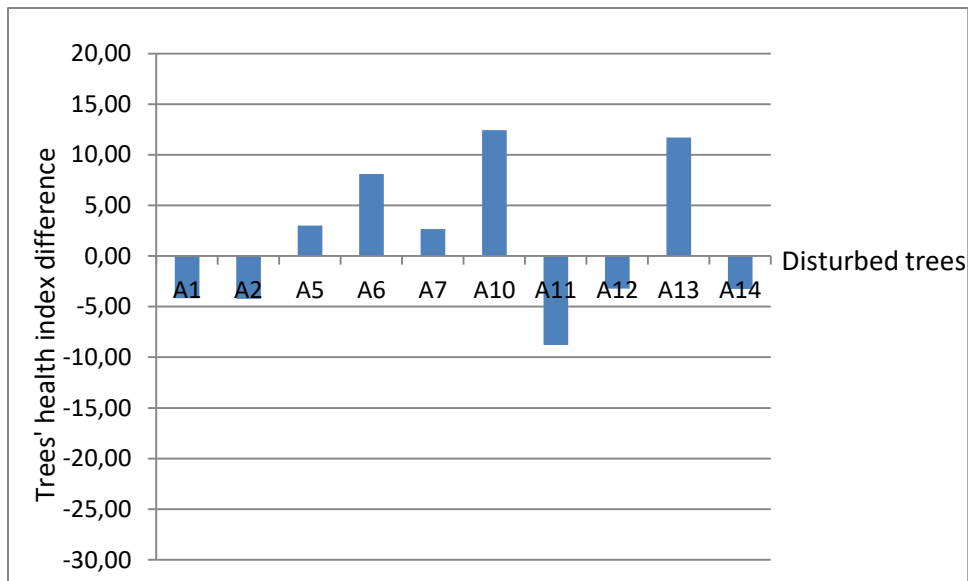
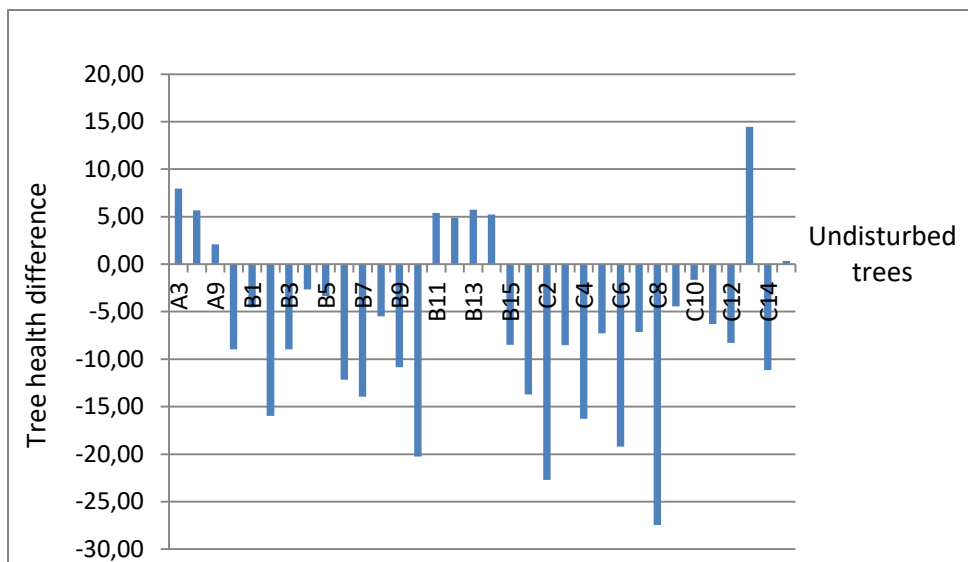Figure 5 : Disturbed trees health index difference

Figure 6 : Undisturbed trees health index difference

I also wanted to test the difference between disturbed and undisturbed trees in Plot A doing an intraplot comparison. As the data were normally distributed, I used the same test. Plot A disturbed trees had a mean change in the health index of 1.43 (±2.3), while Plot A undisturbed trees had a mean change in the health index of 1.69 (±3.8). With a p-value of 0.955 we can say that the mean change in the health index between Plot A disturbed and undisturbed trees is not significantly different.

Plots B and C had data for the change in the health index that were normally distributed, so we did a Student test (t-test) to see if their health index progression were significantly different. Plot B trees had a mean change in the health index of -6.09 (±2.2), while the Plot C trees had a mean change of -9.3 (±2.6). With a p-value of 0.357 we can say that the mean of the change in Plot B trees' health index is not significantly different from the mean of the change in Plot C trees' health index.

2.2. Influence of disturbance on tree health index progression

Here we studied only the disturbed trees, looking at their health index progression before and after disturbance. We can see in Figure 7 and 8 that the trees' health index generally decreased after the disturbance, but get a little better again at week 27. The data was normally distributed so that I was able to do a Student t-test. Plot A disturbed trees before disturbance had a mean change in the health index of 2.62 (±1.42), while Plot A disturbed trees after disturbance had a mean change of -1.95 (±1.72). With a p-value of 0.07 we can state that the health index progression before and after the disturbance was not significantly different.

So, while the mean of the health index progression decreased from 2.62 before disturbance to -1.95 after disturbance, we can say that disturbance did not have a significantly negative effect on the tree health.
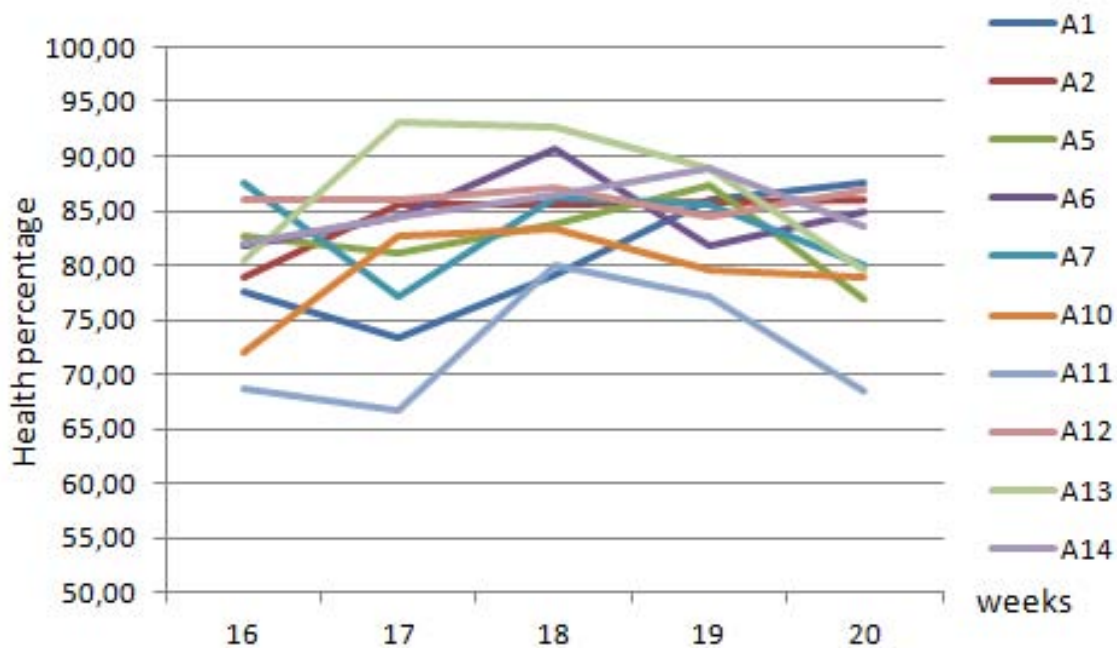

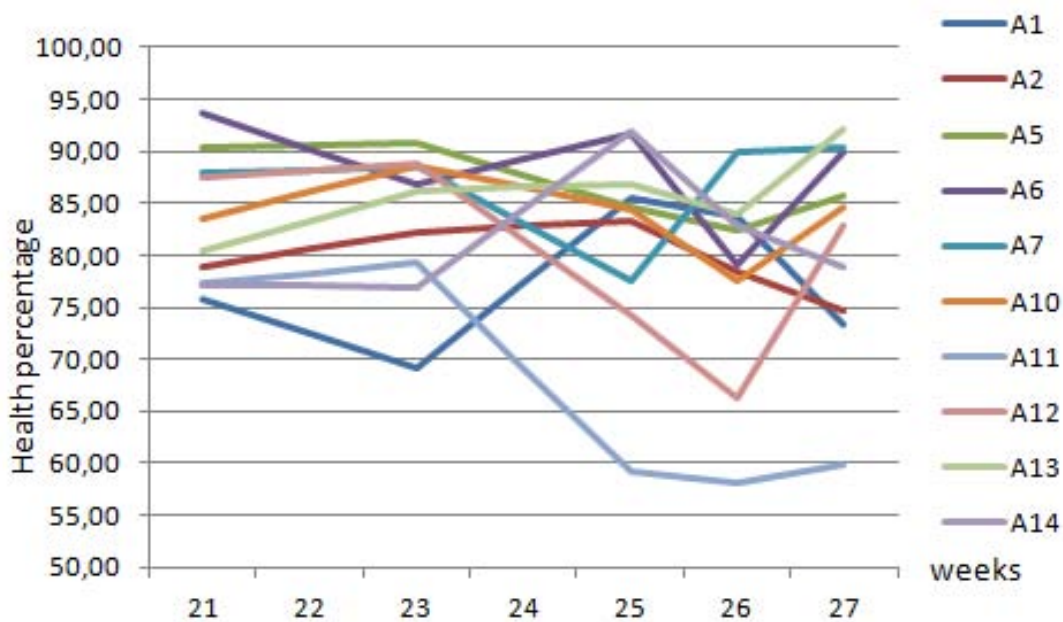Figure 7 : Health evolution in disturbed trees before disturbance

Figure 8 : Health evolution in disturbed trees after disturbance

2.3. Influence of disturbance on leaf damage and leaf colour

We compared changes in leaf damage and leaf colour between the disturbed trees and undisturbed trees using an intrasite comparison using only Plot A. Plot A leaf damage in disturbed trees had a mean change of -3.0 (±5.4), while Plot A leaf damage in undisturbed trees had a mean change of -11.58 (±3.6). The data from both samples was normally distributed so that I used a Student t-test to compare leaf damage in disturbed trees and undisturbed trees. As the p-value is 0.214, the results are not significant. That means that the disturbance does not significantly influence leaf damage.

Plot A leaf colour in disturbed trees had a mean change in the health index of 5.9 (±3.5), while Plot A leaf colour in undisturbed had a mean change of 14.97 (±4,7). The p-value is 0.173 which is not significant either. Disturbance does not appear to have a significant influence on leaf damage, nor leaf colour.

2.4. Influence of disturbance on tree growth

I initially looked at the influence of the disturbance on the increase in tree height using all the disturbed and undisturbed trees across all of the plots to do an interplots comparison. The increase in tree height for disturbed trees had a mean change in the health index of 29.04 (±5.1), while the increase in tree height for undisturbed trees had a mean change of 21.8 (±2.4). As the data was normally distributed, I used a Student t-test. The p-value was high at 0.218 so it was not significant. Then I tried the same test just in Plot A and did an intraplot comparison. The increase in tree height for disturbed trees in Plot A had a mean change in the health index of 29.04 (±5.3), while the increase in tree height for undisturbed trees in Plot A had a mean change of 24.3 (±6.8). The p-value was even higher at 0.812 so the results were not significant and we can say that disturbance has no significant influence on the increase in tree height.

I looked at the influence of the disturbance on the increase in tree diameter using all the disturbed and undisturbed trees across all the plots to do an interplots comparison. The increase in tree diameter for disturbed trees had a mean change of 0.455 (±0.055), while the increase in tree diameter for undisturbed trees had a mean change of 0.309 (±0.034). As the data was not normally distributed, I used a Mann-Whitney test. The p-value was 0.017 so we can say that the mean change in tree diameter is significantly different between disturbed and undisturbed trees. After that, I did an intraplots comparison. The increase in tree diameter for disturbed trees had a mean change of 0.455 (±0.055), while the increase in tree diameter for undisturbed trees in Plot A had a mean change of 0.486 (±0.330). The p-value was 0.873 so we can say that in Plot A the mean change in tree diameter is not significantly different between disturbed and undisturbed trees.

2.5. Influence of leaf damage, leaf colour and the tree health index on tree growth

The increase in tree height had a mean change of 23.50 (±14.34), the progression of leaf damage had a mean change of -7.34 (±11.25), the progression of leaf color had a mean change of -1.52 (±18.50) and the mean change in the health index is -4.43 (±9.57). I used Pearson correlation coefficient to test the correlation between the increase in height and leaf damage first, between the increase in height and leaf colour, and finally between the increase in height and the tree health index. The p-value was significant (p-value = 0.028) for the correlation between height evolution and leaf colour with a weak, positive correlation of 0.331. This indicates that when the colour of the leaves is better (more green), tree height increases a little faster. Leaf damage and the tree health index did not significantly influence tree growth (p-values 0.561 and 0.080, respectively).
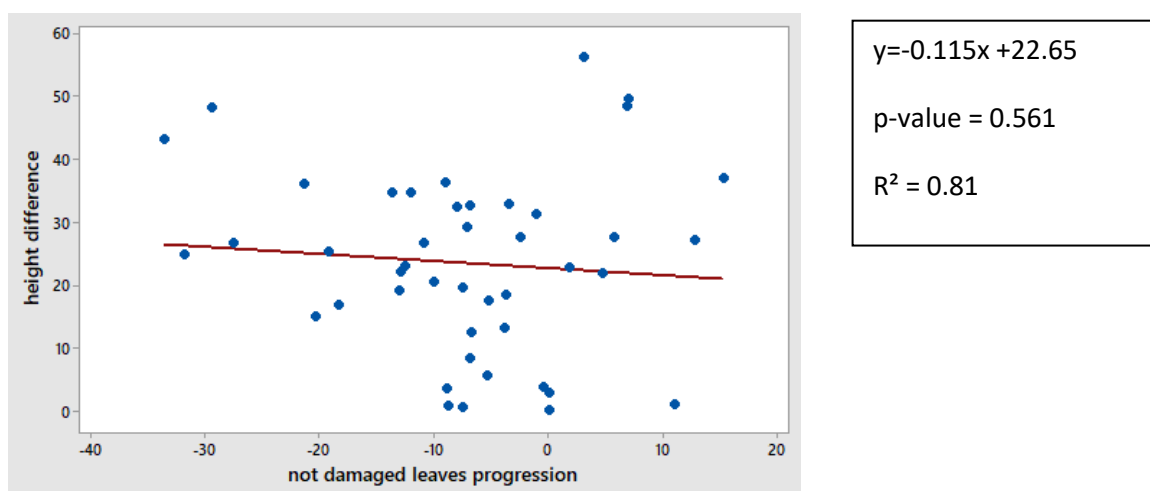
y=-0.115x +22.65

p-value = 0.561

R^2 = 0.81

Figure 9 : Linear regression between the increase in tree height and undamaged leaves progression

y=-0.256x +23.89

p-value = 0.028

R^2 = 10.93
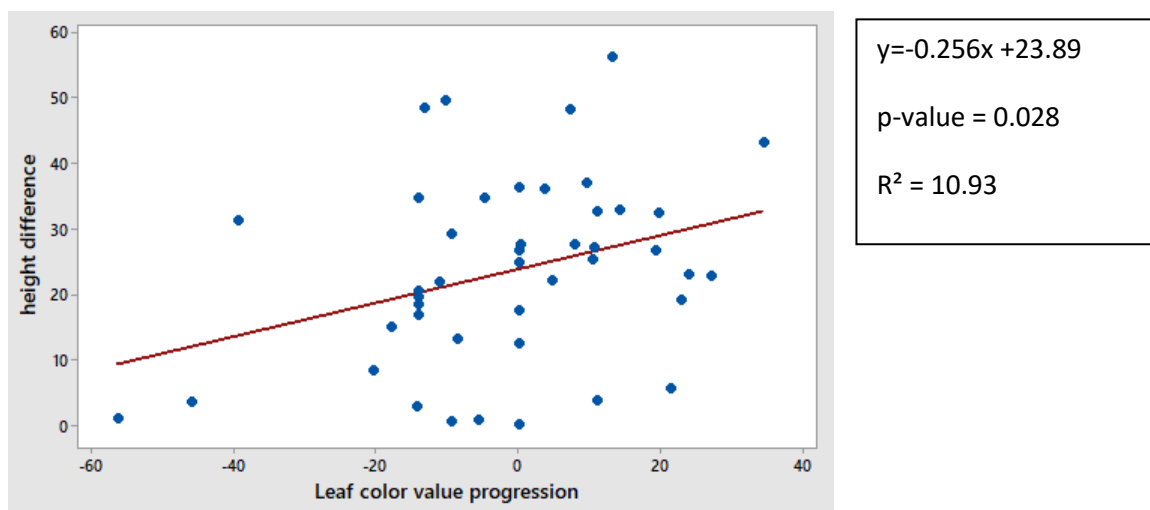
Figure 10 : Linear regression between the increase in tree height and Leaf color progression

y=-0.400x +25.27
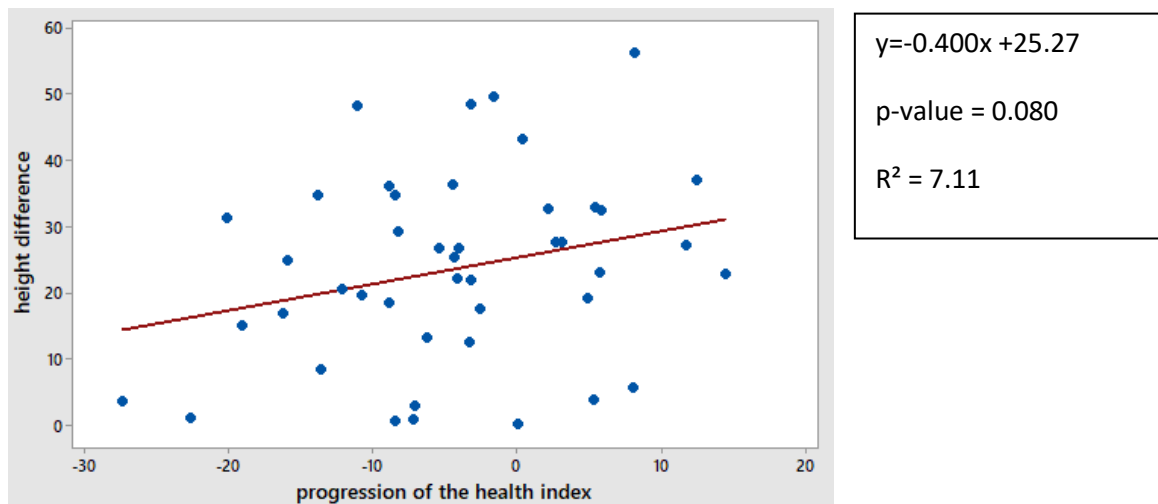
p-value = 0.080

R² = 7.11

Figure 11 : Linear regression between the increase in tree height and health index progression

I used the same test to look at the correlation between the increase in tree diameter and leaf damage first, between the increase of tree diameter and leaf colour, and finally between the increase in tree diameter and the tree health index. The increase in tree diameter had a mean change of 0.34 (±0.20) and the mean change of the other values are the same as above. With a p-value respectively of 0.865, 0.209 and 0.267, we can say that neither leaf damage nor leaf colour nor tree health index have a significantly correlation with the increase in tree diameter.
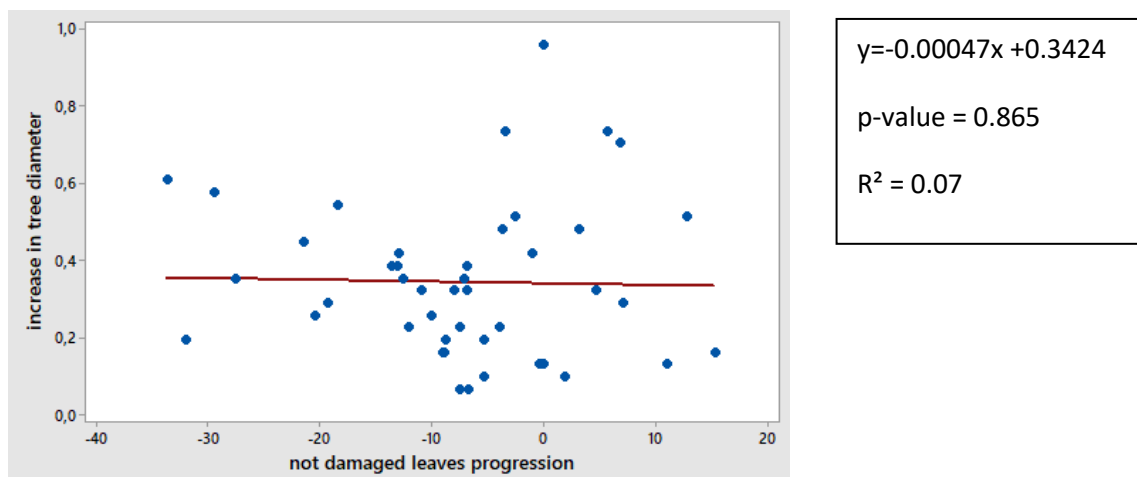

y=-0.00047x +0.3424

p-value = 0.865

R² = 0.07

Figure 12 : Linear regression between the increase in tree diameter and undamaged leaves progression

y=-0.00210x +0.3424

p-value = 0.209

R² = 2.73
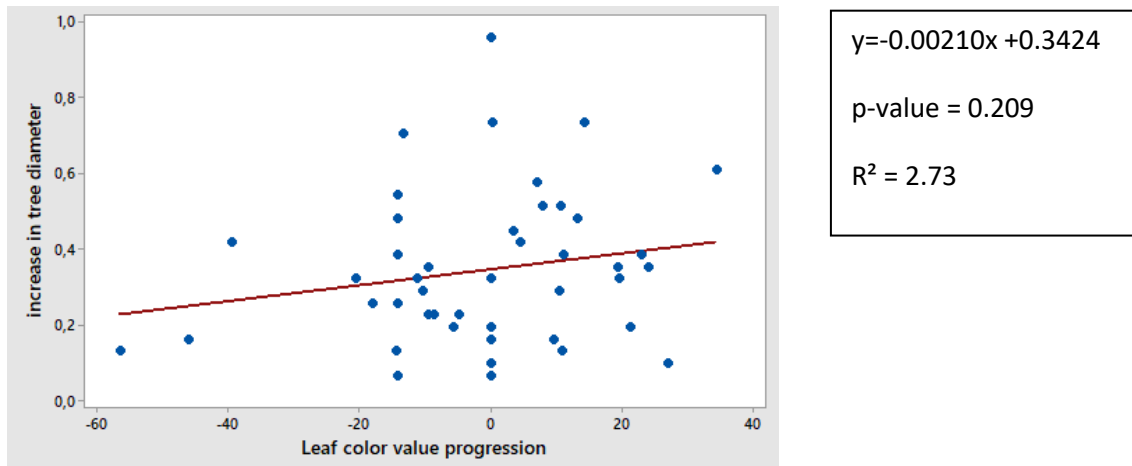
Figure 13 : Linear regression between the increase in tree diameter and leaf color progression

y=-0.00360x +0.3424
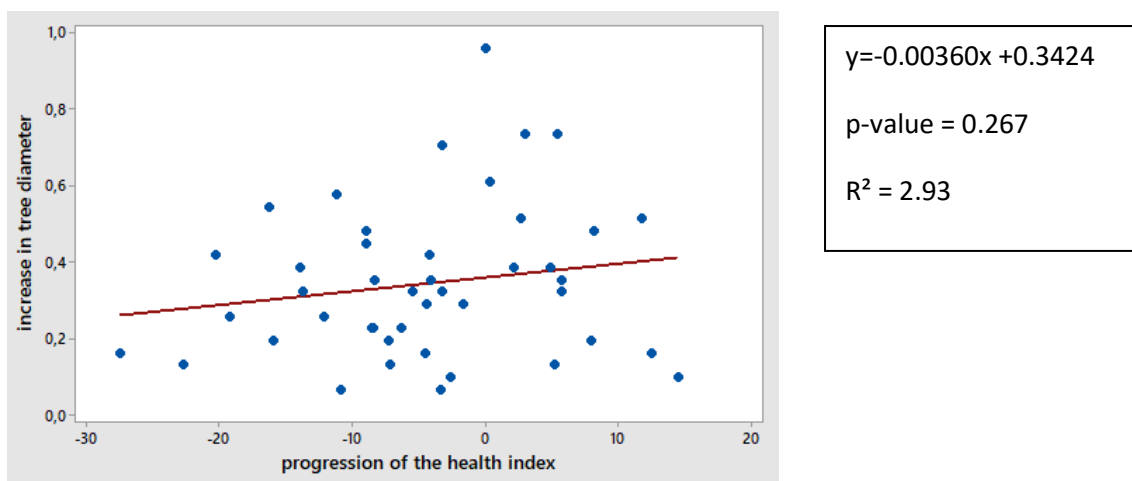
p-value = 0.267

R² = 2.93

Figure 14 : Linear regression between the increase in tree diameter and health index progression

2.6. Influence of environmental conditions on the tree health index

I did a multiple regression to see if the environmental value, such as slope, shade and humidity in the soil, had an influence on the tree health index. Through eliminating step-by-step the environmental conditions that had no impact on the tree health index, the result is that the humidity has a significant impact (p-value 0.014). A coefficient of 0.750 shows that humidity is moderately strongly, positively correlated with the tree health index (Figure 15). The other environmental variables (shade and slope) has no significant impact on the tree health index.
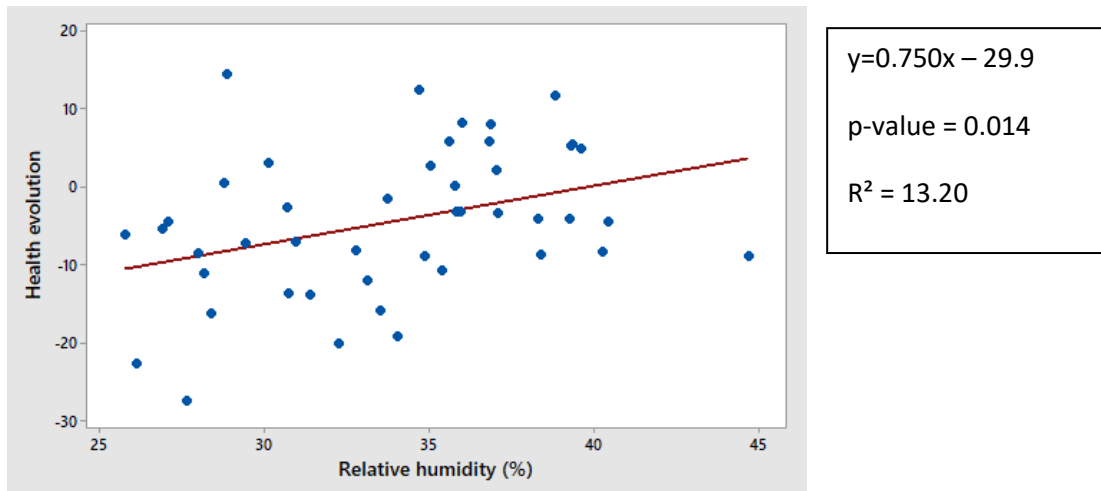
$$y = 0.750x - 29.9$$

p-value = 0.014

$$R^2 = 13.20$$

Figure 15 : Linear regression between health evolution and relative humidity

2.7. Influence of environmental conditions on tree growth

The multiple regression showed that none of the environmental conditions had an impact on tree height increase with all p-values higher than 0.1. The same test was done looking for any environmental impact on tree diameter increase. With a p-value of 0.037 we can state that the relative humidity has an impact on the increase in tree diameter. However, the coefficient is really weak, under 0.1, but positively correlated, so when the humidity increases, the mean tree diameter increases slightly as well (Figure 16).
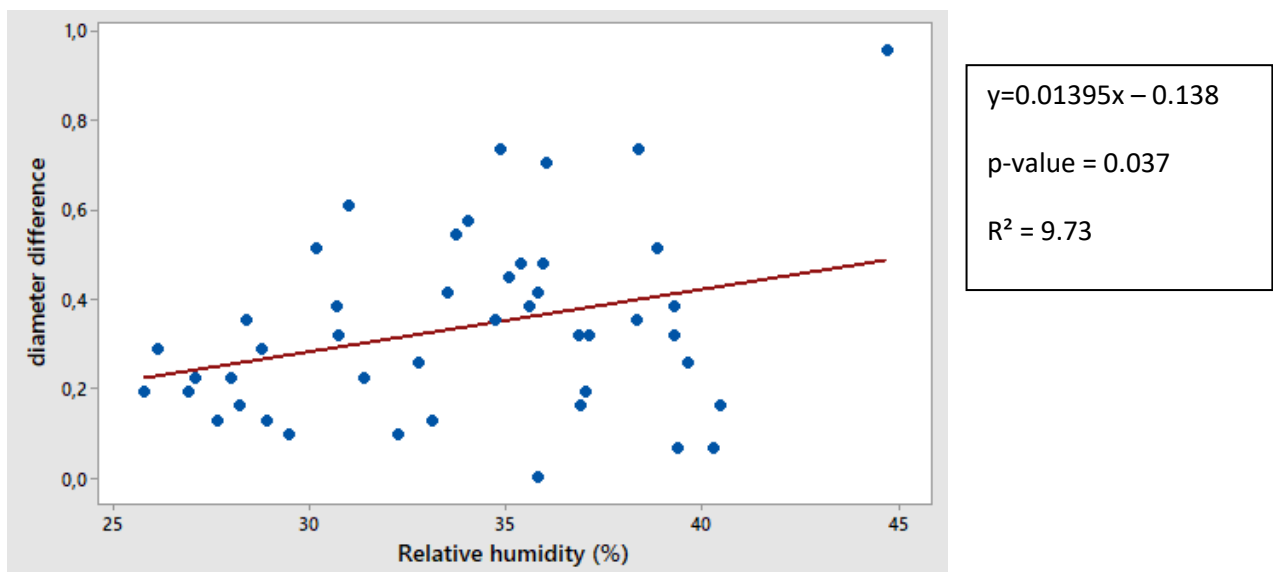

$$y = 0.01395x - 0.138$$

p-value = 0.037

$$R^2 = 9.73$$

Figure 16 : Linear regression between diameter difference and relative humidity

2.8. Difference in relative humidity between each plot

It is important to compare the relative humidity between each plot as we have correlation between relative humidity and tree health index and between relative humidity and tree diameter increase. The data was not normally distributed so I could not use the Student t test and I used The Mann-Whitney U test instead. The relative humidity in Plot A has a mean of 36.92 (±3.07), while in Plot B the relative humidity mean is 35.32 (±4.05) and in Plot C the mean is 29.39 (±2.58). With a p-value of 0.431 we can say that the relative humidity in Plot A

is not significantly different from the relative humidity in plot B. And with a p-value of 0.000 we can state that the relative humidity in Plot C is significantly different from relative humidity in Plot A and B.

3. Discussion

Regarding the health of the trees, we saw that there is a significant difference between the disturbed and undisturbed trees with the intersite comparison, but there is no significant effect if we look at the intrasite comparison in Plot A (the only site with disturbed trees). We cannot say that disturbance has an effect on tree health because the differences seen in the intersite comparison are more likely due to the differences in environmental conditions between the plots. Moreover, the relative humidity is positively correlated with the tree health index and Plot A has the best relative humidity mean with 36.92% (±3.07) compared with 35.32% (±4.05) for Plot B and 29.39% (±2.58) for Plot C. So the trees in Plot A benefits from a better soil humidity and that is at least partially why their health index is better than the other plots. Moreover, the trees' health index in Plot A is better after disturbance than before, so it seems that disturbance have no impact on the tree health index.

Regarding tree growth, we know that disturbance did not have an effect on tree height increase, but it seems to have an effect on tree diameter increase using an interplot comparison. However, we can see that the diameter increase is better for the disturbed trees and we know that the humidity is positively correlated with the diameter increase. So we can state that disturbance has no effect on tree diameter increase.

Furthermore, over all the trees I monitored, only one tree had been almost destroyed by the animals digging the cardboard. The tree's height decreased significantly because the animals broke the principal branch. But that single tree represents only 2% of the total trees I monitored. This tree was also the only little tree of the plot with a height of 16 cm when I began the monitoring. Maybe the other trees were not affected by the disturbance because they were bigger. We cannot state that disturbance would not have an effect in a plot like Plot C where there are mainly little trees. Indeed, depending on their age, height, environmental conditions, the trees can respond differently following animal disturbance (Van Lerberghe, 2015).

The disturbance had no significant effect on leaf damage progression nor leaf color progression. The leaf color is positively correlated with the increase in tree height but the health index progression and the leaf damage are not correlated with the increase in tree height. The increase in diameter is not correlated with the leaf color, nor the leaf damage, nor the health index progression.

4. Limits and improvements

I monitored the trees during only 11 weeks, which is not a lot of time compared to the slow growth and progression of the trees. This project should be followed in a longer time and more plots should be monitored, especially the recently planted plots that have trees younger than 2 years because they are more likely to respond differently to disturbance. I think that it is not necessary to take the data every week, but it is necessary to look every week at the plots to see if they have been disturbed.

The animals could have a tree species preference because some species provide more insect biodiversity in the soil, so it could be interesting to look at the species that are more likely disturbed.

It would be interesting to look at the difference between sapling mortality and older trees mortality versus the total tree mortality in the cloud forest. The tree mortality is an indicator of the forest health so we could compare the tree mortality in primary forest versus in reforested area with GIS (Credit Valley Conservation, 2010).

Conclusion

Cloudbridge reforestation practices have already demonstrated their efficiency during the past 15 years. The reforestation project is going very well and the land has already changed. The animal disturbance that appeared these past few years was a problem for them because it seemed to disturb their recently planted sapling trees. Thanks to the index I set up at the beginning of my project, I was able to follow the tree health and growth progression. By monitoring the trees and looking at any disturbance marks, I was able to compare my data between disturbed and undisturbed trees and between before and after disturbance. I found that the disturbance seemed to have some effect on tree health and growth but it was only due to the differences in environmental conditions between plots. So we can confirm that in the disturbed plot, the disturbance had no impact on tree health and growth. As only one plot was disturbed I cannot state that disturbance have no impact on sapling health and growth. This project has to be carried on to be sure that the disturbance have no impact in any tree health and growth whatever his conditions such as age, height, frequencies of disturbance and time of year.

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