Weed suppression in Cloudbridge Nature Reserve, Costa Rica

A study on the different, possible and most efficient method(s) for suppressing the weeds in the reforested areas of Cloudbridge Nature Reserve

Marloes Fröling
3th – Practical Placement

CLOUDBRIDGE NATURE RESERVE

Hogeschool VAN HALL LARENSTEIN
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Tropical Forestry
Internship Cloudbridge Nature Reserve, Costa Rica
Int. Agr. Hs. Van Hall-Larenstein
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Prologue

For my 3th year internship of the study Tropical Forestry at the University of applied sciences Van Hall-Larenstein, it was needed to participate in a Tropical experience abroad. For this internship it was possible to perform a scientific research.
The idea for my research has grown on the spot in Cloudbridge Nature Reserve in Costa Rica. Manager Tom Gode already proposed in an email to focuse my research on the weed suppression at the Cloudbridge loacation because this was really needed. But I only decided to do this after I explored the area myself and discoverd that there where a lot of areas at the reserve where no trees where growing and I was wondering why. Then I found out that I was really interested in studying the source of this problem; the weeds. I decided to accept Tom's proposal for the weed suppression study in order to help the future reforested areas to develop quicker.

I'd like to thank manager Tom Gode for this opportunity and his support in my research. Also my thanks to the employees of Cloudbridge Nature Reserve, Victor, Edgar and Jeison for all their help with the hard work and Linda,Stefan, Holly and the Familiy from Boulder Colorado for helping out with the planting.

Summary

This research report contains the whole process of the start and set up of the research until the 2nd measurement. It is an ongoing research which will comprise more data in the future, collected by others involved in the Cloudbridge reforestation projects.

For a smooth progress in this research, the reason why this research was set up is first explained. This will be done in the introduction.
Than the research goals and hypothesis are given, followed by an explaination of the materials and research methods.
Furthermore, the results are given and explained and discussed in the discussion, which will lead to conclusion and an answer to the hypothesis.
References are given after the conclusion and in the appendices all the maps, data tables and results are gives.

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Introduction

Cloudbridge Nature Reserve (see appendices A.) is located 2 km east of the village San Gerardo de Rivas in South-West Costa Rica. The reforestation project is going on since 2002 when Ian and Genevieve Giddy decided to buy a piece of deforested land close to the mountain Chirripo for letting trees just grow. Cloudbridge had a lot of succes in all these years with growing trees on their expanding surface. It contains now 283 ha of land that was once all farming land. Some areas have more succes with growing trees than others and you can see these differences when you hike through the forests. This non-profit organisation provides activities as working with volunteers and interns to keep inproving the databases and the amount of new forest and form a corridor for animals and plant species to the nature areas nearby.

2. Problem Analysis

Some areas at the Cloudbridge Reserve have trouble with the growth of new seedlings. The new seedlings are not able to grow because there is an overabundance of invasive grasses that overgrow them, which is a left-over from the pasture lands that where there once before the reserve started. Cloudbridge controls the weeds by cutting them with machetes when necessary (approximately once per month). But this is a very labour intensive method of control that costs a lot of hours and therefore a lot of money. Using chemicals is much easier but in the same time not healthy for the environment.
This research contains a couple of weed control methods that are compared with each other to see which one is the most efficient one for the Cloudbridge reforestation projects. Besides from cutting by hand, Cloudbridge also uses a method of placing cardboard around the new seedlings to slow down the weed growth.
The weeds at the research side are mostly braken ferns, *Pteridium aquilinum* (see picture 1.).

Picture 1. Braken fern, Pteridium aquilinum

3. Research Goal and Questions

The research goal is to find the most cost efficient and effective method(s) for controlling the weed growth in the planted areas of Cloudbridge Reserve.

3.1 Hypothesis:

"If the method of using non-chemical weed suppression and control to kill the weeds within the plantation area is more efficient compared to the industry standard method of treating the planting area with chemicals, cloudbridge has found a way of reducing chemical use in the reforestation of cloud forest in Costa Rica."

3.2 Research questions:

- Will chemical be the cheapest and less labour intensive way to control the weeds?
- What role does shading out the grasses play in controling the weeds?
- Which combination of natural weed control methods is the most effective?
- Which method of supression is most cost efficient?

This research is very relevant because the weeds form an obstruction for a new forest to develop. So knowing which way to control weeds is the most cost effective, less labour intensive and environmental friendly, will solve a lot of problems with the weeds at Cloudbridge Reserve.

4. Materials and Research methods

The study area consist of 16 plots of 10x10 meter, set up halfway of the Sendero Montana trail (see Appendices B.).
4 general methods are used, each followed by one of the two sequel methods (see table Appendices C.). That makes 8 different methods in total which appear twice in different positions in the research area to exclude any external influences, like height, shade by bigger trees, water runoff etc.

The seedlings are planted on these 16 plots with a 2x2 meter distance in between so there is enough space for measurements and development of the trees. 25 seedlings are planted in each plot with a composition of 50% pioneer species, 25% mixed natural climax species and 25% oak species (see list Appendices D and map Appendices E.).

Explanation of the methods:

4.1 Plastic Method

This method consist of using 400 m2 of black plastic to cover 4 plots (see Appendices F. picture 1.). The plastic is spread out close to the ground and tied up with wires to prevent it from blown away. The sun heats up the air under the plastic and so suppresses the weeds under it. The plastic stays on the plots for 4 weeks. Then on 2 of the 4 plots the sequel method of 60 cm of cardboard around the seedlings or manual cutting will be provided.

4.2 Cardboard Method

For this method there is a lot of cardboard collected in the area around Cloudbridge. The cardboard is spread out on 4 plots and attached to the ground with small stakes to prevent it from blown away (see Appendices F. picture 2.). The cardboard stays on the plots for 4 weeks. After this the cardboard will stay on the plots, while forming a sequel method for 2 of the 4 plots at the same time. 2 other plots will have the sequel methods of manual cutting.

4.3 Chemical Method

This methods consist of using the chemical round-up. 4 plots are sprayed with 118 ml of round up per liter water (see Appendices F. picture 3.). This kills all the new emerging weeds. This method is performed at least a week before planting the seedlings. On 2 of the 4 plots the sequel method of 60 cm of cardboard around the seedlings or manual cutting will also be provided.

4.4 Manual cutting

This is the most intensive method which is provided on 4 plots when needed (approximately once a month) and is done with machetes (see Appendices F. picture 4.). On 2 of the 4 plots the sequel method of 60 cm of cardboard around the seedlings or manual cutting will also be provided.

Using all of these different methods with their sequel methods will get a better overview in which method is the most efficient for Cloudbridge. This is determined by looking at the regrowth of the weeds, the development of the trees, the costs, labour insensitivity for maintenance and how healthy it is for the environment.

The weeds on the study area consist mostly of ferns so the results are not really good enough for a conclusion for the total planted areas of Cloudbridge. That is why the 4 general methods are also used on small pieces of grassy areas to compare the results and get a better conclusion for Cloudbridge (see Appendices G.).

5. Results

The results of this research are obtained by compairing 5 different indicators and how they are influenced by the different weed suppression methods. These indicators are measured by the development of the trees, the development of the weeds, the amount of labour in hours, the costs and the influences on the environment.

For obtaining the tree development data, the height, diameter and amount of leaves are measured of all the 400 planted seedlings right after planting and 4 weeks later (approximately a month). Then these measures are compared and the difference between them gives an indication of the development on the seedlings (see table Appendices H.).

The weed indication is obtained by identifying the different weeds per plot and measure the height and the coverage (in%) right after planting and 4 weeks later. The difference between these two measurements gives an indication on the development of the weeds (see table Appendices I.).

The hours of labour of the preparation and the maintenance per plot are tracked and summed up so this gives an indication of how many hours the different methods contain (see table Appendices J.).
The costs include the labour, the amount of hours that the employees of Cloudbridge have worked, and the costs of the materials needed for the methods. These are costs of the black plastic and chemicals (see table Appendices K.).

The indicator of the influence on the environment is given bij a scale of 1 – 10. The method chemicals where given a mark 10 (really bad influence on environment) and the method manual cutting was given an 0, because this has no influence on the environment at all. The other 2 were given a mark by looking at the relationship between the 4 methods and an indication of their influence on the environment (see table Appendices L.).

For each of these indicators a scale distribution was created by summing up all the total data per plot divided by the amount of plots. Then every plot was put in the scale and was given a mark that belongs to that scale (see table Appendices M.).

The marks of the height, diameter and amount of leaves were summed up to give a total mark to the development of the trees. The same was done with the height and coverage of the weeds (see table Appendices N.).
Afterward all the total marks where summed up and a sequence of marks was created of the total 16 plots (see table Appendices O.). At last the plots with the same method where put together and an order of 8 marks formed the final results of this research (see table Appendices P.).

The comparison by using the same methods on a grassy area does not show much different results. The chemicals were working really well, but it includes the same environmental indicator. The plastic and cardboard show the same results too, they are working really well for a small amount of time. But after removing them, the grasses grow back really quick (see pictures Appendices Q.).

6. Discussion

The cardboard method followed by the sequel cardboard method turned out the be the last one in the results table and is thereby the least efficient method for Cloudbridge (see table Appendices P.). Although the costs for this method are really low, because the cardboard is collected for free, the amount of labour hours is very high and thereby the labour costs too. It also occurs that it is hard to spread the cardboard out without any holes in between. The ferns grow back easily in between the cardboard.

The method using chemicals does not appear to be much better, mostly caused by the fact that the environmental indicator playes a hugh role here. Furthermore, the chemicals work well for the first load of weeds, but the new one's will grow afterwards.

Only the manual cutting method followed up by the sequel manual cutting method really occurs to be the most efficient method. And the manual cutting method followed up by the sequel cardboard comes next.
The plastic shows that it works fine for all the weeds except the ferns. They are only suppressed a little while but after removing the plastic they continue growing.
Cloudbridge already worked with the method manual cutting and cardboard around the trees so looking at the results there is not really a new method that pops out. But if you look at the reason why this research was set up (finding a method that is less labour intensive), the amount of labour put in the manual methods is not that much compared with for example the cardboard method. It only costs Cloudbridge 10 dollar per 10m2 per month to cut the weeds. And with a combination of putting cardboard around the trees it can even be less.

7. Conclusion

In conclusion;
Looking at all the 5 indicators, the manual cutting method followed up by the sequel method manual cutting is the most efficient method for Cloudbridge. But added that cardboard around the trees will suppres the weeds even longer and placing plastic as an preparation method to get rid of the weeds (except for ferns), it would be recommended to use the following method:
First placing plastic as a preparation method and continue with placing cardboard around the trees and cut manual when needed for smaller areas.
If the planted area contains more land, than just keep using the method Cloudbridge was already performing in some areas, manual cutting and placing cardboard around the trees.

Answer the Hypothesis;
“If the method of using non chemical weed suppression and control/ kill the weeds within the plantation area is more efficient compared to the industry standard method of treating the planting area with chemicals, cloudbridge has found a way of reducing chemical use in the reforestation of cloud forest in Costa Rica.”

Yes, the method of using non chemical weed suppression and control/kill the weeds is more efficient compared to the industry standard method of treating the planting area with chemicals. So yes, Cloudbridge did found a way of reducint chemical use in the reforestation of cloud forest in Costa Rica.

Answer questions:

- Will chemicals be the cheapest and less labour intensive way to control the weeds?

Together with the method manual cutting, using chemicals is the cheapest and less labour intensive way to control weeds.

- What role does shading out the grasses play in controling the weeds?

By placing black plastic over the weeds, the air under it will warm up and by that the weeds can’t grow well anymore. But this counts for most of the weeds accept for the ferns. These are just suppressed and will continue growing after removing the plastic.

- Which combination of natural weed control methods is the most effective?

The method manual cutting followed up by the sequel method manual cutting or using cardboard around the trees.

- Which method of supression is most cost efficient?

Manual cutting or using chemicals.

References

The information about applying the plastic method is provided by:
Owner of a plantation nearby that recommended using plastic as a suppression method.

Information about cardboard, chemicals and manual cutting is provided by manager Tom Gode.

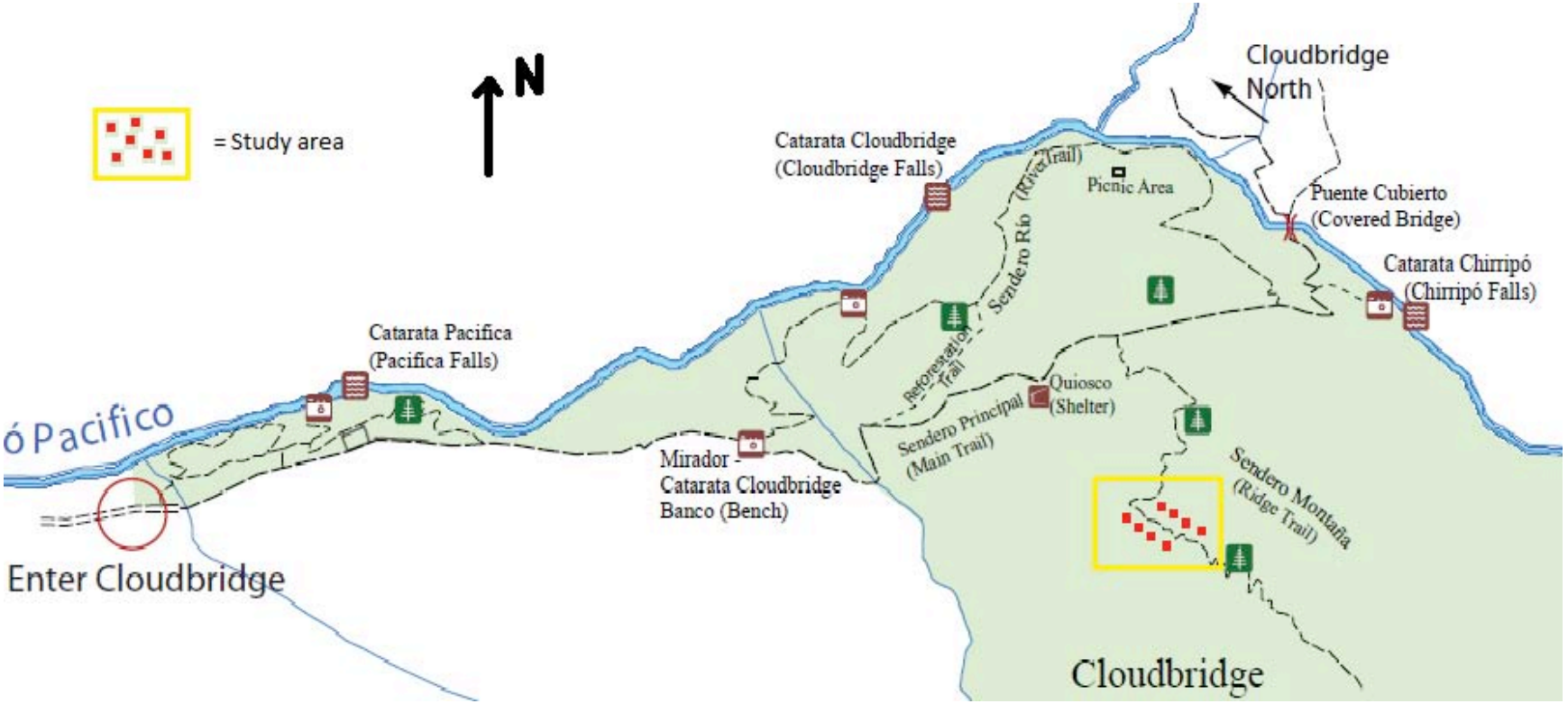
Information about Cloudbridge Nature Reserve is provided by the website of Cloudbridge and Tom Gode.

Information about the costs of this research is provided by Tom Gode.

Zuchowski,W., (2006), *A Guide to Tropical Plants of Costa Rica*, Zona Tropical

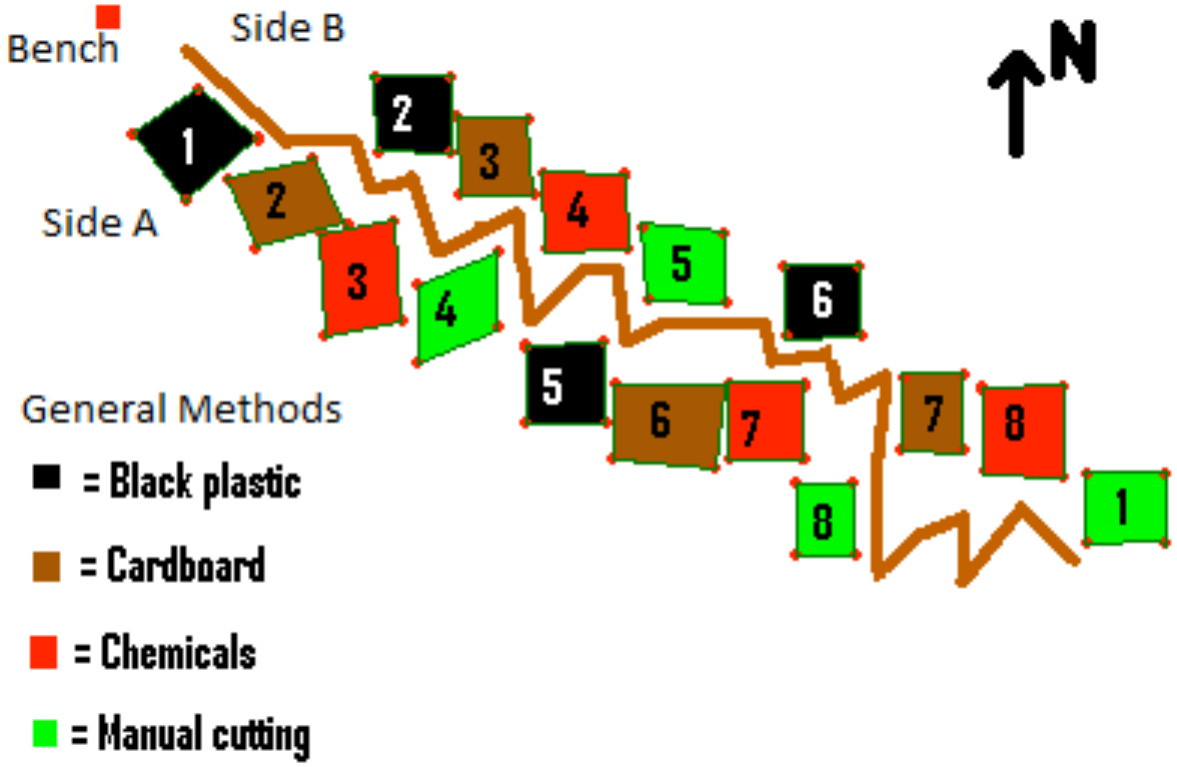
Appendixes

A. Map of the Southern part of Cloudbridge Nature Reserve



Picture 2. Map of Cloudbridge South

B. Study area



Picture 3. Plots on the study area

C. Methods

Plot number	Method number	Plot number	Method number
1A	3	2B	4
2A	5	3B	6
3A	7	4B	8
4A	1	5B	2
5A	4	6B	3
6A	6	6B	5
7A	8	8B	7
8A	2	1B	1

Table 1. Methods

Methods:
1: Weeding by hand followed by cardboard 60 cm around the trees
2: Weeding by hand followed by manual cutting
3: Using black plastic followed by cardboard
4: Using black plastic followed by manual cutting
5: Using cardboard followed by cardboard
6: Using cardboard followed by manual cutting
7: Using chemicals followed by cardboard
8: Using chemicals followed by manual cutting

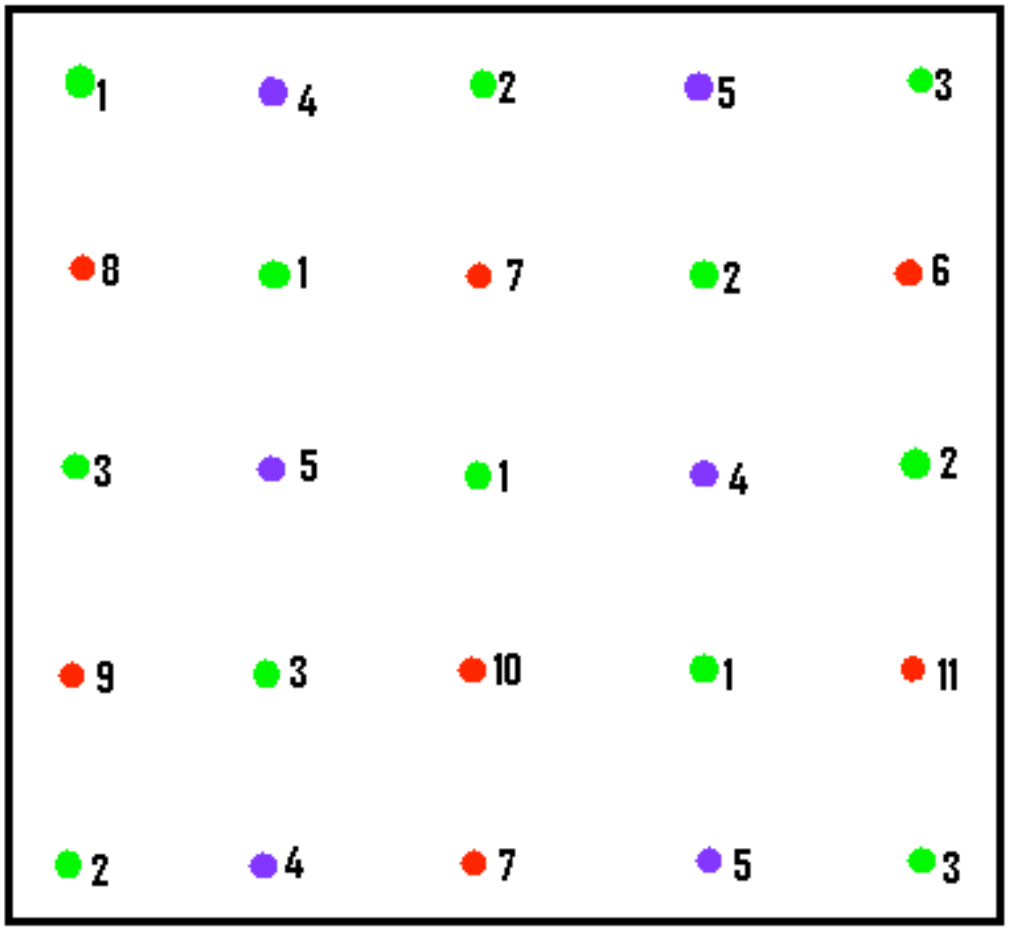
D. Species list

spot nr.	tree nr.	species
1	1	Solanum
2	4	Roble
3	2	Ratacino
4	5	Encino
5	3	Watiti
6	8	Yas
7	1	Solanum
8	7	Cedro
9	2	Ratacino
10	6	Tira
11	3	Watiti
12	5	Encino
13	1	Solanum
14	4	Roble
15	2	Ratacino
16	9	Yos
17	3	Watiti
18	10	Aguacatile
19	1	Solanum
20	11	Aguacote
21	2	Ratacino
22	4	Roble
23	7	Cedro
24	5	Encino
25	3	Watiti

Kind	Species	Amount	Nr	Total amount
Pioneer	Solarum	4	1	64
Pioneer	Ratacino	4	2	64
Pioneer	Watiti	4	3	64
Oaks	Roble	3	4	48
Oaks	Encino	3	5	48
Secundairy	Tira	1	6	16
Secundairy	Cedro	2	7	32
Secundairy	Yas	1	8	16
Secundairy	Yos	1	9	16
Secundairy	Aguacatile	1	10	16
Secundairy	Aguacote	1	11	16

Table 2 and 3. Species list

E. Plot map



Picture 4. Index plots

F. Pictures of methods on plots

1.

2.

3.

4.

G. Pictures of methods on grasses

1.

2.

3.

H. Tree development

1a	Height			1b	Height			2a	Height			2b	Height			3a	Height			3b	Height			4a	Height			4b	Height		
	1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.
1	66	67	1	1	93	93	0	1	91	90	-1	1	43	45	2	1	65	64	-1	1	100	100	0	1	70	71	1	1	66	64	-2
2	30	29	-1	2	41	41	0	2	40	40	0	2	47	48	1	2	28	28	0	2	21	24	3	2	50	49	-1	2	39	38	-1
3	49	48	-1	3	51	50	-1	3	68	68	0	3	52	52	0	3	33	33	0	3	49	47	-2	3	30	30	0	3	33	33	0
4	25	32	7	4	22	23	1	4	33	31	-2	4	54	54	0	4	28	33	5	4	74	78	4	4	28	31	3	4	14	15	1
5	71	71	0	5	91	92	1	5	50	51	1	5	43	45	2	5	101	102	1	5	93	83	-10	5	117	118	1	5	75	76	1
6	18	18	0	6	15	17	2	6	49	50	1	6	24	25	1	6	17	16	-1	6	17	17	0	6	20	19	-1	6	24	23	-1
7	72	71	-1	7	77	78	1	7	81	82	1	7	55	53	-2	7	91	94	3	7	85	84	-1	7	47	46	-1	7	107	108	1
8	26	28	2	8	29	29	0	8	15	16	1	8	13	14	1	8	22	25	3	8	16	19	3	8	26	27	1	8	20	19	-1
9	79	78	-1	9	47	48	1	9	43	43	0	9	52	50	-2	9	32	33	1	9	47	47	0	9	26	28	2	9	35	34	-1
10	46	20	-26	10	59	58	-1	10	43	44	1	10	45	52	7	10	42	45	3	10	30	34	4	10	62	29	-33	10	45	43	-2
11	99	98	-1	11	76	75	-1	11	41	42	1	11	45	46	1	11	103	103	0	11	78	77	-1	11	72	73	1	11	52	51	-1
12	26	29	3	12	23	23	0	12	30	28	-2	12	25	31	6	12	19	17	-2	12	83	83	0	12	23	16	-7	12	29	31	2
13	128	126	-2	13	71	70	-1	13	52	52	0	13	74	76	2	13	66	67	1	13	155	153	-2	13	72	73	1	13	76	77	1
14	24	25	1	14	47	47	0	14	45	46	1	14	47	46	-1	14	38	40	2	14	32	31	-1	14	25	48	23	14	39	39	0
15	62	64	2	15	50	51	1	15	50	51	1	15	36	38	2	15	38	39	1	15	77	77	0	15	25	29	4	15	46	47	1
16	62	66	4	16	21	22	1	16	50	50	0	16	43	23	-20	16	47	47	0	16	26	26	0	16	45	47	2	16	45	46	1
17	66	65	-1	17	96	96	0	17	65	66	1	17	74	73	-1	17	132	129	-3	17	113	113	0	17	125	126	1	17	82	82	0
18	26	28	2	18	45	46	1	18	41	44	3	18	39	39	0	18	29	29	0	18	30	32	2	18	61	62	1	18	46	47	1
19	80	81	1	19	70	69	-1	19	85	86	1	19	122	124	2	19	122	121	-1	19	60	61	1	19	53	55	2	19	85	86	1
20	21	23	2	20	35	34	-1	20	16	19	3	20	17	18	1	20	18	22	4	20	33	34	1	20	56	58	2	20	22	22	0
21	45	44	-1	21	39	39	0	21	72	71	-1	21	40	38	-2	21	26	27	1	21	68	70	2	21	47	46	-1	21	32	31	-1
22	16	17	1	22	41	41	-0,5	22	40	38	-2	22	32	15	-17	22	37	51	14	22	49	49	0	22	30	31	1	22	45	45	0
23	17	17	0	23	32	31	-1	23	12	11	-1	23	15	19	4	23	44	45	1	23	55	59	4	23	29	29	0	23	25	25	0
24	19	24	5	24	25	27	2	24	29	29	0	24	20	19	-1	24	27	28	1	24	78	80	2	24	26	27	1	24	24	23	-1
25	76	76	0	25	100	100	0	25	80	80	0	25	48	47	-1	25	72	70	-2	25	51	52	1	25	71	71	0	25	115	115	0
Total			-4				3,5				7				-15				31				10				3				-1

Table 4. Tree height part 1

5a	Height			5b	Height			6a				6b	Height			7a	Height			7b	Height			8a	Height			8b	Height		
	1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.
1	77	78	1	1	41	39	-2	1	50	51	1	1	85	90	5	1	89	90	1	1	75	80	5	1	125	125	0	1	81	79	-2
2	38	42	4	2	32	47	15	2	42	44	2	2	31	30	-1	2	37	38	1	2	30	29	-1	2	23	36	13	2	39	39	0
3	34	36	2	3	60	59	-1	3	84	82	-2	3	28	29	1	3	94	94	0	3	87	87	0	3	88	87	-1	3	24	25	1
4	14	22	8	4	21	23	2	4	24	23	-1	4	26	34	8	4	27	29	2	4	23	26	3	4	23	22	-1	4	28,5	31	2,5
5	85	85	0	5	83	82	-1	5	47	46	-1	5	69	69	0	5	78	77	-1	5	55	52	-3	5	118	108	-10	5	66	65	-1
6	17	17	0	6	33	35	2	6	24	24	0	6	35	37	2	6	17	17	0	6	23	24	1	6	25	25	0	6	23	23	0
7	45	44	-1	7	60	60	0	7	42	40	-2	7	108	109	1	7	71	70	-1	7	28	28	0	7	92	91	-1	7	95	95	0
8	15	15	0	8	25	125	100	8	14	14	0	8	16	16	0	8	23	23	0	8	25	25	0	8	35	36	1	8	22	23	1
9	40	38	-2	9	63	62	-1	9	62	62	0	9	48	48	0	9	40	41	1	9	36	36	0	9	36	37	1	9	32	31	-1
10	27	30	3	10	62	60	-2	10	37	40	3	10	50	54	4	10	55	60	5	10	72	70	-2	10	51	22	-29	10	48	49	1
11	105	104	-1	11	103	103	0	11	55	54	-1	11	55	58	3	11	77	78	1	11	76	67	-9	11	114	104	-10	11	75	74	-1
12	20	26	6	12	18	20	2	12	23	24	1	12	16	16	0	12	17	18	1	12	22	24	2	12	22	23	1	12	17	16	-1
13	43	42	-1	13	60	60	0	13	47	46	-1	13	82	82	0	13	105	107	2	13	84	83	-1	13	62	62	0	13	80	77	-3
14	65	68	3	14	60	60	0	14	50	51	1	14	23	24	1	14	41	41	0	14	38	40	2	14	42	44	2	14	33	32	-1
15	54	54	0	15	41	43	2	15	40	39	-1	15	59	58	-1	15	46	46	0	15	55	57	2	15	54	54	0	15	29	29	0
16	29	29	0	16	24	26	2	16	18	19	1	16	57	63	6	16	29	29	0	16	50	55	5	16	67	65	-2	16	32	32	0
17	90	88	-2	17	95	94	-1	17	79	78	-1	17	89	91	2	17	70	69	-1	17	58	58	0	17	107	105	-2	17	87	85	-2
18	43	41	-2	18	53	57	4	18	37	35	-2	18	42	44	2	18	48	50	2	18	35	35	0	18	24	23	-1	18	13	14	1
19	58	59	1	19	100	100	0	19	57	57	0	19	65	64	-1	19	98	96	-2	19	63	63	0	19	74	75	1	19	107	102	-5
20	25	26	1	20	34	31	-3	20	21	23	2	20	27	29	2	20	23	27	4	20	12	12	0	20	34	20	-14	20	49	52	3
21	29	29	0	21	43	43	0	21	19	21	2	21	55	54	-1	21	44	44	0	21	67	67	0	21	62	61	-1	21	35	35	0
22	43	44	1	22	46	45	-1	22	19	19	0	22	38	39	1	22	43	43	0	22	40	39	-1	22	25	25	0	22	49	50	1
23	13	14	1	23	13	14	1	23	10	11	1	23	44	48	4	23	17	18	1	23	16	17	1	23	40	40	0	23	28	28	0
24	63	79	16	24	23	22	-1	24	24	17	-7	24	21	21	0	24	30	29	-1	24	19	21	2	24	23	24	1	24	25	24	-1
25	151	149	-2	25	80	77	-3	25	66	65	-1	25	120	121	1	25	83	82	-1	25	70	69	-1	25	80	78	-2	25	78	76	-2
			36				114				-6				39				14				5				-54				-9,5

Table 5. Tree height part 2

Diameter			6a	Diameter			6b	Diameter			7a	Diameter			7b	Diameter			8a	Diameter			8b	Diameter		
1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.
50	50	0	1	44	38,5	-5,5	1	22	22	0	1	18	16	-1,5	1	18	17,5	-0,5	1	13	14	1	1	31	30,5	-0,5
5	6,5	1,5	2	4	5	1	2	5	2	-3	2	2	3,5	1,5	2	5	5	0	2	4	4	0	2	3	2	-1
13	12,5	-0,5	3	13	12	-1	3	17	15,5	-1,5	3	14	15	1	3	15	14	-1	3	16	13	-3	3	39	40	1
0,5	2	1,5	4	1	2	1	4	4,5	4	-0,5	4	1,5	1,5	0	4	2	2,5	0,5	4	0,3	1,5	1,2	4	3	2,5	-0,5
24	24	0	5	26	25	-1	5	36,5	36	-0,5	5	13	12	-0,5	5	22	20	-2	5	17	18	1	5	14	15	1
5,5	7	1,5	6	5	6	1	6	8	8,5	0,5	6	4,5	5,5	1	6	5,5	7	1,5	6	4	6	2	6	8	8,5	0,5
45	43,5	-1,5	7	42	40	-2	7	13	12,5	-0,5	7	20	20	0	7	18	17	-1	7	16	16	0	7	18	20	2
4	6	2	8	3,5	4	0,5	8	3	5	2	8	4	5	1	8	5	5	0	8	11	12	1	8	7	8	1
10	10	0	9	11	10,5	-0,5	9	11,5	12	0,5	9	34	34	0	9	13	13,5	0,5	9	20	21,5	1,5	9	20	23	3
2	4	2	10	2	2	0	10	3,5	3,5	0	10	3	3,5	0,5	10	4	4	0	10	3	3,5	0,5	10	3	3	0
17	17	0	11	37	37,5	0,5	11	1,5	17	15,5	11	13	14	1	11	24	20	-4	11	16	16	0	11	11	10	-1
0,5	2	1,5	12	1	2	1	12	1	1,5	0,5	12	2	1	-1	12	1	1,5	0,5	12	2	2	0	12	0,5	1	0,5
40	40	0	13	41	40	-1	13	15	15	0	13	20	18	-2	13	15	16	1	13	27	27	0	13	25	23	-2
4,5	6	1,5	14	4	5	1	14	1,5	2	0,5	14	3	2,5	-0,5	14	3	4	1	14	2	4	2	14	3	4	1
17	15,5	-1,5	15	28	29	1	15	15,5	16	0,5	15	13	13	0	15	10	12	2	15	19	20	1	15	26	26	0
2	2,5	0,5	16	2	2,5	0,5	16	7	7	0	16	3	3,5	0,5	16	6	6,5	0,5	16	6	7,5	1,5	16	2	3	1
16	16	0	17	17	14	-3	17	19	18,5	-0,5	17	12	10,5	-1	17	12	11,5	-0,5	17	15	15	0	17	17	16	-1
4	5	1	18	3	4	1	18	5	5	0	18	5,5	8	2,5	18	3	3	0	18	2	2	0	18	1,5	2	0,5
42	41	-1	19	48	44	-4	19	37	37	0	19	23	23	0	19	28	26	-2	19	30	28	-2	19	21	21,5	0,5
4,5	4	-0,5	20	7	7,5	0,5	20	5,5	8	2,5	20	5	6	1	20	8	8,5	0,5	20	8	8,5	0,5	20	8	10	2
15	14	-1	21	1	2	1	21	12	12	0	21	21	25	4	21	19	18,5	-0,5	21	14	14,5	0,5	21	15	15	0
5	5,5	0,5	22	2	2	0	22	3	3,5	0,5	22	3	3	0	22	2	3	1	22	1	5	4	22	3	3,5	0,5
3	3	0	23	3	3	0	23	6	5	-1	23	5	5	0	23	5	6	1	23	7	8,5	1,5	23	5	5	0
1	2	1	24	1,5	3	1,5	24	1,5	2	0,5	24	2	3	1	24	2	2	0	24	1	2,5	1,5	24	0,5	2	1,5
19	20	1	25	23	20	-3	25	16,5	6,5	-10	25	15	15	0	25	13	14	1	25	13	13	0	25	12	12	0
		9,5				-9,5				6				8,5				-0,5				15,7				10

Table 6. Tree diameter

1a	Leaves			1b	Leaves			2a	Leaves			2b	Leaves			3a	Leaves			3b	Leaves			4a	Leaves			4b	Leaves		
	1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.
1	2	0	-2	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	11	0	-11	1	0	0	0
2	29	29	0	2	23	23	0	2	34	31	-3	2	38	38	0	2	13	4	-9	2	11	15	4	2	19	27	8	2	17	16	-1
3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
4	35	39	4	4	25	28	3	4	13	13	0	4	86	87	1	4	12	32	20	4	64	62	-2	4	19	22	3	4	14	15	1
5	3	2	-1	5	0	3	3	5	37	43	6	5	3	110	107	5	0	0	0	5	2	0	-2	5	1	0	-1	5	1	0	-1
6	7	7	0	6	5	6	1	6	4	0	-4	6	9	5	-4	6	9	8	-1	6	7	7	0	6	7	7	0	6	4	4	0
7	1	0	-1	7	2	0	-2	7	0	0	0	7	0	0	0	7	0	0	0	7	0	0	0	7	0	0	0	7	0	0	0
8	9	13	4	8	5	4	-1	8	4	3	-1	8	1	2	1	8	7	5	-2	8	2	5	3	8	7	7	0	8	5	0	-5
9	0	0	0	9	0	0	0	9	0	0	0	9	0	0	0	9	0	0	0	9	0	0	0	9	0	0	0	9	0	0	0
10	20	16	-4	10	26	37	11	10	40	42	2	10	47	65	18	10	30	22	-8	10	21	31	10	10	34	9	-25	10	24	24	0
11	0	0	0	11	0	70	70	11	13	15	2	11	33	73	40	11	0	0	0	11	3	38	35	11	0	0	0	11	0	0	0
12	29	45	16	12	23	28	5	12	16	16	0	12	13	29	16	12	16	16	0	12	75	71	-4	12	17	8	-9	12	17	15	-2
13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0	13	1	0	-1
14	22	28	6	14	22	22	0	14	28	19	-9	14	19	19	0	14	16	15	-1	14	14	13	-1	14	40	40	0	14	13	13	0
15	0	0	0	15	0	0	0	15	0	0	0	15	0	0	0	15	0	0	0	15	0	0	0	15	0	0	0	15	0	0	0
16	17	17	0	16	5	5	0	16	9	9	0	16	10	0	-10	16	13	15	2	16	9	11	2	16	12	3	-9	16	13	6	-7
17	8	0	-8	17	0	0	0	17	18	23	5	17	30	26	-4	17	0	0	0	17	6	9	3	17	1	0	-1	17	0	0	0
18	15	14	-1	18	15	15	0	18	18	15	-3	18	15	14	-1	18	21	20	-1	18	13	5	-8	18	7	7	0	18	31	28	-3
19	0	0	0	19	0	0	0	19	0	0	0	19	0	0	0	19	0	0	0	19	7	0	-7	19	0	0	0	19	0	0	0
20	6	6	0	20	13	16	3	20	7	7	0	20	7	7	0	20	6	5	-1	20	13	13	0	20	27	17	-10	20	11	11	0
21	0	0	0	21	0	7	7	21	0	0	0	21	0	0	0	21	0	0	0	21	0	0	0	21	0	2	2	21	0	0	0
22	23	42	19	22	22	22	0	22	25	24	-1	22	15	6	-9	22	26	25	-1	22	24	24	0	22	17	18	1	22	20	20	0
23	2	4	2	23	5	4	-1	23	3	0	-3	23	2	2	0	23	3	5	2	23	3	7	4	23	6	6	0	23	6	4	-2
24	13	30	17	24	26	35	9	24	28	31	3	24	20	24	4	24	30	21	-9	24	62	45	-17	24	14	13	-1	24	20	19	-1
25	44	77	33	25	0	0	0	25	4	0	-4	25	21	76	55	25	0	0	0	25	14	64	50	25	0	80	80	25	0	0	0
Total			84				108				-10				214				-9				70				27				-22

Table 7. Tree leaves part 1

5a	Leaves			5b	Leaves			6a	Leaves			6b	Leaves			7a	Leaves			7b	Leaves			8a	Leaves			8b	Leaves		
	1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.		1st	2nd	Diff.
1	0	0	0	1	0	14	14	1	10	0	-10	1	0	0	0	1	0	0	0	1	0	0	0	1	1	0	-1	1	0	0	0
2	31	32	1	2	31	32	1	2	21	20	-1	2	19	18	-1	2	15	31	16	2	29	22	-7	2	28	31	3	2	18	17	-1
3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0	3	0	0	0
4	6	17	11	4	15	16	1	4	12	12	0	4	24	28	4	4	19	17	-2	4	9	13	4	4	11	12	1	4	20	25	5
5	10	0	-10	5	0	0	0	5	15	71	56	5	11	65	54	5	0	0	0	5	26	19	-7	5	0	0	0	5	0	0	0
6	5	6	1	6	9	8	-1	6	8	7	-1	6	11	11	0	6	10	8	-2	6	8	10	2	6	14	11	-3	6	8	8	0
7	0	0	0	7	0	0	0	7	0	0	0	7	0	0	0	7	0	0	0	7	1	0	-1	7	0	0	0	7	0	0	0
8	2	0	-2	8	10	8	-2	8	0	1	1	8	2	3	1	8	6	6	0	8	2	1	-1	8	10	8	-2	8	2	3	1
9	0	0	0	9	0	0	0	9	0	0	0	9	0	0	0	9	0	0	0	9	0	0	0	9	0	0	0	9	0	0	0
10	7	25	18	10	28	53	25	10	20	18	-2	10	14	26	12	10	35	33	-2	10	23	21	-2	10	33	0	-33	10	41	42	1
11	10	0	-10	11	0	0	0	11	40	97	57	11	20	0	-20	11	7	0	-7	11	21	4	-17	11	0	0	0	11	0	0	0
12	16	22	6	12	13	24	11	12	10	16	6	12	7	8	1	12	21	20	-1	12	11	11	0	12	10	10	0	12	14	14	0
13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0	13	0	0	0
14	89	86	-3	14	24	23	-1	14	21	21	0	14	13	13	0	14	24	24	0	14	17	21	4	14	18	18	0	14	10	9	-1
15	0	0	0	15	0	0	0	15	0	0	0	15	0	0	0	15	0	0	0	15	0	0	0	15	0	0	0	15	0	0	0
16	8	7	-1	16	7	8	1	16	5	7	2	16	2	12	10	16	6	6	0	16	7	9	2	16	12	8	-4	16	8	7	-1
17	20	0	-20	17	0	0	0	17	31	0	-31	17	8	17	9	17	2	0	-2	17	1	0	-1	17	0	0	0	17	0	0	0
18	13	11	-2	18	27	27	0	18	12	12	0	18	41	29	-12	18	19	19	0	18	12	11	-1	18	7	6	-1	18	9	13	4
19	0	0	0	19	0	0	0	19	0	2	2	19	0	0	0	19	0	0	0	19	0	0	0	19	0	0	0	19	0	0	0
20	8	9	1	20	5	5	0	20	9	9	0	20	12	12	0	20	8	9	1	20	6	7	1	20	12	0	-12	20	10	12	2
21	0	0	0	21	0	0	0	21	10	10	0	21	0	0	0	21	0	0	0	21	0	0	0	21	0	0	0	21	0	0	0
22	18	18	0	22	26	32	6	22	10	21	11	22	20	20	0	22	17	17	0	22	15	14	-1	22	23	23	0	22	21	21	0
23	0	1	1	23	3	3	0	23	1	3	2	23	6	3	-3	23	3	5	2	23	5	4	-1	23	12	13	1	23	4	8	4
24	37	36	-1	24	15	15	0	24	12	13	1	24	28	28	0	24	23	22	-1	24	11	21	10	24	15	23	8	24	18	14	-4
25	2	0	-2	25	0	0	0	25	25	7	-18	25	35	20	-15	25	1	0	-1	25	23	29	6	25	0	0	0	25	0	0	0
			-12				55				75				40				1				-10				-43				10

Table 8. Tree leaves part 2

Table 9. Inventory weeds and development

	1st		2nd		Difference		Total per plot	
Species	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Cover (%)	Height (cm)	Height (cm)	Cover (%)
Braken fern (Pteridium arachnoideum)	2	50	13	100	11	50	11	50
Braken fern (Pteridium arachnoideum)	5	100	10	100	5	0	6,8	80
Verbesina turbacensis	0,1	20	1	25	0,9	5		
4047	0,1	10	0,1	15	0	5		
4664	0	0	0,2	30	0,2	30		
Digitaria costaricensis	0	0	0,2	20	0,2	20		
4667	0	0	0,5	20	0,5	20		
Braken fern (Pteridium arachnoideum)	5	80	8	80	3	0	3,3	5
4176	1	50	1	50	0	0		
Geranium guatemalense	0,1	10	0,3	15	0,2	5		
4178	0,2	20	0,3	20	0,1	0		
4179	0,1	10	0,1	10	0	0		
Braken fern (Pteridium arachnoideum)	1	30	5	75	4	45	5,7	90
Digitaria costaricensis	0	0	1,5	20	1,5	20		
Verbesina turbacensis	0	0	0,2	25	0,2	25		
Braken fern (Pteridium arachnoideum)	4	70	6	100	2	30	2,6	100
3807	0,05	10	0,1	10	0,05	0		
4573	0	0	0,1	20	0,1	20		
4574	0	0	0,25	25	0,25	25		
4579	0	0	0,1	10	0,1	10		
4580	0	0	0,1	15	0,1	15		
Braken fern (Pteridium arachnoideum)	5	70	6	80	1	10	2,8	140
Naranilla (Solanum quitoense)	0,2	20	0,3	25	0,1	5		
4149	0,1	40	0,2	40	0,1	0		
Monochaetum floribundum	0,3	10	0,3	25	0	15		
4828	0	0	0,1	20	0,1	20		
4829	0	0	0,3	40	0,3	40		
Verbesina turbacensis	0	0	0,4	15	0,4	15		
4833	0	0	0,4	25	0,4	25		
Digitaria costaricensis	0	0	0,4	10	0,4	10		
Braken fern (Pteridium arachnoideum)	4	50	8	75	4	25	7,2	85
3778	1	25	1	30	0	5		
3779	3	5	3	5	0	0		
Verbesina turbacensis	0,2	100	0,4	150	0,2	50		
3781	0,1	10	0,1	10	0	0		
4676	0	0	3	5	3	5		
Braken fern (Pteridium arachnoideum)	8	70	9	75	1	5	1	5
3751	0,2	20	0,2	20	0	0		
Braken fern (Pteridium arachnoideum)	0,5	30	4	75	3,5	45	4,49	100
3892	0,01	10	0,2	10	0,19	0		
4763	0	0	0,1	20	0,1	20		
4764	0	0	0,2	10	0,2	10		
4765	0	0	0,5	25	0,5	25		
Braken fern (Pteridium arachnoideum)	9	100	12	100	3	0	3,4	55
3750	0,1	20	0,2	50	0,1	30		
4672	0	0	0,3	25	0,3	25		
Braken fern (Pteridium arachnoideum)	1	25	5	80	4	55	4,6	75
3970	0,2	20	0,6	30	0,4	10		
4886	0	0	0,2	10	0,2	10		
Braken fern (Pteridium arachnoideum)	1	50	6	80	5	30	5,5	70
Verbesina turbacensis	0,1	20	0,2	35	0,1	15		
4793	0	0	0,4	25	0,4	25		
Braken fern (Pteridium arachnoideum)	1	30	5	75	4	45	4,3	125
4631	0	0	0,1	35	0,1	35		
Begonia semiovata	0	0	0,1	20	0,1	20		
4636	0	0	0,1	25	0,1	25		
Braken fern (Pteridium arachnoideum)	1,5	100	9	100	7,5	0	7,5	0
Braken fern (Pteridium arachnoideum)	2	50	5	100	3	50	3	65
4670	0	0	0,1	15	0,1	15		
Braken fern (Pteridium arachnoideum)	10	100	10	100	0	0	0	0

J. Labour hours

Plots	Activity	Hours (in min.)	Total
1a	Spreading plastic	25	98,75
	Spreading plastic	25	
	Spreading plastic	15	
	Bringing up plastic	33,75	
1b		0	0
2a	Spreading cardboard	65	388,75
	Spreading cardboard	45	
	Repairing cardboard	30	
	Spreading cardboard	20	
	Bringing up cardboard	228,75	
2b	Spreading plastic	15	173,75
	Spreading plastic	25	
	Spreading plastic	20	
	Cutting weeds (8 times)	80	
	Bringing up plastic	33,75	
3a	Spraying chemicals	15	15
3b	Spreading cardboard	30	443,75
	Spreading cardboard	20	
	Spreading cardboard	25	
	Spreading cardboard	60	
	Bringing up cardboard	228,75	
	Cutting weeds (8 times)	80	
4a		0	0
4b	Spraying chemicals	15	95
	Cutting weeds (8 times)	80	
5a	Spreading plastic	25	213,75
	Spreading plastic	35	
	Spreading plastic	25	
	Spreading plastic	15	
	Cutting weeds (8 times)	80	
	Bringing up plastic	33,75	
5b	Cutting weeds (8 times)	80	80
6a	Spreading cardboard	255	573,75
	Spreading cardboard	90	
	Bringing up cardboard	228,75	
6b	Spreading plastic	25	218,75
	Spreading plastic	25	
	repairing plastic	35	
	Spreading plastic	20	
	Bringing up plastic	33,75	
	Cutting weeds (8 times)	80	
7a	Spraying chemicals	15	95
	Cutting weeds (8 times)	80	
7b	Spreading cardboard	120	438,75
	Spreading cardboard	90	
	Bringing up cardboard	228,75	
8a	Cutting weeds (8 times)	80	80
8b	Spraying chemicals	15	15

Table 10. Amount of labour

K. Costs

	hours of work										
Plot	amount preperation and maintaining				digging holes and planting			Total		Costs	* 2 people
1a	98,75				48			146,75		7,3375	14,675
1b	0				65			65		3,25	6,5
2a	388,75				48			436,75		21,8375	43,675
2b	173,75				48			221,75		11,0875	22,175
3a	15				105			120		6	12
3b	443,75				48			491,75		24,5875	49,175
4a	0				70			70		3,5	7
4b	95				105			200		10	20
5a	213,75				48			261,75		13,0875	26,175
5b	80				70			150		7,5	15
6a	573,75				48			621,75		31,0875	62,175
6b	218,75				48			266,75		13,3375	26,675
7a	95				105			200		10	20
7b	438,75				48			486,75		24,3375	48,675
8a	80				65			145		7,25	14,5
8b	15				105			120		6	12

	plastic costs			chemicals				
Plot	m2	costs		m2	costs		Plot	Total costs
1a	100	40		0	0		1a	54,675
1b	0	0		0	0		1b	6,5
2a	0	0		0	0		2a	43,675
2b	100	40		0	0		2b	62,175
3a	0	0		100	0,3		3a	12,3
3b	0	0		0	0		3b	49,175
4a	0	0		0	0		4a	7
4b	0	0		100	0,3		4b	20,3
5a	100	40		0	0		5a	66,175
5b	0	0		0	0		5b	15
6a	0	0		0	0		6a	62,175
6b	100	40		0	0		6b	66,675
7a	0	0		100	0,3		7a	20,3
7b	0	0		0	0		7b	48,675
8a	0	0		0	0		8a	14,5
8b	0	0		100	0,3		8b	12,3

Table 11. Costs methods

L. Influence on environment

		general method	sequel me	Total				
Plot							manual	0
1a	p + cb	4	2	6			plastic	4
1b	m + cb	0	2	2			cardboard	2
2a	cb + cb	2	0	2			chemicals	10
2b	p + m	4	0	4				
3a	ch + cb	10	2	12				
3b	cb + m	2	0	2				
4a	m + cb	0	2	2				
4b	ch + m	10	0	10				
5a	p + m	4	0	4				
5b	m + m	0	0	0				
6a	cb + m	2	0	2				
6b	p + cb	4	2	6				
7a	ch + m	10	0	10				
7b	cb + cb	2	0	2				
8a	m + m	0	0	0				
8b	ch + cb	10	2	12				

Table 12. Environment influence

M. Totals

	Development of the trees			Development of the Weeds		Labour preperation and maintaining	Costs	Environme
Plot nr.	Height (cm)	Diam. (mm)	Leaves (N)	Height (cm)	Cover (%)	hours (in min.)	in $	
1a	-4	15	84	11	50	98,75	54,675	6
1b	3,5	0,5	108	6,8	80	0	6,5	2
2a	7	3	-10	3,3	5	388,75	43,675	2
2b	-15	5	214	5,7	90	173,75	62,175	4
3a	31	2	-9	2,6	100	15	12,3	12
3b	10	8	70	2,8	140	443,75	49,175	2
4a	3	11	27	7,2	85	0	7	2
4b	-1	1	-22	1	5	95	20,3	10
5a	36	-3,5	-12	4,49	100	213,75	66,175	4
5b	114	9,5	55	3,4	55	80	15	0
6a	-6	-9,5	75	4,6	75	573,75	62,175	2
6b	39	6	40	5,5	70	218,75	66,675	6
7a	14	8,5	1	4,3	125	95	20,3	10
7b	5	-0,5	-10	7,5	0	438,75	48,675	2
8a	-54	15,7	-43	3	65	80	14,5	0
8b	-9,5	10	10	0	0	15	12,3	12
groups of	10,8125	5,10625	36,125	4,574375	65,3125	183,125	35,1	4,75
1	0 - 10	0 - 4,9	0 - 35	0 - 4,9	0 - 65	0 - 179,9	0 - 35	0 - 5
2	11 -20	5 - 9,9	36 - 70	5 - 9,9	66 - 130	180 - 359,9	36 - 70	6 - 10
3	21 - 30	10 - 14,9	71 - 105	10 - 14,9	131 - 194	360 - 539,9	71 - 106	11 - 15
4	31 - 40	15 - 19,5	106 - 140			540 - 719,9		
5	41 - 50		141 - 175					
6	51 - 60		176 - 210					
7	61 - 70		211 - 245					
8	71 - 80							
9	81 - 90							
10	91 - 100							
11	101 - 110							
12	111 - 120							

Table 13. Total methods

N. Tree and weeds marks

	Development of the trees			Score trees	Development of the Weeds		Score weeds	Labour preperation and maintaini	Costs	Environmental influence
Plot nr.	Height	Diam.	Leaves		Height	Cover				
1a	13	1	5	6	3	1	2	1	2	2
1b	12	4	4	7	2	2	2	1	1	1
2a	12	4	8	8	1	1	1	3	2	1
2b	13	3	1	6	2	2	2	1	2	1
3a	9	4	8	7	1	2	1,5	1	1	3
3b	12	3	6	7	1	3	2	3	2	1
4a	12	2	7	7	2	2	2	1	1	1
4b	13	4	8	8	1	1	1	1	1	2
5a	9	5	8	7	1	2	1,5	2	2	1
5b	1	3	6	3	1	1	1	1	1	1
6a	13	5	5	8	1	2	1,5	4	2	1
6b	9	3	6	6	2	2	2	2	2	2
7a	11	3	7	7	1	2	1,5	1	1	2
7b	12	5	8	8	2	1	1,5	3	2	1
8a	13	1	8	7	1	1	1	1	1	1
8b	13	2	7	7	1	1	1	1	1	3

Table 14. Marks per indicator

O. Total score

	Total score
Plot nr.	
1a	13
1b	12
2a	15
2b	12
3a	14
3b	15
4a	12
4b	13
5a	14
5b	7
6a	16
6b	14
7a	13
7b	16
8a	11
8b	13

Table 15.Total marks plots

5b	7
8a	11
2b	12
1b	12
4a	12
1a	13
7a	13
8b	13
4b	13
6b	14
3a	14
5a	14
3b	15
2a	15
6a	16
7b	16

Table 16. Marks in order

1a + 6b	27
1b + 4a	24
2a + 7b	31
2b + 5a	26
3a + 8b	27
3b + 6b	29
4b + 7a	26
5b + 8a	18

Table 17. Total marks summed up

5b + 8a	18	m + m
1b + 4a	24	m + cb
2b + 5a	26	p + m
4b + 7a	26	ch + m
1a + 6b	27	p+ cb
3a + 8b	27	ch + cb
3b + 6b	29	cb + m
2a + 7b	31	cb + cb

Table 18. Marks in order and methods

P. Pictures grassed areas

1. After removing plastic

2. 4 weeks later

3. After spraying chemicals