THE EFFECT OF SOIL PROPERTIES ON THE SUCCESS OF MINE REHABILITATION

IN TABALONG SOUTH KALIMANTAN INDONESIA.

Sjoerdsma, Xander
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van hall larenstein university of applied sciences

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In Tabalong South Kalimantan, Indonesia

Author: X. Sjoerdsma
Student number: 921115001
E- mail address: Xander.sjoerdsma@hvhl.nl

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Internal Supervisor: Dr ir P. J. van der Meer
First External Supervisor: D. Triwibowo
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Abstract

Tropical forest in Tabalong district South Kalimantan are under threat by external factors; one of the main threats to the forests are coal mining operations. Coal mining operations are temporary land use activities because of this mine rehabilitation is an important part of the mine development process.
Mine rehabilitation is designed to restore the landscape to a state where the natural processes such as water balance, soil and ecological processes have been restarted. The restoration of these natural processes is necessary for the development and natural regeneration of a new ecosystem. To help the restoration of the natural processes its necessary to have an understanding of what happens after the rehabilitation process has been started. The focus of this report is to find out how coal mine Rehabilitation on the Tutupan site in the Tabalong district is affected by the following factors; tree species, soil type and year of Rehabilitation. The study site for this research is located on the In Pit Backfill area on the Tutupan site. The following methods were used to help understand how tree species, soil type and year of rehabilitation influence the success of mine rehabilitation; A forest inventory and soil analysis of the top 30 cm of the soil.

The investigated rehabilitation areas have a low amount of available macronutrients, especially N, P and organic carbon. The investigated rehabilitation areas also have a low soil pH and a high potential soil acidity which can cause toxicity for plants. Due to the low soil fertility and acidic nature of the ex-mining site, the tree species used for mine rehabilitation are usually pioneer species. On the In Pit Backfill, 21 tree species were used to rehabilitated the area. The most commonly used species were *Acacia auriculiformis* , *Paraserianthes falcataria* , *Cassia siamea* , *Sesbania grandiflora* and *Leucaena glauca*. However, the dominant species encountered during the forest inventory were *Enterolobium cyclocarpum, Acacia auriculiformis, Mallotus paniculatus, Leucaena glauca and Cassia siamea.* In conclusion, not all of the planted tree species were encountered during the inventory conducted in 2016. From the encountered tree species the following species are the most successful on the In Pit Backfill area; *Enterolobium cyclocarpum*, *Acacia auriculiformis*, *Mallotus paniculatus, Leucaena glauca and Cassia siamea*. The soil conditions and year of planting were taken into account in the determination which species were the most successful.

Further research is necessary to increase the success of the rehabilitation activities. Some research topics that could be investigated are; How to increase the decomposition rate of the organic waste and how to optimise the soil conditions for the microorganisms. It could also be interesting to see what the effect of soil compaction has on the growth and survival rate of the seedlings.

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List of Abbreviations

Al = Aluminium

Avg = Average

C = Carbon

Cm = Centimetre

cmol/kg = centimoles of charge per kilogram of soil

C/N ratio = Carbon to Nitrogen ratio

dS/m = Desi Siemens per meter

EC = Electrical conductivity

Fe = Iron

H2SO4 = sulphuric acid

H2O = Water

H3PO4 = Phosphoric acid

Ha = Hectare

HCL = Hydrochloric acid

IPBF = In Pit Backfill

K2Cr2O7 = Potassium dichromate

KCL = potassium chloride

Mcf = Moisture content factor

Mc = Moisture content

N = Nitrogen

NaOH = Sodium hydroxide

N/Ha = Number per hectare

NH4F = Ammonium fluoride

P2O5 = Phosphorus pentoxide

P = Phosphorus

pH = a numeric scale used to specify the acidity or basicity of an aqueous solution.

PPM = Parts Per Million

R^2 = R square / coefficient of determination

SOM = Soil Organic Matter

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1 Introduction

1.1 Mine Rehabilitation in forested areas

In tropical forest areas around the world a rapid loss and degradation of the forests takes place. Intense land use practices such as logging, conversion of natural forests into plantations and mining are some of the main causes of the loss and degradation of tropical forests (Marjokorpi & Otsamo, 2006).
Coal mining threatens 11.9 million hectares of forest around the world (Olden & Neumann, 2016). In the period 2001- 2013 millions of hectares of forest were lost due to the mining sector. Table 1 gives an overview of the loss in tree cover caused by the mining sector and the forestry sector on a national scale of some of the key mineral exporters around the world.

Table 1 Country Overview: Key mineral exports, contribution of forest and mining sector to GDP and tree cover loss 2001–13 (Chatham House , 2015)

Country	**Key mineral export commodities (those linked to significant deforestation are in bold)**[a]	**Forestry, % of GDP, 2011**[b]	**Mining, % of GDP, 2012**[c]	**Tree cover loss, million ha (and % of total national tree cover) 2001–13**[d]
Indonesia	**Tin, nickel, gold, copper, aluminium (bauxite)**	1.7	1.7	17 (10%)
Brazil	Iron ore	1.1	2.9	36 (7%)
DRC	**Copper, gold, tin, tantalum, tungsten,** cobalt	0.6	18	7 (3%)
Cameroon	Aluminium (bauxite), **gold**	2.8	0.2	0.5 (2%)
Ghana	**Gold**, manganese	3.5	13	0.5 (7%)
Guyana	Aluminium (bauxite), **gold**	4.1	22	0.1 (0.5%)
Liberia	Iron ore, **gold**	15.2	29	0.6 (7%)
Peru	**Gold, tin, copper,** zinc, lead, silver	0.8	13	2 (2%)

Even though the total forest area affected by mining may be small on a national level, the local impact on the environment can be significant. Because of the impact on the local environment of mines, there is growing pressure from local groups and communities to start with mine rehabilitation before and after the closure of the mine (Sigurd, 2013). To help mitigate the effect of mining activities on the local environment mining operations should be conducted with an understanding and respect for the local environment (Policy and Corporate Services Division Environmental Assessment Branch, 2009).

One of the measures that can be taken to limit the effects of mining on the environment is by making mine rehabilitation an integral part of the mine development process (Knoot & Waal, 2009).
Mine rehabilitation is the process of restoring the area to its natural state. Mine rehabilitation is successful if the natural processes such as water balance, soil and ecological processes are restored (Policy and Corporate Services Division Environmental Assessment Branch, 2009). The soil processes are necessary for the development and growth of the trees (Dighton & Krumins, 2014). The supporting capacity of the topsoil for plant growth is usually low in post-mining areas (Fitrah, Djati, Leksono, & Priatmadi, 2015).

Mine rehabilitation can be used to facilitate, accelerate and direct natural successional processes so as to increase biological productivity, reduce rates of soil erosion, increase soil fertility including soil organic matter (International Tropical Timber Organization, 2002). The use of environmental management plans is encouraged to increase the chances of the mine rehabilitation activities being successful (Policy and Corporate Services Division Environmental Assessment Branch, 2009).
The environmental management plan contains the following aspects; the rehabilitation objective, A site description, design of how the area needs to look after the rehabilitation has been conducted, A plan for

erosion control and topsoil treatment and a revegetation planning. The revegetation planning includes species selection, seed collection and planting of the seedlings (Minerals Council of Australia, 1998).

Another use of mine rehabilitation can be to establish improved pastures for livestock or areas suitable for forestry activities. In the Bowen Basin Australia for example, the goal of mine Rehabilitation is both improved pastures and the establishment of native ecosystems on former mine sites (Bell, 2001).

One of the most commonly used methods of mine rehabilitation is the "in pit backfill" (IPBF) method for pit closure.

What is IPBF? Overburden and waste rock material is used to close the old mine pit after all the coal has been mined (figure 1).

The old pit is closed by piling all the overburden and waste rock material from the new pit on top of each other; this creates a hill and dale topography with up to 15-20 m difference in height. The overburden and waste rock material are covered with a thin layer of topsoil (Chadwick, Highton, & Lindman, 1987).

Figure 1 Mine closure with the In Pitt Backfill method (World Coal Institute, 2005)

The requirements of mine rehabilitation are different for each country but in recent years many countries have developed and adopted laws, national programmes and specific policies for environmental protection. Most laws applicable to the mining industry seek to control land management, protect resources and regulate land rehabilitation and landscape restoration (Chadwick, Highton, & Lindman, 1987). In Indonesia, it is by law required to have a mine closure plan (PWC, 2011).

Trends in mine rehabilitation over the last ten years.

Over the last 20 years, mining companies throughout Australia have adopted the objective to establish a sustainable native ecosystem after mine closure (Nichols, Grant, & Bell, 2005). To help implement this new objective, a framework for the development of sustainable mine rehabilitation policies has been developed by the industry and other organisations (Department of Industry Tourism and Resources, 2006).

1.2 Mining and mine rehabilitation in Indonesia

In Indonesia a rapid loss and degradation of the forests takes place. About 1.3-2 million hectares of forests are annually lost as a result of intensive land use practices (Marjokorpi & Otsamo, 2006). One such land use that threatens the tropical forests of Indonesia is mining. Over the last decade, the mining and forestry sector was responsible for ten percent of the deforestation taking place in Indonesia (Chatham House , 2015). Indonesia has vast deposits of coal; the estimated amount is 57 trillion tonne (Fatah, 2008). The production of coal has over the course of a decade increased from 60 million tonnes in 2000 to 304 million tonnes in 2012 (Stiles, 2014). Today Indonesia is the world's largest exporter of coal (Sigurd, 2013). To meet the demand for coal large forest areas have been opened to exploration expeditions. After the coal has been found the forests are perforated by mining activity (Sigurd, 2013). The provinces with the largest coal deposits in Indonesia are; East Kalimantan, South Sumatra and South Kalimantan. The coal in these provinces is located some meters below the surface (Sigurd, 2013).

The most commonly used mining method in Indonesia is opencast mining. Opencast mining involves the removal of the overburden of soil and rock. Once the coal seam is exposed, it is drilled, fractured and systematically mined in strips (World Coal Institute, 2005).

Without rehabilitation this mining method contributes to; land degradation and forest cover destruction, floods and health problems (Fatah, 2008). To combat these problems mining companies have under the current Indonesian laws a mandatory requirement to conduct rehabilitation operations. The laws that affect the mining industry in Indonesia and their requirements are briefly explained below.

According to the forestry law, the utilisation of forest areas for non-forestry activities is permitted in both production forest areas and protected forest areas on obtaining a borrow and use permit from the minister of forestry (PWC, 2011). In protected forest areas only underground mining is allowed, subject to some conditions. On the other hand in forest areas designated as production forest opencast mining and underground mining is permitted. Underground mining can be divided into two methods, room-and-pillar and longwall mining. In room-and-pillar mining, coal deposits are mined by cutting a network of 'rooms' into the coal seam and leaving behind 'pillars' of coal to support the roof of the mine. Longwall mining involves the full extraction of coal from a section of the seam or 'face' using mechanical shearers (World Coal Institute, 2005). Mining operations are prohibited in forests areas designated as conservation forest. Use of forest areas for mining needs to be compensated this can be done by either land compensation or compensation payments (PWC, 2011).

Under the current mining law of Indonesia mining can only be carried out in areas designated by the central government as open for mining (PWC, 2011). Mining licenses need to be obtained to mine in these areas. The mining law also states that a holder of an exploration license must include a reclamation plan in its exploration work plan and budget (PWC, 2011). A holder of an operation production license must prepare a five-year reclamation plan and a post-mining plan (PWC, 2011).
A post-mining plan needs to contain the following aspects; A Monitoring program to assess the effectiveness of the reclamation measures and to identify any corrective action that may be needed.
A program if needed for long-term care and maintenance after mine closure, such as treatment of mine discharge water (Fraser Institute, 2012).

The environmental laws of Indonesia state that mining companies that have an environmental or social impact should obtain and maintain an environmental impact planning document (PWC, 2011). The environmental impact planning document consists of an environmental impact assessment, an environmental management plan and a monitoring plan (PWC, 2011).

Both the mining and environmental law in conjunction require that mining companies think about and conduct mine rehabilitation to reduce the environmental impact of the mining operations. The fact that both laws have a rehabilitation aspect means that it has become more important to companies to conduct and monitor the Rehabilitation effort (PWC, 2011).

What happens in Indonesia in mine rehabilitation?
Most coal mining companies, particularly the small and medium-sized ones, lack knowledge about the best-practices for mine Rehabilitation, even though there are some good examples of successful mine Rehabilitation in East Kalimantan. The majority of these mining companies lack the technical capacity to conduct quality post-mining rehabilitation (GPFLR Learning Network, 2012).

The lack of knowledge by the mining companies is exacerbated by the fact that the district level government. Which responsible for advising these companies on mine rehabilitation and the regulations that describe the standards for mine rehabilitation (GPFLR Learning Network, 2012). Is sometimes even less well-informed than the companies themselves, about the environmental regulations and how to apply the best mine-site rehabilitation methods in the field. To combat these problems NGO's such as Tropenbos International Indonesia work together with the Environmental Leadership & Training Initiative (ELTI) and the Bogor Agricultural University (IPB) to provide training about mine site Rehabilitation to mining companies and government officials (Environmental Leadership & Training Initiative , 2012).

1.3 Mine Rehabilitation in Kalimantan

The landscape of Kalimantan is dominated by its coal production. An enormous area, corresponding to the surface area of Belgium, has been allocated to mining concessions, according to Jatam's report Deadly Coal (Sigurd, 2013). Organisations active in the area point to the risk that the mining companies contribute to more deforestation (Sigurd, 2013). Currently, disrupted land in South Kalimantan has reached 33,726.22 hectares, with 18,700.36 hectares reclaimed and 9,047 hectares re-vegetated (Sumedi, 2013).

In South Kalimantan, there are a three large authorised coal mining contractors, PT. Adaro Indonesia, PD Baramarta and PT. Arutmin Indonesia. There are also many small-scale coal miners without licenses. Almost every district of South Kalimantan Province contains several illegal coal mines, and their numbers are growing (Fatah, 2008).
In 1997, 157 individuals or businesses of this type were recorded, rising to 445 in 2000 and 842 in 2004 (Fatah, 2008). Although the coal mining business seems to be profitable for both individuals and businesses, the benefits of this activity to the region are unclear (Fatah, 2008). The coal mines have a significant impact on the forests found in the province. According to Greenpeace analysis of mining concession and land cover maps approximately 14% of the total forested area in South Kalimantan is located in coal mining concessions (Greenpeace Southeast Asia- Indonesia, 2014). Because of this mine rehabilitation should be one of the highest priorities in combating environmental problems.

For this study, we focus on one of the large coal mining companies Pt. Adaro Indonesia. PT Adaro Indonesia exploits the largest single-site coal mine in the southern hemisphere. The primary mining location is at Tabalong district South Kalimantan, Indonesia. Pt. Adaro operates under a first-generation CCA (coal co-operation agreement) with the Indonesian Government this agreement is valid until 2022 (Pt. Adaro Indonesia, 2014).

1.4 Problem analysis

The natural regeneration of forests on mined sites is extremely slow (Peterson & Heemskerk, 2001). To help this slow regeneration of forests mine rehabilitation activities take place. The goal of these activities is to restore the natural process on former mining sites. The rehabilitation of opencast mining sites is a challenge. Especially the development of dump material into a biologically active, sustainable soil is a challenge (Dunger & Wanner, 2001). The development of the soil is important because former mining areas usually have a low amount of macronutrients, especially N, P, K, Na, and Ca, as well as a high level of acidity (Fitrah, Djati, Leksono, & Priatmadi, 2015).

The rehabilitation process on the study site took place over a period of multiple years. After finishing the planting stage, no follow-up monitoring took place in the rehabilitation area. Because of this; there is no information available about what happened to the planted trees or the development of the soil.

Without this information, it is not possible to refine the rehabilitation process.
Now the Adaro has asked for research about the conditions of the trees and soil on the rehabilitation sites to help their rehabilitation team with future projects.

1.5 Objective and Research Question

The overall objective of this study is to determine how mine Rehabilitation activities in tropical forest areas in Indonesia can be improved.

More specifically the success rate of mine Rehabilitation on the Tutupan site in South Kalimantan is determined, taking into account the tree species, soil type, and year of rehabilitation.

The following research questions were addressed:

- What species are used for mine rehabilitation on the In Pit Backfill and what is the density of these species?
- What are the soil conditions on the rehabilitation site In Pit Backfill?
- How is seedling performance affected by rehabilitation year and soil conditions?
- Which of the used tree species is most successful for mine rehabilitation at the Tutupan site?

1.6 Content of this report.

The next chapter, methodology, describes the used research methods and analyses.
The following chapters show the results, discussion, conclusion and recommendations.
In the discussion, the results are explained, and the results are compared with literature findings. From the results and the discussion, conclusions are drawn, and recommendations are made for future research.

2 Methodology

2.1 The study site

The study site is located on the Tutupan pit, more precisely on the In Pitt Backfill. For this research inventory plots were established in the areas that were rehabilitated in 2010, 2011 and 2012. Figure 1 shows the different rehabilitation areas on the Tutupan and Wara pits. It also shows the study location on the IPBF. The size of the in 2010, 2011 and 2012 rehabilitated areas are;

- 2010: 22.49 Ha
- 2011: 34.66 Ha
- 2012: 33.53 Ha

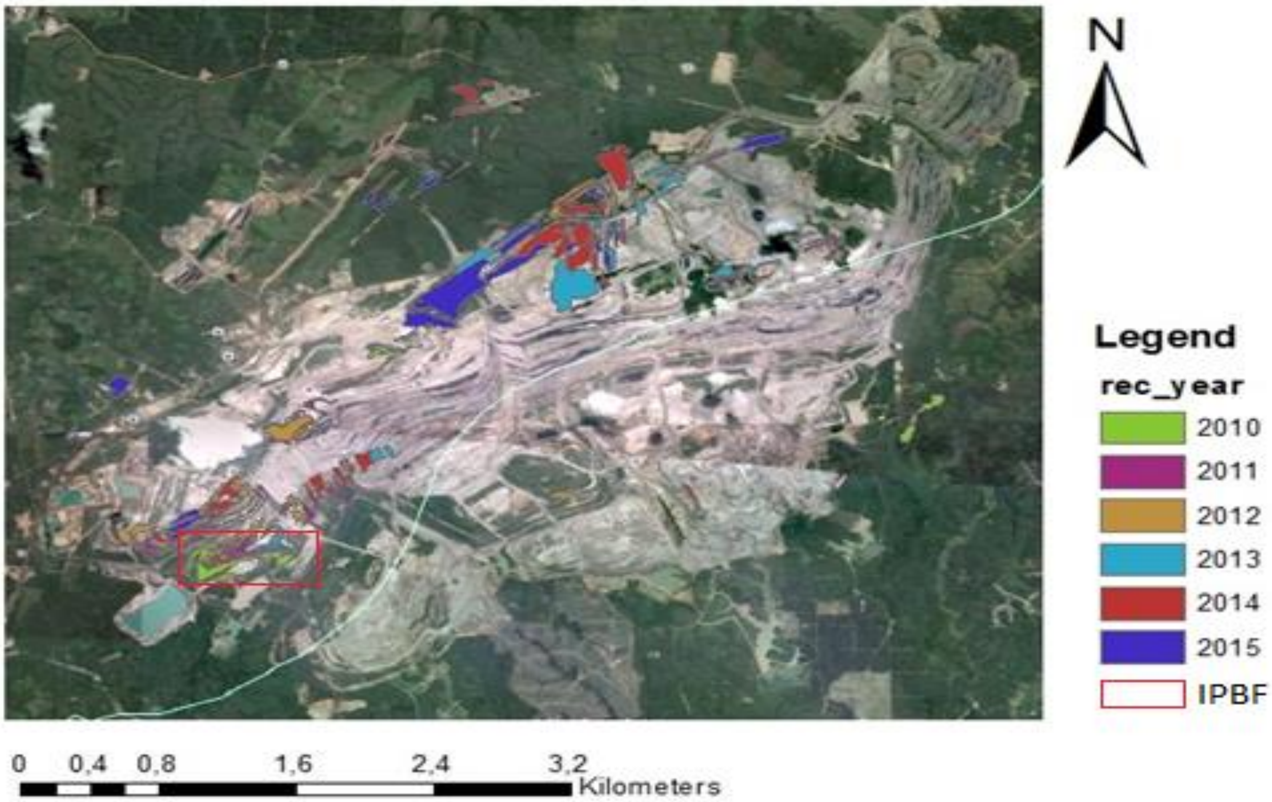

Figure 2 Location of the Rehabilitation areas on the Tutupan and Wara Pits.

2.1.1 Mine rehabilitation method used by Pt. Adaro

The first stage of mine rehabilitation is the planting of legumes. The legumes are used as a temporary soil cover to prevent erosion. The method used to plant these legumes is hydroseeding (Pt. Adaro Indonesia, 2014). The next step is to plant trees as a method to prevent soil erosion over longer periods of time. The trees that are initially planted are all pioneer species. The hope is that natural regeneration takes place in the Rehabilitation areas.

Table 2 gives an overview of the land cleared for mining activities in 2012 and 2013 for each of the mining pits. Pt Adaro aims to reclaim 198 hectares of mined land per year. Table 2 shows that this goal has been accomplished in 2012 and 2013.

Table 2 Table of Total Cleared, Managed, Used and Rehabilitated Land in 2012 and 2013 (Pt. Adaro Indonesia, 2014)

Area	Total land that was cleared/expanded to be managed / used (in hectares)	Total rehabilitated land (in hectares)	Total land that was cleared/expanded to be managed / used (in hectares)	Total rehabilitated land (in hectares)
Wara	414,7	15,7	257,4	11,4
Paringin	86,4	11,6	234,5	45,0
Tutupan	1.115,3	199,8	384,4	211,6
Total	1.616,5	227,1	876,3	268,0

2.2 Fieldwork

A forest inventory was conducted to find out which tree species are growing on the rehabilitation site and what the basic stand characteristics of the forest are. See Appendix 1 for the field form. The following methodology was used;

- A plot of 20x50 meters was established in the target vegetation.(See Figure 2.)
- Inside this plot, all trees with a diameter of 2 cm or larger were identified, and the diameter was measured as well as the log height until the crown is estimated.
- In each target area, the goal was to establish Five inventory plots of 0.1 Ha each.

The tree data was analysed in the following way;

- The collected data was entered into a database
- Averages per species were calculated for the density and height

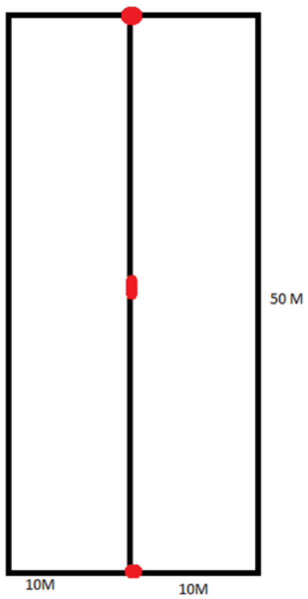

Figure 3 Inventory plot and sample locations

2.3 Soil Surveys.

- To get an insight into the soil conditions of the Rehabilitation site soil samples were taken on three locations within the inventory plots see figure 2.
- The samples are of the first 30 cm of the soil.
- These samples are used for the soil analysis.
- See Appendix 13 for the location of where the samples were taken

All soil samples were air-dried, crushed, and sieved (2 mm) before determining the following parameters.

Soil moisture content.
The soil sample was weight before it is placed in the oven, and then again after it was removed from the oven. The weight of the sample was used to calculate the soil moisture content.

pH in H2O.
The pH determinates with the help of a combined meter (MI805 martini instruments).
This meter was used to determine the pH and Electrical conductivity in the sample.

Potential Acidity of the soil.
The pH was determinate with the help of a combined meter (MI805 martini instruments).
This meter was used to determine the pH in KCL. The pH gives an indication of the potential acidity of the soil.

Available phosphorus.
With a spectrophotometer, the abs of the samples are determined. The abs value was used to calculate the available phosphorus.

Amount of Organic carbon in the topsoil (0-15 cm)
The organic carbon content of the topsoil was determined with the help of titration. The sample was prepared with $K_2Cr_2O_7$ and H_2SO_4. There was also a Blanco sample for comparison with the samples that contain the soil sample.

Soil organic matter in the topsoil (0-15 cm).
The organic carbon content was used to calculate the amount of Soil organic matter in the topsoil.

The total amount of nitrogen in the topsoil
The total amount of nitrogen was determined by distillation and titration. The samples are prepared with Se reagent, H_2SO_4, NaOH 40%. There was also a Blanco sample for comparison with the samples that contain the soil sample. The titration sample contains boric acid 2% and four drops of indicator (MMBCG) and the distillate.

Decomposition rate
Carbon to nitrogen ratio gives an indication of the decomposition rate of the organic waste.
For a more detailed description of the steps taken during each test see Appendix 2.

2.4 Data analysis

SPSS was used to conduct a multiple stepwise regression analysis has been conducted to investigate how soil characteristics and year of planting did affect height growth.
The confidence limits for this analysis was set at 95%.

To help structure and select the data necessary for the different statistical tests and calculations Microsoft access is used. The calculations are done in Microsoft Excel.
The calculation used for the density is; N found/hectare investigated
The calculation of the relative average growth rate is; (Average Height – plant height)/ years (Vogt, Watkins, Mincey, Patterson, & Fisher, 2015)

3 Results

3.1 R1 What species were used for mine Rehabilitation and what is the density in which these species occur.

During the initial planting activities, 21 tree species were used to rehabilitated the study area. The most commonly used species were *Acacia auriculiformis* (30%), *Paraserianthes falcataria* (12%), *Cassia siamea* (11%), *Sesbania grandiflora* (11%), *Leucaena glauca* (10%). From the 21 species that were used during the initial rehabilitation activities in 2010, 2011 and 2012 (Appendix 3). Only 12 species were encountered during the inventory in 2016. Table 3 shows the species found during the inventory. From one of the species, only the local name was known. This species is marked with – on the table.

Table 3 Found trees during the forest inventory.

Tree species	scientific name
Akasia	*Acacia auriculiformis*
Balik angin	*Mallotus paniculatus*
gmelina	*Gmelina arborea*
Johar	*Cassia siamea*
Kaliandra	*Calliandra callothyrus*
Lamtoro	*Leucaena glauca*
Ponjaea	-
Sengon	*Paraserianthes falcataria*
Sengon buto	*Enterolobium cyclocarpum*
Trembesi	*Samanea saman*
Turi	*Sesbania grandiflora*
Waru	*Hibiscus macrophyllus*

Appendix 3 shows that most of the initially planted tree species were not found during the forest inventory. Because of this the list of species studied during this research is reduced to the species found during the inventory see Table 3.

From the 12 species shown in Table 3, *ponjaea* is the only species that was not initially planted.
Of the planted species *Enterolobium cyclocarpum* is the most frequently occurring species see Appendix 4 for an overview of all the basic stand characterstics of all the species encountered during the inventory .

Of the 12 species found, five species occur in each of the three rehabilitation areas *Enterolobium cyclocarpum, Cassia siamea, Calliandra callothyrus, Samanea saman and Leucaena glauca*.

Of these five species, only *Enterolobium cyclocarpum* and *Cassia siamea* have ten or more trees in each rehabilitation year.

Three of the species found, occur only in one of the rehabilitation years *ponjaea* (2010), *Paraserianthes falcataria* (2010) and *Gmelina arborea* (2012).
Of the species shown in Table 3 *ponjaea* is the only species that was not originally planted on any of the Rehabilitation areas. The *ponjaea* trees found in the 2010 rehabilitation area occurs here because of natural regeneration of trees from surrounding areas.

Other species that were found during the inventory that ware not planted in that specific rehabilitation year were *Hibiscus macrophyllus* in the 2011 rehabilitation area and *Sesbania grandiflora* in 2012 rehabilitation area. These species were planted in other rehabilitation areas, and natural regeneration caused them spread to new areas. See Appendix 3 and 4 for more detailed information about the species planted in each of the rehabilitation areas.

What is the density in which the trees species were found?

For each of the species found during the inventory, the density per hectare has been calculated.

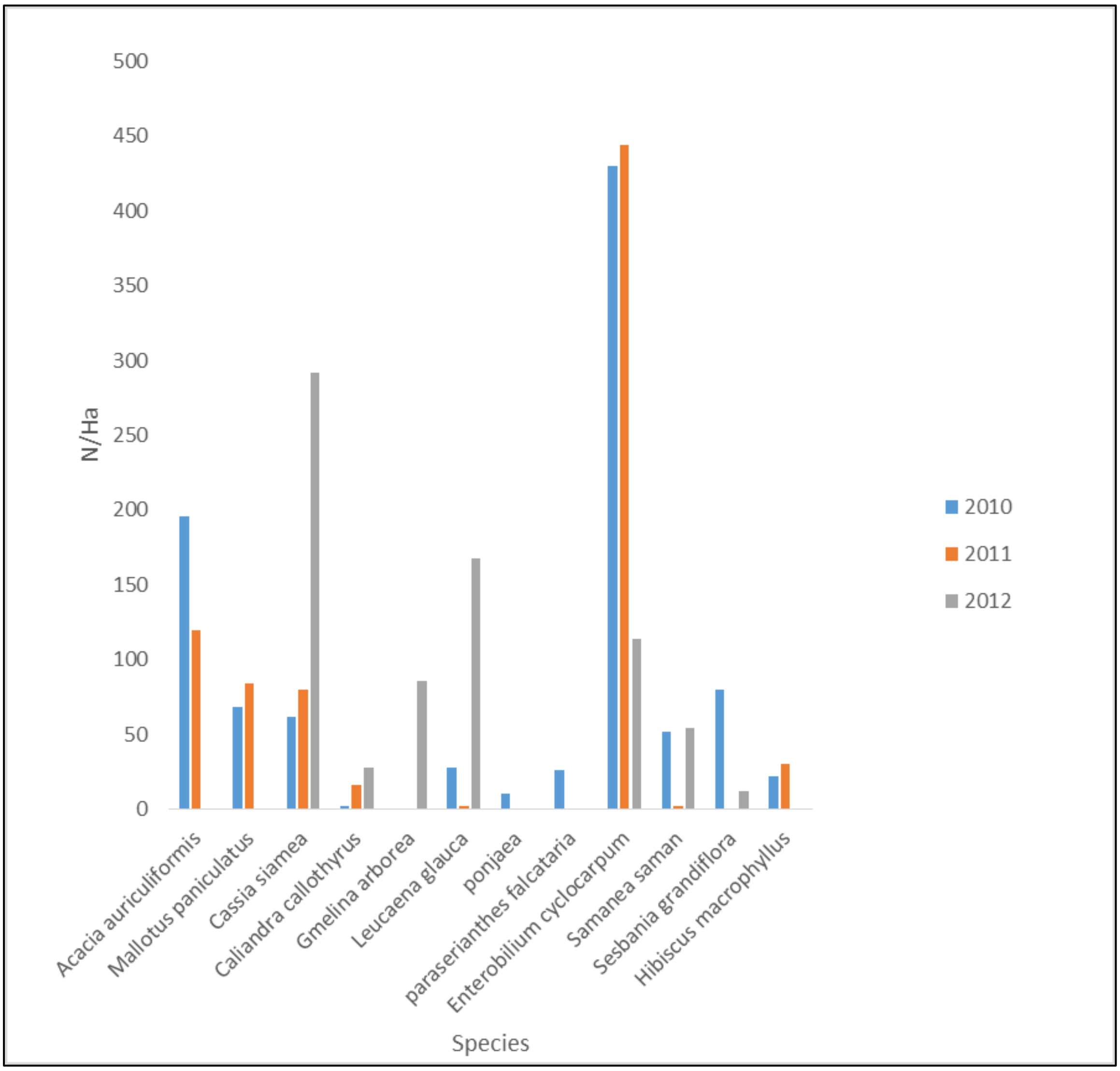

Figure 4 Shows the density in which species were found during the inventory in 2016 on the IPBF.

Enterolobium cyclocarpum dominate the tree composition in the 2010 rehabilitation area. *Enterolobium cyclocarpum, Acacia auriculiformis, Mallotus paniculatus and Sesbania grandiflora* are the most commonly found tree species in the 2010 rehabilitation area. *Ponjaea* was not originally planted in 2010 but was still found during the inventory in 2016. The fact that *ponjaea* is found is possible because of natural regeneration of trees from surrounding areas.

The current tree composition in the 2011 rehabilitation area is not dominated by one species. *Enterolobium cyclocarpum*, *Mallotus paniculatus*, *Acacia auriculiformis* and *Cassia siamea* are the species that occur in the highest density. *Hibiscus macrophyllus* was not originally planted in 2011 but was still found during the inventory in 2016. The fact that *Hibiscus macrophyllus* is found is possible because of natural regeneration of trees from surrounding areas.

The current tree composition in the 2012 Rehabilitation area is dominated by one species *Cassia siamea*. *Enterolobium cyclocarpum*, *Gmelina arborea*, *Samanea saman* and *Leucaena glauca* are the most commonly found species in 2012 rehabilitation year.

3.2 R2 What are the soil conditions on the Rehabilitation site (IPBF)?

Table 4 gives an overview of the investigated soil characteristics per reclamation year. The investigated areas were reclaimed in 2010, 2011, 2012. For the precise location of where the soil samples were taken see Appendix 5. A remark about the available Phosphorus in the 2012 reclamation year. The average from plot 14 was only taken from two of the three sample locations because of a significant difference in the numbers found in samples from the third location. For more detailed information about the individual samples collected see Appendix 6 and 7.

Table 4 Overview of the soil characteristics per rehabilitation year.

Rehabilitation year	Average pH in H2O	Average EC (dS/m)	Average pH in KCL	Average Moister content (%)	Average C-organic (%)	Average organic matter (%)	Average available Phosphorus	Average Total N (%)	Average C/N
2010	5,4	0,047	4,9	2,3	1,303	2,242	2,17	0,028	87,047
2011	5,9	0,071	5,2	2,1	1,155	1,986	3,93	0,022	118,113
2012	5,4	0,164	4,8	3,6	1,583	2,723	3,17	0,030	155,291

The results of the soil analysis show the following.

- The pH found in the different rehabilitation years was on average acidic 5.9- 5.4 (see Table 4). The 2010 and 2012 rehabilitation areas have an average pH of 5.4; this means that the soil is acidic. The 2011 rehabilitation area has an average pH of 5.9; this means that the soil is slightly acidic.
- The potential soil acidity of the in the different rehabilitation years was on average acidic with a pH of 5.2- 4.8 (see Table 4). This pH level means that the soils a high potential to become acidic.
- The soil moisture content shows a large variety it ranges from 2.1% up to 3.6%. On average, the soil moisture is on the low side.
- The EC in the rehabilitations areas is < 1 this means that the salinity of the soil is very low.
- The Available P_2O_5 in the different rehabilitation areas ranges from 2.17 up to 3.93 PPM. The amount of available P_2O_5 is very low in the reclamation areas.
- The total amount of Nitrogen in the soil for all the rehabilitation years is < 0.1 which means that the amount is very low.
- The amount of organic carbon in the topsoil in the different rehabilitation areas ranges from 1.155 up to 1.583. The amount of organic carbon in the topsoil of the different rehabilitation years low is.
- The amount of soil organic matter in topsoil is on average low in all three rehabilitation years. The amount of soil organic matter varies between 1.986 % and 2.723%.
- C/N ratio is very high in each of the Rehabilitation years this means that there is a slow decomposition rate of the organic waste material.

For the precise criteria used, see Appendix 2.

3.3 R3 How was seedling performance affected by Rehabilitation year and soil conditions?

The estimated average height is used as an indication of seedling performance.

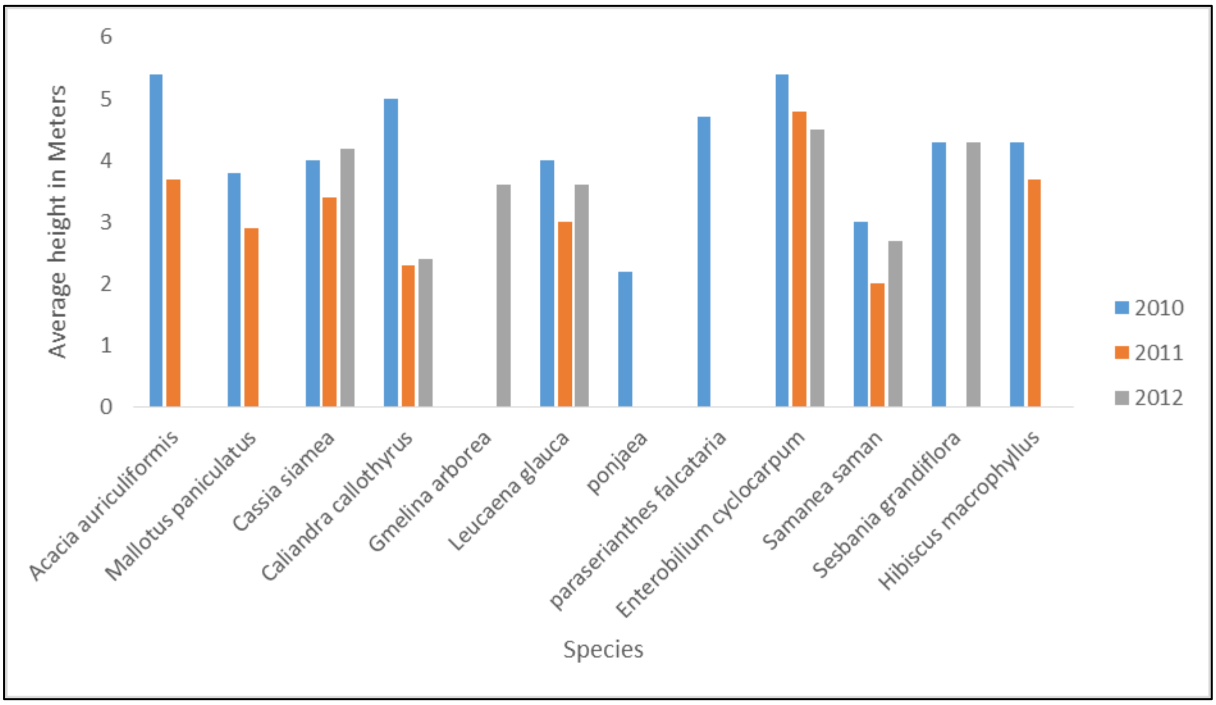

Figure 5 shows the average height of meter per reclamation year for each of the species found during the inventory.

Figure 5 shows that the average height of the *Cassia siamea* trees in the 2012 rehabilitation area is higher than in the other areas. The average height of *Sesbania grandiflora* is the same in 2010 and 2012. Figure 5 also shows that the average tree height is the lowest in the 2011 rehabilitation area.
A single factor ANOVA test was conducted to investigate if there was a significant difference between the average height of the five species that occur in each of the different rehabilitation years. The P value is 0.199 (Table 5) this means that there was no significant difference in height.

Table 5 Average height differences between different rehabilitation years

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3,628	2	1,814	1,85165	0,199132	3,885294
Within Groups	11,756	12	0,979667			
Total	15,384	14				

The estimated height of the trees found during the forest inventory is used in conjuncture with the collected soil data to determine which of the soil characteristics have the most significant influence on the performance of the trees.

The tree species used in the stepwise regression analysis have at least ten individual trees in a rehabilitation year. From all of these trees, the height is used as an indication of the performance of the seedlings.

The following factors have a significant influence on the differences in height between all the trees found in the rehabilitation areas; Year of planting, EC of the soil, C/N ratio and the soil moisture content see Table 6 .

These factors together can explain 8.9 percent of the differences in height between the different trees. Of these 8.9 percent, 7 percent is explained by the reclamation year in which the trees were found.

Table 6 summary of the factors that have a significant influence on the height of the trees.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	,265[a]	,070	,070	1,4778	,070	96,805	1	1278	,000	
2	,286[b]	,082	,081	1,4692	,012	16,067	1	1277	,000	
3	,293[c]	,086	,083	1,4668	,004	5,027	1	1276	,025	
4	,299[d]	,089	,087	1,4643	,004	5,367	1	1275	,021	1,285

a. Predictors: (Constant), Reclamtion_year

b. Predictors: (Constant), Reclamtion_year, average_EC

c. Predictors: (Constant), Reclamtion_year, average_EC, Average_C_N

d. Predictors: (Constant), Reclamtion_year, average_EC, Average_C_N, Average_smc

e. Dependent Variable: Height

In the next paragraph, a comparison between *Enterolobium cyclocarpum and Cassia siamea* is made to show that the soil characteristics that influence the height of the trees can differ between species and rehabilitation area.

3.3.1 Species comparison *Enterolobium cyclocarpum* versus *Cassia siamea*.

The soil characteristic that influences the difference in height between the individual trees of *Enterolobium cyclocarpum* and *Cassia siamea* the most is different for each of the Rehabilitation years and each of the species.

For *Enterolobium cyclocarpum* the soil characteristics that influences the difference in height the most are pH in 2010 rehabilitation area and potential soil acidity in 2011 rehabilitation area as shown in Table 7 and 8

The pH has an R^2 of 0.80. The pH explains 8 percent of the difference in height between the individual *Enterolobium cyclocarpum* trees planted in 2010
The potential soil acidity has an R^2 of 0.073. The potential soil acidity explains 7.3 percent of the differences in height between the individual *Enterolobium cyclocarpum* trees planted in 2011.

Table 7 Summary *Enterolobium cyclocarpum* planted in 2010

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,282[a]	,080	,075	1,8012	,080	18,471	1	213	,000

a. Predictors: (Constant), pH

b. Dependent Variable: Height

Table 8 Summary *Enterolobium cyclocarpum* planted in 2011

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,271[a]	,073	,069	1,3870	,073	17,413	1	220	,000

a. Predictors: (Constant), Pot_pH

b. Dependent Variable: Height

For *Cassia siamea* the soil characteristics that influence the difference in height the most are the C/N ratio in the 2011 rehabilitation area and the available phosphorus in the 2012 rehabilitation area as shown in Table 9 and 10.

The C/N ratio has an R^2 of 0.326. The C/N ratio explains 32.6 percent of the differences in height between the individual *Cassia siamea* trees encountered in 2011 rehabilitation area.

The available P_2O_5 has an R^2 of 0.047. The available P_2O_5 explains 4.7 percent of the differences in height between the individual *Cassia siamea* trees encountered in the 2012 rehabilitation area.

Table 9 Summary *Cassia siamea* planted in 2011

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	,571[a]	,326	,308	,7665	,326	18,342	1	38	,000

a. Predictors: (Constant), C_N

b. Dependent Variable: Height

Table 10 Summary *Cassia siamea* planted in 2012

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	,216[a]	,047	,040	,9414	,047	7,032	1	144	,009

a. Predictors: (Constant), Av_ P_2O_5

b. Dependent Variable: Height

This example shows that the limiting factors for growth differ per species and Rehabilitation year. However, at the same time, they are connected because the pH and potential acidity of the soil can influence the C/N ratio and the amount of available P.

4 Discussion

4.1 What species are used for mine rehabilitation on the (IPBF) and what is the density in which these species occur.

Due to the low soil fertility of ex-mining sites, the species used for mine rehabiliatation are usually the pioneer ones. Pionier species can survive under harsh conditions on ex- mining sites. The following pioneer species were successfully used in Sumatra; *Paraserianthes falcataria, Leucaena leucocephala, Sesbania grandiflora, and Acacia mangium* (Wiryono, 2013). Two of these species were utilized in the rehabilitation process on the Tutupan site; *Sesbania grandiflora* and *Paraserianthes falcataria*.

During the inventory 12 of the 21 used species were found. The species composition in the investigated areas was dominated by *Enterolobium cyclocarpum*, *Acacia auriculiformis*, *Mallotus paniculatus, Leucaena glauca and Cassia siamea.* One of the encountered species in the 2010 reclamation area *ponjaea* occurs here because of natural regeneration from trees that surround the 2010 reclamation areas. The *ponjaea* seeds can be dispersed by human activities, animals, or abiotic factors such as the wind. Another possibility is that the seeds were already present in the seedbank in the topsoil (Soendjoto, Dharmono, Mahrudin, Riefani, & Triwibowo, 2014).

With the exception of *Leucaena glauca* the dominant species found during the 2016 inventory differ from the dominant species encountered during an earlier study on the 2012 reclamation area. The dominant species found during the 2014 research were; *Cassia siamea*, *Enterolobium cyclocarpum*, *Gmelina arborea*, *Samanea saman* and *Leucaena glauca*.
The dominant species from the 2014 research are; *Leucaena glauca*, *Melastoma affine, E. dulcis, D. linearis* (Soendjoto, Dharmono, Mahrudin, Riefani, & Triwibowo, 2014).

The plant species and the number of individuals per hectare varied per rehabilitation area (figure 3). The fact that some the originally planted species were not encountered during the inventory can be caused by a number of factors (Soendjoto, Dharmono, Mahrudin, Riefani, & Triwibowo, 2014).

- The plant died or did not grow because it could not adapt to the conditions on the reclaimed land.
- The plant could be present outside the sampling plot but was not present in the sampling plot.
- The plant was recorded under another name or as an unknown species because there was no expert on taxonomy available.

4.2 The soil conditions on the rehabilitation site (IPBF)?

The soil in former mining areas is usually physical, chemical, and biologically degraded soil. The soil used for mine closure is composed of overburden and waste rock material which have a low amount of macronutrients, especially N, P, K, Na, and Ca, as well as a high level of acidity (Fitrah, Djati, Leksono, & Priatmadi, 2015).

One of the main preconditions for a successful biological rehabilitation is information about the soil (Chadwick, Highton, & Lindman, 1987). The reason for this is that the soil is a complex milieu of physical and biological entities that regulates the availability of nutrients for plant growth (Dighton & Krumins, 2014).

The investigated areas are no exception they show low amounts of macronutrients, especially N, P_2O_5 and organic carbon (Table 4) consequently the investigated areas have a high C/N ratio. The investigated areas also have a low soil pH and a high potential soil acidity, which can cause toxicity to plants (Wiryono, 2013). In a study conducted on the 2012 reclamation area in 2014, the area was described as marginal land. This study found that the 2012 reclamation area has a low pH (4.5), a very low P_2O_5 level (2.5 ppm), low N (0.14 %), C-organic (1.15 %) and a high Al saturation (0.68 cmol/kg) (Soendjoto, Dharmono, Mahrudin, Riefani, & Triwibowo, 2014). In comparison with this study from 2014 the following soil properties have increased; the pH, C-organic and the available phosphorus. The total Nitrogen has decreased as compared to the numbers found in 2014 (Table 4). The most likely explanation for this increase could be that the soil has had more time to develop and restart the soil processes.

In the next paragraphs, the relation between the plant growth and the soil conditions will be explained.

The pH is a good chemical indicator for the soil quality (Fitrah, Djati, Leksono, & Priatmadi, 2015). If the pH is less than 5.5, the P can react with Al and Fe. If this happens then, the P can become fixed and is no longer available to the plants. Maintaining soil pH between 6 and 7 will result in the highest level and most efficient use of available P (Busman, Lamb, Randall, Rehm, & Schmitt, 2009).
The average pH of the investigated areas was between 5.9 and 5.4 this is within the normal pH for ex-ming sites according to a study conducted by Burger and Zipper that says that the soil of old mining sites should be moderately acidic (pH 5.5 to 6.5) (Burger & Zipper, 2011). The average pH of the soil is also comparible to the soil pH in a primary Endertia forest in Tabalong district which is on average 5.8 (Jones & Prasetyo, 2002).

The potential soil acidity has a significant influence on tree growth. This influence can be explained by the fact that the potential soil acidity is based on the amount of exchangeable Al3+. Al3+ reduces root growth by inhibiting cells; it can reduce Ca uptake, and it fixes soil Phosphorus (Dr Broome, Soil Acidity and Liming, 2013). A study conducted in 2014 on the 2012 reclamation area states that the soil has a high Al saturation (0.68 cmol/kg) (Soendjoto, Dharmono, Mahrudin, Riefani, & Triwibowo, 2014).

Microbial activity is affected by the C/N ratio in the topsoil. The C/N ratio in the study area is very high which maens that the decomposition rate is very slow. Nitrogen is necessary for the metabolism and growth of the microbes, a shortage of nitrogen can slow de decomposition process down (University of Minnesota Extensions, 2016). The Total amount of Nitrogen in the investigated areas is very low.
If only a low amount of nitrogen is present in the soil, the microbes will compete with the plants for it. Nitrogen is the main component of all proteins, enzymes and chlorophyll produced by the trees because of this trees require it in large amounts. Nitrogen also regulates the use of K, P and other minerals by plants (Dr Broome, Nitrogen, Nitrogen Cycle and Phosphorus, 2013).

The microbial activity can also be influenced by other environmental factors such as soil moisture content, organic matter and the soil pH (Dr Broome, Soil Organisms and Organic Matter, 2013). If the soil moisture levels are too high or low, they can inhibit the growth of the microorganism. Different microorganism uses a different kind of organic matter as a food source. The pH range differs for different microorganism (Dr Broome, Soil Organisms and Organic Matter, 2013).

Phosphorus plays a role in in the maturation process of plants. Phosphorus is present in every living cell. Without phosphorus, photosynthesis would not sustain necessary plant functions because Phosphorus works as an energy storage and transfer structure (Dr Broome, Nitrogen, Nitrogen Cycle and Phosphorus, 2013). Phosphorus is also important for the microbes, which are responsible for the decomposition of organic waste. The study area has a very low amount of Available phosphorus the amount ranges from 2.17 PPM up to 3.93 PPM.

Organic carbon is the main source of energy for soil microorganisms. Organic carbon can affect growth because it is both an energy source for the trees and a trigger for nutrient availability (Edwards, Wood, Thurlow, & Ruf, 1999). If there is a low amount Organic-C it can reduce microbial biomass activity and nutrient mineralisation because there is a shortage of energy sources (Edwards, Wood, Thurlow, & Ruf, 1999). The study site has a low amount of Organic Carbon The amount ranges from 1.155% up to 1.583%.

Soil organic matter (SOM) contents of the reclaimed areas on the IPBF was low. The formation of a SOM layer on old mining sites via natural plant growth takes a long time (Taberima, Mulyanto, Gilkes, & Yahya, 2010). SOM contains phosphorus and other nutrients like Nitrogen, Potassium and Sulphur (Dr Broome, Nitrogen, Nitrogen Cycle and Phosphorus, 2013). These are all essential nutrients for plants and trees.

4.3 How is seedling performance affected by rehabilitation year and soil conditions?

With the current data set, it is not possible to determine if there is a significant difference in the average height of all the trees between the different rehabilitation years. The reason for this is that the species composition varies some species are not found in each year. The outcome of the analysis could be heavily influenced by this. The results of an ANOVA test (Table 5) that excluded the species that do not occur each year shows that there is no significant difference between the average tree height in the different reclamation years.

However, what can be determined is the influence of the rehabilitation year and the soil properties on the differences in the height of the seedlings. The performance of the seedlings is strongly affected by the reclamation year and the soil properties EC of the soil, C/N ratio and the soil moisture content. In a study conducted on the 2012 reclamation area on the IPBF in 2014, the area was descript as marginal land (Soendjoto, Dharmono, Mahrudin, Riefani, & Triwibowo, 2014). The investigated areas have a low amount of macronutrients, especially N, P_2O_5 and organic carbon (Table 4) because of this the investigated areas have a high C/N ratio. The investigated areas also have a low soil pH and a high potential soil acidity this can cause toxicity to plants (Wiryono, 2013).

Enterolobium cyclocarpum and *Cassia siamea*, the soil characteristic that influences the growth of these species the most is different for each of the rehabilitation years and each of the species.

The average height of the *Enterolobium cyclocarpum* trees found in the 2010 and 2011 rehabilitation areas was 5 -5.5 meters. A study conducted in Puerto Rico shows that 5-year-old trees growing along with other species had an average height of 6 m (Rocas). The average height of the trees found in the 2010 and 2011 rehabilitation areas is a little lower than the height found in Puerto Rico after a comparable period.

4.4 Limitations

During the forest inventory several limiting factors were encountered;
There could have occurred a bias in the location of the inventory plots because the study areas needed to be reachable by road. This was necessary because of the limited amount of time that was available for data collection in the field.

Another limiting factor could be that there wasn't a professional tree spotter was available to help with the identification of the trees during the inventory. As a result of this some trees could not be identified, and because they could not be identified, they were excluded from the statistical analysis and calculations. It is also possible that some trees were wrongly identified. The calculation of the density of the trees has been conducted under the assumption that the trees were correctly identified. It can be that the density is not accurate because a tree was identified wrongly.

Will conducting the soil analysis some limiting factors were encountered
There was no information available about the soil condition on the study site before Rehabilitation took place. Because of this it is not possible to make a comparison between the situation before the rehabilitation process was started and the current situation. The monitoring of the development of the soil process is harder because you don't have a reference point.

For the available Phosphorus in plot 14, the average is only taken from two of the three sample locations because of a significant difference in the numbers found in samples from the third location.

Another possible limiting factor is the amount of data that was collected. The data that was used during the calculations and the statistical analysis was collected in 5 plots per rehabilitation year. The results of the calculations and the statistic tests are not as strong as they could be, more data collected over a longer period is necessary to increase the strength of the results. Plot one was a test plot and was used to see if the chosen method for data collection works. This plot is excluded from all the analysis because it was located in a 2001 rehabilitation area in Buper Paringin, Paringin is another mining pit, and not enough plots were established in this area.

5 Conclusion

The overall objective of this study is to determine how mine Rehabilitation activities in tropical forest areas in Indonesia can be improved.

Species used for mine rehabilitation on the (IPBF) and the tree density in which these species occur.
On the In pit Backfill 21 different species were used during the initial reclamation activities conducted in 2010, 2011 and 2012. From these 21 species, only 11 species were found during the inventory. The species composition is dominated by *Enterolobium cyclocarpum*, *Acacia auriculiformis*, *Mallotus paniculatus*, *Leucaena glauca and Cassia siamea.* These species occur in the highest density and could be planted in lower densities. One species (*ponjaea*) was found during the inventory of the 2010 rehabilitation area but was not planted.

The soil conditions on the site (IPBF).
The study area is located on marginal land, soil conditions show some small variation between the different rehabilitation areas. All of the investigated areas have a low amount of macronutrients, especially N, P and organic carbon. The pH level found in the various rehabilitation years was on average acidic. The soil also has a high potential acidity. A low pH level and a high potential soil acidity influence which microorganisms are present in the soil.

Seedling performance.
The nutrient availability in the soil on the Tutupan site is low because the decomposition rate of the organic waste is slow. The low amount of available nutrients and the low pH affect the performance of the seedlings, most of the planted seedlings do not survive, from the 19 planted species only 11 were found during the inventory. The soil properties that have the largest influence on seedling performance can differ per species and rehabilitation year. The trees found during the forest inventory of the 2012 area have a higher average height than trees in the other areas.

In conclusion, not all of the planted tree species were encountered during the forest inventory conducted in 2016. From the encountered tree species the following species are the most successful; *Mallotus paniculatus*, *Cassia siamea*, *Enterolobium cyclocarpum*, *Leucaena glauca* and *Samanea saman*.
These five tree species occur in at least two of the three studied rehabilitation areas and they occur in the highest density of all the investigated species. The performance of the seedlings is influenced the most by the reclamation year and by the following soil the EC of the soil, C/N ratio and the soil moisture content.

6 Recommendations

Further monitoring of the rehabilitation areas is necessary to look into the success of the rehabilitation effort. Base measurements of the soil should be taken before rehabilitation takes place. These measurements can be used as comparison material for the data collected during the monitoring. The monitoring should be done at multiple locations and over a longer period. Every year a forest inventory and soil analysis should be conducted at the same location.

The focus of the monitoring should be on the vegetation especially the trees and on the soil condition on the Rehabilitation sites. For the trees, it is important to look at the height, diameter, species composition, survival rate and age of the trees. For the soil different soil properties such as pH, potential acidity and nutrient balance in the soil should be investigated. If species are encountered during the inventory that was not initially planted such as *ponjaea*, they could be included in the list of species used for reclamation.

Other research topics that could be looked at in the future are; how to combat acid soils on a large scale, how to increase the decomposition rate of the organic waste or the effect of soil compaction on tree growth and survival. These studies could help to find a way to increase the growth and survival rate of the seedlings. A method that could be used to investigate the decomposition rate of the organic waste material. Is to study the microorganisms that are present in the soil and what their function is in the different soil processes. Further research into how to optimise the soil conditions for the microorganisms could be conducted.

It could be useful to look at what species are used by other mining companies in Indonesia and if it is possible to use them on the Tutupan site. On Papua, for example, native plants like *Metroxylon sago, Pometia pinata*, and *Casuarina equisetifolia* were successfully used (Taberima, Mulyanto, Gilkes, & Yahya, 2010).

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Appendix 1 Field form Forest inventory

date	Plot nr.	waypoint	s-coord	e-coord	Slope %	# dead trees
tree spotter	Canopy cover%	Vegetation type	Remarks			

Tree species	DBH (cm)	Height (m)	remarks

Appendix 2 Soil characteristics tests

Soil moisture content.

- 5 grammes of air dried soil (W1) are dried in an oven at 105 °C for 4 hours to remove the moisture from the sample.
- After the drying time is over the sample is weighed again (W2), after that the sample is removed and the empty cup is weighed (W3).
- To establish the moisture content (mc) the following formula is used
- mc= (W1-(W2-W3))/W1*100 this gives the moisture content in percent.
- To calculate the moisture content factor (mcf) the following formula is used
- mcf= 100/(100-mc)

pH in H2O.

- First way of 10 grammes of the soil sample.
- At 50 ml of demineralized water to the soil sample.
- Put the sample on the shaker for 1 hour at a shaking speed of 200 rpm.
- Let the sample rest for 15 minutes.
- Then start analysing the sample with a pH meter.
- The electrical conductivity (EC) is measured with the same sample.
- For each of the soil samples, two separate tests are done.

The criteria used to establish the level of acidity, and electrical conductivity of each sample during both tests are (Eviati, 2009).

The criteria for pH in H_2O:

.) High Acidity	<4.5
.) Acidic	4.5 - 5.5
.) Slight Acidity	5.5 - 6.5
.) Neutral	6.6 - 7.5
.) Slight Alkalinity	7.6 - 8.5
.) Alkaline	> 8.5

The criteria for electrical conductivity in dS/m:

.) Very low	< 1
.) Low	1-2
.) Medium	2-3
.) High	3-4
.) Very High	> 4

Potential Acidity of the soil.

- Way 5 grammes of the soil sample.
- 25 ml of KCL solution is added to the sample.
- Put the sample on the shaker for 1 hour at a shaking speed of 200 rpm
- Let the sample rest for 15 min.
- A pH meter is used to measure the pH of the sample.
- The pH in KCL should be lower than the pH in H_2O if this is not the case then it is necessary to redo the test.

.) High Acidity	<4.5
.) Acidic	4.5 - 5.5
.) Slight Acidity	5.5 - 6.5
.) Neutral	6.6 - 7.5
.) Slight Alkalinity	7.6 - 8.5
.) Alkaline	> 8.5

The criteria used to establish the level of acidity in each sample during the test (Eviati, 2009).

Available Phosphorus.

- Start with sieving the air dried soil with a 0.5 mm sieve.
- Weigh 2 grammes of the soil.
- At 14 ml of extraction reagent of 0.03 N NH_4F in 0.025 N HCl.
- Shake the sample for 5 minutes at 200 rpm.
- Filter the sample through filter paper (Whatman No. 2).
- Extract 2 ml of the filtered sample.
- At 8 ml of mixed reagent Ammonium Molybdate.
- Shake the sample and let it rest for 30 min.
- Place the sample in a Spectrophotometer the concentration of Phosphorus in the test sample is read on the colorimeter; this gives a reading in abs.
- The abs value is used to calculate the ppm reg. =(abs-0,0035)/0,1057
- Ppm, P is calculated with the next formula ppm P= sample weight/extraction reagent * ppm reg.
- The ppm P_2O_5 is calculated with the following formula ppm P_2O_5 = ppm P * 2.29
- After this, the ppm P_2O_5 *mcf is calculated (Eviati, 2009).
- The outcome of this calculation is translated into the following criteria;

Criteria of Available Phosphorus- P_2O_5 Bray 1 (ppm) (Eviati, 2009)

.) Very Low	<4
.) Low	5-7
.) Medium	8-10
.) High	11-15
.) very High	>15

Amount of Organic carbon in the topsoil (0-15 cm)

- Sieve (0.5 mm) the samples of the topsoil (0-15 cm).
- Weigh of 0.5…. grammes of the sieved soil.
- At 10 ml of $K_2Cr_2O_7$ to the soil samples and prepare one sample without soil (Blanco) as a reference sample all the other steps are the same.
- Let it rest for 30- 45 minutes.
- At 10 ml of H_2SO_4 to the samples, and let the samples rest for 1-1.5 hour.
- At demineralised water, to the sample, till the volume reaches 100 ml, let the sample rest for 1 hour.
- Take 10 ml of the sample and at 1 ml of H_3PO_4 and four drops of indicator (ferroin 0.025N). Start titration with luruton standard ferro sulphate 0.2N titration solution until the colour changes to dark red.

To calculate the percentage C-organic in the soil the following formula is used;
(ml ferro sulphate in sample- ml ferro sulphate in blanco sample)* standardization ferro sulphate 0.2 n/ (sample weight*1000)*12.01115/4*100*1.3*mcf*100/10 (Eviati, 2009).

The following criteria are used for Organic Carbon (%) (Eviati, 2009)

.) Very Low	<1
.) Low	1-2
.) Medium	2-3
.) High	3-5
.) Very High	>5

Soil organic matter in the topsoil (0-15 cm).
Calculate the amount of soil organic matter (SOM) in percent Organic matter (%) = Total organic carbon (%) x 1.72 (Wayne, Daniel, & Jessica, 2016) The total organic carbon used in the formula is taken from the results of the earlier done C-organic tests.

The total amount of nitrogen in the topsoil

- Sieve (0.5 mm) the samples of the topsoil (0-15 cm).
- Weigh of 0.5…. grammes of the sieved soil.
- At 0.5 grammes of Se reagent to the soil sample and prepare one Blanco sample without soil but the other steps are the same.
- At 4 ml of H_2SO_4.
- Place the samples on a hot plate for 4 hours; the hot plate needs to be at the highest level. After this let the sample cool off.
- At demineralised water till the volume reaches 100 ml.
- At 20 ml of NaOH 40% to the sample.
- Place 25 ml of boric acid 2% in an Erlenmeyer and at four drops of indicator (MMBCG).
- Start the distillation process waits till the distillate changes colour to blue/ green.
- With the distillate, start titration with HCl standard 0.03 N solution till the colour changes to dark pink.

The following formula is used to calculate the total N in percentages;
(ml titration solution soil sample- ml titration solution blanco)* Standardization HCl 0.03 N* 14* mcf*100/ (sample weight*1000) (Eviati, 2009).

The following criteria are used Total N (%) (Eviati, 2009)

.) Very Low	<0.1
.) Low	0.1-0.2
.) Medium	0.21-0.5
.) High	0.51-0.75
.) Very High	>0.75

Decomposition rate

- Carbon to nitrogen ratio if the C: N ratio is too high (excess carbon), decomposition slows down.
- The following formula is used to calculate the C/N ratio;
  C/N ratio in percent= C- organic in percent/ Nitrogen in percent

The criteria used for C/N ratio (Eviati, 2009)

.) Very Low	<5
.) Low	5-10
.) Medium	11-15
.) High	16-25
.) Very High	>25

Appendix 3 Overview of the planted speciesand the density in which they were planted

Reclamation year	Species_local	Scientific name	Number of trees	N/ha	Current number of trees	N/Ha current trees
2010	akasia	*Acacia auriculiformis*	13739	610,9	98	196
2010	alaban	*Vitex rotundifolia*	151	6,7	0	0
2010	angsana	*Pterocarpus indicus*	382	17,0	0	0
2010	bagok		53	2,4	0	0
2010	balik angin	*Mallotus paniculatus*	98	4,4	34	68
2010	berunai		19	0,8	0	0
2010	eucaliptus	*Eucalyptus deglupta*	475	21,1	0	0
2010	Gmelina	*Gmelina arborea*	977	43,4	0	0
2010	jabon	*Anthocephalus sp.*	145	6,4	0	0
2010	johar	*Cassia siamea*	2406	107,0	31	62
2010	Kaliandra	*Caliandra callothyrus*	314	14,0	1	2
2010	kemiri hutan	*Aleurites moluccana*	58	2,6	0	0
2010	lamtoro	*Leucaena glauca*	1571	69,9	14	28
2010	ponjaea		0	0,0	5	10
2010	Sengon	*Paraserianthes falcataria*	3406	151,4	13	26
2010	Sengon buto	*Enterolobium cyclocarpum*	130	5,8	215	430
2010	trembesi	*Samanea saman*	2528	112,4	26	52
2010	Turi	*Sesbania grandiflora*	3891	173,0	40	80
2010	waru	*Hibiscus macrophyllus*	38	1,7	11	22
2011	akasia	*Acacia auriculiformis*	557	16,1	60	120
2011	alaban	Vitex rotundifolia	80	2,3	0	0
2011	balik angin	*Mallotus paniculatus*	100	2,9	42	84
2011	eucaliptus	*Eucalyptus deglupta*	325	9,4	0	0
2011	gmelina	*Gmelina arborea*	286	8,3	0	0

2011	johar	*Cassia siamea*	950	27,4	40	80
2011	Kaliandra	*Caliandra callothyrus*	605	17,5	8	16
2011	lamtoro	*Leucaena glauca*	1896	54,7	1	2
2011	Sengon	*Paraserianthes falcataria*	1653	47,7	0	0
2011	Sengon buto	*Enterolobium cyclocarpum*	294	8,5	222	444
2011	trembesi	*Samanea saman*	745	21,5	1	2
2011	Turi	*Sesbania grandiflora*	452	13,0	0	0
2011	Waru	*Hibiscus macrophyllus*	0	0,0	15	30
2012	akasia	*Acacia auriculiformis*	926	27,6	0	0
2012	alaban	*Vitex rotundifolia*	25	0,7	0	0
2012	bagok		46	1,4	0	0
2012	balik angin	*Mallotus paniculatus*	38	1,1	0	0
2012	bambu	*Bambusoideae*	5	0,1	0	0
2012	ceri		7	0,2	0	0
2012	gmelina	*Gmelina arborea*	760	22,7	43	86
2012	johar	*Cassia siamea*	2213	66,0	146	292
2012	kaliandra	*Caliandra callothyrus*	1280	38,2	14	28
2012	kemiri hutan	*Aleurites moluccana*	37	1,1	0	0
2012	lamtoro	*Leucaena glauca*	1524	45,5	84	168
2012	pengomea	*Pongamia pinnata*	137	4,1	0	0
2012	sengon	*Paraserianthes falcataria*	2554	76,2	0	0
2012	Sengon buto	*Enterolobium cyclocarpum*	376	11,2	57	114
2012	sungkai	*Peronema canescens*	8	0,2	0	0
2012	trembesi	*Samanea saman*	418	12,5	27	54
2012	Turi	*Sesbania grandiflora*	1120	33,4	6	12

Appendix 4 Overview of the basic tree data

Appendix 4 gives an overview of the average diameter, height and the number of trees per tree species found in 2010, 2011 and 2012 Rehabilitation area.

The average diameter, height and the number of trees per tree species found in 2010

Tree species	scientific name	Number of trees	Avg Height	Avg Diam	N/Ha
akasia	*Acacia auriculiformis*	98	5,4	10,3	196
Balik angin	*Mallotus paniculatus*	34	3,8	7,2	68
johar	*Cassia siamea*	31	4,0	7,0	62
Kaliandra	*Calliandra callothyrus*	1	5,0	16,0	2
Lamtoro	*Leucaena glauca*	14	4,0	5,7	28
ponjaea		5	2,2	4,8	10
Sengon	*Paraserianthes falcataria*	13	4,7	8,0	26
Sengon buto	*Enterolobium cyclocarpum*	215	5,4	10,1	430
Trembesi	*Samanea saman*	26	3,0	5,9	52
Turi	*Sesbania grandiflora*	40	4,3	8,3	80
unkown	unkown	1	3,0	3,0	2
Waru	*Hibiscus macrophyllus*	11	4,3	7,3	22

The average diameter, height and the number of trees per tree species found in 2011

Tree species	scientific name	Number of trees	Avg Height	Avg Diam	N/Ha
akasia	*Acacia auriculiformis*	60	3,7	7,3	120
Balik angin	*Mallotus paniculatus*	42	2,9	5,1	84
johar	*Cassia siamea*	40	3,4	5,7	80
kaliandra	*Calliandra callothyrus*	8	2,3	4,1	16
Lamtoro	*Leucaena glauca*	1	3,0	4,0	2
Sengon buto	*Enterolobium cyclocarpum*	222	4,8	10,2	444
Trembesi	*Samanea saman*	1	2,0	4,0	2
Unkown	unkown	25	4,8	6,6	50
waru	*Hibiscus macrophyllus*	15	3,7	6,3	30

The average diameter, height and the number of trees per tree species found in the 2012 Rehabilitation area.

Tree species	scientific name	Number of trees	Avg Height	Avg Diam	N/Ha
Gmelina	*Gmelina arborea*	43	3,6	7,7	86
Johar	*Cassia siamea*	146	4,2	8,7	292
Kaliandra	*Calliandra callothyrus*	14	2,4	4,8	28
Lamtoro	*Leucaena glauca*	84	3,6	7,7	168
Sengon buto	*Enterolobium cyclocarpum*	57	4,5	12,6	114
Trembesi	*Samanea saman*	27	2,7	7,7	54
Turi	*Sesbania grandiflora*	6	4,3	8,0	12

Appendix 5 Location of the Soil Samples.

location	Latitude (decimal)	Longitude (decimal)	location	Latitude (decimal)	Longitude (decimal)
P01S1	115,4888889	2,3099444	P09S1	115,4836944	2,2317222
P01S2	115,4891667	2,3096944	P09S2	115,4835556	2,2316667
P01S3	115,4891111	2,3098056	P09S3	115,4838889	2,2318611
P02S1	115,4800278	2,2378333	P10S1	115,4830000	2,2319444
P02S2	115,4800833	2,2379167	P10S2	115,4831667	2,2318333
P02S3	115,4802500	2,2379722	P10S3	115,4828611	2,2322222
P03S1	115,4831389	2,2351667	P11S1	115,4827222	2,2324722
P03S2	115,4830556	2,2353056	P11S2	115,4827778	2,2325278
P03S3	115,4832500	2,2350278	P11S3	115,4825556	2,2326944
P04S1	115,4827222	2,2348056	P12S1	115,4835833	2,2385278
P04S2	115,4829444	2,2346944	P12S2	115,4834722	2,2380833
P04S3	115,4827500	2,2349722	P12S3	115,4832778	2,2380278
P05S1	115,4826389	2,2350000	P13S1	115,4842222	2,2300556
P05S2	115,4836667	2,2319722	P13S2	115,4841944	2,2301944
P05S3	115,3334444	2,2322500	P13S3	115,4840000	2,2304444
P06S1	115,4830278	2,2329167	P14S1	115,4843333	2,2289167
P06S2	115,4828889	2,2330000	P14S2	115,4843333	2,2289167
P06S3	115,4831667	2,2327500	P14S3	115,4841667	2,2291667
P07S1	115,4839167	2,2326389	P015S1	115,4839722	2,2294167
P07S2	115,4839444	2,2324722	P015S2	115,4840556	2,2294444
P07S3	115,4838611	2,2326944	P015S3	115,4838889	2,2296944
P08S1	115,4844167	2,2331389	P016S1	115,4836944	2,2290000
P08S2	115,4840833	2,2333056	P016S2	115,4835278	2,2293333
P08S3	115,4845556	2,2331667	P016S3	115,4833889	2,2293889

Appendix 6 Soil data per plot.

Rehabilitation year	Plot-Nr	pH in H2O	EC (dS/m)	pH in KCL	Moister content (%)	C-organic (%)	organic matter (%)	available Phosphorus (PPM)	Total N (%)	C/N
2010	P02	4,2	0,017	3,8	1,1	0,639	1,100	2,94	0,015	77,152
2010	P03	4,4	0,021	4,1	3,2	1,341	2,307	1,83	0,044	39,469
2010	P04	6,1	0,052	5,6	2,1	1,457	2,506	1,76	0,043	66,698
2010	P05	6,0	0,114	5,4	3,0	1,639	2,819	2,03	0,022	100,106
2010	P06	6,3	0,033	5,7	2,1	1,441	2,479	2,29	0,018	151,808
2011	P07	4,9	0,029	4,3	1,8	1,080	1,858	6,42	0,055	60,347
2011	P08	4,8	0,018	4,2	0,7	0,954	1,641	7,83	0,006	194,387
2011	P09	6,5	0,123	5,6	3,1	1,391	2,392	1,93	0,021	101,342
2011	P10	6,8	0,072	6,1	2,2	1,372	2,360	1,58	0,018	107,561
2011	P11	6,7	0,112	5,9	2,9	0,977	1,681	1,91	0,011	126,927
2012	P12	7,1	0,063	6,2	2,8	2,003	3,446	1,93	0,018	101,608
2012	P13	6,0	0,094	5,5	4,7	1,155	1,987	1,87	0,011	103,484
2012	P14	4,8	0,203	4,2	4,7	1,566	2,693	5,73	0,071	279,039
2012	P15	5,6	0,238	5,1	3,5	1,662	2,859	2,19	0,032	78,927
2012	P16	3,7	0,220	3,2	2,4	1,530	2,632	4,11	0,018	213,398

Appendix 7 Results soil tests

No.	Sampling Date	Sample Code	Rehabilitation Year	Soil pH in H2O		EC		Soil pH in KCl		MC	C-organic		SOM	Available Phosphorus		Total N		C/N	
				Result	Criteria	Result (dS/m)	Criteria	Result	Criteria	Result (%)	Result (%)	Criteria	Result	Result (ppm)	Criteria	Result	Criteria	Result	Criteria
1	12-apr-15	P01 S01 (0-15)	**2001**	7,4	Neutral	0,128	Very low	6,9	Neutral	2,09	1,233	Low	2,121	3,02	Very Low	0,06	Very Low	20,98	High
2		P01 S01 (15-30)		7,8	Slight Alkalinity	0,122	Very low	7,0	Neutral	1,80				81,96	Very High				
3		P01 S02 (0-15)		6,1	Slight Acidity	0,030	Very low	5,5	Slight Acidity	1,53	0,933	Very Low	1,604	2,39	Very Low	0,03	Very Low	28,81	Very High
4		P01 S02 (15-30)		7,3	Neutral	0,062	Very low	6,7	Neutral	2,17				74,18	Very High				
5		P01 S03 (0-15)		7,6	Slight Alkalinity	0,157	Very low	6,7	Neutral	1,72	0,678	Very Low	1,166	1,16	Very Low	0,04	Very Low	16,11	High
6		P01 S03 (15-30)		7,9	Slight Alkalinity	0,145	Very low	6,7	Neutral	2,09				0,39	Very Low				
7	15-apr-15	P02 S01 (0-15)	**2010**	4,3	Very Acidity	0,019	Very low	3,7	Very Acidity	1,32	0,742	Very Low	1,276	4,53	Very Low	0,03	Very Low	23,02	High
8		P02 S01 (15-30)		4,2	Very Acidity	0,017	Very low	3,8	Very Acidity	1,15				1,00	Very Low				
9		P02 S02 (0-15)		4,3	Very Acidity	0,016	Very low	3,8	Very Acidity	0,92	0,542	Very Low	0,932	4,67	Very Low	0,00	Very Low	131,66	Very High
10		P02 S02 (15-30)		4,4	Very Acidity	0,016	Very low	3,8	Very Acidity	1,23				2,99	Very Low				
11		P02 S03 (0-15)		4,1	Very Acidity	0,015	Very low	3,8	Very Acidity	0,94	0,634	Very Low	1,091	2,53	Very Low	0,01	Very Low	76,78	Very High
12		P02 S03 (15-30)		4,1	Very Acidity	0,019	Very low	4,0	Very Acidity	1,08				1,92	Very Low				
13	15-apr-15	P03 S01 (0-15)		4,3	Very Acidity	0,020	Very low	4,0	Very Acidity	6,87	1,895	Low	3,259	1,22	Very Low	0,09	Very Low	21,90	High
14		P03 S02 (0-15)		4,3	Very Acidity	0,022	Very low	4,1	Very Acidity	2,22	0,891	Very Low	1,532	1,94	Very Low	0,02	Very Low	49,23	Very High

15		P03 S02 (15-30)		4,3	Very Acidity	0,020	Very low	4,1	Very Acidity	1,60				3,47	Very Low				
16		P03 S03 (0-15)		4,5	Very Acidity	0,023	Very low	4,1	Very Acidity	2,30	1,238	Low	2,129	0,70	Very Low	0,03	Very Low	47,28	Very High
17		P04 S01 (0-15)		6,4	Slight Acidity	0,054	Very low	6,0	Slight Acidity	2,85	2,215	Medium	3,809	1,48	Very Low	0,04	Very Low	49,45	Very High
18		P04 S01 (15-30)		7,1	Neutral	0,083	Very low	6,5	Slight Acidity	2,91				1,02	Very Low				
19		P04 S02 (0-15)		6,8	Neutral	0,038	Very low	6,3	Slight Acidity	1,33	1,284	Low	2,208	0,54	Very Low	0,01	Very Low	138,81	Very High
20		P04 S02 (15-30)		7,1	Neutral	0,044	Very low	6,1	Slight Acidity	1,47				0,38	Very Low				
21		P04 S03 (0-15)		4,7	Acidity	0,047	Very low	4,6	Acidity	1,61	0,872	Very Low	1,500	1,46	Very Low	0,07	Very Low	11,83	Medium
22		P04 S03 (15-30)		4,6	Acidity	0,050	Very low	4,1	Very Acidity	2,18				5,66	Low				
23	19-apr-15	P05 S01 (0-15)		6,8	Neutral	0,223	Very low	6,2	Slight Acidity	3,60	2,020	Medium	3,475	2,44	Very Low	0,01	Very Low	145,92	Very High
24		P05 S01 (15-30)		6,7	Neutral	0,128	Very low	6,1	Slight Acidity	4,04				1,34	Very Low				
25		P05 S02 (0-15)		5,0	Acidity	0,070	Very low	4,3	Very Acidity	3,94	1,738	Low	2,990	1,82	Very Low	0,01	Very Low	123,02	Very High
26		P05 S02 (15-30)		5,2	Acidity	0,085	Very low	4,6	Acidity	1,93				3,94	Very Low				
27		P05 S03 (0-15)		6,2	Slight Acidity	0,098	Very low	5,6	Slight Acidity	2,07	1,159	Low	1,993	1,16	Very Low	0,04	Very Low	31,38	Very High
28		P05 S03 (15-30)		5,9	Slight Acidity	0,083	Very low	5,3	Acidity	2,13				1,47	Very Low				
29		P06 S01 (0-15)		6,5	Slight Acidity	0,028	Very low	5,9	Slight Acidity	2,51	1,250	Low	2,150	1,48	Very Low	0,01	Very Low	90,92	Very High
30		P06 S01 (15-30)		6,1	Slight Acidity	0,028	Very low	5,6	Slight Acidity	3,42				1,02	Very Low				
31		P06 S02 (0-15)		5,4	Acidity	0,023	Very low	5,1	Acidity	1,11	1,332	Low	2,291	3,30	Very Low	0,00	Very Low	318,09	Very High
32		P06 S02 (15-30)		5,9	Slight Acidity	0,032	Very low	5,5	Acidity	1,33				5,00	Very Low				
33		P06 S03 (0-15)		6,7	Neutral	0,039	Very low	6,1	Slight Acidity	2,25	1,742	Low	2,996	1,63	Very Low	0,04	Very Low	46,42	Very High
34		P06 S03 (15-30)		7,3	Neutral	0,051	Very low	6,1	Slight Acidity	2,01				1,32	Very Low				

35		P07 S01 (0-15)	**2011**	3,8	Very Acidity	0,030	Very low	3,6	Very Acidity	0,83	1,157	Low	1,990	7,72	Low	0,01	Very Low	83,82	Very High
36		P07 S01 (15-30)		4,3	Very Acidity	0,027	Very low	4,1	Very Acidity	1,18				4,22	Very Low				
37		P07 S02 (0-15)		4,5	Acidity	0,022	Very low	3,8	Very Acidity	0,61	0,796	Very Low	1,369	16,25	Very High	0,14	Low	5,76	Low
38		P07 S02 (15-30)		4,1	Very Acidity	0,035	Very low	3,5	Very Acidity	1,34				3,77	Very Low				
39		P07 S03 (0-15)		6,8	Neutral	0,028	Very low	5,9	Slight Acidity	2,97	1,287	Low	2,214	3,83	Very Low	0,01	Very Low	91,46	Very High
40		P07 S03 (15-30)		5,8	Slight Acidity	0,034	Very low	5,0	Acidity	3,57				2,75	Very Low				
41	20-apr-15	P08 S01 (0-15)		4,3	Very Acidity	0,013	Very low	3,9	Very Acidity	0,34	0,522	Very Low	0,899	8,95	Medium	0,00	Very Low	133,76	Very High
42		P08 S01 (15-30)		4,5	Very Acidity	0,013	Very low	4,0	Very Acidity	0,30				8,65	Medium				
43		P08 S02 (0-15)		5,4	Acidity	0,019	Very low	4,7	Acidity	1,58	1,666	Low	2,866	8,61	Medium	0,00	Very Low	371,52	Very High
44		P08 S02 (15-30)		5,8	Slight Acidity	0,036	Very low	5,1	Acidity	1,63				2,91	Very Low				
45		P08 S03 (0-15)		4,4	Very Acidity	0,012	Very low	3,8	Very Acidity	0,21	0,673	Very Low	1,157	10,92	Medium	0,01	Very Low	77,88	Very High
46		P08 S03 (15-30)		4,2	Very Acidity	0,015	Very low	3,8	Very Acidity	0,16				6,97	Low				
47		P09 S01 (0-15)		4,5	Acidity	0,051	Very low	3,9	Very Acidity	1,90	0,765	Very Low	1,315	1,37	Very Low	0,02	Very Low	42,55	Very High
48		P09 S01 (15-30)		4,9	Acidity	0,063	Very low	4,3	Very Acidity	2,92				1,70	Very Low				
49		P09 S02 (0-15)		6,8	Neutral	0,186	Very low	5,5	Slight Acidity	5,02	2,014	Medium	3,464	1,58	Very Low	0,01	Very Low	221,92	Very High
50		P09 S02 (15-30)		7,2	Neutral	0,121	Very low	6,1	Slight Acidity	4,15				1,41	Very Low				
51		P09 S03 (0-15)		7,6	Slight Alkalinity	0,117	Very low	6,7	Neutral	2,87	1,393	Low	2,396	2,17	Very Low	0,04	Very Low	39,56	Very High
52		P09 S03 (15-30)		8,0	Slight Alkalinity	0,199	Very low	7,0	Neutral	1,76				3,38	Very Low				

53		P10 S01 (0-15)		7,7	Slight Alkalinity	0,081	Very low	6,9	Neutral	2,98	1,493	Low	2,569	1,08	Very Low	0,01	Very Low	165,88	Very High
54		P10 S01 (15-30)		7,8	Slight Alkalinity	0,098	Very low	6,7	Neutral	3,73				0,93	Very Low				
55		P10 S02 (0-15)		6,6	Neutral	0,106	Very low	6,5	Slight Acidity	2,05	0,998	Very Low	1,716	0,76	Very Low	0,03	Very Low	31,65	Very High
56		P10 S02 (15-30)		5,7	Slight Acidity	0,071	Very low	5,5	Acidity	2,12				1,84	Very Low				
57		P10 S03 (0-15)		6,2	Slight Acidity	0,032	Very low	5,4	Acidity	0,93	1,625	Low	2,795	3,35	Very Low	0,01	Very Low	125,15	Very High
58		P10 S03 (15-30)		7,0	Neutral	0,045	Very low	5,8	Slight Acidity	1,62				1,52	Very Low				
59	21-apr-15	P11 S01 (0-15)		7,4	Neutral	0,054	Very low	6,2	Slight Acidity	2,28	1,015	Low	1,746	0,91	Very Low	0,01	Very Low	114,75	Very High
60		P11 S01 (15-30)		7,5	Neutral	0,062	Very low	6,2	Slight Acidity	1,88				1,37	Very Low				
61		P11 S02 (0-15)		7,3	Neutral	0,140	Very low	6,9	Neutral	3,75	0,942	Very Low	1,621	1,87	Very Low	0,00	Very Low	219,50	Very High
62		P11 S02 (15-30)		6,9	Neutral	0,170	Very low	5,6	Slight Acidity	5,24				1,74	Very Low				
63		P11 S03 (0-15)		4,4	Very Acidity	0,121	Very low	4,0	Very Acidity	1,66	0,974	Very Low	1,675	3,99	Very Low	0,02	Very Low	46,53	Very High
64		P11 S03 (15-30)		7,0	Neutral	0,128	Very low	6,3	Slight Acidity	2,70				1,54	Very Low				
65		P12 S01 (0-15)	**2012**	7,1	Neutral	0,046	Very low	6,3	Slight Acidity	1,62	1,031	Low	1,773	2,91	Very Low	0,01	Very Low	84,37	Very High
66		P12 S01 (15-30)		7,4	Neutral	0,084	Very low	6,6	Neutral	1,64				1,53	Very Low				
67		P12 S02 (0-15)		6,4	Slight Acidity	0,051	Very low	5,8	Slight Acidity	5,40	3,999	High	6,879	1,59	Very Low	0,03	Very Low	145,53	Very High
68		P12 S02 (15-30)		6,5	Slight Acidity	0,055	Very low	5,6	Slight Acidity	3,73				3,13	Very Low				
69		P12 S03 (0-15)		7,5	Neutral	0,073	Very low	6,3	Slight Acidity	2,37	0,979	Very Low	1,685	1,07	Very Low	0,01	Very Low	74,92	Very High
70		P12 S03 (15-30)		7,6	Slight Alkalinity	0,070	Very low	6,4	Slight Acidity	2,33				1,38	Very Low				

71		P13 S01 (0-15)		7,3	Neutral	0,093	Very low	6,4	Slight Acidity	9,42	1,703	Low	2,930	0,82	Very Low	0,01	Very Low	115,85	Very High
72		P13 S01 (15-30)		7,5	Neutral	0,133	Very low	6,6	Neutral	9,36				0,82	Very Low				
73		P13 S02 (0-15)		6,5	Slight Acidity	0,044	Very low	5,9	Slight Acidity	2,54	1,310	Low	2,253	2,63	Very Low	0,01	Very Low	96,31	Very High
74		P13 S02 (15-30)		6,5	Slight Acidity	0,146	Very low	6,0	Slight Acidity	2,75				4,66	Very Low				
75		P13 S03 (0-15)		4,4	Very Acidity	0,037	Very low	4,0	Very Acidity	1,50	0,452	Very Low	0,777	1,06	Very Low	0,00	Very Low	98,30	Very High
76		P13 S03 (15-30)		4,0	Very Acidity	0,110	Very low	3,7	Very Acidity	2,63				1,23	Very Low				
77	22-apr-15	P14 S01 (0-15)		4,0	Very Acidity	0,197	Very low	3,5	Very Acidity	5,11	3,463	High	5,956	0,94	Very Low	0,00	Very Low	733,72	Very High
78		P14 S01 (15-30)		4,6	Acidity	0,577	Very low	4,4	Very Acidity	9,98				0,66	Very Low				
79		P14 S02 (0-15)		6,8	Neutral	0,082	Very low	5,5	Slight Acidity	1,95	0,466	Very Low	0,802	3,54	Very Low	0,00	Very Low	99,65	Very High
80		P14 S02 (15-30)		6,6	Neutral	0,142	Very low	5,7	Slight Acidity	3,13				1,08	Very Low				
81		P14 S03 (0-15)		3,5	Very Acidity	0,088	Very low	3,0	Very Acidity	3,98	0,768	Very Low	1,321	38,96	Very High	0,21	Low	3,75	Very Low
82		P14 S03 (15-30)		3,4	Very Acidity	0,130	Very low	2,9	Very Acidity	4,24				48,08	Very High				
83		P15 S01 (0-15)		6,0	Slight Acidity	0,043	Very low	5,4	Acidity	2,77	1,309	Low	2,251	2,32	Very Low	0,07	Very Low	20,12	High
84		P15 S01 (15-30)		6,0	Slight Acidity	0,052	Very low	5,4	Acidity	1,63				1,68	Very Low				
85		P15 S02 (0-15)		5,9	Slight Acidity	0,034	Very low	5,3	Acidity	6,84	2,752	Medium	4,734	1,28	Very Low	0,02	Very Low	144,90	Very High
86		P15 S02 (15-30)		6,1	Slight Acidity	0,092	Very low	5,5	Slight Acidity	6,09				0,79	Very Low				
87		P15 S03 (0-15)		4,5	Very Acidity	0,159	Very low	4,0	Very Acidity	1,86	0,925	Very Low	1,591	0,76	Very Low	0,01	Very Low	71,76	Very High
88		P15 S03 (15-30)		5,2	Acidity	1,050	Low	5,0	Acidity	1,98				6,32	Low				
89		P16 S01 (0-15)		3,8	Very Acidity	0,051	Very low	3,2	Very Acidity	0,75	0,972	Very Low	1,673	2,73	Very Low	0,00	Very Low	212,51	Very High
90		P16 S01 (15-30)		3,7	Very Acidity	0,043	Very low	3,2	Very Acidity	0,53				9,89	Medium				

91		P16 S02 (0-15)		3,9	Very Acidity	0,183	Very low	3,4	Very Acidity	2,89	1,781	Low	3,064	2,32	Very Low	0,00	Very Low	386,92	Very High
92		P16 S02 (15-30)		3,9	Very Acidity	0,644	Very low	3,6	Very Acidity	1,63				3,07	Very Low				
93		P16 S03 (0-15)		3,5	Very Acidity	0,169	Very low	2,8	Very Acidity	3,98	1,837	Low	3,160	1,72	Very Low	0,05	Very Low	40,76	Very High
94		P16 S03 (15-30)		3,5	Very Acidity	0,228	Very low	2,8	Very Acidity	4,51				4,90	Very Low				

Appendix 8 Relation between soil characteristics and variation in height.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	211,408	1	211,408	96,805	,000[b]
	Residual	2790,979	1278	2,184		
	Total	3002,388	1279			
2	Regression	246,087	2	123,043	57,006	,000[c]
	Residual	2756,301	1277	2,158		
	Total	3002,388	1279			
3	Regression	256,903	3	85,634	39,800	,000[d]
	Residual	2745,484	1276	2,152		
	Total	3002,388	1279			
4	Regression	268,413	4	67,103	31,294	,000[e]
	Residual	2733,975	1275	2,144		
	Total	3002,388	1279			

a. Dependent Variable: Height

b. Predictors: (Constant), Reclamtion_year

c. Predictors: (Constant), Reclamtion_year, average_EC

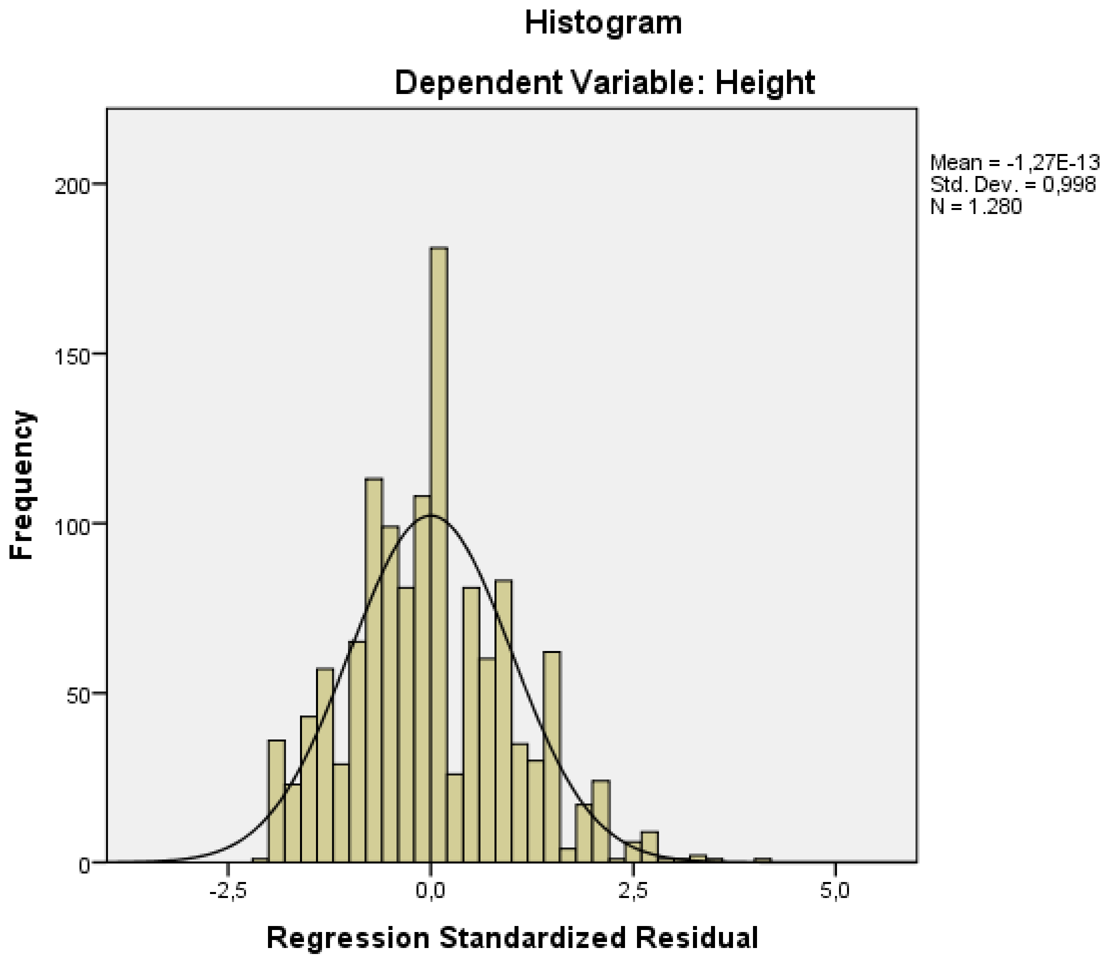
d. Predictors: (Constant), Reclamtion_year, average_EC, Average_C_N

e. Predictors: (Constant), Reclamtion_year, average_EC, Average_C_N, Average_cm

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	1003,585	101,559		9,882	,000					
	Reclamtion_year	-,497	,051	-,265	-9,839	,000	-,265	-,265	-,265	1,000	1,000
2	(Constant)	1386,253	138,954		9,976	,000					
	Reclamtion_year	-,687	,069	-,367	-9,943	,000	-,265	-,268	-,267	,528	1,896
	average_EC	3,238	,808	,148	4,008	,000	-,104	,111	,107	,528	1,896
3	(Constant)	1477,221	144,546		10,220	,000					
	Reclamtion_year	-,733	,072	-,391	-10,188	,000	-,265	-,274	-,273	,486	2,058
	average_EC	2,806	,829	,128	3,384	,001	-,104	,094	,091	,499	2,004
	Average_C_N	,002	,001	,072	2,242	,025	-,067	,063	,060	,688	1,453
4	(Constant)	1538,930	146,737		10,488	,000					
	Reclamtion_year	-,763	,073	-,408	-10,457	,000	-,265	-,281	-,279	,470	2,129
	average_EC	1,982	,901	,091	2,200	,028	-,104	,062	,059	,421	2,373
	Average_C_N	,002	,001	,084	2,589	,010	-,067	,072	,069	,670	1,492
	Average_cm	,115	,050	,076	2,317	,021	-,048	,065	,062	,655	1,527

a. Dependent Variable: Height



Histogram
Dependent Variable: Height
Mean = -1,27E-13
Std. Dev. = 0,998
N = 1.280
Frequency
200
150
100
50
0
-2,5
0,0
2,5
5,0
Regression Standardized Residual

Appendix 9 Location Rehabilitation areas.