A COMPARISON OF GROWTH PERFORMANCE OF TREES SPECIES PLANTED TO RESTORE THE DEGRADED AREA OF FORMER COPPER MINING IN MAMUT, RANAU, SABAH

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ABSTRACT

This study was conducted to assess the growth performance of trees planted in the former copper mining area in Mamut, Ranau, Sabah. Three different species observed on an ongoing basis are Paraserianthes falcataria (Batai), Eucalyptus deglupta and Pinus caribea. The trees' growth and health were surveyed and recorded by using tree evaluation form. The measurement of tree growth was based on height and diameter at breast height (DBH); while tree crown, foliage colour and density, tree disease and tree regeneration were used to determine tree health. A total number of 105 trees of P. falcataria, 70 trees of E. deglupta and 123 of P. caribea were observed and measured in the area. The estimation of tree growth performance was based on the mean of height and DBH/year. The trees' ages were based on year of the tree planted, with P. falcataria in 1992, E. deglupta 1993 and P. caribea 1997. It was found that P. caribea recorded the highest value of mean DBH cm/year which was 2.20 cm/year, followed by P. falcataria (0.52 cm/year) and E. deglupta (0.41 cm/year). The highest value of mean height/year was also confined to P. caribea with 0.85 m/year followed by E. deglupta (0.48 m/year) and P. falcataria (0.27 m/year). The P. caribea planted in Mamut have the highest level of adaptation (86.73%) which was based on the comparison with the tree heights of the same species in more favourable areas. This was followed by E. deglupta (16.38%) and P. falcataria (10.34%) respectively. The highest mortality rate confined to P. falcataria (85.5%) followed by E. deglupta (78.3%) and the lowest was P. caribea (21.2%). The P. caribea was found to be adapted well to the degraded land of the upland area in the former copper mining in Mamut. The species is suggested to be considered in species selection for the restoration of degraded land in the nearby areas of the upper part of Mount Kinabalu area.

Key words: Restoration, Mining area, Degraded land, Mountain Area, Mount Kinabalu, Species Selection

Introduction

Land degradation occurs due to many factors such as deforestation for agricultural land, timber plantation, development for infrastructure expansion, forest fires, urbanisation and mining activities. In Malaysia, land degradation caused by land use changes is vary in the three regions of Sabah, Sarawak, and the Peninsular Malaysia. Timber extraction and shifting cultivation were recorded as the main causes of deforestation in Sabah and Sarawak. The conversion of land area to agriculture, mainly palm oil production has recently become the important causes of deforestation in the State (Wicke et al., 2008; Wicke et al., 2011). Underlying drivers such as agricultural and forestry prices, economic growth and policy and institutional factors played a role in the land use change in Malaysia. The estimated total degraded land in the state as reported by Wicke et al. (2008) is about 5.5 million hectare (or nearly 17% of the total Malaysian land area). The mineral sector in Malaysia is contributed only 7% to the GDP with the natural gas and oil accounted for 95% of the total contribution (Tse, 2005). Apart from natural gas and oil other minerals produced are bauxite, coal, feldspar, gold, ilmenite, iron ore, kaolin, mica, monazite, sand and gravel, struverite, tin, and zircon. Malaysia also imported metallic and non-metallic minerals to meet its demand (Tse, 2005).

Mining is an activity that promoting development booms but can bring impact to the environment with the extent of damage that depend on the type of mining and processing methods being used (Aryee et al. 2003; Chakravarty et. al., 2012). The extent of land involved in mining is relatively small and, therefore, it is not seen as a key factor of primary deforestation (Chakravarty et. al., 2012). Mining activities generate a lot of waste rocks and tailings, which get deposited at the surface. The environmental problems related to mining activities are deforestation, habitat destruction, biodiversity erosion and environmental pollution that include dust and air pollution, water pollution, noise pollution, hydro-geological disturbances, the silting of rivers, waste lands and mining pools with slime, and the disturbance of the aesthetics of the landscape (Kundu and Ghose, 1997; Tse, 2005; Sheoran et. al., 2010). Other impacts of mining are overburden dumps, acidic mine drainage and dumps, elevated sand contents and multiple mines wastes such as soil erosion, air and water pollution, toxicity, loss of biodiversity, geo-environmental disasters, and ultimately loss of economic wealth (Wong, 2003; Ghose, 2005; Sheoran et. al., 2010). The degraded mining land become a concern because the damage due to mining activity towards environment degradation. In Ranau, the local concern related to the copper mining were included river contamination and air pollution of dust produced from the tailing. The mining constitutes a major hazard to man and environment by way of overburden deposits and drainage (Chauhan, 2010; Valaiya 1990).

Many countries regarded the ecological restoration and mine reclamation as important parts of the sustainable development strategy (Sheoran et al. 2010). The degraded soils, the waste rocks, and tailings of the mining area require proper intervention such as natural regeneration, enrichment and tree plantation to minimize the impacts of mining on the environment and preserving eco-diversity (Rodrigues et al. 2004). There has been a various way of integrating the rehabilitations of mines with conservation of the environment. Post-mining site reclamation and restoration are the final and crucial stage, which requires proper planning and commitment from the authorities or the project proponent. Some successful previous effort to rehabilitate the tin ex-mining grounds in peninsular Malaysia are the planting of oil palms (Yap, 2007). Others ex-mining ground were also developed for constructions such as housing estates in Selangor, Kuala Lumpur, and Perak. The ex-mining pools are also used for recreation purposes, provided sand to the construction industry, converted into landfills and also used for flood control (Yap, 2007).

Revegetation is widely used to restore the ecological integrity and to reduce erosion and protect soils of the disturbed areas. Restoration assisting the recovery of an ecosystem with respect to its structure, functional properties and exchanges with surrounding landscape and ecosystems through soil development processes (Sheoran et. al., 2010; Lamb et. al., 2012). Forest restoration is identified as one of climate mitigation options with a low-cost approach to reducing greenhouse gas emissions and contribute to a variety of consequences for catchment-scale water cycles (Ponette-González et al. 2014; Locatelli et al. 2015). The success remediation of mine spoils and tailings is influenced by the appropriate selection of tolerant plant species which can survive and regenerate in the severe conditions of the dump material and surface and on their ability to stabilize the soil structure (Madejon et al., 2006; Sheoran et al. 2010). A vigilant consideration is required during the selection of exotic or native species in the reclamation of the degraded area. This involves factors that include species tolerant level to metal contaminants and nutrient-deficient soils, drought-resistant, fast-growing, easy to establish, have dense canopies and root systems and well adapted to the local environment. It is suggested that indigenous species are preferable to exotics because they are most likely to fit into the fully functional ecosystem and are climatically adapted (Chauhan, 2010; Sheoran et. al., 2010; Li et al., 2003; Chaney et al., 2007). The selection of fast-growing exotic species that can adapt to the extreme ecosystem and climate conditions, however, may necessary to expedite the restoration of the degraded mining land. This paper present the study on growth performance of tree planted namely *P. falcataria*, *E. deglupta* and *P. caribea* to restore the former copper mining in Mamut, Ranau, Sabah. The objective was to determine the best species that able to survive and adapted to the severe ecosystem of the ex-mining area.

Methodology

The study site was located in the former copper mine between 5° 36'- 6° 25' N and 116° 30' - 117° 5' E of Mamut, Ranau, Sabah. The mining operations in this area began in 1975 until 1998. It was recorded as the largest ever open copper mining in Malaysia (Azizli et al., 1995). The mining is located about 68 kilometres to the east of the capital city of Kota Kinabalu and in the southeast of Mount Kinabalu with the altitudes of 1300m to 1600m above sea level. The terrain of the area is mainly with hills gradient with more than 30° slope. The average temperature is around 25.7 °C during the day and 15 °C to 18 °C at night. The average of annual precipitation of the area is above 2500mm.

The method of mining used was open-pit that using drilling, blasting, loading with hydraulic shovels and wheeled loaders and hauling with off-highway trucks (Mangalai, 1995). The tailing dam was located at about 15 km away at Kg. Lohan. It was recorded that about 120000 tonnes of concentrate were produced and exported each year (Mangalai, 1995). The mineral production from the year of commencement to 1998 was estimated to be more than 2.2 million tons of mineral mixtures containing more than 520,000 tonnes of copper, 41 tonnes of gold and 268 tonnes of silver (DANCED, 1998). The total exports valued from 1975 to 1990 were estimated at 2.3 billion that contributed about 186.6 million ringgit annually in mineral royalties to the state government or 2.5% of the total exports of Sabah.

Survey that based on 'Total Avery Sampling' technique (Avery and Burkhart, 2002) was used to collect the data of the trees planted in the mining area. The study was conducted on a continuous basis that includes the collection of information on the tree growth, and the tree health as indicators to determine the overall growth performance of the trees planted in the area. The assessment involved measurement and observation of all the trees planted namely *P. falcataria* with (105 trees/0.24 ha), *E. deglupta* (70 trees/0.29 ha) and *P. caribea* (123 trees/0.25ha). The data of every tree were collected using 'tree assessment form' that contains the information as shown in Table 1. The data collected from the field were analysed with the combination of secondary information available from the ex-personal staff of Mamut Copper Mine office in Ranau. Both quantitative and qualitative were used in the data analyses.

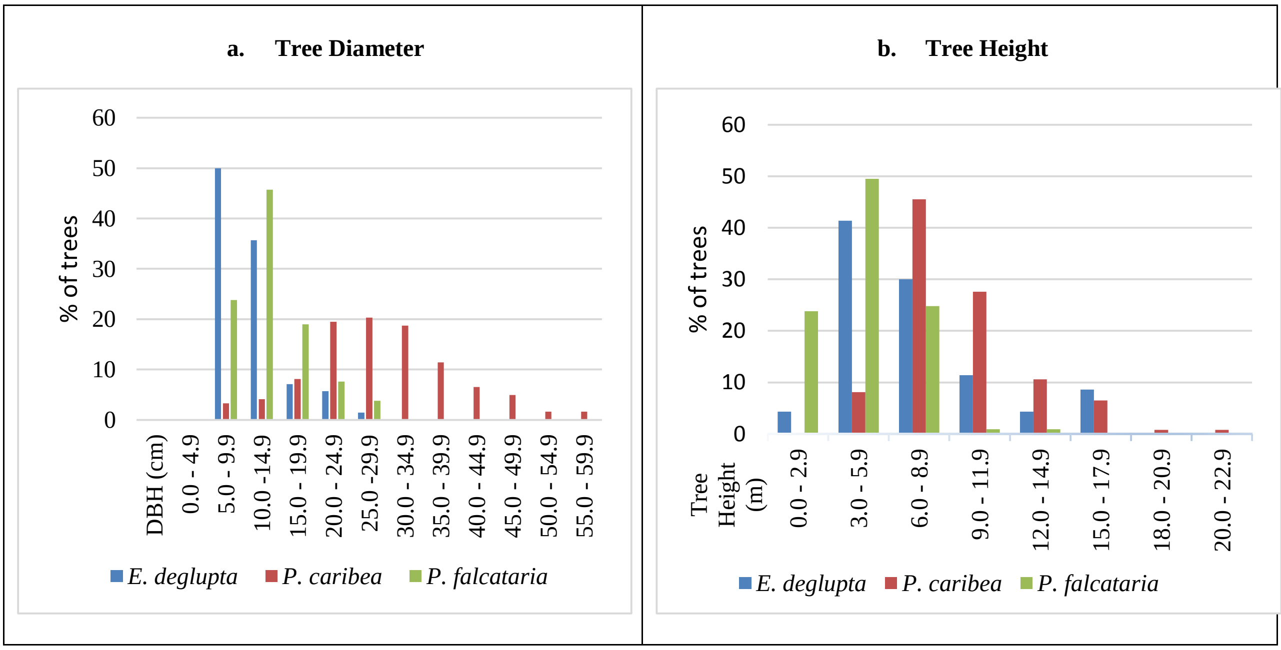
Table 1: Indicators of tree growth performances

Indicators	Measurement / Observations
1) Tree Growth	a. DBH (cm) - diameter measurement by using measuring tape. b. Height (m) - height measurement using Suunto Clinometer
2) Tree Health Condition	a. Tree crown – The tree's crown were categorized as normal and abnormal. i. Normal (uniformity and dense leaves), ii. Abnormal (a significant shortfall of leaves (Innes, 1993)). b. Leaf colour – Assessment and categorization based on i. Normal (green and healthy), ii. Chlorotic (yellowish leaves) and iii.Necrotic (brownish and indicating of dead leaves) c. The density of the leaves – i. Normal (leaves on the favourable conditions with dense and green), ii. Rare (scarcity and significant of light penetration) d. The disease - the presence or not existence of tree disease symptom. e. Regeneration - the presence of tree regeneration.

Results

All the trees were categorized into diameter classes (DBH) on the scale of 0 to 5 cm interval (Figure 1.a). Most of the *P. falcataria* (45.7%) were within the DBH class of 5.0 to 9.9 cm with a mean diameter of 31.8 cm DBH. The *E. deglupta* were mainly recorded in the 0.0 - 4.9 cm DBH class (50%) with 19.6 cm mean DBH. Most of the *P. caribea* were recorded within the DBH classes of 15.0 - 19.9cm and 20.0 - 24.9cm with each 20%, respectively. The mean DBH for the species was 24.19cm (Figure 1.a). The mean height of *P. falcataria* is 4.35 m. A total number of 41.4% of the species is within the tree height class of 3.0 m to 5.9 m. The *E. deglupta* recorded the mean height of 7.25 m with most trees were recorded at the height class of 3.0 m - 5.9 m (50.0%). The mean height of *P. caribea* is 9.36 m with most of the trees (45%) were recorded within the height class of 6.0 - 8.9m (Figure 1.b).

Figure 1: Tree Growth a) Diameter (cm/DBH) b) Height (meter)



Most of the trees surveyed (84.8%) have a normal crown formation. This category was mainly recorded for *P. caribea* (89.4%) followed by *P. falcataria* (85.0%) and *E. deglupta* (68.6%) (Figure 2.a). The color of the leaves of *P. falcataria* trees was mostly recorded under a normal condition with 60% out of the total trees enumerated. There was a total percentage of 21% of the species that show necrotic and 19% recorded under chlorotic. The *E. deglupta* recorded a percentage of 61.4% with necrotic leaves. This was followed by normal green with 28.6% and chlorotic 10%. *P. caribea* recorded the highest percentage of normal color (85.4%) followed by chlorotic and necrotic with 12.2% and 2.4% respectively (Figure 2.b). The density of the leaves of *P. falcataria* is mainly under normal condition (54.3%) while 45.7% were recorded under the category of rare density. The *E. deglupta* recorded a similar trend with both normal, and rare density of leaves recorded 50%. *P. caribea* recorded the highest percentage of normal density with 87% out of the total species enumerated (Figure 2.c). About 21% of the *P. falcataria* shows the infection of tree disease while 79% did not indicate any presence of the symptom. There was no tree disease recorded for the *E. deglupta* while a total percentage of 4.1% of *P. caribea* were recorded with the infection of tree disease (Figure 2.d).

Figure 2: The comparison of growth performance of *E. deglupta*, *P. Caribea*, and *P. falcataria* planted at the former copper mine in Mamut, Ranau based on Tree crown (a), Leaves colour (b), Leaves density (c) and Disease symptom (d).

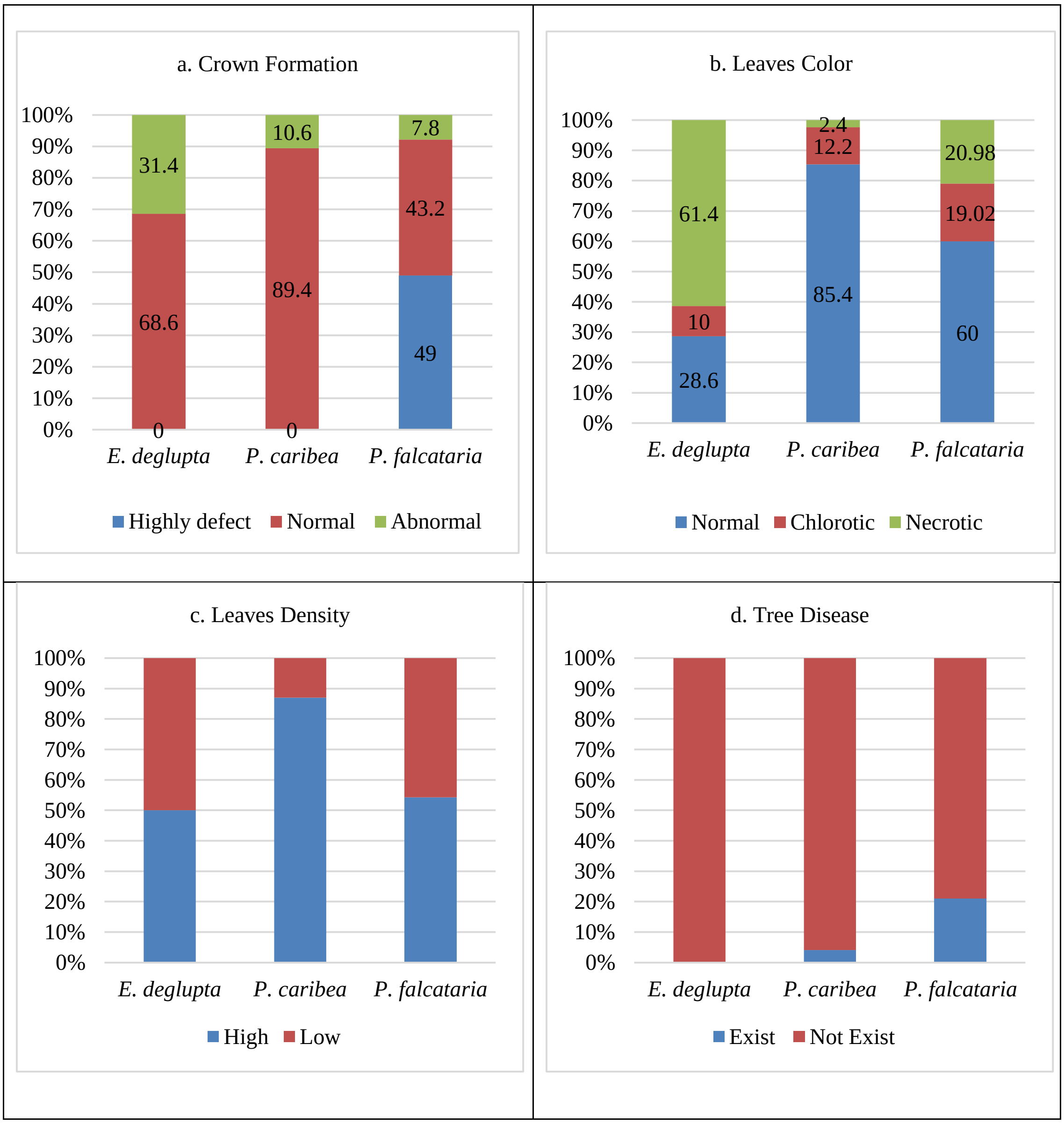


Table 2 shows the general estimation of the percentage of tree mortality for the three species planted in Mamut copper mine area. The highest percentage of mortality was *P. falcataria* (85.5%), followed by *E. deglupta* (78.3%) and the lowest was *P. caribea* (21.2%).

Table 2: Percentage of tree mortality

Species	Area Planted (ha)	Spacing (m)	Est. Initial Number of Seedling	Enumerated on the ground	Mortality (%)
P. falcataria	0.24	2x2	600	105	85.5
E. deglupta	0.29	3x3	322	70	78.3
P. caribea	0.25	4x4	156	123	21.2

Discussion and Conclusions

The growth performance of the tree species planted to restore the former mining of Mamut is shown in Table 2. The highest average DBH (cm)/year recorded is confined to *P caribea* (2.20 cm/yr.), followed by *P. falcataria* (0.52 cm/yr.) and *E. deglupta* (0.41 cm/yr.). In term of tree height, it was also recorded as highest with the *P caribea* species (0.85 m/ha) followed by E deglupta (0.48 m/ha) and P. falcataria (0.27 m/ha).

Table 3: Data of mean height and DBH of difference species planted in the former mining area in Mamut.

Species	DBH (mean) (cm)	Avg. DBH(cm)/year	Height (mean) (m)	Avg. Height (m)/year
P. falcataria	8.31	0.52	4.35	0.27
E. deglupta	6.19	0.41	7.25	0.48
P. caribea	24.19	2.20	9.36	0.85

*Tree ages based on year of planting (*P. falcataria* in 1992, *E. deglupta* 1993 and *P. caribea* 1997)

A comparison of growth performance in Mamut area with the mean height of the species in other places is shown in Table 5. The data of *P. falcataria* is based on trees planted in the favourable area in Indonesia as recorded by Orwa et al. (2009). The mean tree height of the species at the age of 15 years is 39 meters. The data of *E. deglupta* were recorded from a trials plot in Papua New Guinea show that the tree can reach a height of 44 meters within 15 years (Kashio and White, 1996). The data of *P. caribea* that was taken from China recorded a mean height of the 15.6 meters at the age of 16 years old (Wang et al., 1998). Information on the performance growth from the other favourable sites indicated significant differences as compared with the growth of trees planted in the former mining area. The *P. caribea* shows the highest value of performance growth of 86.73% as compared with the species planted in the fertile area. The value is followed by the *E. deglupta* with 16.38%, and the lowest was confined to *P. falcataria* which recorded only 10.34% compare to growth performance in the fertile area (Table 4). This differences could be anticipated with factors such as genetic composition. Other factors are related to treatment and maintenance applied throughout the tree growth such as weeding, fertilizing and the overall soil condition of the planting site. In this study, the *P. caribea* was identified having the best growth performance as compared with the other species of *P. falcataria* and *E. deglupta*.

Table 4: Comparison of growth performance of trees planted in Mamut with other growth recorded from the fertile site.

		P. falcataria	*E. deglupta*	*P. caribea*
Fertile site	age	15	15	16
	mean height (m)	39.0	44.2	15.6
	mean height (m)/year *(y)*	2.60	2.94	0.98
Mamut copper mining	age	16	15	11
	mean height (m)	4.35	7.25	9.36
	mean height (m)/year *(x)*	0.27	0.48	0.85
Species adaptation level (as compared with optimum condition / fertile site)	*(x/y)* x 100	10.38	16.33	86.73

Tree mortality rates can be influenced by genetics and the environmental factors. The soil condition of the former mining influencing the percentage of tree mortality. According to Li (2006), the high content of copper (Cu) in soil make the copper mines not suitable for the vegetation growth. The altitude can also influence the growth and mortality rates of the trees planted. Every species has an optimum level of altitude for planting suitability. The Mamut mining is located at the altitude between 1,300 to 1,600 meter above sea levels, whereby the *P. falcataria* can grow well up to the altitude of 1,200 meters and has the best growth on the site with altitude below 800 meters (Ti & Tangau, 1991). The *E. deglupta* can be cultivated at the altitude ranges from 150 to 500 meters above sea level but also and can grow at the altitude up to 1,800 meters above sea level (Salleh, 1996; Orwa et al. 2009). *P. caribea* can grow up to the altitude of 1,500 above sea level, but it grows best at the altitudes below 1,000 meters (Ti & Tangau, 1991). In this study, *P. caribea* is found to be more successful than *E. deglupta* and *P. falcataria*. There are many other factors related to the growth suitability of the trees planted such as the influence of soil composition, the range of annual precipitation and insect infestation.

Overall, the observation on the pattern of tree health of all the tree planted was at a normal state. About 60% of the *P. falcataria* enumerated show a normal growth pattern while *E. deglupta* 95.7% and *P. caribea* 99.2% respectively. The changes of leaves colour is a sign of the tree health deterioration, which could be used as a measure to assess tree health and forest health index (Innes, 1993). The *P. caribea* has the highest percentage with normal foliages colour which indicates the healthiest among the three species planted. The latest observation also shows the existent of natural regeneration of *P. caribea* that spread on some part of the degraded area. There is no regeneration observed for the *P. falcataria* and *E. deglupta.*

Conclusion

After the closure of the mining operations in Mamut, a slight effort has been made to restore the degraded area. This includes the planting of ground cover of grass and trees. There were four main exotic species planted sparsely in the area namely *P. caribea, E. deglupta*, *P. falcataria* and *Acacia sp.* However, there has been no maintenance or silvicultural treatment such as weeding being conducted to allow the optimum growth of the trees. This study was only observed and monitored the physical characteristics of the trees in term of tree height, diameter (DBH), the tree health that is based on trees foliage, crown formation and the existence of tree diseases and regeneration. The planted trees were survived, but the highly degraded soil in the area has caused to the deficiency of growth of the trees. The growth performance of the tree planted is significantly different as compared to thus planted in more favourable soil in other sites. It was observed that the *E. deglupta* have the highest mortality rate compare to the others species. In some part of the area, it has been succeeded naturally by the native species such as *Isachne sp.*, *Thysanolaena maxima*, *Miscanthus floridulus var. Malayanus*, *Dacrydium elatum*, *Macaranga kinaballuensis*, and *Vaccinium cordifolium.* The *D. elatum* was observed as native species that pioneering and highly adapted to some part of the degraded area. It has denominated most part of the steep area facing the Bukit Hampuan forest reserve. The *P. Caribea* is identified as the most tolerate exotic species to the degraded former mining area. The species was also recorded being cultivated by the community in the nearby upland area of Kundasang and nowadays can be sighted growing and spread naturally along the road of Bundu Tuhan-Kundasang-Pinousok (Lintangah et al., 2010). It is suggested that any restoration activity in the former mining area should be intensively monitored. Apart from the importance of species selection, the treatment and maintenance of the trees planted should be carried out regularly to expedite the restoration of the area. Future program of tree planting in the area should consider the selection of native species such of *D. elatum* which has proven to be adapted well to the surrounding environment of the degraded area.

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