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Tailings reclamation trials at PT Freeport Indonesia in Mimika, Papua, Indonesia

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Abstract

Tailings produced by PT Freeport Indonesia (PTFI) operations are deposited in a designated area of 230 km^2 in the lowlands of Mimika Regency of the Papua Province of Indonesia. To minimise lateral impacts, PTFI built and maintains two levees along the east and west sides of the deposition area. The area between the two levees is known as Modified Ajkwa Deposition Area (Mod-ADA). Currently research and development are ongoing to evaluate tailings reclamation approaches for eventual mine closure.

There is an area in the western part of the Mod-ADA that is no longer actively receiving tailings as a result of the modification of the west levee. In this area trials are carried out as part of the reclamation program. At closure, the area where tailings are deposited can be divided into four zones, based on tailings particle size, geomorphology, hydrogeology and suitable vegetation types. The most appropriate conversion of inactive tailings deposition area into natural forest through natural succession process and re-vegetation or into productive agricultural uses varies depending on these zones. Tailings soil is classified as Entisolic and is characterised by low to very low content of nitrogen (N), phosphorous (P), potassium (K), and organic carbon and high calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), sulphur (S), and pH level ranging from medium to high (pH 6-8). The high pH level of tailings soil reduces mobility of nutrients and metals in soil solution and availability of these elements to plants. The tailings reclamation demonstration projects are carried out in an inactive former tailings area. Demonstrations and research projects include planting various agriculture crops, plantation crops and forest trees. In some areas primary natural succession is observed to successfully grow pioneer plants.

The paper presents results of several of the trials including data on metal uptake in agricultural crops, growth and viability of forest plantation species, and the results of the natural succession process in re-establishing a high degree of biodiversity in a former tailings area. Approximately 160 plant species have been successfully grown on the former tailings deposition area. Laboratory tests performed on the edible parts of plants grown in tailings indicate that the metal content is below the maximum allowable limits of Indonesia Governmental Standard.

1 Introduction

PT Freeport Indonesia (PTFI) is a copper and gold mining company that has been operating in the Mimika Regency, of the Papua Province, since 1972**.** Currently PTFI processes 220,000–240,000 tons ore per day. The ore processing is conducted at the Mill (MP-74) using well-known flotation process, which produces concentrate and tailings. Tailings are finely ground natural rock residue from the processing of mineralised ore amounting to approximately 97% of the processed ore and only 3% represent the concentrate containing copper, gold and silver.

In accordance with the approval of the 300-K Environmental Impact Assessment (EIA), tailings are deposited on a designated area in the lowlands, known as Modified Ajkwa Deposition Area (Mod-ADA). To manage the tailings deposition in the lowlands which will continue until the end of the mine, PT Freeport Indonesia built the barrier levees on the East side (54 km) and West side (50 km), with the distance between the two levees ranging from 4–7 km. The total area utilised for the deposition of tailings in the lowlands is about 230 km^2. A new west levee was constructed at a location inside the previous west levee

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location. This change provided an area no longer receiving tailings, called the Double Levee Area, which is an area between the Old West Levee and the New West Levee. In the Double Levee Area, PT Freeport Indonesia has conducted reclamation activities and natural succession processes have resulted in recovery of the area.

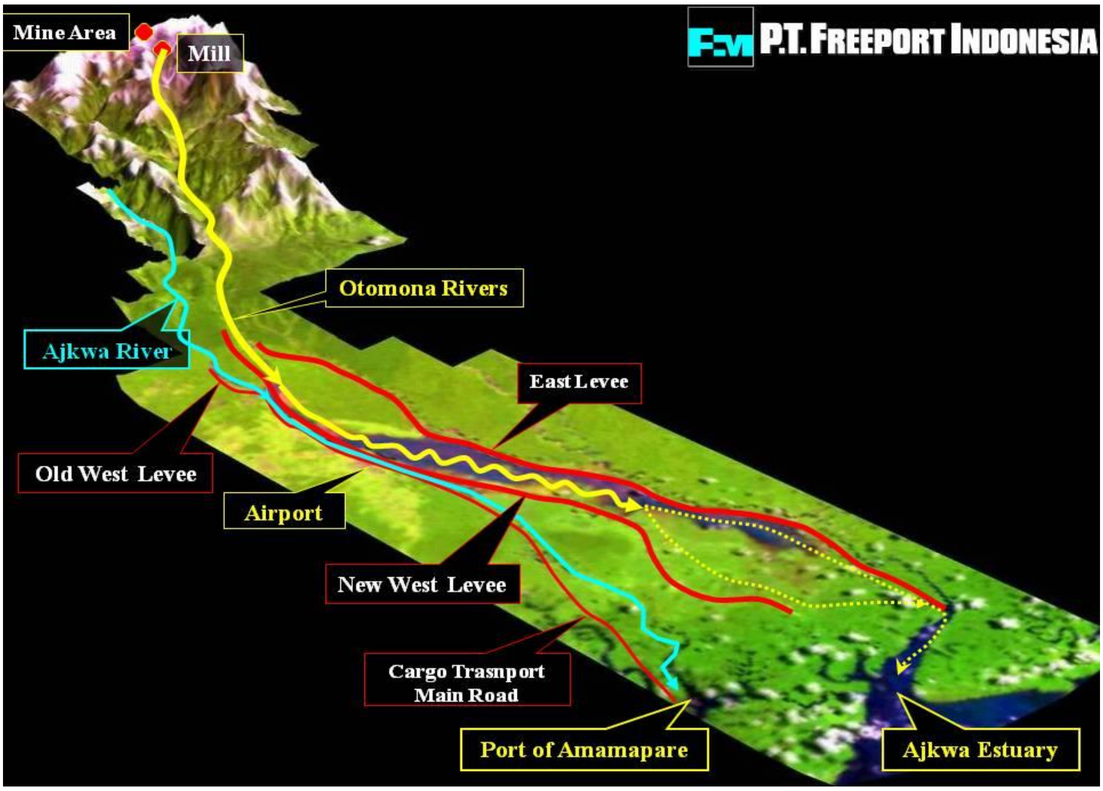

Figure 1 View of Mod-ADA

Tailings particle size is classified into four categories: coarse (>175 µm), medium (150–175 µm), fine (38–75 µm), and very fine tailings (<38 µm). Tailings sedimentation start taking place in the lowlands at MP–34 whereas the coarse size tailings are mostly deposited in the upper part of Mod-ADA, medium tailings in the middle part of Mod-ADA, fine tailings in lower part of Mod-ADA and very fine tailings are deposited in the Ajkwa Estuary and coastal zone. PTFI has conducted comprehensive studies for many years to provide sound, scientific data for reclamation of disturbed land currently and after mine closure. Studies of tailings reclamation on tailings area shows that tailings can be readily revegetated/replanted with forestry and agricultural plants. In fact, on the tailings that are stabilised, natural succession of vegetation takes place rapidly developing into forest land.

2 Tailings soil characteristics

Tailings contain lots of minerals with the physical characteristic coarse, medium, fine and very fine that influence the process of soil formation. The high rainfall (3,500–4,000 mm/year), temperature (25–27°C) and humidity (>90%) in the lowland where the tailings are deposited, helps the process of soil formation. Total content of quartz and feldspar (albite, orthoclase, microline, sanidine, anorthite) in tailings is high while total content of clay (montmorilonite, kaolinite, haloisite, chlorite, talk) as well as organic matter content is low to very low (<1%) (Taberima, 2009). Clay minerals and organic matter are very important and needed in the development process of tailings into soil. Cation exchange capacity (CEC) of clay minerals and organic matter help the soil to absorb nutrients, maintain soil moisture, and prevent loss of nutrients due to leaching by rainfall and run-off. Tailings have low cation exchange capacity, even without CEC, which is shown from pH H_2O > pH KCl or pH H_2O = pH KCl.

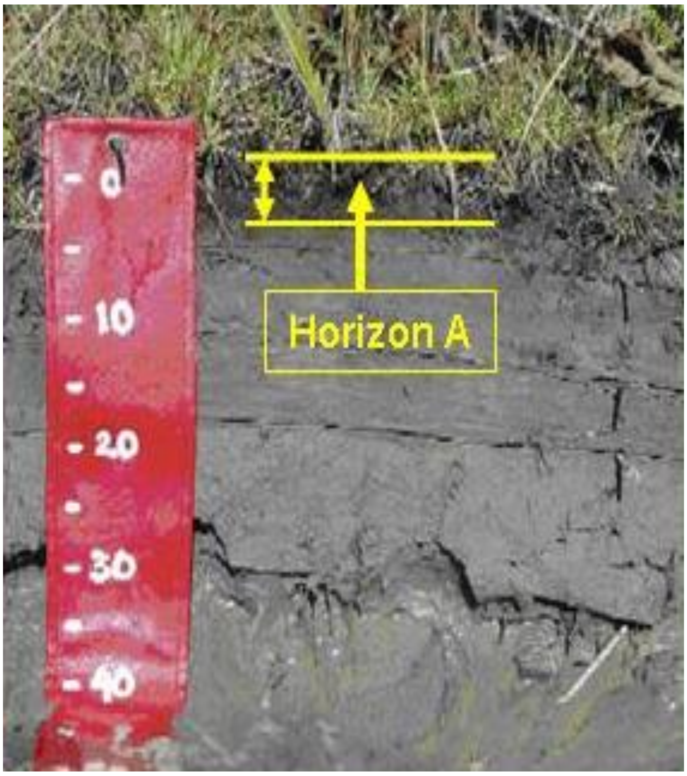

Figure 2 Soil profile on tailings

Soil developement from tailings in the deposition area is relatively very young. CEC is low because the content of clay mineral and organic colloids is also low, so the nutrient cation is easily dislodged by leaching process due to climatic factors. Tailings are classified as entisol (Taberima, 2009). Entisol has no profile development with the possible exception of a thin, dark or light colored A horizon. Entisol generally has no horizon, including the establishment of sub-horizon, except for the top soil as A (Ap), ochric, histic, and C. Morphologically, Entisol does not have a development structure except in top soil or surface layer (Sanchez, 1992). Materials of tailings origin in the Double Levee Area that no longer receives active tailings consist of horizon A and C, with a massive structure and is composed of > 80% coarse materials (sand clay to sand) and the rest is fine materials/silty (see Figure 2).

Base on PTFI's tailings monitoring program, tailings soil is characterised by low to very low content of nitrogen (N), phosphor (P), potassium (K), and organic carbon but high in calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), Zinc (Zn), sulphur (S), base saturation and pH level ranging from medium to high (pH 6-8). The high pH level of tailings soil causes low mobility of nutrients in soil solution and nutrients availability to plants. Physically, in the area where coarse tailings are deposited, the soil drainage is generally good with no water-logging or inundation, whereas in the area with fine tailings the soil drainage is poor with high soil moisture content and occasionally inundated. Generally plants that grow on certain soil type have a mechanism to adapt to the existing soil physical and chemical conditions. Plants can regulate the nutrient uptake and exude the nutrients and metals that are not required by the plants. With this phenomenon, natural succession of vegetation takes place considerably rapidly in the inactive tailings deposition area.

However, if part of tailings deposition area is going to be converted into agricultural area having soil characteristics mentioned above, it requires efforts in (1) selecting type of plants that can grow with the existing soil condition, (2) selecting plants that can accelerate the soil building process, (3) the use of soil microorganisms such as *Mycorrhizae* and *Rhizobium*, and (4) soil amelioration with organic matter.

3 Approach of tailings reclamation

In general, the area where the tailings are deposited can be divided into four types which are presented in the following table.

Table 1 Four characteristics of tailings

Character	Type-1	Type-2	Type-3	Type-4
Particle size	Medium – coarse	Medium – fine	Mix of medium – fine – very fine	Very fine
Drainage	Very good	Moderate	Bad – water logged/inundated	Very bad
Moisture	Moderate	High	Very high	Very high
Nutrient	Very low	Low	Low – moderate	Low
Land use	Forest or agro-forestry	Agriculture with amelioration	Wetland/aqua culture	Mangrove forest

Based on types of deposition area above, there are three approaches being considered by PTFI to reclaim tailings soil after final mine closure: (1) allow natural succession to take place in the fresh inactive tailings deposition area, (2) convert the fresh inactive tailings deposition area into agriculture (includes estate crops plantation, forest plantation or agro-forestry) and possibly (3) convert the area where natural succession process has taken place after several years into agriculture, forest plantation or agro-forestry.

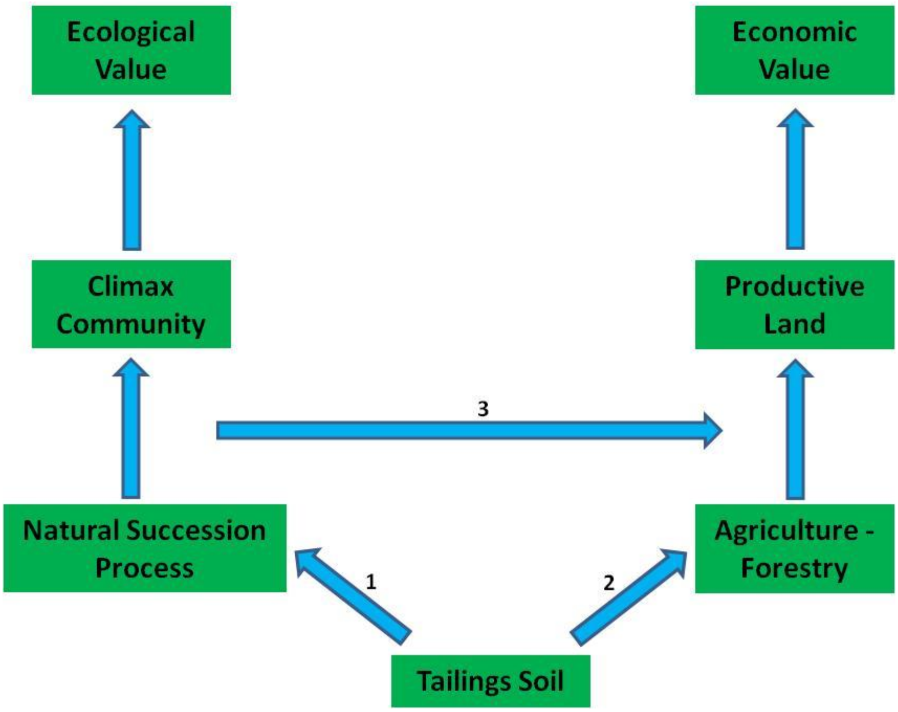

Figure 3 Diagram of tailings reclamation approaches

In the first approach (natural succession, see Figure 2), pioneer grass plants (primarily *Phragmites karka*) and other lower type plants that invade the inactive tailings deposition area are left to develop naturally. Pioneer plants produce abundant biomass that add and establish quickly an essential carbon base in the soil. Soil-microclimate, -microorganisms, and -nutrient status will gradually improve, and through time other plants invade the area and the vegetation becomes more and more diverse. Eventually, the area develops into climax community within several decades (see Figure 3). Through this approach, conversion of tailings area has ecological value.

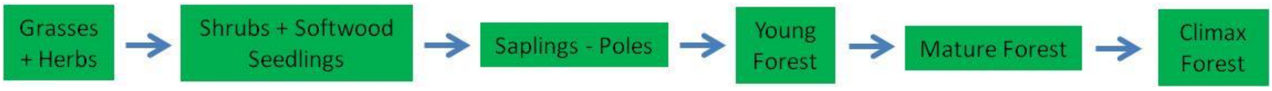

Figure 4 Stage of natural succession process on tailings area

In the second approach (agriculture-forestry, see Figure 3), conversion of the inactive tailings deposition area into productive agricultural land uses will require extra efforts to support tailings soil for the plant growth. PTFI has conducted several studies and trials on reclamation techniques, plants selection and soil improvement techniques at the Tailing Reclamation Research Centre that was established in 1996. Results of some of the studies have been implemented in field scale. As described in Section 2, organic carbon content in tailings is low to very low. To support better agricultural plant growth, amelioration of organic matter into the tailings soil is required. Plant biomass such as Water Hyacinth, *Phragmites karka*, and *Hydrilla verticillata* as well as other plant debris are abundantly available in PTFI work area. Compost is produced from mixing this plant biomass with cattle manure from feedlot.

The third approach is a combination of the first and second approach (see Figure 3). Several years (5–10) after the natural succession process has taken place, the area may begin to be converted into productive agricultural land or agro-forestry. Through the natural succession process, the tailings will have gained additional organic materials useful as nutrients to the initial growth of plants. Organic matter from land clearing can be converted into compost which can support the development of productive land for reclamation/re-vegetation.

Figure 5 Conversion of natural succession area to grow sago

4 Reclamation trials

PT Freeport Indonesia has conducted reclamation activities on the inactive tailings deposition area since 1992. A portion of this tailings area covering approximately 6,430,000 m^2 has been converted into productive land through land reclamation programs including agriculture, forestry and agro-forestry. Cumulatively, until 2011, 160 species of plants have been successfully grown on the tailings area. Some plants that grow well on tailings soils include a legume cover crop (LCC), native plant species such as Casuarina, Matoa and Sago, fast-growing legume trees *Gliricida sepium*, *Enterolobium cyclocarpum*, *Sesbania glandiflora*, *Caliandra* sp. and *Leucaena leucocephala*, and agricultural crops such as pineapples, melons, bananas, peppers, cucumbers, tomatoes, eggplant, beans, rice, spinach and chili.

Reclamation using forest plants, other than *Casuarina equisetifolia*, requires organic material supplied by using in situ composting method in the planting hole. A composting technique is used to prevent leaching by runoff due to high rainfall in the work area PTFI. Tailings contain very low organic matter and therefore require the compost at a rate of as much as 60-80 tons/ha. Legume crops require less compost than other plants because of their ability to fix nitrogen. Beginning in 2001, planting in tailings on a large scale has been carried out by planting *Casuarina equisetifolia*, followed by planting matoa in 2003, fast growing species of legume trees such as *Gliricida sepium*, *Enterolobium cyclocarpum*, *Sesbania glandiflora*, *Caliandra* sp. and *Leucaena leucocephala* in 2004 and *Calophyllum inophyllum* in 2007.

4.1 *Casuarina equisetifolia*

Casuarina equisetifolia, now called 'Casuarina', distributes from peninsular Thailand and throughout the Malaysian region towards northern and eastern Australia, Melanesia and Polynesia. Recently, approximately 250 ha of Casuarina planted on tailings area Type-1, grew well without amendment of organic matter and with minimum maintenance compared to other trees. Casuarina has the benefit that is more than just timber production. In some places Casuarina is used for furniture, coastal reclamation, tannin production, pulp and firewood. Casuarina is an excellent firewood and can produce a high quality of charcoal (Sosef et al., 1998). In Mimika District, the local community in general uses Casuarina as a firewood.

Growth performance of Casuarina trees on tailings is comparable and even better compared with trees growing on non-tailings soil. Table 1 shows comparison of plant height (m) and trunk diameter (diameter at breast height [dbh] in cm) of Casuarinas that grow in Senegal (coastal dunes), the Philippine (sandy beach) and on tailings in Mimika. Sosef et al. (1998) and Soerianegara and Lemmens (1994) reported that early growth of Casuarina can be very rapid, occasionally exceeding 3 m/year. In Indonesia, the annual mean increment was 1.8–2.1 m in height and 1.6–2.0 cm in diameter.

Table 2 Comparison of Casuarina growth on different media and places

Age	PTFI Tailings		Senegal (Coastal Dunes)		Philippines (Sandy Beach)	
	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)
1	3.6	4.2	1–2	-	1.6	0.6
2	4.7	6.9	2–4	-	2.3	1.8
3	8.6	11.5	-	-	2.6	2.7
3.5	11.2	14.2	-	-	-	-
5	13.7	17.7	7–10	3–4	-	-

In China (along coastal dunes), seedlings can reach 3 m tall one year after planting, but trees in average plantation may be 7–8 m tall and 5–7 cm diameter after four years. In Senegal, the growth is fast during the first seven years and it decreases progressively and stops when the stand is 25 years old (Turnbull, 1981). Casuarina that grow on Type 1 tailings reach 3.6 m tall after one year planting with 4.2 cm in diameter and 13.7 m tall after five years with 17.7 cm in diameter (see Figure 5). The height average growth rate within five years is 2.7 m/year with average diameter growth rate of 3.5 cm/year.

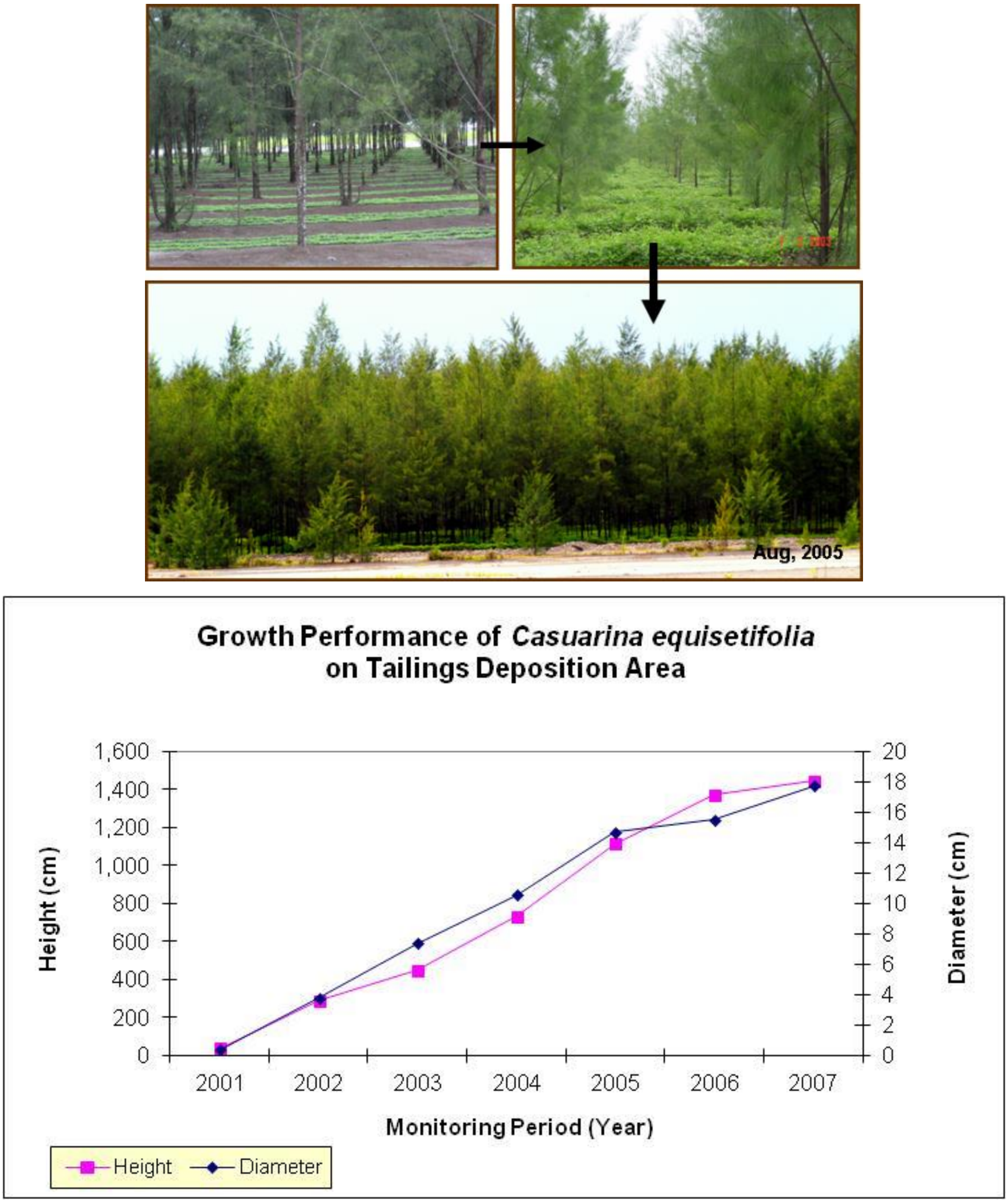

Figure 6 Casuarina plantation on tailings type 1 and the growth performance

4.2 Matoa (*Pometia pinnata*)

Pometia pinnata (matoa or kasai) consists of two species and is native to Sri Lanka and the Andaman Island, throughout South-East Asia, towards Fiji and Samoa. Matoa is cultivated for its fruits, within its natural area of distribution, which can have a thick and sweet-tasting arillode like rambutan. The roasted seeds of Matoa are also edible. A decoction of the leaves and bark is used medicinally against fever and sores (Soerianegara and Lemmens, 1994).

Matoa (kasai) is medium weight timber; it is not hard, and faintly resembles ‘meranti’ and mahogany. It is a good general-purpose wood for interior construction. Although matoa is frequently mentioned as a promising timber for export, little information is available on harvested and traded volumes (Soerianegara and Lemmens, 1994). Matoa (*Pometia pinnata*) is abundant in the forest of Mimika region. Local people harvest the fruit from the forest during fruiting seasons by cutting the trees. It is not known whether matoa has been planted in larger scale in Papua or other parts of Indonesia.

Matoa plant has been tried to grow on Type 1 tailings area. More than 1,100 tree seedlings were transplanted in 5 ha area in June 2003 (see Figure 7). The growth of matoa on tailings was on average 0.83 m/year in height and 1.84 cm/year in diameter. It reaches in average 2.3 m tall and 5.1 cm in diameter four years after planting (see Figure 7). In the natural forest, the height growth of matoa in the first years is rapid (3–5 m/year) but may be much less i.e. 11.6 cm in the first year (Soerianegara and Lemmens 1994).

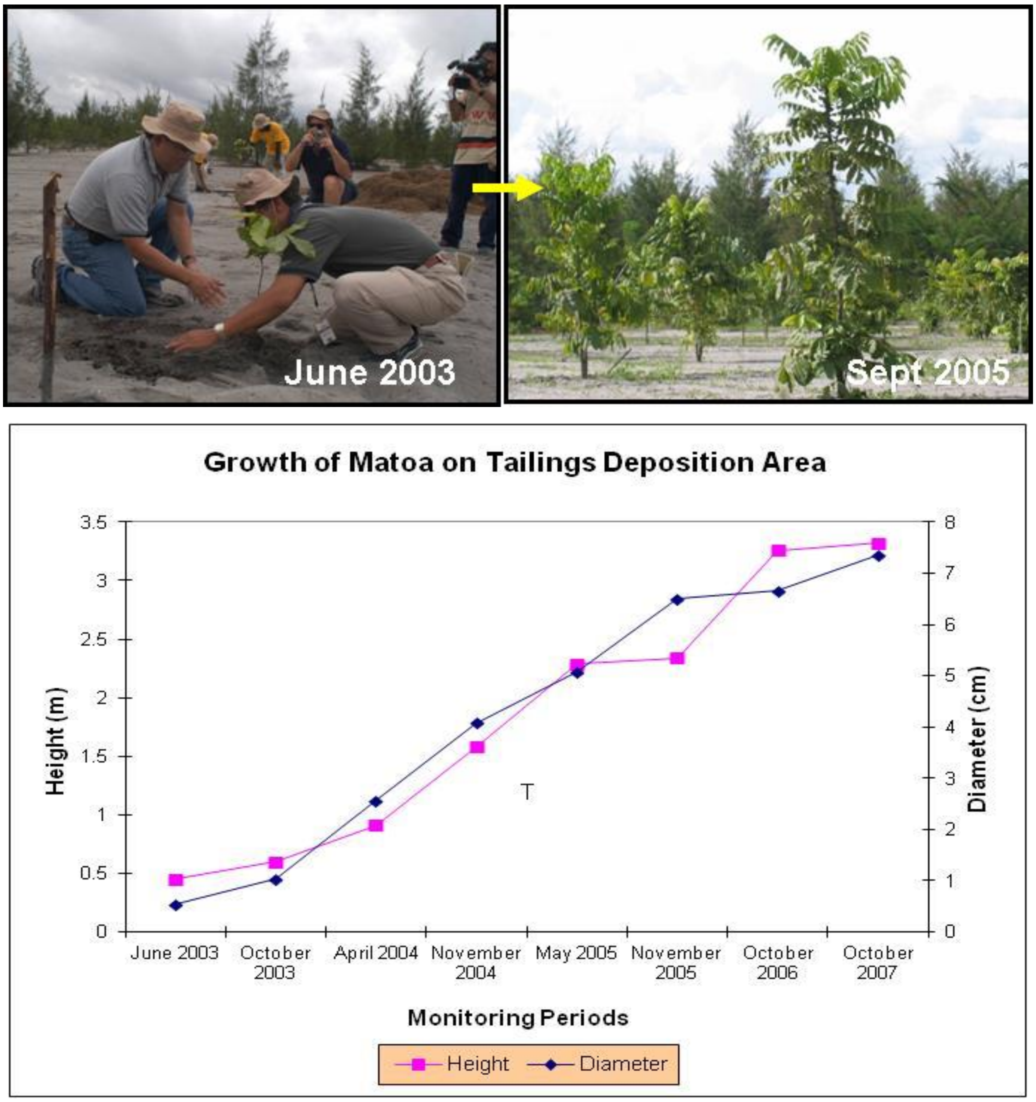

Figure 7 Matoa plantation on tailings type 1 and the growth performance

4.3 Oil palm (*Elaeis guineensis*)

Elaeis guineensis (kelapa sawit) is indigenous to the tropical rainforest belt of West and Central Africa between Senegal and North Angola. The introduction of oil palm into South-East Asia started with four seedlings planted in Bogor Botanic Gardens (Indonesia) in 1884. Offspring of these palms formed the basis for oil palm plantation industry, which started to develop from 1911 mainly in Sumatera. The uses of oil extracted from oil palm include edible products, soaps detergents, cosmetics, resins, fatty acids, bio-fuel for diesel engines, etc. (Vossen and Umali, 2002).

Oil palm is heleophile crop of the tropical lowlands that can grow on various soils like latosol, young volcanic soils, alluvial clays and peat soils, and is tolerant of relatively high soil acidity (pH 4.2–5.5). Major criteria for suitability are soil depth (> 1.5 m), organic carbon (> 1.5% in the top soil), and cation exchange capacity (> 100 mmol/kg). Soils should be well drained with no sign of permanent water-logging (Vossen and Umali, 2002).

A planting trial of oil palm was conducted in Type 2 tailings soil in 1998 and covered an area of about 0.5 ha. Seven years after planting the plant reached height of about 5–7 m and some of the trees were already fruiting but not quite promising. Oil palm does not thrive well on tailing soil, perhaps because of the alkaline pH and low CEC.

Figure 8 Oil palm tree grown on tailings type 2, seven years after planting

4.4 Betel nut (*Areca catechu*)

The exact origin of *Areca catechu* (pinang) is not known, but it likely originated from central Malaysia where it is known to be of very ancient cultivation and variability of the genus *Areca* is the greatest. The cultivation of areca palm spread from Malaysia to the Indian subcontinent in pre-historic times. At present areca palm is cultivated pantropically but is of greatest importance in South and South-East Asia, where it is grown in almost every villages (Vossen and Wessel, 2000).

The uses of ripe and unripe seeds (nut) of areca palm are chewed as a stimulant, alone or in combination with leaf of betel pepper (*Piper betle* L.) and some slake lime. In parts of India, Thailand and Malaysia, the offering and chewing of areca nuts fulfils an important religious and social function.

The nut of areca palm is widely used in Asian medicine. The husks, young shoots, buds, leaves, and roots also have medicinal uses. The nuts have been used to obtain dyes and tannin. Areca palm stems provide useful building material. In South-East Asia the fragrant flowers are used in ceremonies, such as weddings and funerals (Vossen and Wessel, 2000).

Areca palm was planted on Type 2 tailings soil in the year 2003 covering an area of about 1 ha. About 400 plants were planted on a 5 x 5 m grid. Prior to transplanting, a mixture of water hyacinth and hydrilla plant biomass as well as manure was added in each planting hole (0.5 x 0.5 x 0.5 m). Plant growth within two years appears to be normal and reach plant height in average 1.5 m.

Figure 9 Betel nut tree grown on tailings type 2, two years after planting

4.5 Sago (*Metroxylon sagu*)

Sago palm originates from Papua and Moluccas and has been dispersed beyond South-East Asia and the nearby Pacific Islands. In Indonesia, the palm is now found in parts of Sulawesi, Kalimantan, Sumatera and West Java. The world's largest contiguous sago palm swamps and forest are found in New Guinea, totaling a roughly estimated 5–6 million ha, with 4–5 million ha on the Indonesian part of the island (Flach and Rumawas, 1996).

Of the total sago palm area of 5-6 million ha, only an estimated 210,000 ha is planted. Planted areas are estimated be 130,000 ha in Indonesia, 40,000 ha in Malaysia (mainly Sarawak and Sabah), 20,000 ha in Papua New Guinea, 10,000 ha on the Pacific Islands, 5,000 ha in the Philippines, 5,000 ha in Thailand and 1,000 ha in Brunei. Most sago starch is consumed locally or traded on local markets. It accounts for less than 3% of international trade in starches (Flach and Rumawas, 1996).

Sago palm is well suited to humid tropical lowland, occurring naturally up to 700 m above-sea-level (up to 1,200 m in Papua New Guinea). The best conditions for sago palm growth are an average temperature of at least 26^{o}C and a relative humidity of 90%. Natural stands of sago palm occur on swampy coastal plains, river floodplains and higher up on flat valley floors.

The vegetative growth of sago plant is divided into two stages i.e. a rosette stage of 3.5–6 years and a trunk stage of 4–14 years. Starch is stored in the pitch of the trunk, which is gradually filled from the base upward. The total life span of sago palm ranges between 11–23 years. Within this age, suckers of various ages may have developed under a parent palm (Flach and Rumawas, 1996).

Attempts to grow sago palm as a staple food source for local people in Papua, was tried successfully on Type 3 tailings soil. More than 200 suckers (seedlings) of five good-quality-sago species were planted on Type 3 tailings area in August 2000, covering an area of about 2 ha. The suckers (seedlings) were brought in from Sentani, Jayapura, which is rich in many varieties of good sago palm that grow in Papua (10–13 types).

Figure 10 shows height growth rate of the five sago varieties grown on tailings. Within seven years after planting the height reaches 15–16 m with average growth rate of 2 m/year. There are no apparent differences on the growth rate between one variety and another.

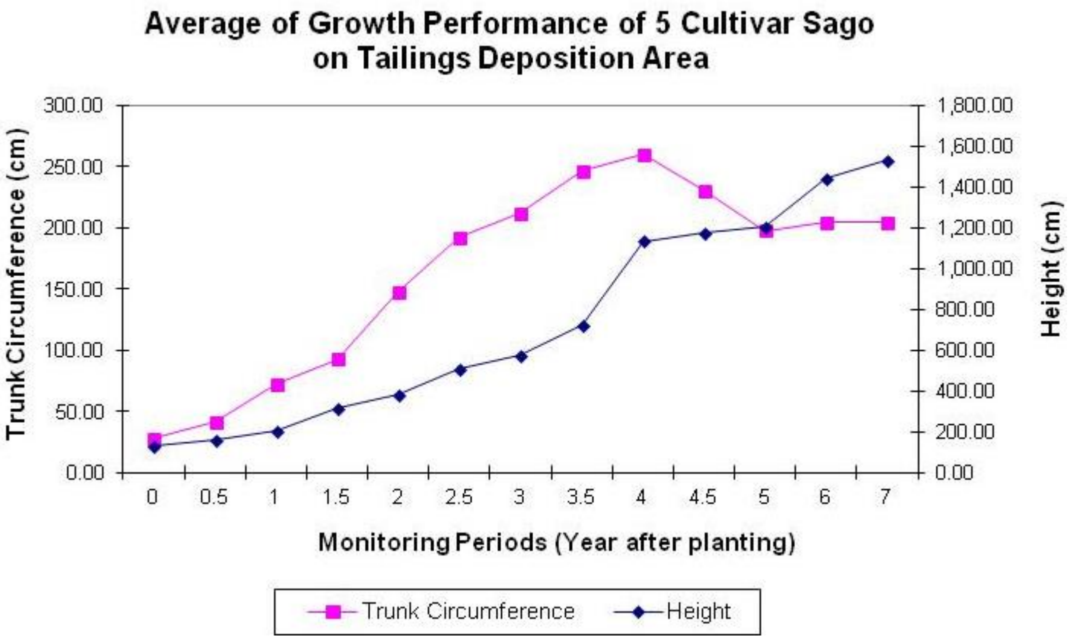

Figure 10 Growth performance of sago on tailings type 3

In the beginning of growth stage, the indicated trunk circumference was actually a midrib measurement, because the trunk was not yet formed. In figure 10, the data shown beginning in year five is an actual trunk diameter measurement.

5 Agriculture trials

One of the potential tailings utilisation methods post mining is agricultural land. Figure 11 shows some of the various crops that have been cultivated on the tailings area, such as pineapple, melon, banana, chili, cucumbers, tomatoes, eggplants, corn, lettuce, mustard, celery, sweet potatoes, taro, string beans, soya beans and cabbage.

Addition of organic materials is one of the absolute requirements for agricultural crops cultivation on tailings area. Compost and plant immersion in the ground (in situ composting) are sources of organic material in agriculture trials. To ensure the crops are safe for consumption, the edible parts were sent to the laboratory to analyse metal content. The metal analysis is conducted by PTFI's Timika Environmental Laboratory (TEL) by using inductively coupled plasma atomic emission spectrometry (ICP). Samples are prepared by weighing and adding a certain amount of Nitric Acid (HNO_3) and Hydrogen Peroxide (H_2O_2) in plant tissue sample. The sample then undergoes the destruction process to dissolve metals using ETHOS Microwave Digestion-1 and analysed with ICP.

Samples of edible plants and fruit grown on tailings as well as wild forest plant part (mainly leave) are routinely collected and analysed for metals uptake. Each plant type sample is collected from both tailings and non-tailings area to compare the metal contents.

Laboratory testing performed on the edible plants and fruits indicate that metals uptake from the mineral naturally contained in the tailings is minimal and levels of metals remain below the maximum allowable level stipulated in the national Food and Drug Administration Decree No.03725/B/SK/B/VII/SK. In 2004, about 300 samples from edible plants, fruits and wild forest plants were collected for metal-uptake analysis. Selected analytical results are shown in Table 2. There were no significant differences in metal contents between plants that grow on tailings compared to plants growing on non-tailings soils.

Figure 11 Agriculture trials on tailings area

Table 3 Metal content in several edible plants and forest plants grown on tailings and mineral soil

Plant Type	Plant Name	Location	Metal Concentration (mg/kg Wet Weight)			
			As	Cu	Pb	Zn
Fruit	Banana	Tailings	<0.20	1.70	<0.20	3.52
		Non-Tailings	<0.20	1.10	<0.20	1.72
	Melon	Tailings	<0.20	0.45	<0.20	1.32
		Non-Tailings	<0.20	0.46	<0.20	1.15
	Watermelon	Tailings	<0.20	0.40	<0.20	1.11
		Non-Tailings	<0.20	0.57	<0.20	1.21
	Pineapple	Tailings	<0.20	1.81	<0.20	1.48
		Non-Tailings	<0.20	0.54	<0.20	1.16
Vegetables	Chilli	Tailings	< 0.20	1.33	< 0.20	2.49
		Non-Tailings	< 0.20	1.88	< 0.20	2.36
	Eggplants	Tailings	<0.20	0.96	< 0.20	1.43
		Non-Tailings	<0.20	1.01	< 0.20	1.75
	Spinach	Tailings	<0.20	2.83	<0.20	2.65
		Non-Tailings	<0.20	2.59	<0.20	2.66
	Tomatoes	Tailings	<0.20	0.54	<0.20	1.75
		Non-Tailings	<0.20	0.56	<0.20	2.13
	Long bean	Tailings	<0.20	0.92	0.06	1.32
		Non-Tailings	<0.20	0.99	<0.20	6.06
Food sources	Sweet potatoes	Tailings	<0.20	1.60	<0.20	2.22
		Non-Tailings	<0.20	1.06	<0.20	3.20
	Sago	Tailings	<0.20	0.38	<0.20	0.42
		Non-Tailings	<0.20	0.41	<0.20	0.98
Forest plant	*Adina nerifolia*	Tailings	<0.20	2.67	<0.20	4.55
		Non-Tailings	<0.20	2.55	<0.20	4.72
	Ficus armitii Miq.	Tailings	<0.20	1.69	<0.20	7.63
		Non-Tailings	<0.20	2.51	<0.20	8.03
	Nauclea orientalis	Tailings	<0.20	3.17	<0.20	5.50
		Non-Tailings	<0.20	1.62	<0.20	5.36
Threshold values of the Indonesia (National) Food and Drug Administration Decree No.03725/B/SK/B/VII/SK			1.00	5.00	2.00	40.00

6 Conclusions

Tailings as residue from ore processing, which are deposited in the lowlands of PTFI project area, can be readily colonised by pioneer plants and through natural succession process will eventually become climax community (forest) within several decades. Several species important to the local population such as matoa, sago, and betel nut have been shown to thrive in tailings soils. Casuarina trees thrive due to their nitrogen fixing capabilities and provide important fuel to the local community. In addition, through organic matter amelioration, the tailings deposition area could support productive agricultural uses after final mine closure. Laboratory analytical results of the harvest of edible plants and fruits from tailings indicate low metals accumulation and that the harvest is safe to consume.

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