

Afforestation of Tin Tailings in Malaysia

LH Ang and WM Ho

Forest Research Institute Malaysia
Kepong, 52109 Kuala Lumpur, Malaysia
Tel: 06 0362702284/ E-mail : anghl@frim.gov.my

Abstract: Tin mining activities in Peninsular Malaysia since the 1930's, has resulted in ex-mining land covering approximately 113,700 ha. Large tracts of these degraded former lowland dipterocarp forests remain idle till this day. Only about 9.7% of the ex-mining land has been converted into housing estates, fruit orchards, vegetable farms, recreational parks, and golf courses. ex-mining land consists of sand and slime tailings. The sand is infertile and the area has harsh microclimate, whereas slime is more fertile but is normally water-logged. Both types of tin tailings require further improvement before they can be suitably used as production sites of high-value timber. This paper aims to [1] discuss the status of research and development on afforestation of tin tailings in Malaysia, [2] enumerate the suitable techniques employed to improve site properties of tin tailings for the establishment of high value timber species, [3] assess the survival and growth of the timber species grown on tin tailings, and lastly [4] highlight the advantages of tin tailings as a timber production area.

Keywords: ex-mining land, sand tailings, slime tailings, afforestation, high value timber species, rehabilitation

1 Introduction

Large tracts of tin tailings remain unproductive although they have great potential for conversion into timber production sites. Chan (1990) showed that only 4,730 ha (4.2%) of the ex-mining land had been utilised for agriculture and 5.5 % for other uses. In addition, the suitability of tin tailings for agricultural production is questionable in respond to the recent findings on its toxicity. The excessive uptake of heavy metals in the agricultural produce cultivated on tin tailings has rendered the site unsuitable for food crop production. Some of the heavy metals namely cadmium, mercury, arsenic and lead found in the fruits and vegetables produced from the ex-mining land have exceeded the permissible limits for human consumption (Ang *et al*, 1998). Hence, research activities focusing on the utilisation of tin tailings for timber production were carried out since the 1960's and a more systematic approach on the research has been conducted recently.

2 Objectives

This paper aims to document afforestation techniques of tin tailings, evaluate the performance of these tree species grown on the sites, and highlight the potential advantages derived from afforestation of the degraded land.

3 Status of research and development

The ex-mining land in Peninsular Malaysia covers approximately 113,700 ha (Chan 1990) comprising of tin tailings (85.6%) and water bodies (14.4%). Tin tailings covering 97,260 ha located mainly in the states of Perak, Selangor /Kuala Lumpur and Johor, can be classified into slime and sand. The extent of slime is estimated to cover approximately 10 % to 20 % of the ex-mining land and the remaining area is sand (Lim *et al*, 1981). Research activities focusing on afforestation were carried out since the 1960's (Mitchell 1957). The tin tailings can be greened with timber tree species but would require high inputs of fertilisers. Small sporadic research plots were established from 1950 to 1960 in various ex-mining sites located mainly within the vicinity of towns in the peninsula, however, most of

these planted sites had been destroyed by development in the 1990s. A more systematic approach on the research has been conducted recently. The research conducted by Mitchell (1957) in the early 1960s has significantly provided new understanding of suitable species and techniques of tree planting on ex-mining land. Fertiliser trials conducted by the universities in the last decade did not yield significant output as the rate of application suggested is not cost effective. In 1997, Forest Research Institute Malaysia (FRIM) established a small scale forest plantation consisting of timber species with end uses ranging from pulpwood to high value cabinet wood and sawn timber species on a piece of ex-mining land covering about 50 ha.

4 Improvement of tin tailings

Site amelioration efforts are needed and they depend completely on the species selected for growing on tin tailings (Ang 1994). For timber tree species which require no additional modification of microclimate of tin tailings, the amelioration of soil and proper water management would be sufficient. Three main types of tin tailings are documented in the project site namely slime, sand and sandy slime. Sandy slime can be easily cultivated with timber tree species. Sand tailings would normally require higher input of fertilisers and a better irrigation system as in agricultural production, whereas slime area requires a good drainage system to reduce water-logging but it is a better site than sand for growing tree species.

4.1 Improvement of sand tailings

If the sand dune is situated > 4 m above standing water table level (a.s.w.l), a drought period of two weeks will dry up all the available water to 15 cm depth from the surface (Ang *et al.*, 1997). The cause of such great evaporative demands is mainly due to the particle size distribution of sand tailings which comprises $> 90\%$ coarse sand. The high porosity of sand has inverse relationship with its water retention capacity. The low water retention capacity of sand eventually spells the need of irrigation in farming practices. However, in forestry this approach of water supply to sand tailings reduces the competitiveness in the final cost analysis of timber production.

The main approach adopted for improvement of sand dunes situated > 4 m a.s.w.l is to reduce water loss from the root zone during dry period. The seedling is normally planted in a big hole where the root-ball is lowered to 45 cm below the surface of the sand. Hence, the root zone loses less water from evapotranspiration. All the timber species such as *Hopea odorata* and mahogany established using big-hole planting technique have recorded $> 90\%$ survival with mean annual increment (MAI) of 0.8 to 1.2 m y^{-1} at stand age one year-old. A more costly technique involves the levelling of the sand dune to about 1.5 to 2 m a.s.w.l. has also been employed for the establishment of research trials. Thus improvement of the available water and reduction of excessive water loss from the sand dunes are of paramount importance ensuring successful tree growing on the ex-mining site.

The mechanical impedance of sand is reckoned to be high and caused impedance to root growth (Ang & Lim 1997). The compaction introduced to the sand tailings was due to the movement of heavy machines during levelling. The penetration resistance of sand at 0 cm—22.9 cm depth ranges from 0.5 ± 0.2 to 2.2 ± 1.2 MPa but higher values of penetration resistance ranges from 2.2 ± 1.2 to 3.2 ± 2.3 MPa were determined at 23 to 61 cm depths (Ang *et al.*, 1997). High mechanical impedance of sand tailings can be overcome by ploughing to a depth of about 35 to 45 cm by a tractor, followed by an application of peat or organic waste such as empty fruit bunch of oil palm. A big-hole planting was found to be effective for growing *Hopea odorata* on sand tailings in the project site. The planting technique was developed to create an optimised rooting space, and to reduce the cost of deep ploughing. The average size of the planting hole was 1.5 m length \times 1 m width \times 1 m depth, and was prepared using a back-hoe machine. About 2/3 depth of the hole was filled back with sand particles. Mechanical impedance is also a problem for slime especially during dry season.

Infertile sand tailings has been the main obstacle for enhancing growth and survival of timber tree species. Sand is poorer than slime in fertility according to previous studies (Table 1). Many studies showed that introduction of organic fertiliser either from plant materials or animal wastes to sand tailings would improve its fertility and also improve its physical properties. This approach has been used to

improve the nutrient status of sand tailings in the project site. The details of the fertiliser regime are described in the subsequent sections.

Table 1 Some chemical properties of sand dunes and water-logged slime of ex-mining land. The soil samples were collected at depths of 0 cm—15 cm to 15 cm—30 cm

Properties	Durian series ¹	Sand tailings ²	Slime tailings ³
Wet pH	4.2	4.2—4.32 4.3—5.1*	3.2 4.0—6.5*
Organic Carbon (%)	1.74	0.042—0.062	1.4
N (%)	0.16	0.012	0.20
Available P (ppm)	5.40	0.48—0.76 <0.01 *	15
Exchangeable cations (m.e/100g soils)			
[K ⁺]	0.28	0.013—0.018 0.012—0.03*	0.19
[Mg ²⁺]	0.44	0.03 0.007—0.059*	0.30
[Ca ²⁺]	0.26	0.06	0.17
CEC	7.5	1.62—1.92 1.0—1.95*	25.27

Sources: ¹ Amir Husni (1983), ² Ang *et al.*, (1994), ³Lim *et al.*, (1994), and * Ang *et al.*, 2001.

4.2 Improvement of slime tailings

Slime consists of more than 90% of clay and silt particles. This has caused water-logging in slime areas after a rainfall of more than 7 mm/day. However, some raised sites of slime tailing were found to be colonised by a variety of pioneer shrubs and tree species. For the planting effort to be meaningful the slime must be ploughed as described earlier and made into raised planting bed of about 20 cm to 25 cm height with 1.5 m width. Construction of a drain with dimensions of 1.5 to 2 m depth × 0.75 m to 1m for 20—30 planting beds, leading to existing waterway, proves to be efficient for draining the rainwater during heavy downpour.

Dry slime forms hard ground, which eventually cracks if the drought prolongs. The cracking of dry slime would normally break the feeder roots and inhibit the growth of plants. The reduced growth was mainly due to lower nutrient and water uptakes. Hence, two rounds of rotovation to a depth of 30 cm to 40 cm, and a round of ploughing before tree planting are required to overcome mechanical impedance and to prevent the cracking of slime during dry seasons.

Low pH is the main concern for growing timber tree species on slime tailings (Table 1). Application of ground magnesium limestone (GML) is absolutely necessary, if the ex-mining land is originally a peat swamp forest. The soil pH of the project site is from 4.0 to 6.5, and with the application of about 200g GML/planting point, the growth of the seedlings was observed to be more healthy at one year after planting. Similarly, Lim *et al.*, (1994) observed that improvement of growth for timber species grown on slime tailings after the low pH of 2.65—3.85 of the planting site was corrected by the application of 5 t ha⁻¹ GML.

5 Species and their growth

The criteria for species selection depend mainly on the type of tailings. The species must be economically viable, environmentally adaptable and silviculturally possible. Table 2 shows the growth

performance of some timber species on tin tailings. The survival and growth rate vary between species and sites. Species that are suitable for growing on improved slime tailings are *Khaya ivorensis*, *Fagraea crenulata*, *Swietenia macrophylla* and *Hopea odorata*, whereas high-value species that are favourable for growing on improved sand tailings are *Swietenia macrophylla*, *Pinus caribaea*, *Hopea odorata*, and *Khaya ivorensis*. The rotation period of the timber stand established on tin tailings is anticipated at 35 to 40 years.

Table 2 Some growth parameters of timber species planted on tin tailings

Species	Stand age (y)	Survival (%)	hMAI (m/y)	DMAI (cm/y)	Source
Sand tailings					
<i>Swietenia macrophylla</i>	2	70	0.6—1.2	n.a.	Ang <i>et al.</i> , 2001
<i>Hopea odorata</i>	2	95	1.0—1.8	n.a.	Ang <i>et al.</i> , 2001
<i>Acacia mangium</i>	2	50	0.6—1.3	n.a.	Ang <i>et al.</i> , 2001
<i>A. mangium</i> × <i>A. auriculiformis</i>	2	65	0.9—1.6	n.a.	Ang <i>et al.</i> , 2001
<i>A. aulocarpa</i>	37	n.a.	0.64	0.85	Ang, 1994
<i>A. auriculiformis</i>	32	n.a.	0.67	0.78	Ang, 1994
<i>A. mangium</i>	4	n.a.	2.95	2.87	Ang, 1994
<i>Pinus caribaea</i>	26	n.a.	0.74	0.76	Ang, 1994
<i>P. elliotii</i>	33	n.a.	0.50	0.59	Ang, 1994
<i>Casuarina equisetifolia</i>	30	n.a.	1.00	0.78	Ang, 1994
Slime tailings					
<i>Khaya ivorensis</i>	2	85	0.3—2.1	n.a.	Ang <i>et al.</i> , 2001
<i>Fagraea crenulata</i>	2	97	1.2—2.3	n.a.	Ang <i>et al.</i> , 2001
<i>Peronema canescens</i>	1	85.4	0.5—2.5	n.a.	Ang <i>et al.</i> , 2001
<i>Acacia mangium</i>	3.8	n.a.	n.a.	3.4	Lim <i>et al.</i> , 1984
<i>Araucaria hunsteinii</i>	3.7	37.5	n.a.	1.3	Lim <i>et al.</i> , 1984
<i>Gmelina arborea</i>	3.7	27.5	n.a.	2.9	Lim <i>et al.</i> , 1984
<i>Paraserienthes falcataria</i>	3.8	93.5	2.8	3.9	Lim <i>et al.</i> , 1984
<i>Fagraea crenulata</i>	30	67.0	0.7	0.9	Ang, 1987
<i>Melauca leucadendron</i>	30	63.0	0.5	0.7	Ang, 1987

6 Advantages of afforestation

Modification of the microclimate and improving the site fertility are two benefits derived from the establishment of forest stand on ex-mining land. Modification of the microclimate will enhance the site suitability for growing more valuable timber species and the value added short-term rotation medicinal herbs, for example, *Eurycoma longifolia*. The survival of this precious herb, which is believed to have aphrodisiac properties, was more than 85% underplanted the mangium stand at one year after planting. However, only 5% of this herb was observed to survive in the open. The litter production from a 3.4 year-old *Acacia auriculiformis* stand grown on sand was estimated to be $18.8 \pm 9.0 \text{ t ha}^{-1}$ of organic materials (Ang & Ang 2000). The organic materials would also attract and house many species of soil fauna and flora e.g. earthworm and fungi which will increase the decomposition rate and thus improve the soil chemical properties of the site.

Timber species such as *Pinus* species, *Flindersia brayleyana* and *Swietenia macrophylla*, can yield timber as high as USD 30,000 ha^{-1} to 40,000 ha^{-1} at 40 years after planting (Ang & Ang 2000). In addition, environmental services such as carbon sequestration must also be counted in economical terms. The same study also estimated the value of environmental service through carbon sequestration of a *Pinus merkusii* stand grown on tin tailings was USD 5,928.4 ha^{-1} . Hence, afforestation of ex-mining land and

other forms of degraded lands must be encouraged and supported by funding agencies that are primarily concerned with conservation of the environment.

Lastly, in Peninsular Malaysia alone, the lack of suitable land for the establishment of forest plantation has affected the industry adversely. Hence, the establishment of high-value timber species on sand tailings may supplement the supply of timber. In addition, the World Bank (1991) reported that forest plantations look more attractive from the economic point of view provided that they are established on idle lands. Zakaria and Ang (1992) have shown that afforestation of 100,000 ha of the ex-mining land in the peninsula alone with *Acacia mangium* at 7 years rotation would provide about 1 million m³ of pulpwood, or reconstituted materials. Every 2.1 t of *Acacia mangium* wood produce 1 t of paper (Salleh & Mohd Nor 1992). This amount of pulpwood materials can produce 0.238 million ton of paper and paperboard in the peninsula (Salleh & Mohd Nor 1992). This shows that afforestation of idle land can reduce the pressure of converting poorly stock logged-over forest into forest plantations.

7 Conclusion

Afforestation of ex-mining land is practical and normally rewarded with financial benefits and environmental advantages. In addition, it will improve the site quality of tin tailings. Hence, greening efforts of tin tailings should be encouraged.

Acknowledgements

The authors are grateful to Forest Research Institute Malaysia (FRIM) for permission to attend the conference and the International Soil Conservation Organization for sponsoring the presentation of this paper in the conference.

References

- Amir Husni, M.S. 1983. Semi-detailed soil survey of Rantau Panjang Forest Reserve, Batu Arang, Selangor and a report on the soil survey of part of the Kemasul F.R. , Pahang. Research Pamphlet No. 90.
- Ang, L.H. 1994. Problems and prospects of afforestation on sandy tin tailings in Peninsular Malaysia. *Journal of Tropical Forest Science* 7(1): 113-128.
- Ang, L.H. 1987. Some potential tree species for reclamation of tin tailings. Paper presented at the National MPTS Seminar, December 1986. Forest Research Institute Malaysia. 14 pp.
- Ang, L.H., W.M. Ho, T.B. Ang, K, Baskaran. 2001. Establishment of a high value timber production area on tin tailings. Paper presented in International Conference of Forestry & Forest Products Research. 1-3 October, 2001. Kuala Lumpur. 11 pp.
- Ang, L.H, T.B. Ang . 2000. Greening the tin tailing areas in Malaysia. Pp 195-205 in Appanah, Safiah @ Yusmah, M.Y., Astinah, W.J. & Khoo, K.C. (eds.) Proceedings of the International Conference on Forestry and Forest Products Research, 2-4 November 1997. FRIM, Kepong. Malaysia.
- Ang, LH, H.T. Chan, H.A., Darus. 1994. A cost-effective technique for establishment of *Acacia auriculiformis* and *Acacia mangium* on sand tailings. Pp 270-278 in Appanah, S. Khoo, K.C., Chan, H.T., & Hong L.T. (eds.) Proceedings of the International Conference on Forestry and Forest Products Research, 1-2 November 1993. FRIM, Kepong. Malaysia.
- Ang, L.H., H.T. Lim. 1997. Species site matching for afforestation of tin tailings in Peninsular Malaysia. Pp 370-384, in the Proceedings of the International Conference on land Reclamation & Rehabilitation., 25-27 August 1997. Golden Sands Resort, Penang, Malaysia.
- Ang, L.H., Y. Maruyama, W. Seel, C. Mullins. 1997. The suitability of *Acacia auriculiformis* A. Cunn × Benth. and *Acacia mangium* Willd. for afforestation of high sand tailings. Pp 407-424, in the Proceedings of the International Conference on Land Reclamation & Rehabilitation., 25-27 August 1997. Golden Sands Resort, Penang, Malaysia.
- Ang, L.H., T.B. Ang, L.T. Ng 1998. Site toxicity of tin tailings and its implications on land use in Peninsular Malaysia. In pp 116-123, In proceedings of Malaysian Science and Technology Congress'98. 23-25 November, 1998. Kota Kinabalu, Malaysia.

-
- Chan, Y.K. 1990. The mining land-an overview of the current situation in Peninsular Malaysia. Paper presented at the seminar on ex-mining land and BRIS soils: Prospects and Profit. 15-16 October 1990. Kuala Lumpur, 17 pp.
- Lim, K.H., S.T. George, C.F. Chee, Hussain 1994. A trial on planting of fast growing timber species on tin tailings. Pp 63-71 in Appanah, S. Khoo, K.C., Chan, H.T. & Hong, L.T. (eds.) Proceedings of Conference on Forestry and Forest Products Research, 1-2 November 1993. FRIM, Kepong. Malaysia.
- Lim, K.H., L. Maene, G. Maesshalck, G. ,W.H. Wan Sulaiman. 1981. Reclamation of tin tailings for agriculture in Malaysia. Tech. Bull. Fac. of Agric. UPM. 61 pp.
- Mitchell, B.A. 1957. Malayan tin tailings-prospects of rehabilitation. *Malayan Forester* 20: 181-186.
- Salleh, M.N., Y. Mohd. Nor. 1992. Potential of forest plantation species for pulp and paper reconstituted products industries. Pp 145-159 in Proceedings of National Seminar of Forest Plantations. 24-25 February 1992. Kuala Lumpur.
- World Bank. 1991. A World Bank Country Study: Malaysia-Forestry Sub-sector Study. Report No. 9775-MA. Washington, D.C. 175 pp.
- Zakaria, I.,L.H. Ang. 1992. Degraded land as an alternative for forest plantation development in Peninsular Malaysia. Pp 37-48 in Proceedings of National Seminar of Forest Plantations. 24-26 February 1992, Kuala Lumpur.