IMPORTANT ROLES OF SPECIES-SITE MATCHING IN AFFORESTATION OF AN EX-TIN MINE

Ho, W.M.,
Ang, L.H.,
Tang, L.K.

ABSTRACT

Sites for forest plantation establishment are usually infertile areas compared to those alienated for agriculture purpose. Idle ex-tin mine covers about 60,000 ha in the Peninsular Malaysia. It consists of slime and sand tailings. The potential of ex-tin mines for afforestation purpose is proven and demonstrated in Tin Tailings Afforestation Centre. The purpose of this study is to identify timber tree species suitable for growing on sand and slime tailings. The site constraints of ex-tin mine for tree growing are discussed and their amelioration techniques and approaches are documented. Suitable species for growing on sand and slime tailings are also recorded. This paper briefly discusses the species-site matching for greening the ex-tin mine with timber tree species.

Keywords: afforestation, sand tailings, slime tailings, species-site matching

Introduction

Problematic sites in Malaysia include ex-tin mines, landfills, grasslands together with degraded secondary forests covered 4.6 million ha (Ahmad Zainal, 1992). Ex-tin mine alone covers 113,700 ha of which 70% still remains idle (Chan, 1990; Abd Latif & Ang, 2014). Due to land scarcity particularly in urban areas, some of these ex-tin mines have been converted into agricultural areas, housing estates or recreational areas.

Ex-tin mine is infamous for its poor site quality for growing plants. Fertilizers and irrigation required for turning ex-mines into agriculture purpose are very costly and thus limit their large-scale and long-term use. In addition, with the discovery of unacceptably high levels of heavy metals in food crops grown on tin tailings recently has rendered it a less preferable site for food production. Idle ex-tin mines normally have long stretches of desert-like sand, cannot be recovered naturally due to adverse changes brought to the ecosystem by agents of degradation. These adverse changes include [1] the lack of mother trees or seed sources, [2] adverse soil properties and microclimate, and [3] repeated disturbance by the same agents that preclude the process of regeneration, for instance re-mining.

Rehabilitation of the degraded land with timber tree species is a better option of land use and would improve the soil properties and also can act as a wood production area. Once the land is alienated for forest plantation development, appropriate artificial regeneration approaches shall be employed to green the ex-tin mine. Hence, appropriate site preparation techniques will ensure optimal growth of trees on ex-tin mine (Ang & Ho, 2004). The selection of suitable species is another important factor for successful growing of trees on ex-tin mine. Due to economic constraints during site preparation, planters would often have to determine cost-effective site preparation techniques suitable for a limited species choice. In order to narrow down for achieving one to three species of growing with minimal site preparation, a discipline of species-site matching is employed. Species-site matching is selecting either a suitable species or a group of species for growing on a problematic site which has main site properties similar to the natural habitat of the choice species. Therefore, for any afforestation project to be successful, the right timber species must be selected for different site properties.

Information on species-site matching using tropical rainforest species on ex-tin mine through site amelioration is still scarce and not well-documented. This paper aims to highlight some site constraints of an ex-tin mine and site amelioration techniques together with selection of suitable tree species.

STUDY SITE

The approach of this paper is to highlight successful timber tree species grown in Forest Research Institute Malaysia Research Station in Bidor (SPF Bidor) or it is also popularly known as Tin Tailings Afforestation Centre (TTAC). TTAC houses more than 70 species of rainforest species and six exotic timber species. The research station is established on tin tailings left by Malaysia Mines Cooperation in the 1940s. It is located about 138 km north of Kuala Lumpur and is easily accessible. The extent of the station is about 121.5 ha and comprising sand tailings, ponds and slime tailings.

METHODOLOGY

Site Constraints and Amelioration

Soil degradation can be attributed to human activities such as logging and mining, and the degree of degradation depends on the scale as well as the intensity of anthropological activities. Normally, minimal disturbance does not cause drastic changes of existing vegetation and soil properties. The worst form of degradation is tin mining where complete alteration of soil profiles and soil composition were made to extract tin ore. Generally, three main site properties namely microclimate, soil and water table level are adversely changed during mining activities.

Microclimate

Microclimate determines ecological patterns in both plant and animal communities and also survival. The important role of microclimate is recognized in ecological research (Shirley, 1945). Adverse microclimate reduces decomposition activity of decomposers and adversely affecting influx of nutrients to the soils. In addition, the high heat kills most of the seedlings of tropical rainforest species especially in a barren ex-tin mine.

Soil composition

Soil composition of degraded areas normally does not change much except in the case of ex-tin mine. Most of the human activities in impoverished forest lands do not contribute to alteration of soil composition. However, mining activity causes a change in the soil composition. In order to extract mineral ores from the concentrate of the processed materials, the soil will be subjected to water separation producing two extreme soil formations known as sand and slime tailings. Sand tailings have particle size more than 0.05 mm include sand and gravels.

As such, the sand and gravel tailings require additional fine soil particles such as silt and clay to improve their soil physical properties for growing tree species. The addition of silt and clay components, besides organic wastes, will also allow the retention of water in soil compared to sand alone particularly during drought period.

Mechanical impedance

Main physical properties of sand tailings that require further improvement for growing plants include mechanical impedance. High mechanical impedance >1.5 MPa is commonly encountered in ex-tin mines and logged-over forests or any form of degradation involving heavy machinery. The mechanical impedance of sand is reckoned to be high and caused impedance to root growth (Ang & Ho, 2004). The compaction introduced to the sand tailings was due to the movement of heavy machines during leveling.

High mechanical impedance of sand tailings can be overcome by deep-hole planting technique, followed by an application of peat or organic wastes such as empty fruit bunch of oil palm. The average size of the planting hole is 1.5 m length x 1 m width x 1 m depth, and prepared using an excavator. About 2/3 depth of the hole was filled back with sand particles. However, mechanical impedance develops in slime tailings during drought. Normally, deep plough to 0.45 m must be carried out on slime tailings before any meaningful tree-growing can be carried out.

Unfavorable water table level

Sand tailings are often dry during drought period due to low water retention capacity. Drought period of two weeks will dry up all the available water to 15 cm depth from the surface (Ang *et al*., 1999). The cause of such evaporative demand effects 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 main approach adopted in the site preparation of the project site where the sand dunes are situated at > 4 m above surface water level (a.s.w.l.) was to reduce water loss from the root zone during dry period. The level of sand tailings determines its suitability for rehabilitation and restoration with plant species. If sand dunes are situated more than 4 m a.s.w.l., a drought of two weeks (rainfall <4 mm/day) would dry up the available water from 0 to 15 cm depth of sand dune (Ang *et al*., 1999). The inability of sand dunes to hold water during dry season is mainly due to its high composition of sand and gravel. The high permeability of sand results in low water retention capacity and it is costly to irrigate timber species compared to high value production of agriculture produce.

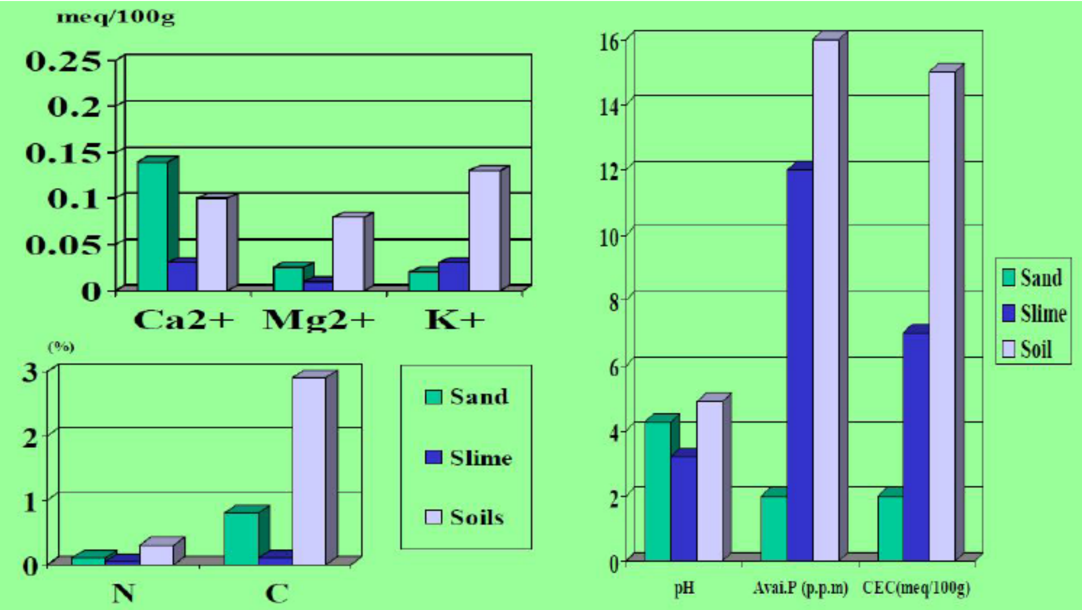
In order to ameliorate allow adaptation of plants to the sand tailings, another approach was developed by planting seedlings in a pit of lower than 45 cm surface of sand dune situated at 4 m a.s.w.l. using the big-hole planting technique. The planting hole is 1 m to 1.5 m deep and 0.5 m to 1 m wide, and is enriched with empty fruit bunches of oil palm at the bottom and filled to 0.45 cm below the surface of the sand dune. This method of planting proves to be a success in establishing Dipterocarp and leguminous climax rainforest species on 6 to 10 m sand dunes in TTAC. Water-logging is a common problem in slime tailings. It has been overcome by providing good drainage system of digging a deep hole of 1 to 1.5 m so that excess water in the slime could be drained off and thus improving the aeration of the tailings (Ang & Ho, 2004).

Soil chemical properties

Sand tailings have lower concentration of macronutrients and some of the important trace elements compared to the mineral soils as shown in Figure 1 (Ang & Ho, 2004). Soil properties of sand tailings have been the main obstacle for enhancing growth and survival of timber tree species. Sand is poor in fertility.

Many studies showed that introduction of organic fertilizer either from plant materials or animal wastes to sand tailings would improve its fertility and also physical properties. This approach has been used to improve the nutrient status of sand tailings in the project site. Low pH is the main concern for growing timber tree species on slime tailings. 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 in each planting point, the growth of the seedlings was observed to be healthier at one year after planting.

Figure 1: A comparison of some major nutrients of slime and sand tailings with good mineral soils



Thick weed cover

Shifting cultivation site and grassland normally have one same problem, the ferocity of weeds especially *Imperata cylindrica* and *Melastoma malabathricum*. These weeds render the planting for rehabilitation and restoration purpose meaningless as the roots of the weed and their fast-growth rate suppress the growth of the seedlings either from harvesting the photosynthetically active radiation or competing for soil moisture and nutrients in the root region.

Removing of weed cover is the main task before planting. Three methods of weeding are practiced in TTAC: manual, mechanical and chemical methods.

SPECIES FOR SLIME AND SAND TAILINGS

Species for slime tailings

Suitable species are Malabera (*Limahlania crenulata*), *Acacia* spp. (*Acacia aulacocarpa*, *A. auriculiformis*, *A. mangium*, *A. crassicarpa*), *Acacia* hybrid (*A. mangium* x *A. auriculiformis*), Jelutong (*Dyera costulata*), Merawan siput jantan (*Hopea odorata*), mahogany (*Swietenia macrophylla*), African mahogany (*Khaya ivorensis*) and keladan (*Dryobalanops oblongifolia*)

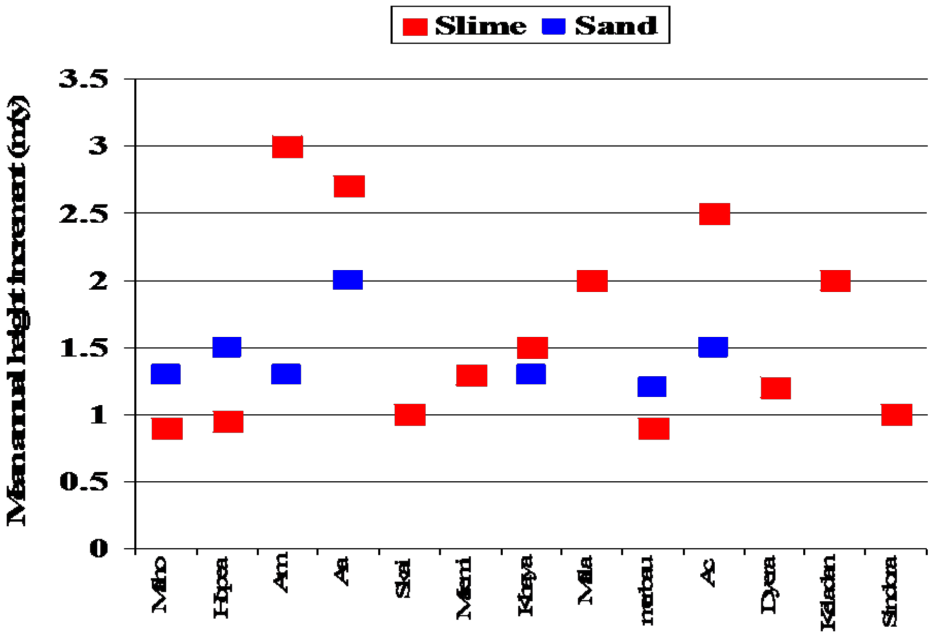
Species for sand tailings

Rosewood (*Dalbergia pinnata)*, *Acacia* spp. (*A. aulococarpa*, *A. auriculiformis*, *A. mangium*, *A. crassicarpa*), *Acacia* hybrid (*A. mangium* x *A. auriculifomris*), Jelutong (*D. costulata*), Merawan siput jantan *(H. odorata*), mahogany (*S. macrophylla*) and African mahogany (*K. ivorensis*) grown sustainably on sand tailings (Ang & Ho, 2004).

Mean Annual Height Increment

Mean annual height increment of some tree species grown on slime and sand tailings is shown in Figure 2. These are the timber species have achieved the sustainable phases at stand ages of 8 to 10 years after planting.

Figure 2: Tree species reaching sustainable phase in 8 to 10 years after planting.



Note: Maho (*Swietenia macrophylla*), Hopea (*Hopea odorata*), Am (*Acacia mangium*), Aa (*Acacia auriculiformis)*, Skai (*Peronema canescens*), Maemi *(Maesopsis eminii*), Khaya (*Khaya ivorensis*), Mala (*Limahlania crenulata*), Merbau (*Intsia palembanica*), Ac (*Acacia auriculiformis* x *Acacia mangium*), Dyera (*Dyera costulata*), Keladan (*Dryobalanops oblongifolia*) and Sindora (*Sindora coriacea*).

Briefly, the adaptation of these tree species to environmental stresses such as heat and drought could basically be divided into two main groups namely drought and heat tolerant species or drought or heat tolerant species. All the timber species grown in TTAC are suitable for open planting and they are either heat tolerant or heat avoidant species. Heat tolerant species like *H. odorata* and *Intsia palembanica*, *Peronema canescens* and *S. macrophylla* but when the water loss became lower than the critical stem water content, they started to shed leaves. The rest are heat-avoidant species, especially the acacias.

Swietenia macrophylla grows well in soils with good drainage and similarly for species such as *H. odorata* and *I. palembanica* whereas *L. crenulata* naturally occurs in freshwater swamp. *Acacia mangium* and *Dryobalanops oblongifolia* prefer fertile wet sites like improved slime tailings. However, *P. canescens*, *Sindora coriacea* and *D. costulata* prefer well-drained site but with high available soil water in the root zone.

CONCLUSION

Our study found that all the timber species listed above are more suitable for growing on slime tailings except *H. odorata*, *I. palembanica* and *S. macrophylla*, which require more well-drained soils like sand tailings. The selected tree species need to be provided a suitable environment that will enable them to grow under the harsh conditions of ex-tin mine. The results evidently show that timber species can be grown in both impoverished slime and sand tailings with appropriate site amelioration techniques that can still be cost-effective. Sand tailings could be improved with the addition of clay and silt, found in slime tailings, and agricultural wastes. Meanwhile, slime tailings would also be a suitable growing site for timber species if the problem of water-logging can be solved for example by providing a good drainage system.

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Ho, W.M.
Forest Biotechnology Division
Forest Research Institute Malaysia, 52109 Kepong, Selangor.
E-mail: howaimun@frim.gov.my

Ang, L.H.
Forest Biotechnology Division
Forest Research Institute Malaysia, 52109 Kepong, Selangor.
E-mail: anglh@frim.gov.my, treefriend2011@gmail.com

Tang, L.K.
Forest Biotechnology Division
Forest Research Institute Malaysia, 52109 Kepong, Selangor.
E-mail: tlkuen@frim.gov.my