Site suitability assessment for sustainable forest plantation establishment of *Dyera costulata* in a West Malaysian tropical forest

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Abstract
The recent depleting resources in global wood supply have prompted the need to establish forest plantation to compensate for the reducing commodity. *Dyera costulata* has been earmarked as one of the potential species for forest plantation establishment. The objective of the study was to evaluate the topsoil chemical and physical properties of a lowland tropical forest for *Dyera costulata* plantation establishment. Standard soil survey method was used for surveying before composite soil samples were taken according to each soil series, namely Batang Merbau (BMU), Bungor (BGR) and Semantan (SMN) at 0-30 cm depth. Soil samples were subjected to standard soil chemical and physical analysis. All soils were well drained except for SMN. Sand content varied from the range of 48-74%; silt (4.5 – 11%) and clay (18-50%). Nitrogen (N), phosphorus (P), and potassium (K) contents were low in all soil series. The carbon concentration in SMN was the highest, 1.6% which was 44% and 25% higher than BMU and BGR respectively. The soils showed a pH range from 3.9 to 5.0. Magnesium (Mg) and calcium (Ca) were abnormally high in SMN but was low in BGR and BMU. The CEC increased in the order of BM<BG<SM.

Key Words
Soil properties, planted forest, tropical soil, physical characteristics, nutrient requirement.

Introduction

The surge in economic development and industrialization activities in the current global trends has concurrently increased the demand for wood supply. The continuous exploitation of natural forest for timber has called for desperate measures in establishing sustainable forest harvesting and forest plantation. Plantation forestry can supply timber, reduce deforestation, restore degraded soils, enhance biodiversity, stabilize carbon sinks and provide revenue for local economy. In Malaysia, there are plans by the government to increase the forest plantation area from 250,000 to 500,000 ha (FRIM, 2007). One such indigenous species selected for reforestation is *Dyera costulata*. This threatened fast-growing indigenous timber species from the family *Apocynaceae* can be found in Peninsular Malaysia in lowland secondary forests. *Dyera costulata* is mainly used for artistic tools such as pencils, picture frames, carvings and furniture making. Successful *D. costulata* forest plantation ventures would rely on suitable climate, topography, species, and other inherent soil properties. Soil physical, chemical, and biological characters are important determinants used in the selection of sites for plantation forest. Thus, the objective was to evaluate the soil physical and chemical properties of a lowland tropical forest for successful *D. costulata* plantation establishment.

Materials and methods

The site, covering 811 ha was located at Semantan, sub-district of Temerloh in Pahang, West Malaysia (3^{o} 25' N;102^{o} 12' E). The area was covered by secondary forest, mainly *Acacia mangium*, shrubs and bushes. The mean annual rainfall from 2004 -2007 was 1800-2030 mm and the temperatures ranged from 23^{o}C to 34 ^{o}C respectively for the same period. A standard semi-detailed soil survey was undertaken (Soil Survey Division Staff 1993). Traverses were established every 800 m intervals in an east-west direction to cut across major geological formations which was present from north to south. Soil inspection was done at regular depth of 20 cm to 120 cm depth using a Jarret auger at fixed distances of every 200 m along the traverse. However, only topsoil information (0-30 cm) was presented due to space constraints. Soil sampling was carried out for determination of physical and chemical properties using standard soil chemistry laboratory analysis methods. The terrain classes were delineated using a topographical map and verified in the field using a clinometer. Three soil pits were dug to be examined and described and they represent the most dominant profiles, namely Batang Merbau (BMU), Bungor (BGR) and Semantan (SMN) series.

Results

The complete analytical data was used for the classification of soil series were not presented here due to space limitations. Generally, all profiles were deep soils and had subangluar blocky soil structure at different variations (Table 1). SMN was developed on riverine alluvium whereas BGR and BMU from argillaceous parent materials. BMU and SMN soils had sandy clay texture, but BGR had a clay texture. BMU and BGR were well drained however, SMN was not. Only BMU was found on undulating to very hilly topography compared to SMN on undulating terrain, and BGR on undulating to rolling terrain. All three soils exhibited high contents of sand in the topsoil, which was from the range of 44-71% (Table 2). The silt content was fairly low, between 5 – 11%. The highest clay content was in SMN (49.5%), followed by BGR (26%) and 18% in BMU.

Table 1: Soil description of major soil series in Semantan sub-district, Temerloh Pahang.

West Malaysian classification	USDA classification	Slope	Degrees (°)	Area (ha)	Description
Batang Merbau (BMU)	Typic Paleudults	Undulating to very hilly	2-6° to 12-20°	461	Deep soil (>100cm), brownish yellow (10YR 6/6), fine to medium sandy clay, moderate medium & coarse subangular blocky structure medium & coarse subangular blocky structure, friable to slightly firm, well drained
Semantan (tentative) (SMN)	Aquic Hapudults	Undulating	2-6°	90	Deep soil (>100 cm), gray (5Y 5/1), fine sandy clay to fine sandy clay loam,moderate medium and coarse subangular blocky structure, presence of manganese and quartz grain, slightly firm to firm,imperfectly drained
Bungor (BGR)	Typic Paleudults	Undulating to rolling	2-6° to 6-12°	260	Deep soil (>100 cm), strong brown (7.5YR 5/6), fine to medium sandy clay to heavy clay, moderate medium and coarse subangular blocky structure,slightly firm to firm,well drained

Nitrogen contents were lower than 1% for all soil types. The carbon concentration in SMN was the highest, 1.6% which was 44% and 25% higher than BMU and BGR respectively. Base saturation level in SMN was higher than BMU and BGR, 2-fold & 7-fold respectively. The availability of P was considered very low which was less than 4 mg/kg for all soil types. The soils showed pH range from 3.9 to 5.0. Potassium was also in the low range, which was less than 0.5 cmol/kg. Mg was abnormally high in SMN but was poor (low) (less than 0.1 cmol/kg) in BGR and BMU. The CEC increased in the order of BM<BG<SM.

Table 2. Chemical & physical properties major soil series at 0-30 cm depth in Semantan sub-district, Temerloh, Pahang.

West Malaysian classification	Sand	Silt	Clay	N	Org. C	Base Saturation Percentage	Available P	Dry pH H_20	K^+	Mg^{++}	Ca^{++}	CEC
	%						mg/kg		cmol/kg			
Batang Merbau (BMU)	71	11	18	0.1	0.9	5.4	3.6	4.2	0.04	0.03	0.07	5.0
Semantan (SMN)	44	6.5	49	0.2	1.6	10.9	3.4	5.0	0.04	0.53	1.32	17.6
Bungor (BGR)	69	5	26	0.	1.2	1.6	2.9	3.9	0.05	0.09	0.0	14.0

Discussion and recommendation

Only deep (> 100 cm) soils with suitable drainage of the BMU and BGR soil series were considered as *Dyera costulata* requires deep and well drained soils (Ab.Rasip *et al.* 2004) [Table 1]. However, establishment of forest crop was not advisable on terrain of more than 25^o for BMU due to erosion risks and problems due to establishment and management. SMN was only marginally suitable due to poor drainage, which may cause ponding effects during heavy rainfall. Construction of drains or trenches may help to drain excessive water if planting was considered. Soil texture had major effects on forest species growth, especially on water holding capacity, aeration and organic matter retention (Fisher and Binkley 2000).The soils of the surveyed area were moderately fine textured (Table 1), where clay content was more than 20% (Table 2), which was suitable for proper root growth and anchorage.

Although a clear standard on soil chemical requirements for tropical forest species in Malaysia is unavailable, it is common that *Hevea brasiliensis* (rubber) is used as a benchmark for tree plantation. Our results for N, P and K showed very low concentrations compared to guidelines suggested by Pushparajah (2009) which was 0.11-0.2% for total N, 251-350 mg/kg for available P and 0.51-2.0 cmol/kg for exchangeable K, respectively. In tropical soils, the P content is relatively low due to many reasons such as insoluble complexes, precipitation by ferum, aluminum and manganese ions and also they are easily susceptible to fixations (Friesen and Blair 1981). Low levels of N, P and K can be compensated with applying standard NPK 12:12:12 fertilizer (50 -100 g) into planting hole (Krishnapillay 2002) with organic amendments as a starter boost for this species. Periodic fertilization will become necessary to maintain a uniform growth of *D.costulata* for favourable production.

In forest plantations, hardy species such as *D. costulata* has the ability to withstand low to slightly acidic pH, between pH 4-5. This is quite common in forest soils predominantly due to exchangeable aluminum. Soil ameliorations with ground magnesium limestone (GML) which has Ca and Mg source is recommended for both BGR and BMU if pH drops below 3.5, to maintain important nutrients such as N, P, K, Ca, Mg and micronutrients. The low to moderate levels of CEC and base saturation were normal in tropical forest soils due to the acidic nature of the soil caused by excessive leaching associated high tropical rainfall (Lim 2003). High base saturation in SMN was correlated with the high levels of Mg and Ca in this soil, although these bases are believed to be transported by river from external limestone sources.

Conclusion

There were no serious limitations to the use of the surveyed area for *Dyera costulata* plantation except for areas with extreme slopes in Batang Merbau. The low inherent fertility status of Bungor and Batang Merbau Series can be overcome by adequate fertiliser application. Semantan was marginally suitable and adequate drainage management is required.

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