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Soil Survey of Banggi Island Forest Reserve, Sabah for Teak Plantation

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Abstract

A detailed reconnaissance soil survey was conducted within Banggi Forest Reserve, Sabah (latitude 7°14’N to 7°21’N and longitudes 117°4’ E to 117°12’ E). The highest peak of this area is approximately 529 meters above sea level with 95.6% of the slopes ranging from 2° to 35°. The main geological body of this area is shale, sandstone and mudstone of upper Cretaceous to recent Quarternary age class. The climate of Banggi Island is typically hot and humid and influenced by north-east and south-west monsoon winds. Based on the soil survey, 11 soil series and 6 soil associations were established in this area belonging to Paliu, Kumansi, and Tanjung Lipat family. The area, classified as suitable, marginal, marginally-unsuitable and unsuitable were 7030 ha, 1601 ha, 441 ha, and 2134 ha, respectively. The unsuitable areas were mainly confined to the hilly terrain which is dominated by rock outcrops and shallow profiles. The higher terrains have mainly shallow profiles where the parent materials were encountered within 0-50 cm from the surface horizon. Soil occurring over topography exceeding 35° gradient is considered as not suitable for teak plantations. In Banggi Island Forest Reserve, 62.8% of the total area is suitable for teak planting.

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1. Introduction

Teak wood is renowned for its durability and beauty. It belongs to *Verbenadceae* family and is classified as medium hardwood. The wood is golden in colour, highly lustrous and having a density of 660 kg/m^3 (on dry basis). The price of the teak timber was between 149-448 USD/m^3 depending upon timber size and quality (Kollert and Cherubini, 2012). Teak wood is highly valued and mainly used for furniture making, veneer and decorative woodworks. The teak plantation was first introduce in 1950’s, in northern states of Peninsular Malaysia (Zuhaidi, 2011). Despite early involvement of Malaysia in teak plantation, the total hectarege of teak plantation in Malaysia in the year 2010 was 4,800 ha, lowest among the South East Asian countries (Zuhaidi, 2011, Kollert and Cherubini, 2012). One of the constraints in cultivating teak is soil suitability. The quality of teak growth depends on the depth, structure, porosity, drainage and moisture-holding capacity of the soil. It develops best on deep, well-drained and fertile soils, especially on volcanic substrata such as igneous and metamorphic soils or on alluvial soils of various origins. The optimal soil pH is between 6.5 and 7.5 and stunted growth of teak occurs when there is calcium deficiency in the soil (Kaosa-ard, 1981, Krishnapillay, 2000). Due to its economic value and huge market demand the potential of planting teak wood in Banggi Island Forest Reserve in Sabah, Malaysia was explored by surveying the soil suitability of the area for teak plantation. Tropical soils are highly variable comprising recent sand through podzols, volcanic ash soils to highly weathered soils rich in oxides. Wyatt-Smith, (1957) observed a significant difference in the growth performance of teak when planted under different soils. At present, there is no clear definition for suitable, marginal and unsuitable soils for teak crop cultivation. The present common practice is to plant the teak crop and worry about the soils properties later. This is the reason why the initial planting of teak in Kuala Selangor, Selangor, Malaysia on marine clay soil was a complete failure until drains were being built to contain the high water-table (pers. comm.). Thus, the current study focused on the classification of the soils in Banggi Island Forest Reserve (secondary forest) for teak cultivation.

2. Materials and Methods

Study site

The forest reserve of Banggi Island is located in the northern part of Banggi Island, Sabah, Malaysia. It is located at latitude 7°14'N to 7°21'N and longitude 117°4' E to 117°12' E (Figure 1). Banggi Forest Reserve has been logged in the past. This is obvious by the poor stocking and most of the trees are of small to medium size. The forest can be described as sparse and with thick under growth. In the northern region, the topography described has very steep terrain exceeding 35° and the highest peak is approximately 529 m above sea level (asl).

Figure 1: Location of the Banggi Island Forest Reserve, Sabah.

Climate

Climatological data of the survey site is described based on the information collected from the field station located in the vicinity of the Kudat Airport (Unpublished). The optimum temperature is recorded in the month of April to the month of May, with extremes of 28.1°C and 28.4°C, respectively. It is also noted that the drought period is recorded from the month of March, April to May, with precipitation of 30 mm, 40 mm and 70 mm, respectively, whilst high precipitation recorded from the month of November, December and January ranging from 220 mm, 305 mm and 290 mm, respectively (Figure 2). The salient features of the monsoon winds resulting from the air circulation give rise to mean annual temperatures and high mean annual rainfall of 27.4°C and 1654.5 mm, respectively.

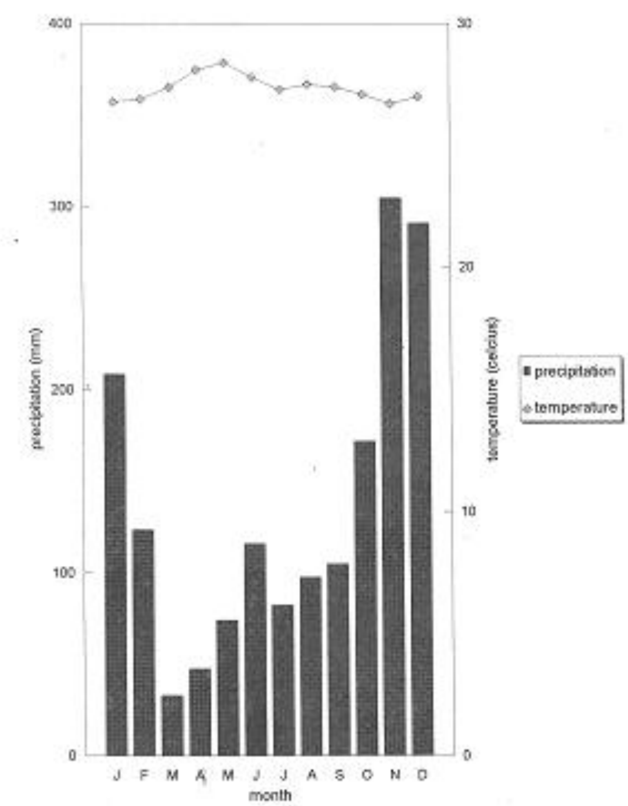

Figure 2: Mean annual rainfall and temperature of Kudat, Sabah. (Source: Amir, 1998)

Geology

The geology of the island is formed from three rock types: igneous, sedimentary and metamorphic, although only minor outcrops of the latter occurred . The rocks range in age from Upper Cretaceous to Recent Quaternary and the continuing deposition of sedimentary rocks can be seen at the many mangrove swamps in the coastal lines. The rocks have been subjected to complex tectonic movement and the structure is difficult if not impossible to define. Many of the sedimentary rocks are steeply dipping and there is abundant evidence of folding and fracturing.

Survey methodology

A topography map of 1:50,000 and 1: 25,000 was used as guideline. *Rentis* lines were planned on the Base Map to ensure they cut across as many landscapes as possible. *Rentises* were cut 300m apart whilst soils are checked using auger for every 200 m apart along the line. Auguring was carried out using Jarret auger and each auguring removed 15cm soil depth. A depth of 1.2m is examined at each auguring point. These soils series were classified based on following soil criteria; parent material, texture of topsoil and subsoil, profile development, soil colour, drainage class and pedological feature as described by Paramananthan (1986). The depth of strongly compacted layer is categorised under 3 groups, namely: 0 – 50 cm (shallow soil), 50-100 cm (moderately deep soil), >100 cm (deep soil). The soil class and soil suitability classification followed the description of Wong (1987).

Table 1: The soil class and soil suitability classification used provided by Wong (1987).

Class	Description
I	Soils are suitable for widest range of crops. Profitable under moderate level of management. Good water holding capacity and nutrient retention.
II	Moderate level of management is required in order to obtain satisfactory yields. Management practices may include erosion control and minor drainage work.
III	Soils are suitable for narrow range of crops. Management practices may include erosion control, intensive fertilization, drainage and irrigation works involving moderate expenses.
IV	Soils are suitable for very narrow range of crops, often to a specific crop. High level of management is required to prolong the productivity on such soils. Soil conservation and amelioration measures are necessary for long term cultivation.
V	Soils are not suitable for crop establishment.

3. Results and Discussions

The total 11,206 ha of Banggi Island Forest Reserve, 52.8 % of the slope were 9° - 16° (Table 2) and 62.8% of the soils belong to Class I and Class II which are suitable for teak plantation (Table 3). The survey found 3 main soil family (Paliu, Kumansi and Tanjung Lipat), 11 soil series and 6 associations in the Banggi Island Forest Reserve, Sabah (Table 4 and 5).

Soils derived from alluvial deposits - Paliu family

Soils of Paliu were deep, well drained, of alluvial deposition and occur along the banks of larger rivers of riverine origin. These are localised soils. These soils occur on level terrain. The surface of the Paliu consisted of brown (10YR4/3) to dark yellowish brown (10YR4/4) fine sandy clay loam or clay loam with weak medium to fine subangular blocky structures and friable consistence. Occasionally, some fine black manganese concretions, fine mica flakes and pockets of sand are encountered at depth. The subsoil ranged from yellowish brown (10YR5/6-5/8) to brownish yellow (10YR 6/6-6/8) in colour. Whilst, the texture varied from fine sandy clay loam to fine sandy clay. Structure are moderate, medium, subangular blocky and consistence is friable.

Paliu deep/Penambang Series

This soil type is found along the river banks. The soil texture ranges from fine sandy clay loam to fine sandy clay with mica flakes and manganese concretion. The soil is deep (>100 cm), dark yellowish brown (10YR 3/4-4/4) in colour and well drained. Generally the soils are found on flat to undulating terrain (0-8°). Paliu deep covers an area of 284 ha (2.5%) of the surveyed area (Table 5). The topsoil (10 cm deep) of Paliu deep is loamy in texture and dark darkish in colour and rich in organic matter. The subsoil texture is fine sandy clay loam to fine sandy clay, yellowish brown in colour (10YR 3/4), whilst the soil structure is coarse subangular blocky. This soil type is suitable for teak.

Paliu moderately deep phase/ Penambang moderately deep phase

This soil is a moderate version of Paliu deep, where the parent material mudstone/sandstone is encountered at the depth of 50-100 cm. Manganese concretion is sparsely found in soil profile. The presence of the parent material between the depths of 50-100 cm inhibits the root development to a certain extent. The soil type covers an area of 129 ha which is approximately 1.2% of the Banggi Island Forest Reserve.

Soils derived from mudstone or shale - Kumansi family

Soils of Kumansi are shallow to deep, well drained soil found extensively in the Banggi Island Forest Reserve. They are developed over sedimentary rocks in which the finer textured rocks of shale, mudstone and slump deposits dominate. These rocks range in colour from black to red and could sometimes be partly tuffaceous. Soils of Kumansi occur on undulating to very steep terrain (2° - >35°). Soils of the Kumansi are characterized by their yellowish to red colour. Texture in these soils is generally fine sandy clay loam in the surface but changes to fine sandy clay in the subsoil. Occasionally clay loams and silty clay to clay textures have also been encountered but these are normally quite localised. Drainage in these soils is generally good but infiltration can be somewhat slow causing temporary wetness on the surface. The weathered shale or sandstone is encountered at depths within 50 cm (shallow phase), 50-100 cm (moderately deep phase) and below 100 cm (deep phase). The topsoils of Kumansi are often a dark yellowish brown (10YR 4/4) fine sandy clay loam with weak to moderate medium to fine subangular blocky structure and friable consistence. The subsoils consist of a yellow (10YR 7/6-7/8), brownish yellow (10YR 6/6-6/8), yellowish brown (10YR 5/6-5/8) to strong brown (7.5YR 5/6-5/8) fine sandy clay. The red variant have red (2.5YR 4/6-4/8) to yellowish red (5YR 5/6-5/8) colours. Structures in the subsoils are moderate, medium subangular blocky and consistence friable to firm with depth. Patchy clayskins occur on ped faces. Soils of the Kumansi occupy 10,648 ha or 95% of the Banggi Island Forest Reserve.

Kumansi deep (Bungor deep)

Kumansi deep soil is dark yellowish brown (10YR 3/6) to yellowish brown (10YR 3/6) in colour. The soil texture is fine sandy clay, where the percentage of clay mineral is between 35-60%, whilst the silt content not exceeding 30%. The Peninsular Malaysia equivalent to this soil is Bungor series. It’s a deep soil with no pedological obstruction within 100cm. This soil is classified as well drained and very much suitable for teak planting. The soil structure is medium to fine subangular blocky and friable.

Kumansi moderate (Kuala Brang moderately deep)

The soil physical and chemical characteristic is similar to Kumansi deep except depth to pedological feature. The soil is moderately deep (50-100 cm) white chips of mudstone parent material found in the solum but can be easily penetrated during auguring. The formation of the hardpan is believed to be a band of rocks, which are loosely packed since it was easily penetrated during auguring. This soil type can be considered as marginal for teak crop.

Kumansi shallow / Kuah shallow

This soil is a shallow version of the Kumansi deep with the parent materials encountered within 0-50 cm depth. Rocky outcrop of the mudstone and shale are a common feature on the surface horizon. Based on soil depth and the presence of parent material within 0-50 cm this soil can be classified as unsuitable for teak planting.The topsoil is yellowish brown to brownish yellow

Table 2: The land terrain classification in Banggi Island Forest Reserve, Sabah

Topography	Slope(°)	Terrain Class	Land Area (ha)	Percentage (%)
Flat	0 – 2	1	-	-
Undulating	3 – 8	2	1,418	12.6
Rolling	9 – 16	3	5,913	52.8
Hilly	17 – 26	4	2,085	18.6
Very Hilly	26 – 30	5	510	4.6
Extremely Hilly	31 – 35	6	779	7.0
Steepland	> 35	7	501	4.4
		Total	11,206	100

Table 3: Soil classes, hectarage and soil suitability for crop establishment for Banggi Forest Reserve, Pulau Banggi, Sabah.

Soil Class	Land Area (Ha) [%]	Soil Suitability
Class I	824 [7.3]	Suitable
Class I + Class II	369 [3.3]	Suitable
Class II	5837 [52.2]	Suitable
Class II(terrain)	1601[14.4]	Marginal
Class II(terrain) + Class IV	367[3.2]	Marginal - Unsuitable
Class II + Class IV	74[0.6]	Marginal - Unsuitable
Class III	829[7.4]	Unsuitable
Class III + Class IV	413[3.6]	Unsuitable
Class IV	391[3.8]	Unsuitable
Class V	501[4.5]	Unsuitable

Table 4: Soil types found in Banggi Island Forest Reserve, Sabah

Soil Family	Soil series/associations
Paliu/deep	Penambang
Paliu/moderately deep phase	Penambang moderately deep phase
Kumansi/deep	Bungor(deep)
Kumansi/deep-Kumansi/moderate association	Bungor-Kuala Brang association
Kumansi/shallow-Kumansi/moderate association	Kuah-Kuala Brang association
Kumansi (olive)/deep	Bungor olive variant
Kumansi(olive)/deep-Kumansi (olive)/moderate association	Bungor (olive)-Kuala Brang (olive) association
Kumansi (olive)/shallow	Kuah olive variant
Kumansi (olive)/moderate	Kuala Brang olive variant
Kumansi (red)/deep	Bungor red variant
Kumansi (red)/moderate	Kuala Brang red variant
Kumansi(red)/shallow	Kuah red variant
Kumansi(red)/deep-Kumansi(red)/moderate association	Bungor red variant-Kuala Brang red variant association
Kumansi (red) / shallow-Kumansi (red)/moderate	Kuah red variant-Kuala Rang red variant association
Kumansi/deep-Kumansi(olive)/deep association	Bungor-Bungor olive variant association
Tanjong Lipat/deep	Serdang

Tanjong Lipat/moderate	Nami

Table 5: Division of land area by soil types in Banggi Island Forest Reserve,

Soil family/Phase	Terrain Class	Soil Class	Suitability	Description	Land Area (ha)	Percentage (%)
Paliu/deep	2	I	Suitable	Deep, well drained, yellowish brown, fine sandy clay loam to fine sandy clay, friable, recent alluvial	284	2.5
Paliu/moderate	2	II	Suitable	Moderately deep, well drained, yellowish brown, fine sandy clay to fine sandy clay loam, friable, recent alluvial	129	1.2
Kumansi/deep	2	I	Suitable	Deep, well drained, yellowish brown, fine sandy clay, friable, mudstone/shale	540	4.8
	4	II (terrain)	Marginal		64	0.6
Kumansi/deep - Kumansi/moderate association	3	II	Suitable	Moderately or deep soil, well drained, yellowish brown, fine sandy clay, friable, mudstone/shale	1111	10.0
	4	II(terrain)	Marginal		816	7.2
	5	III	Unsuitable		136	1.2
	6	III	Unsuitable		150	1.3
Kumansi/shallow - Kumansi/moderate association	3	II + IV	Marginal - Unsuitable	Shallow or moderately deep soil, well drained, yellowish brown, fine sandy clay, friable, mudstone/shale	74	0.6
	4	II (terrain) + IV	Marginal - Unsuitable		367	3.2
	5	III + IV	Unsuitable		240	2.1
	7	V	Unsuitable		501	4.5
Kumansi (olive)/deep	3	II	Suitable	Deep, well drained, light olive brown, fine sandy clay, friable, mudstone/shale	254	2.3

Kumansi (olive)/deep – Kumansi (olive)/moderate association	2	I + II	Suitable	Moderately or deep soil, well drained, light olive brown, fine sandy clay, friable, mudstone/shale	166	1.5
	3	II	Suitable		401	3.6
	4	II(terrain)	Marginal		215	2.0
	5	III	Unsuitable		87	0.8
Kumansi (olive)/shallow	5	IV	Unsuitable	Shallow, well drained, light olive brown, friable, mudstone/shale	47	0.4
Kumansi (olive)/moderate	3	II	Suitable	Moderately deep, well drained, light live brown, friable, mudstone/shale	59	0.5
Kumansi (red)/deep	3	II	Suitable	Deep, well drained, dark reddish brown, fine sandy clay, friable, mudstone/shale	2245	20.0
	4	II(terrain)	Marginal		275	2.5
Kumansi (red)/shallow	2	IV	Unsuitable	Shallow, well drained, dark reddish brown, friable, mudstone/shale	96	0.9
	3	IV	Unsuitable		131	1.2
	4	IV	Unsuitable		72	0.6
Kumansi (red)/moderate	3	II	Suitable	Moderately deep, well drained, dark reddish brown, friable, mudstone/shale	221	2.0
	4	II	Marginal		68	0.6
Kumansi (red)/deep – Kumansi (red)/moderate association	2	I	Suitable	Moderately or deep soil, well drained, dark reddish brown, fine sandy clay, friable, mudstone/shale	203	1.8
	4	II(terrain)	Marginal		163	1.5
	6	III	Unsuitable		456	4.1
Kumansi (red)/shallow – Kumansi (red)/moderate association	6	III + IV	Unsuitable	Shallow or moderately deep soil, well drained, dark reddish brown, friable, mudstone/shale	173	1.5

Kumansi/deep – Kumansi (olive)/deep association	3	II	Suitable	Deep, well drained, yellowish brown or dark reddish brown, fine sandy clay, friable, mudstone/shale	1317	11.8
Tanjung Lipat/deep	3	II	Suitable	Moderately deep, well drained, brownish yellow, friable, sandstone	100	0.8
Tanjung Lipat/shallow	4	IV	Unsuitable	Shallow, well drained, brownish yellow, friable, sandstone	45	0.4
Paliu/deep	2	I	Suitable	Deep, well drained, yellowish brown, fine sandy clay loam to fine sandy clay, friable, recent alluvial	284	2.5
Paliu/moderate	2	II	Suitable	Moderately deep, well drained, yellowish brown, fine sandy clay to fine sandy clay loam, friable, recent alluvial	129	1.2
Kumansi/deep	2 4	I II (terrain)	Suitable Marginal	Deep, well drained, yellowish brown, fine sandy clay, friable, mudstone/shale	540 64	4.8 0.6
Kumansi/deep - Kumansi/moderate association	3 4 5 6	II II(terrain) III III	Suitable Marginal Unsuitable Unsuitable	Moderately or deep soil, well drained, yellowish brown, fine sandy clay, friable, mudstone/shale	1111 816 136 150	10.0 7.2 1.2 1.3
Kumansi/shallow - Kumansi/moderate association	3 4 5 7	II + IV II (terrain) + IV III + IV V	Marginal - Unsuitable Marginal - Unsuitable Unsuitable Unsuitable	Shallow or moderately deep soil, well drained, yellowish brown, fine sandy clay, friable, mudstone/shale	74 367 240 501	0.6 3.2 2.1 4.5
Kumansi (olive)/deep	3	II	Suitable	Deep, well drained, light olive brown, fine sandy clay, friable, mudstone/shale friable, mudstone/shale	254	2.3

Kumansi (olive)/deep – Kumansi (olive)/moderate association	2	I + II	Suitable	Moderately or deep soil, well drained, light olive brown, fine sandy clay, friable, mudstone/shale	166	1.5
	3	II	Suitable		401	3.6
	4	II(terrain)	Marginal		215	2.0
	5	III	Unsuitable		87	0.8
Kumansi (olive)/shallow	5	IV	Unsuitable	Shallow, well drained, light olive brown, friable, mudstone/shale	47	0.4
Kumansi (olive)/moderate	3	II	Suitable	Moderately deep, well drained, light live brown, friable, mudstone/shale	59	0.5
Kumansi (red)/deep	3	II	Suitable	Deep, well drained, dark reddish brown, fine sandy clay, friable, mudstone/shale	2245	20.0
	4	II(terrain)	Marginal		275	2.5
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	3	IV	Unsuitable		131	1.2
	4	IV	Unsuitable		72	0.6
Kumansi (red)/moderate	3	II	Suitable	Moderately deep, well drained, dark reddish brown, friable, mudstone/shale	221	2.0
	4	II	Marginal		68	0.6
Kumansi (red)/deep – Kumansi (red)/moderate association	2	I	Suitable	Moderately or deep soil, well drained, dark reddish brown, fine sandy clay, friable, mudstone/shale	203	1.8
	4	II(terrain)	Marginal		163	1.5
	6	III	Unsuitable		456	4.1
Kumansi (red)/shallow – Kumansi (red)/moderate association	6	III + IV	Unsuitable	Shallow or moderately deep soil, well drained, dark reddish brown, friable, mudstone/shale	173	1.5
Kumansi/deep – Kumansi (olive)/deep association	3	II	Suitable	Deep, well drained, yellowish brown or dark reddish brown, fine sandy clay, friable, mudstone/shale	1317	11.8

Tanjung Lipat/deep	3	II	Suitable	Moderately deep, well drained, brownish yellow, friable, sandstone	100	0.8
Tanjung Lipat/shallow	4	IV	Unsuitable	Shallow, well drained, brownish yellow, friable, sandstone	45	0.4

(10YR 5/6-6/6) in colour and as the depth increases the soil turns to lighter shades of olive brown (2.5Y 5/4-5/6). The subsoil has a mixture of colours but the dominating colour is olive greyish brown (2.5Y 5/2), whilst the texture is fine sandy clay. The massive formation of the parent rocks, encountered at 0-50 cm depth and impenetrable to auger may suggest that this soil type as unsuitable for growing teak crop. This massive rock formation will limit the taproot to establish itself in the subsoil and to anchor the plant firmly into the solum. In addition, heavy downpour may retard the infiltration rate to some extent and may result in surface flow and removal of organic and nutrients from the surface area, resulting in poor fertility status of this soil.

Kumansi olive deep / Bungor olive variant

Kumansi olive deep soil derived its name from its dominating olive colour which range from dark yellowish brown (10YR 4/6) to brownish yellow (10YR 6/6). The subsoil is light olive brown (2.5Y 5/4) and the texture is sandy clay. This soil is very much similar to Bungor series of Peninsular Malaysia, except the colour. This soil is suitable for teak planting since the soil is deep and having a friable texture. The drainage is well drained and the soil structure ranges from fine to medium subangular blocky.

Kumansi olive moderate (Kuala Brang olive variant)

In terms of soil physical and chemical characteristics, this soil is very much similar to Kumansi olive deep except for the depth to the soil pedological feature, where the parent material is found between 50-100 cm from the surface horizon with flakes of sandstone and mudstone embedded in solum. This soil parent material can easily be broken through during auguring process. This is an indication that the roots can easily penetrate through and may not be a serious limiting factor to root growth. The occurrence of parent rock as hardpan but loosely packed may suggest that this soil can be classified as marginal to teak planting.

Kumansi olive shallow (Kuah olive variant)

This is a shallow soil and the parent material is encountered within the depth of 0-50 cm. The parent material is derived from mudstone and shalestone. Rocky outcrop of mudstone and shale is a common feature in this area. Based on the soil depth, this soil can be classified as not suitable for teak planting due to the presence of massive parent rock which will inhibit root growth. The soil has an olive brown colour to olive dark brown of (2.5Y 2.5/2) and (5Y 4/4-3/4), respectively. The soil texture is fine sandy clay loam to fine sandy clay.

Kumansi red deep (Bungor red variant)

The soil is dusky red in colour (2.5YR 2.5/2) with a texture of fine sandy clay (35-60%). The Peninsular Malaysia equivalent of this soil is Bungor red variant. It is a deep soil with no obstruction within 100 cm depth and is derived from sandstone and mudstone. The soil is friable with fine to medium subangular blocky structure. This soil is suitable for teak crop, with no pedological obstruction for vertical and lateral root growth.

Kumansi red moderately deep / Kuala Brang red variant moderately deep

The soil is dusky red in colour (2.5YR 2.5/2) with a texture of fine sandy clay (35-60%). The Peninsular Malaysia equivalent of this soil is Kuala Brang red variant. The mudstone/sandstone parent material is encountered within the depth range of 50-100 cm. The parent rock is easily penetrated with the screw auger, suggesting that the teak roots will be able to penetrate through into the deep zone of the subsoil. The soil is dusky red in colour (2.5YR 2/5/2) with a texture of fine sandy clay (35-60%). The soil is friable with fine to medium subangular blocky structure. It is a well drained soil, but during heavy rainfall the rate of infiltration may somewhat be slowed down due to the presence of the parent rock. This soil type can be classified as suitable to marginal for teak crop.

Kumansi red shallow / Kuah red variant

This soil is very much similar to the soil of Kuah series in Peninsular Malaysia. The mudstone/shale parent rock can be found within 50 cm depth from the surface. Rocky outcrop is a common feature and this may reduce the planting surface area. This soil type is not suitable for teak planting. In order to use this soil, heavy input of management is required such as ploughing to break the hardpan and fertilizing.

Soils developed from sandstone (Tanjung Lipat family)

Soils of Tanjung Lipat are moderate to deep, well drained soils found locally in the study area. They are developed over isolated hills where sandstone dominates the shales and mudstones. In general, soils of the Tanjung Lipat are shallow to deep brownish yellow to yellow fine sandy clay loam soils. Structures are generally weak to moderate subangular blocky and consistence is friable. Patchy clayskin occur on ped faces. The topsoil of the Tanjung Lipat are often brown (10YR 4/3) to dark yellowish brown (10YR 4/4) fine sandy loam or fine sandy clay loam with weak medium to fine subangular blocky structures and friable consistence. The subsoils are uniformly brownish yellow (10YR 6/8) to strong brown (7.5YR 5/8) fine sandy clay loam. Structures are weak to moderate medium subangular blocky and consistence friable. Thin patchy clayskins occur on ped faces. In shallow phase soil, the weathered sandstone is encountered within 50 cm while it occurs between 50 to 100 cm in the moderately deep phase and below 100 cm in deep phase. Soils of the Tanjung Lipat occupy 145 ha or 1.3% in the study area.

Tanjung Lipat deep / Serdang series

The soil is brownish yellow (10YR 6/8) to yellowish brown (10YR 5/8) in colour, but some profiles have uniform colour throughout but some with lighter shades as the soil depth increases (light yellowish brown 10YR 6/4). The soil is sandy clay loam and well drained, whilst the subsoil is fine loamy sand which is brownish yellow to light yellowish brown in colour. The soil structure is fine to medium subangular blocky, whilst the consistency is weak. Suitable for a wide range of crop and this soil covers an area of 100 ha (0.8%) of the surveyed area.

Tanjung Lipat moderate (Nami series)

A moderately deep soil with pedological obstruction between 50-100 cm and more. The sandstone at this depth is on medium to coarse grain. This soil covers an area of 45 ha (0.4%) of the area surveyed. The suitability of this soil is governed by the topography. On higher terrain the soil may e classified as marginal to unsuitable but on lower terrain it may be classified as suitable to marginal.

Climatically, Banggi Island, had almost identical weather conditions to that of Mata Air Forest Reserve, Perlis (Amir, 1998), where teak flourish gregariously, where the latter mean annual mean rainfall is below 1800 mm and mean annual temperature of 28^{o}C to 30^{o}C and having a low spell of annual rainfall from December to March. Banggi Island on the other hand enjoys a dry spell from March to May, with mean annual temperature of 28^{o}C with of less than 50 mm, recorded in these three months, which can be considered and distinct dry spell period. These types of moisture and temperature regimes are suitable for teak crop, even even though the ideal should be that of the Thailand, Laos and Myanmar, with distinct drought period of 5 to 6 months with annual precipitation of 600-800 mm, and annual temperature regime of 28-32^{o}C in their northern regions (Amir, 1999).

Beside soil texture and gradient, soil pH, soil nutrient and elevation should be taken into consideration. The optimal soil pH for teak is between 6.5 and 7.5. However, most Malaysia soils are acidic in nature with pH ranging between 4-4.5. This pH range is considered marginal for teak and liming is necessary (Amir, 2001). Soil formation is depend upon the parent material which in turn influences the soil fertility status (Tavernier and Eswaran, 1972). A preliminary fertilizer study conducted by (Sundralingam, 1982) showed P as the nutrient promoting height and diameter of teak seedlings. However, this caused a problem in the plantation of teak in the tropics as tropical soils are highly weathered and easily leached (Owen 1953). Thus, application P is recommended for promoting the growth of teak in the tropics. Generally, Sabah is a young geological formation compared to Peninsular Malaysia (Paramananthan, per. comm.) and thus much fertile than most of the latter soil types and therefore in terms of fertility these soils may not be the limiting factor.

The calcium content of the soil is also an important factor; calcium deficiency in the soil results in stunted growth of teak (Kaosa-ard, 1981). In Malaysia, the best grown teak have been reported on alluvial and marine clay soils, which are known to occur at low elevation (not exceeding 100 m asl.) (Amir, 2001). Interestingly, in Tanzania, teak wood grown at elevation 465 – 885 m asl had better strength properties compared to those grown at 460 m asl. and between 160 and 560 m asl (Hamza et al. 1999). In Nigeria, teak was found to grow well in the south-western part of the country where the elevation ranges between 120 to 480 m asl. (Akindele, 1991). Besides these, more depth study on the teak planting methods, fertilization regime, amount of rainfall, pest and disease management and plant density in the respective locality would be helpful to maximise the potential profits return in future.

4. Conclusions

The soil of Banggi Island Forest Reserve is a good area for teak cultivation, with accommodative temperature and moisture regimes, with intermittent low spell rainfall period of three months. This dry period (March to May) should be avoided when introducing new plantlets into the area in order to avoid high mortality rate. Ninety five percent of Banggi Island Forest Reserve soils are Kumansi soil type with majority of the described soil properties suitable for teak planting. However, limitation for suitability of teak planting is more restricted by terrain and rock outcrop. Despite this limitation, the whole island can be use as teak sivilculture activities with recommended soil amendments programs.

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6. References

Akindele, S. O. (1991). Development of a site index equation for teak plantation in southwestern Nigeria. Journal of Tropical Forest Science, 4: 162-169.

Amir, H. M. S. (1998). The performance of teak crop when planted on various soil types in Peninsular Malaysia. Paper presented at the Malaysian Science and Technology Congress. 7-8 November 1998, Kuala Terangganu, Peninsular Malaysia.

Amir, H. M. S. (1999). The teak industry in Peninsular Malaysia its progress and prospects. Paper presented at the International Teak Conference. 23-25 August, Chiang mai, Thailand.

Amir, H. M. S. (2001). Teak (*Tectona grandis*) management practices in Peninsular Malaysia. Forest Research Institute Malaysia, Kuala Lumpur.

Hamza, K. F. S.,. Makonda, F. B. S, Iddi, S. and Ishengoma, R. C. (1999). Differences in wood properties of *Tectona grandis* grown in Tanzania, International Teak Conference-Teak Beyond Year 2000, Chiang Mai, Thailand.

Kaosa-ard, A. (1981). Teak (*Tectona grandis* Linn. F.)- its natural distribution and related factors. Natural History Bulletin of the Siam Society 19: 55-74.

Kollert, W., and Cherubini, L.. (2012). Teak resources and market assessment 2010 (*Tectona grandis* Linn. F.). Forestry Department, Food and Agriculture Organization of United Nations, Rome, Italy.

Krishnapillay, B. (2000). Silviculture and management of teak plantations. Unasylva 201, 51: 14-21.

Owen, G. (1953). Studies on phospate problem in Malaysian soils. Journal of Rubber Research Institute, 14: 1-11.

Paramananthan, S. (1986). Field legend for soil surveyors in Malaysia. Universiti Pertanian Malaysia, Serdang, Selangor.

Sundralingam, P. (1982). Some preliminary studies on the fertilizers requirements of teak. The Malayan Forester, 45.

Tavernier, R., and Eswaran, H. (1972). Basic concept of weathering and soils genesis in humid tropics. Proceedings - 2nd ASEAN Soil Conference.

Wong, I. F. T. (1987). Soil-crop suitability classification for Peninsular Malaysia. Soil Management Services Branch, Department of Agriculture.

Wyatt-Smith, J. (1957). A note on teak in north-west Malaya. The Malayan Forester 20: 129-139.

Zuhaidi, A. Y. (2011). Current teak plantation industries in Malaysia: Linking between government efforts, investors dilemma and research outputs, International Teak Conference, Planted Teak Forests-a globally emerging forest resource, San Jose, Costa Rica.