ASSESSING SOIL CHARACTERISTIC UNDER REFORESTATION
OF INDIGENOUS TREE SPECIES:
A CASE STUDY AT SAMPADI FOREST RESERVE, LUNDU

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ABSTRACT

Vast area of tropical rainforests is degraded by human activities every year. The degraded lands are left as low productivity and low biodiversity. In Sarawak, the forests is decreasing due to land use conversions required for other developments such as agriculture, clearing for commercial, housing and industrial purposes. The remaining forest stands, even at the remote areas and lack of accessibility due to mountainous geological formation are also under increasing pressure from the logging activity. Reforestation activities have been launched to convert the degraded area into productive forests. This study is conducted to clarify the soil under reforestation area and to determine whether the soil is suitable for the growth of the dipterocarp species, *Shorea macrophylla* in Sampadi Forest Reserve, Lundu. The soil profile of the study area was examined in-situ from a soil pit that was dug with the size of 10×10m² at the reforestation area planted with *Shorea macrophylla* in year 1996. A vertical section of the soil from the surface through all its horizons was observed to verify the soil profile. The soil profile composed of O, A, B₁, B₂, and B₃ horizons. The status of soil under reforestation clarified in this study. Laboratory results for the soils indicated that the soil pH at the study area to be acidic and the readings were increased with the increasing depth. The soil organic matter in the upper horizon was indicated to be higher and this contributes to the higher organic nutrient at the A horizon, consequently improved the fertility status of the soil. The values of bulk density at the study site were ranging from 1.15 g cm⁻¹ to 1.64 g cm⁻¹. On the other hand, the soil hardness of all identified horizons was measured ranging from 17mm to 22mm. It was indicated that the soil hardness increased with the increasing of depth. From this study, it was revealed that rehabilitating using *Shorea macrophylla* definitely offers a potential to improve site productivity.

Key words: reforestation; soil characteristic; dipterocarp species; *Shorea macrophylla*; Sarawak
ABSTRAK

Setiap tahun, keluasan hutan hujan tropika didapati semakin berkurangan akibat aktiviti manusia. Kawasan hutan yang diterokai secara berleluasa tanpa kawalan menyebabkan produktiviti tanah yang merosot dan biodiversiti yang berkurangan. Di Sarawak, hutan semakin berkurangan disebabkan penerokaan kawasan hutan untuk pertanian, komersial, perumahan dan perindustrian. Hutan di kawasan pergunungan juga tidak ketinggalan dalam mengalami tekanan yang meningkat daripada aktiviti pembalakan. Pelaksanaan aktiviti penghutanan semula telah dilancarkan untuk menanggulangkan kawasan hutan yang telah diterokai menjadi produktif. Oleh itu, kajian ini dijalankan untuk mengkaji kualiti tanah di bawah kawasan penghutanan semula dan untuk menentukan sama ada tanah adalah sesuai untuk pertumbuhan spesies dipterokarp, Shorea macrophylla di Sampadi Forest Reserve, Lundu. Profil tanah dikaji dengan menggunakan tanah saiz $10 \times 10\text{m}^2$ di kawasan penanaman semula hutan yang ditanam dengan Shorea macrophylla dalam tahun 1996. Keratan tegak tanah dari permukaan diperhatikan untuk mengesan profil tanah yang terdiri daripada O, A, B1, B2 dan B3 ufuk. Status tanah di bawah penghutanan semula juga dijelaskan dalam kajian ini. Keputusan maklumat menunjukkan bahawa tanah di kawasan kajian adalah bersifat asid kuat dengan bacaan pHw kurang daripada 5 dan bacaan didapati meningkat dengan kedalaman yang semakin meningkat. Kandungan organik tanah di ufuk atas yang lebih tinggi menyumbang kepada status kesuburan tanah. Ketumpatan tanah di kawasan kajian adalah di antara $1.15 \text{g cm}^{-1}$ kepada $1.64 \text{g cm}^{-1}$. Seterusnya, kekerasan tanah telah diukur antara dari $17\text{mm}$ ke $22\text{mm}$. Kajian juga menunjukkan bahawa kekerasan tanah meningkat dengan kedalaman yang semakin meningkat. Implikasi yang penting daripada kajian ini menunjukkan bahawa pemulihan tanah menggunakan Shorea macrophylla menawarkan potensi untuk meningkatkan produktiviti tapak. 

Kata Kunci: Penghutanan semula; ciri-ciri tanah; spesies dipterokarp; Shorea macrophylla; Sarawak
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INTRODUCTION
1.1 Introduction

Tropical forests cover approximately 17% of the terrestrial biosphere, yet they account for an estimated 43% of global net primary productivity (NPP) and 27% of the carbon stored in forest soils (Melillo et al., 1993; Brown and Lugo, 1982), which are intimately tied to the quantity of water and nutrient elements in the soil and their rate of cycling through the ecosystem (Silver, 1998).

Humid tropical forest is a prime biome for potential carbon sequestration because of the large annual biomass production during the 12-month growing season (Körner, 1998) which supplies millions of people with life support requirements, for timber, food, water and other resources (Bazzaz, 1998).

Ward and Robinson (1990) observed that vegetation increases the infiltration capacity of soil by retarding surface water movement, reducing raindrop impact and improving soil moisture. Forest floor protects the surface soil from rainfall splash, limiting the formation of physical crusts (Thomas, 1998) and reducing the risk of erosion. Positive interactions can be the result of plant effects on soils, such as increases in resource availability, amelioration of micro-climate and soil conditions and increases in pollination (Callaway, 1995).
Körner (1998) mentioned that it is critical to recognize that tropical forests occur in a wide range of environments varying in elevation, in soil, in rainfall and in the intensity of seasonality. Even in the same forest types there can be great differences in species composition and successional age. Tropical soils under these forests also vary greatly in physical and chemical properties, particularly with regard to organic matter content, nutrient availability, depth of the rooting zone and moisture availability (Richards, 1996; Whitmore, 1984).

Therefore, rehabilitation through reforestation of degraded forestland due to intensive and over-utilization, thereby exhausting the organic and mineral contents, becomes very important in order to inhibit the loss of soil nutrients and improve vegetation composition as well as for environment concern. It is vital to understand and assess the environment of the rehabilitation area such as the soils characteristics (Ishizuka et al., 2000; Ohta, 1990a) species selection or site suitability (Appanah and Weinland, 1993) and tree planting techniques (Arifin et al., 2008).

1.2 Problem of statement

Global implications of local land use decisions, and how these decisions affect the quality or health of the soil, which through various ecosystems such as forest ecosystems affects the well-being of human and all other organisms (Doran et al., 1996).
Based on the data from the FAO (2012), the highest tropical deforestation rate among the tropical countries is Brazil followed by Indonesia and Myanmar as shown in Figure 1. The tropical deforestation rates showed from year 2000 to 2005 and ranked in descending order by the highest amount of average annual forest loss for 25 tropical countries.

![Tropical deforestation rates, 2000-2005](Source: mongabay.com, image by Rhett A. Butler, 2005)

**Figure 1** Tropical deforestation rates from 2000 to 2005

Malaysia's deforestation rate is accelerating faster than that of any other tropical country in the world, according to data from the United Nations. Analysis of figures from the FAO (2012) showed that Malaysia's annual deforestation rate jumped almost 86% between the 1990 to 2000 period and 2000 to 2005. In total, Malaysia lost an average of 140,200 hectares or 0.65% of its forest area per year since 2000. For comparison, the Southeast Asian country lost an average of 78,500 hectares or 0.35% of its forests, annually during the 1990s.
Most soils are prone to degradation by land misuse and soil mismanagement. Commercial logging, shifting cultivation, urbanization industry and other forms of encroachment are all principal causes of deforestation in tropical regions (Geist and Lambin, 2002; ITTO, 2002).

**Causes of deforestation**

The declining forest cover in Malaysia results primarily from agricultural and forest conversion for oil-palm plantations and other forms of agriculture, urbanization, extraction of natural resources and forest fires from big and small scale farmers.

In Brazil, rainforests is converted into pasture for cattle ranching and for soy beans, which is used as raw material in many food products and as food for farm animals. In Indonesia and Malaysia a lot of rainforests is cleared for oil palm and acacia trees. Oil palm is an important fuel and raw material in many food products, soaps and cosmetics while acacia trees are fast growing trees that are planted for cheap timber and pulp for paper. The conversion of forest to oil palm plantations can be considered one of the biggest threats to the remaining forests on Borneo. In Malaysia, the average annual growth rate of oil palm areas was nearly 8% between 1998 and 2003 (as shown in Figure 2) and over 1.6 million ha of oil palms now exist in Sabah and Sarawak. In Kalimantan the area used by palm plantations grew by 11.5% to nearly a million ha in 2003 (WWF Germany, 2005).
In Sarawak, its soils are only moderately to marginally suitable for oil palms. Unlike Sabah, Sarawak is linking oil palm development to forestry in the sense that contiguous land areas under a single management regime may have timber production from natural forests as well as oil palm plantation development. Also in Sarawak, there are schemes whereby land held under native customary tenure is developed with large plantations and profits are shared by customary landowners and plantation developer. Much of lowland Sarawak is peat swamp and it remains uncertain whether the bulk of this land will be developed with oil palm plantations.

Deforestation has been causing various environmental problems in Southeast Asia. There are many causes of deforestation and the main cause is population growth. As the population of Southeast Asian countries increases rapidly, there is a huge increase in demand for houses. Many forest areas were cleared in order to give way for
housing estates in order to meet this huge demand. Like Indonesia, the Malaysian government sponsored transmigration programs to open up rainforest for cash crop production. Between 1956 and the 1980s, Malaysia converted more than 15,000 km² of forest for resettlement programs. Forests have to make way as urban areas expand into surrounding forested areas. In order to link the cities or town areas, road projects have opened new areas to colonization.

Rainforests cover also cleared to support the industrial activities and extraction of resources such as commercial logging for timber and mining for minerals. The wood from timber is exported to other countries and processed to be made into products such as expensive furniture. In some countries also, people depend very much on charcoal as a source of fuel. The very high demand of charcoal drives deforestation, as forest is cleared and the trees are used to produce charcoal. Some forest areas also happens to sit on land that is rich in minerals such as fossil fuels like oil and coal, limestone and aggregates suitable for constructions, metals such as gold, silver and copper or tin. In order to gain the access to the natural resources, roads network are also built to make it easier for people and companies to enter the forests to extract resources such as the logging roads for timber extraction.

the severe 1997-1998 ENSO event primary forest areas burned easily (Siegert et al., 
2001) as prior drought stress led to the shedding of leaves by evergreen species and 
accumulation of dry litter on the forest floor. In addition, fire is also often used to 
clear forested land as it is cheaper than employing labourers and bringing in 
machinery to remove the trees and vegetation. The vegetation is cleared and left to 
dry out, then the area is set on fire. Burning of forests has been taking place on a small 
scale for many thousands of years by small groups of subsistence farmers, which is 
known as ‘slash and burn’ agriculture. Apart from that, burning of forests is employed 
by large companies to make way for agriculture plantation, such as oil palm. The 
valuable timber is extracted first, and the remaining vegetation is burned.

Awareness among Malaysian in understanding the important of reforestation for 
degraded land and how it impact the soil properties play a major roles in sustaining 
the soil resource management. Forests are also providing many goods and services to 
the growing population and restoration is urgently required.

1.3 Objectives

Thus, this study is conducted to clarify the soil under reforestation area and to 
determine whether the amount environment variables in the study area especially soil 
is suitable for the reforestation activities. Understanding the soil condition or 
characteristics is vital in determining the success of any reforestation effort. Apart 
from that, information on the soil condition is critical in predicting the growth 
performance of the species. The growth also can be improved by the use of
appropriate fertilizers, adapted species, selected provenance and genetically improved planting materials.
Chapter 2

LITERATURE REVIEW
CHAPTER 2
LITERATURE REVIEW

2.1 General overview of tropical rainforest

Tropical rainforest climatic patterns consist of warm temperatures and high level of precipitation which often results in poor soils due to leaching of soluble nutrients. Soil types are highly variable in the tropics and are result of a combination of several variables such as climate, vegetation, topographic position, parent material and soil age (Aragao, 2009).

Most tropical soils are characterized by significant leaching and poor nutrients and fall into two classifications which include ultisols and oxisols. Ultisols are known as well weathered, acidic red clay soils, deficient in major nutrients such as calcium and potassium. Similarly, oxisols are acidic, old, typically reddish, highly weathered and leached, however are well drained compared to ultisols. The clay content of ultisols is high, making it difficult for water to penetrate and flow through. The reddish color of both soils is the result of heavy heat and moisture forming oxides of iron and aluminum, which are insoluble in water and not taken up readily by plants. Soil chemical and physical characteristics are strongly related to the above ground productivity and forest structure and dynamics. The physical properties of soil control
the tree turnover rates whereas chemical properties such as available nitrogen and phosphorus control forest growth rates (Moreira et al., 2011). The soils of the eastern and central Amazon as well as the Southeast Asian Rainforest are old and mineral poor whereas the soils of the western Amazon (Ecuador and Peru) and volcanic areas of Costa Rica are young and mineral rich. Primary productivity or wood production is highest in western Amazon and lowest in eastern Amazon which contains heavily weathered soils classified as oxisols (Aragao, 2009). Additionally, Amazonian soils greatly weathered, making them devoid of minerals like phosphorus, potassium, calcium, and magnesium, which come from rock sources. However, not all tropical rainforests occur on nutrient poor soils, but on nutrient rich floodplains and volcanic soils located in the Andean foothills, and volcanic areas of Southeast Asia, Africa, and Central America.

From coastal mangrove, freshwater and peat swamp forests through the heartland of the dry lowland rainforest to montane rain forest, these characteristic vegetation types of the tropical rain forest climate survive in their primitive, untouched state only in few locations (Yamada, 1997). The enormous size and diversity of tropical rain forests vegetation can be classified into those occurring in locations that are temporarily or permanently immersed in water and those occurring on dry land.

Mangrove occurring on lowland inundated to a greater or lesser degree by seawater. The freshwater swamp forest grows on wetland along rivers and is temporarily or permanently inundated by nutrient-rich, freshwater. Whereas for peat swamp forest, it
is a highly distinctive type of forest growing on peat with 1 meter to 20 meters deep. The vegetation of this ecosystem has unique characteristics and is adapted to harsh environmental conditions. The swamp area consists of nutrient-poor rainwater and brackish acidic water can be found drained from the area. Species richness of the peat swamp forest could be influenced by soil nutrient status and rainfall. Anderson (1961) found that the flora of the Rejang Delta, including Maludam National Park was richer and denser than that of swamps elsewhere in Sarawak and Brunei.

Soil consists of mud and sand in mangrove, clay in freshwater swamp forest and peat in peat swamp forest. So, the vegetation in these forests adapted themselves by means of various root structures, such as pneumatophores, prop roots, buttress roots and aerial roots, which are characteristic of individual species.

In addition, dry lowland forest consisted of mixed dipterocarp forest. It is the largest proportion of forest type in Malaysia, which measured from the upper margin of the wetland to the elevations of about 1,500 meters. This forest type are mostly found in Sumatra, Malaysia, Mindanao and some other countries in Southeast Asia which consisted with variety of species, dominated with Dipterocarpaceae species. The trees have the characteristics of straight trunks, hemispherical crowns and large buttress roots. Moreover, large woody climbers wind around the trunks, and epiphytes grow on tree branches. At the altitudes of more than 1,500 meters, Dipterocarpaceae species is replaced with montane forest, which is characterized mainly by the abundance of epiphytes and climbers. Tree trunks are clothed in mosses and lichens, and wrapped around with epiphytic climbers. In the tree crowns, above the branches, epiphytic
orchids and ferns overlap each other densely. As the increasing altitude and the transition to moss forest, the volume of mosses increases to twice the thickness of the tree trunks. The tree heights decrease with altitude and at around 3,000 meters, the forest consists of a single layer of trees about 10 meters tall. Unlike the lowland, herbaceous vegetation can be found in the mountains.

Peninsular Malaysia's primary forests are mostly gone, though some magnificent forest still exists in Taman Negara, a national park. Most of Malaysia's remaining primary forest exists on the island of Borneo in the states of Sabah and Sarawak, but the majority of the forest area in Malaysian Borneo, especially the lowlands has been selectively logged, resulting in reduced biodiversity. Substantial areas of primary forests today only can be found in the steep mountains. Loggers are now operating in more marginal areas on rugged mountain slopes, which increase the risk of soil erosion and mudslides.

### 2.2 Problems in tropical rain forests

The greatest environmental challenge faced by the human today and the future is to preserve the most diverse and complex ecosystem of the tropical rain forest. They also have been attracted the world's attention and become the main topics debated all over countries as the most abundance forest with biodiversity have been disappearing rapidly, due to over exploitation of anthropogenic activities, natural and biological factors.
In mid twentieth century, the exploitation of rain forests began, as human population is increasing, vast forest covers were cleared for developments, for instance the clearing for urbanization industry, economic return such as extraction of valuable timber, agriculture purposes and many others. Especially the natives’ communities are depending on the rain forest in sustaining their livelihood. Most of the communities are clearing the forest for shifting cultivation. As to meet the requirements, the deforestation rates of the tropical forest will definitely increases which trigger the global environmental concerns. The environmental destruction and the conservation of genetic resources have attracted worldwide attention and through movements to protect the ecosystems of the tropics.

Apart from that, the knowledge on the information of tropical rain forest is still lacking and very limited. Up until today, only few researchers’ or scientists’ understood the complex structure and the unique atmosphere of tropical rain forests. The forestry offices kept all the information recorded, including the maps and data on timber volume available in the rain forests, land uses and the status of the surrounding. However, the information provided can be lacking due to only few forests is available and for limited number of useful tree species or could be due to the limited access to the forest. Information on tropical forest is usually easier to obtain when the logging roads is available and detailed information on the locality is provided. Lack of accessibility and communication available is one major obstacle causing the difficulty to find the genetic resources of the desired species or population of rain forests.
As for the natural factors, the most influential is climate. The droughts caused by the El Nino phenomenon deteriorating the generally favourable environment for plant life. The harsh climate with high temperature and heavy rainfall causes immense problems for the tropical rainforest. High temperature and prolonged drought is a major problem which create forest fire and a major hindrance to the reforestation activities. A slight decrease in the rainfall volume would produce flowering and fruiting of trees. However, a sudden heavy rainfall wash away a large volume of top soils, causing the appearance of some regions of abnormal soil morphology that renders reforestation impossible. The duration of the rainy season must be taken into consideration in planning forestry operation, from nursery preparation to transplanting.

The researches on the soils of tropical forests indicated that their nutrient contents are generally lower than those in the temperate zones. The soils productivity is dependable on the rapid conversion of dead plant material to inorganic matter which constant supply of the litter falls is vital. However, once the forests are cleared, the supply of plant materials is disturbed, the soils rapidly become diminished and heavy rainfall and strong sunlight cause further deterioration of its physical properties. The deterioration of tropical rain forests is also due to the forest fires whether the fire is manmade or natural occurrences. The natural conditions are mutually interrelated. Furthermore, the biological factors are also an important part of the forest-related problems for instance the issue of diversity, distribution and breeding system of the species. In the tropics, the greatest diversity of agents involved in cross-fertilization has developed.
2.3 Restoration of tropical forest through reforestation

Reforestation is used when forests are established artificially on land which has carried forest within the previous 50 years, involving the replacement of the previous crop by an essentially different one (Pancel, 1993).

The valuable timber trees from dipterocarpaceae family are often heavily logged for commercial timber both local and international, resulting in low density of remaining valuable species (Hamzah et al., 2009). It was estimated that about 13 million hectares of the world’s forests are lost annually due to deforestation (FAO, 2005). According to Butler (2006), approximately 140,200 ha or 0.65% of Malaysia’s forested area are lost annually since 2000. The removal of trees without sufficient reforestation has resulted in damage to habitat and biodiversity loss accompany with increasing soil compaction, erosion and decrease in soil fertility (Geist and Lambin, 2002; Williamson and Neilson, 2000).

Globally, as the world and countries’ leaders are more concerns of the climate change due to deforestation and realize that efforts have to be made, the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCC), which entered into force on February 16, 2005, promotes the adoption of policies for controlling deforestation in the developing countries and would allow tropical nations to take meaningful role in preventing dangerous interference in the climate change (Santilli et al., 2005). Tropical countries government can reduce deforestation through adequate
funding of programs designed to enforce environmental legislation, support for economic alternatives to extensive forest clearing (including carbon crediting), and building institutional capacity in remote forest regions, as recently suggested in part of the Brazilian Amazon (Nepstad et al., 2002; Fearnside, 2003, Santilli et al., 2005).

The lowland rainforests of Southeast Asia are globally significant and among the most diverse forests in the world supporting a sizeable proportion of the world’s biodiversity (Myers et al., 2000; Davies et al., 2005). On a large scale, tropical rainforests have a prominent role in ameliorating and maintaining global climate change by reducing the accumulation of greenhouse gases (Shukla et al., 1990, Hamzah et al., 2009). By the process of photosynthesis, forests capture and store carbon dioxide from the atmosphere, mitigating the effects of climate change. For instance, the undisturbed forests of the Amazon currently act as a sink for atmospheric carbon dioxide (Malhi et al., 2004). However, forest clear-cutting in the Brazilian Amazon increase ~30% from 2001 (18,165 km²) to 2002 (23,266km²) and 2004 (23,750±950km²) (Santilli et al., 2005). Annual deforestation in Indonesia, some 17,000km² from 1987-1997, increased to 21,000km² in 2003, with carbon emissions similar to those in the Amazon (Houghton et al., 2003). Deforestation accounts for 18% of global greenhouse gas emissions (Angelsen et al., 2009).

Through their natural functions, the forest can also provide environmental services valued by people. For example, by absorbing minerals and chemicals through their roots, the trees can remove pollution from the soil and from the freshwater that runs