Assessing the Effect of Silviculture Treatments and Soil Quality on the Planted Dipterocarp Species after Enrichment

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

An assessment after different silviculture treatment was conducted on the growth performance and survival of planted *Dryobalanops beccarii* on 2005 in Gunung Apeng National Park (GANP). Two study plots with different silviculture treatments and control plot were established namely T1 (bush slashing (control)) and T2 (selective girdling+ bush slashing). The growth performance of planted trees in terms of tree survival, total height and stem diameter were assessed for period of 72 months. Composite and undisturbed soil samples were collected at several random points within each study plots at 0-10 cm and 30-40 cm depth for the determination of soil physicochemical properties. Soil profile description was conducted in each plot to determine the morphological properties of the soils existing in the study area. The findings showed that the survival at T1 and T2 were 82.9% and 79.2%, respectively. Meanwhile, the average diameter and tree height recorded in T1 were 7.5 cm in diameter and 8.3 m in height, followed by T2 with 9.4 cm in diameter and 9.2 m in height. In terms of mean annual increment in diameter and height, T2 showed higher in MaiD and MaiH than T1 ($p < 0.001$). Then, the soil at the study area was acidic with a pH of less than 5, mostly sandy clayed in textural class and a moderate level of the nutrient. The type of soil at the study site was determined as grey-white podzolic soil which with strongly acidic with low nutrient content, deficiency moisture, and aeration. To conclude long terms effects of the selective girdling on the planted tree still rather insufficient due to other ecological factors.

Keywords: *Dryobalanops beccarii*, growth performance, survival, soil properties, silviculture treatment

Menilai Kesan Rawatan Silvikultur dan Kualiti Tanah pada Spesies Dipterokap yang Ditanam Selepas Penanaman Secara Pengayaan

ABSTRAK

Sebuah kajian telah dijalankan mengenai kadar tumbesaran dan kemandirian Dryobalanops beccarii yang ditanam pada 2005 di Taman Negara Gunung Apeng (GANP). Terdapat dua plot kajian yang berbeza rawatan silvikultur iaitu plot T1 (penebasan rumpai (kawalan)) dan plot T2 (menggelang terpilih+ penebasan rumpai). Kadar tumbesaran dari segi kemandirian pokok, tinggi dan lilitan pokok sepanjang 72 bulan telah dikaji. Sampel tanah iaitu sampel tanah komposit dan sampel tanah asal pada kedalaman 0-10 cm dan 30-40 cm telah diambil secara rawak di dalam kawasan kajian bagi mengenal pasti ciri fizikokimia tanah. Deskripsi profil tanah dalam setiap plot kajian telah dilakukan untuk menentukan ciri morfologi tanah dalam kawasan kajian. Hasil kajian menunjukkan kemandirian pokok di T1 ialah 82.9% dan T2 79.2% selepas 72 bulan. Purata lilitan dan tinggi pokok di T1 adalah 7.5 cm bagi ukur lilit dan 8.3 m bagi ketinggian pokok manakala di T2 adalah 9.4 cm bagi ukur lilit dan 9.2 m bagi ketinggian pokok. Purata kenaikan tahunan dalam ukur lilit dan ketinggian pokok, T2 lebih tinggi dalam MaiD dan MaiH berbanding T1 ($p < 0.001$). Untuk fizikokimia tanah, pH tanah di kawasan kajian berasid dengan pH rendah dari 5, tektur berpasir dan nutrisi yang sederhana. Jenis tanah dalam kawasan kajian dikenal pasti sebagai "grey-white podzolic soil" yang bercirikan nutrisi, kelembapan dan pengudaraan yang rendah. Untuk membuat kesimpulan bagi kesan jangka panjang menggelang terpilih belum mencukupi kerana kepelbagaian faktor ekologi.

Kata kunci: *Dryobalanops beccarii, kadar tumbesaran, kemandirian, ciri tanah, rawatan silvikultur*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

%	Percentage
µs	Micro-semen
Al	Aluminium
Avg	Average
AvP	Available phosphorus
Cmolc	Centi mol per charge
Ca	Calcium
CEC	Cation exchange capacity
cm	Centimetre
D. beccarii	*Dryobalanops beccarii*
ECEC	Effective cation exchange capacity
Exch.	Exchangeable
GANP	Gunung Apeng National Park
g	gram
H	Hydrogen
K	Phosphorus
kg	Kilogram
M. gigantea	Macaranga gigantea
m	Meter
mg	Milligram
ml	Millilitre

MaiD	Mean annual increment in Diameter
Maih	Mean annual increment in Height
Mg	Magnesium
Na	Sodium
RLI	Relative light intensity
sp.	species
SOM	Soil Organic Matter
Stdev	Standard deviation
TN	Total nitrogen
YR	Red yellow

CHAPTER 1

INTRODUCTION

1.1 Study Background

Malaysia is one of the countries in Asian that have a large area covered with tropical forest. Mok (1992) reported that the total natural forest area in Malaysia was estimated at 19.49 million ha or about 56.3% of the total land area. Tropical forests are considered as the most productive among all terrestrial ecosystems as they possess the functional roles for biodiversity conservation, world climate enhancement and soil conservation (Whitmore, 1998). As in Malaysia especially the Sarawak region, it is estimated about 70% of the land is still considered as natural forest (Mok, 1992) but only 256,000 ha have been constituted as the Totally Protected Areas (TPA), 3.96 million ha as State Forest and only 4.5 million ha as Permanent Forest Estate (PFE). The forest that not been declared as protected forest has been used for the development and agricultural activities such as plantation of crops, housing areas and others. To make matter worse, many of the land in Sarawak have been deforested due to the high demand in the timber industries in which associated with logging activity. Moreover, Gaveau et al. (2014) also had reported that, by the year 2010, the forest area had been reduced by 16.8 million ha in which indicated 30.2% forest loss where 164,444 km^2 of the deforestation occur in lowland coastal area (< m a.s.l).

Even though sustainable logging might be able to minimise the environmental impacts, but uncontrolled logging activities will bring catastrophic effects such as reducing the water quality, alter the biodiversity as well as reducing the productivity of the biological populations (Jaya, 2002). Moreover, Montagnini et al. (1997) also stated that the conversion of forested areas to non-forest lands such as to pasture and agriculture has resulted in the

permanent reduction of indigenous species. Aside from diminishing the timber product, deforestation also leads to major forest soil problems in which will result specifically the tropical lands become rapidly eroded and infertile. stated that most soils in the tropical regions are infertile, and once the natural forest has been cleared, nutrients can be rapidly lost consequently leading to longer forest recovery time (Sanchez et al., 2003; Juo & Franzlueebber, 2003).

Hence, conservation and preservation activities are necessary for the sake to maintain the stability and productivity of the forest. Without any protection measures, our forest will be undergone depletion in no time. As this occurs, many destructive effects will be happened such as the shortage of timber, loss of natural water catchment area as well as loss of precious biodiversity values. In worst case scenario, depletion of forest can lead to climate change and global warming. Increasing the awareness on the importance of restoring the nature from the bottom part is essential and a sustainable way in managing the forest should be implemented as has been applied by the authorities and NGO. In addition, reforestation is a must in order to rejuvenate our forest back to nature stated. Some researchers also pointed out the importance of reforestation in the tropics comprises productions of timber and other goods and services as well as aiding the recovery of biodiversity by re-establishing forest cover (Lamb et al., 2005; Benayas et al., 2009). By conducting reforestation in degraded land areas due to anthropogenic activities will bring lots of benefits to the humanity in which some of those are enhancing carbon sequestration for climate change mitigation (Silver et al., 2000), and regulation of water cycles (Bruijnzeel, 2004; van Dijk & Keenan, 2007).

Meanwhile, to ensure the successfulness of the reforestation program, it should be accompanied by proper ways or techniques applied such as implementations of enrichment

planting and suitable silviculture practices. Enrichment planting is one of the methods used in attempts to supplement natural regeneration as well as to enhance the low tree growth performances in natural succession (Chai & Udarbe, 1977; Appanah & Weinland, 1993). Examples of enrichment planting such as the gap created artificially by human interventions involved in reducing above-ground vegetation (Wyat-Smith, 1963; Adjers et al., 1995) thus, reduce the competition between the planted tree with the adjacent bushes and shrubs. These practices also can be used to rehabilitate logged-over areas in tropical rainforest by using the indigenous tree species where the process involves planting the nursery-raise seedlings in a cleared line or in gaps that been created naturally or artificially (Wyat-Smith, 1963).

Silvicultural practices are one of the various practices aside from enrichment planting which can be used in order to control the establishment, growth, composition and quality of the forest plantation. Moreover, silviculture treatment is also used widely in the management of forest with the aim for the conservation of the indigenous tree species to promote the growth of the indigenous tree species and to maintain and enhance the utility of the forest for any defined management purposes. Generally, the silviculture treatment is the numerous treatments that can be applied to forest stands in order to maintain and enhance their value for any purpose (Smith, 1986). According to Blaser et al. (2011), the silvicultural structure is commonly used to manage the dry inland forest in Malaysia in which mostly dominated by the Dipterocarpaceae family. Colin et al. (2018) reported that silvicultural practices are preferred for forest restoration purposes because they allow the direct manipulation of stand composition and structure.

The application of the silviculture treatments such as choice of species and site, site preparation, planting technique, spacing, weeding and leaning, thinning, pruning,

fertilisation and bush slashing and selective girdling also have been used in the forest plantation in Sarawak. In addition, the main intentions of using the silviculture method are to change and accelerate change or maintain tree and stand conditions. Besides that, silviculture treatment methods give almost no harm to the forest ecosystem and can contribute to sustainable forest management as well as promotes better growth for the planted species in the forest plantation. There are many silvicultural treatments that can be applied to the forest plantation and one of them is through fertilizer application. However, bush slashing, thinning and pruning are among the most common silviculture treatments that are being applied as part of the forest management practices in the forest plantation sector of Sarawak (Ashton, 2004).

Aside from cultural practices in reforestation efforts, understanding the soil nutrient dynamic also important in order to sustainably rejuvenate the disturb secondary forest. According to Ishizuka et al. (2000) and Arifin et al. (2008), once the natural forests have been cleared, soil nutrients are lost through erosion and leaching resulting in low soil nutrient stocks. Therefore, to continuously obtain the economic, environmental, social and cultural benefits of the forest, the damage must be repaired by various technical approaches, such as rehabilitation.

1.2 Problem Statement

Reforestation efforts need comprehensive understanding and assessment on the ecosystem involved as an attempt to provide proper practices in the future. Moreover, reforestation also needs to comprise various aspects such as vegetation composition, species selection, silviculture intervention and soil condition in order to rejuvenate the degraded land in sustainable manners. Numerous measures have been proposed to improve forest management (Graaf, 1986; Lamprecht,1989; Fredericksen & Mostacedo, 2000; Fredericksen & Putz, 2003) but such managements are to ensure future timber yields in forest plantation context (Jackson et al., 2002). Even though there were researchers have presented the progress of reforestation activities for the purpose of rehabilitating degraded areas at tropical region especially Malaysia region (Nik Muhamad et al., 1994; Suhaili et al., 1998; Norisada et al., 2005; Arifin et al., 2008) and Sarawak (Sakurai et al., 2006), there are knowledge gaps on the enrichment planting and in secondary forest as well as the performance of the planted tree species (Ramos & del Amo, 1992; Adjers et al., 1995; Kammesheidt, 2002). Romell (2007) also stressed out on concluding the effect of various silviculture treatment and the optimal conditions for enrichment planting are difficult due to variability in the forest nature and dynamic. Even though the example of enrichment practice either in forest plantation or forest reserve has been reported (Romell, 2007), but to conclude the effect of various silviculture.

In addition, rehabilitation of the degraded forest ecosystems also needs a well-understanding of the soil conditions (Ohta et al., 2000). Most studies are more focusing on the evaluation and assessment of planted trees as well as the changes of the surrounding ecosystem under monoculture plantation of fast-growing exotic species (Cole et al., 1996; Tilki & Fisher, 1998; Norisada et al., 2005; MacNamara et al., 2006), there are less

informations in characterizing soil fertility in which portray the soil conditions under the reforestation in less diverse secondary forests. Furthermore, the soil empirical data on the properties of rehabilitated degraded forest land planted with dipterocarp species and non-dipterocarp species is inadequate (Ariffin et al., 2007). Although there are several studies on the soil properties of tropical rainforests in Sarawak have been conducted, but it is rather limited (Ishizuka et al., 2000). The information available on the performance and survivability of planted indigenous tree species under reforestation as executed by the local authorities in Sarawak is ongoing research and the development of the silvicultural practices still in assessment for achieving the most suitable methods for reforestation. Understanding the soil-plant relationship in the dipterocarp forest is essential for better management in order to create sustainable forest rehabilitation.

In this study, we introduced a silvicultural approach to maintain the forest structure and protect its ecological functions. Several studies have been performed on reforestation activities with indigenous tree species using various planting techniques to rehabilitate degraded land areas (McNamara et al., 2006; Hattori et al., 2013; Perumal et al., 2017; Jaffar et al., 2018). Thus, planting the original indigenous species to rejuvenate a specific forest area is essential, as these species can thrive better in the surrounding environment. *Dryobalanops beccarii* was planted to rejuvenate the forest ecosystem in Gunung Apeng National Park (GANP) after anthropogenic events (logging and forest clearance for agricultural purposes) in the area as this tree species indigenously grow on the hill (Ashton 2004). The implementation of selective girdling along with reforestation efforts is important. As Wasli et al. (2014) described in their preliminary assessment of the growth performance of planted trees under forest rehabilitation, proper silvicultural practices along a line planting system can potentially reduce competition between the dominant pioneer trees and the

planted *D. beccarii*. Considering this finding, the specific objective of this study is to determine the effectiveness of additional silvicultural treatment, selective girdling, on the growth performance of planted *D. beccarii* in GANP.

1.3 Objective

Reforestation efforts in the tropical region need comprehensive understanding and proper management during pre-planting and post-planting maintenance. This is due to heavy precipitation throughout the year with no clear dry season especially in the Borneo region which can indirectly affect the soil condition and stand growth performances. In addition, the information on the soil properties in the reforestation area also needs to be fully utilised in order to select the suitable species for planting, proper site preparation and post-planting management. Aside from that, managing the forest through enrichment planting and silviculture treatment as a post planting practice also needs to be taken into consideration. Suitable silviculture treatment such as bush slashing and selective girdling can be implemented under line planting technique as it can maximise the output of the treatment. However, to what extent we can apply the treatments and how effective the treatment application is still rather insufficient.

Hence, the overall objectives of this research were:

i. To characterise the soil quality status in the reforestation area under enrichment planting of Dipterocarp species.

ii. To determine the effectiveness of selective girdling practice as an additional silviculture treatment on the growth performance of planted *D. beccarii* at Gunung Apeng national park.

CHAPTER 2

LITERATURE REVIEW

2.1 Tropical Rainforest and its Current Situation in Malaysia

Generally, Malaysia is divided into two mains continents which are the Peninsular Malaysia and Borneo in which still possess magnificent rainforest that have vast kinds of biodiversity and ecosystem. According to Richards (1952), almost half of Peninsular Malaysia is still covered by tropical rainforest. Meanwhile, in East Malaysia that compromise of Sarawak and Sabah is still mostly covered by the rainforests, but the rate of deforestation increases over time. The tropical rainforest in Malaysia can be divided into two main types of forest that are the lowland dipterocarp forest and hill dipterocarp forest in which possesses up to 3000 timber species (Oldfield, 2002).

Besides, the tropical rainforest in Malaysia plays important role in the ecosystem that acts as a water catchment area, sources of food, traditional medicine, habitat for flora and fauna, sources of high-grade timber, as well as living places for the indigenous people (Jomo et al., 2004). Recently, our tropical rainforests have undergone great depletion due to huge increase in demand for the timber, thus resulting in huge areas of the rainforest that have been cleared for timber and agricultural purposes. This resulting in the loss of water catchment area, extinction of the flora and fauna, reduce the clean water supply and other negative impacts on the forest land occurred. Yong (2014) also reported that Malaysia is one of the global hotspots of forest loss because of the deforestation and degradation due to the timber industries and oil palm industries. It is stated that 14.4% of forest loss since the year 2000 till the year 2012 as the result of the logging activities (both legal and illegal) and conversion of the forested land to other land uses such as the oil palm industry.

Meanwhile, Rautner et al. (2005) also stated that the Borneo's forests are disappearing at a very fast rate as compared to the percent of total forest land area in the mid-1980s. That in percentage values only about 50.4% of Borneo is still forested as compared to 57.5% in the year 2000. In additions, 16.8 million ha of forest loss was reported from 1973 – 2010 where part of these losses was mainly due to extensive forest clearance for multipurpose of forest product utilization (Gaveau et al., 2014) and logging of the tree for timber (Jomo et al., 2004).

2.2 Effort of Reforestation of the Degraded Forest in Sarawak

Generally, reforestation is an effort of replanting the tree after some disturbances (ITTO, 2002). Blaser et al. (2011) also stated that Permanent Forest Estate has been certified under the Malaysian Timber Certification Scheme, as the forest plays many important roles in the economy. On the other hand, forest plantation has been practicing a long time ago in Sarawak in which started in 1979. This due to the planted forest is an important element in the tropical area since it can fulfill many of the productive and protective roles of the natural forest. Moreover, Woon & Haron (2002) also stated that reforestation products not only for protection purposes, but it also can be harvested for export purposes if it organised in a sustainable manner. Meanwhile, if it adequately planned, it can help stabilise and improve the environment.

Moreover, the conservation of local flora and fauna and ecological stability require complementary action within integrated land use and development plans (Awang et al., 1981). The Forest Department Sarawak (2014) reported that timber is one of the most valuable products and has high demand across the countries but leading to excessive logging that will be resulting in deforestation. Hence, an effective encounter measure as the action

of replanting the tree species in the area that undergone logging activities (Forest Department Sarawak, 2014). Aside from that, another aim in reforestation activity in Sarawak is to recover the degraded land, preserve the environment as well as to produce 15 million cubics of timbers from 1 million hectares of forest plantation (Razali et al., 2015). This reforestation effort might be adequate to cover up the loss in trees due to logging and adequate supply for timbers in the future.

As in Sarawak, the Forest Department of Sarawak (1999) reported that the total area which had been reforested was about 18,969 hectares, consisting of 2,222 hectares of rattan species and 16,747 hectares of timber species since the period of reforestation program implementation. Among the species being planted were *Shorea macrophylla*, *Acacia mangium*, *Dryobalanops* spp., *Durio zibethinus*, *Shorea pinanga*, and *Hevea brasiliensis* in the aim to rejuvenate the forest in Sarawak after anthropogenic activities.

2.3 General Information and Description on Dipterocarpaceae: *Dryobalanops beccarii* Dyer

The Dipterocarpaceae family plays an important role in the ecology and economies of Asian forest (Poore, 1989). This family tree species contributes to the timber industry for domestic needs in seasonal evergreen forests in Asia. In addition, Panayotou & Ashton (1992) stated that the forest also sources of variety of minor products on which many forest dwellers are directly dependent for its survival. Besides that, the dipterocarps also consist of important timbers for domestic needs in the seasonal forest of Asia. The Dipterocarpaceae family distribution usually can be found in the lowland forest of Borneo, a shade-tolerant tree and it is the dominant tree family in Southeast Asia that forms high proportions of the emergent and main canopy strata of the forest (Manokaran, 1996). Apart from that, the family Dipterocarpaceae is well known for the timber values since it has a good quality of