STRUCTURE OF DISTURBED MIXED-DIPTEROCARP FOREST AT MOUNT JAGOI COMMUNITY FOREST, BAU: AN ASSESSMENT 24 YEARS AFTER LOGGING

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Bachelor of Science with Honours
(Plant Resource Science and Management)
2012
Structure of Disturbed Mixed-Dipterocarp Forest at Mount Jagoi Community Forest, Bau: An Assessment 24 Years after Logging

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A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science with Honours

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DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. No portion of the work referred to in this dissertation has been submitted to support of an application for another degree qualification of this or any other university or institution of higher learning.

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ACKNOWLEDGEMENT

First of all, I would like to thank my project supervisor, Prof Dr Gabriel Tonga Noweg for his dedication, valuable advice, and determination in helping me to conduct this study. I would like to extend my profound gratitude to Mr Jugah ak. Tagi from Sarawak Biodiversity Centre in helping me to identify tree species and giving me countless information and also to Associate Prof Dr Alexander Kiew Sayok for providing me reference resources on this study. I would also like to thank the Institute of Biodiversity and Environmental Conservation (IBEC) team and Research Assistants especially Mr. Ik Wadell Ik Pahon as well as the Jagoi Development Community for their support in forms of guidance, finance, and any other needs during my study trip to Mount Jagoi. To my close family members and friends who had helped and support me in completing this study I thank you all for the love and support you have given me.
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LIST OF ABBREVIATIONS

MDF – Mixed Dipterocarp Forest

DBH – Diameter Breast Height

GPS – Global Positioning System
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Structure of Disturbed Mixed-Dipterocarp Forest at Mount Jagoi Community Forest, Bau: An Assessment 24 Years after Logging

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ABSTRACT

Forest Inventory was carried out at Mount Jagoi, Bau, between July 2011 and April 2012 to assess the condition of the forest stand 24 years after logging and to compare the stand structure with the structure of undisturbed forest. Sample plots of 10 m x 40 m were randomly chosen in a logged-over mixed Dipterocarp Forest and Kerangas Forest at several localities within the Gunung Jagoi community forest. Results indicate that the number of taller trees was higher in the undisturbed mixed-dipterocarp forests which were at the Sobak Ayak Girituong, Otak Bowang, and Bikubu Taub compared to the logged-over area at Spolup Hill and the kerangas forest at Po Aub Hill. The most abundant species found in undisturbed forest is Cinnamomum sp. while in logged-over forest, Shorea sp. and Artocarpus odoratissimus were the most abundant. Hevea brasiliensis is the most abundant species in kerangas forest. The highest above ground biomass per hectare was found in the undisturbed forest with the value 9612 metric ton/ha while the lowest was found in kerangas forest with the value 1502 metric ton/ha.

Key words: Stand structure, disturbed mixed-dipterocarp, above ground biomass.

ABSTRAK

Inventori hutan telah dikendalikan di Gunung Jagoi, Bau antara Julai 2011 hingga April 2012 bagi menilai keadaan struktur hutan yang telah dijalani pembalakan 24 tahun yang lepas dan untuk membandingkan struktur hutan tersebut dengan struktur hutan yang tidak diganggu. Plot sampel seluas 10 m x 40 m dipilih secara rawak dalam Hutan Dipterokarp bekas pembalakan dan juga di Hutan Kerangas pada beberapa buah tempat dalam hutan komuniti Gunung Jagoi. Hasil kajian menunjukkan bilangan pokok yang lebih tinggi telah dijumpai di hutan yang tiada gangguan iaitu di Sobak Ayak Girituong, Otak Bowang, dan Bikubu Taub, berbanding di hutan yang telah menjadi bekas pembalakan, iaitu Bukit Spolup, dan di hutan kerangas iaitu Bukit Po Aub. Spesies pokok yang banyak dijumpai di hutan yang tidak diganggu adalah Cinnamomum sp. manakala di hutan bekas pembalakan, Shorea sp. dan Artocarpus odoratissimus adalah yang banyak ditemui. Hevea Brasiliensis pula banyak dijumpai di hutan kerangas. Nilai biojisim permukaan tanah per hektar yang tertinggi didapati di hutan yang tidak diganggu, iaitu 9612 metrik ton/ha manakala yang terendah didapati di hutan kerangas, iaitu 1502 metrik ton/ha.

Kata kunci: Struktur hutan, hutan bekas pembalakan, biojisim permukaan tanah.
INTRODUCTION

Background

Forest stand dynamics is the study of temporal changes in forest stand structure including stand behaviour during and after disturbances (Oliver & Larson, 1996). Forest structure is a broad concept that relates to species distribution patterns, species quantities, species diversity (Schaberg et al., 2008) and mapped patterns or mosaics of species associations (Lewis, 2009). According to Oliver and Larson (1996), the distribution can be described either by species; by vertical or horizontal spatial patterns; by size of living and/or dead plants or their parts, including the crown volume, leaf area, stem, stem cross section, and others; by plants ages; or combinations of the above. Kohyama (1993) suggested that incorporating both horizontal and vertical structure into models of forest dynamics increases the conditions under which stable species co-existence occurs, even when the species are all non-pioneers.

Stand structure also varies significantly among lowland tropical forests (Clark et al., 1999a). Tropical rain forests are characterized by their well-developed canopy architecture, with multiple crown layers, and vertical species partitioning may also contribute to tree species co-existence (Richards, 1996; Kohyama, 1996; Turner, 2001).

Lowland tropical rain forest is among the most diverse vegetation in the world (Whitmore, 1984; Richards, 1996). The most widespread lowland rainforest formation in Borneo is mixed dipterocarp forest (MDF) (Palmiotto et al., 2004). MDF occurs over a broad range of red-yellow ultisols and species composition and forest structure can vary quite
dramatically with small scale edaphic and topographic gradients (Austin et al., 1972; Newbery & Proctor, 1984; Baillie et al., 1987; Davies & Becker, 1996).

Meanwhile, disturbances are regarded any relatively discrete events that disrupt the stand structure and/or change resource availability or the physical environment (Pickett & White, 1985). Both non-human and anthropogenic disturbances are considered, since tree response does not distinguish between non-human and human activities (Oliver & Larson, 1996). Many forest management models used to project future forest composition and timber volume by species, assuming that forest succession is a static process (Frelich & Reich, 1998). Frelich and Reich (1998) also added that forests repeat the same regeneration and sucessional stages after each disturbance.

**Problem Statement**

Part of Mount Jagoi forest was logged 24 years ago. This logged-over section has been left to regenerate back slowly. The recovery of these logged-over forest lands is critical to the integrity of the whole Gunung Jagoi as a bigger ecosystem. As stated earlier, the forest does not only provide valuable timber for local domestic needs, but also provide the other sources such as habitat for wildlife, source of wild food and more importantly, catchment for water that supply the surrounding villages.

There are two possible scenarios of regeneration potential for the logged-over forests:

i. The intensity of logging at Mount Jagoi is varied, and this affects the ability of the forest to recover its full production capacity that contains high volume of timber.
ii. If the logging intensity is high, it is likely that the forest loses its maximum capacity to reproduce timber sustainably.

Objectives

Based on the problem statements mentioned above, the general objective of this study is to assess the condition of the forest stand 24 years after logging. The specific objectives of the study, therefore, are:

i. To assess the stand structure of the logged-over forest.

ii. To estimate the biomass content of the logged-over forest stand.

iii. To assess tree species diversity as well as to compare the mentioned parameters (stand structure, biomass content, and tree species diversity) between logged over forest and undisturbed dipterocarp forest stands.

Study and Limitation

This study is carried out on a hill forest which is dominated by mixed dipterocarp forest (MDF) and kerangas forest. It is located at Jagoi area, in West Sarawak.

The possible limitation of the study is that the result is only relevant to similar forest conditions in Sarawak. Forest conditions in other parts of the state may differ as determined by differences in soil and other climatic differences.
DISTURBANCES AND STAND DEVELOPMENT

Forests can be described by their composition, function, and structure (Franklin et al., 1981). Composition is the assemblage of organisms (living and non-living) that exist within the forest (Stone & Porter, 1998). A forest stand is a spatially continuous group of trees and associated vegetation having similar structures and growing under similar soil and climatic conditions (Oliver & Larson, 1996). According to Stone and Porter (1998), conversely, structure – which is the physical arrangement and characteristics of the forest – is a highly visible and described component. Meanwhile, Kimmins (1996) simply states that stand structure is the vertical and horizontal organization of plants.

The destruction and degradation of tropical forests is now recognized as one of the greatest environmental threats and tragedies of all time (Riswan & Hartanti, 1994). According to Riswan and Hartanti (1994) again, these include commercial logging, large road construction, dam and mining projects, conversion of forests into cattle ranches and plantations, transmigration and resettlement programmes.

In many regions of Southeast Asia, man is today confronted with a situation where the natural primary forests have either already disappeared or will do so in the very near future (Schulte & Schone, 1996). It is also added that the remaining are residual or secondary forests, which are considerably different from the primary forests with respect to species composition, structure, dynamics and stability.

Past disturbances have a lasting effect on forest structure and dynamics, and forests at different stages of development can be expected to behave differently in terms of ecosystem
processes and response to management (Peart, Cogbill, & Palmiotto, 1992). The major land-use problem in tropical forests has been the clear-felling of entire stands leading to excessive forest fragmentation (Johns, 1992). According to Johns (1996), timber harvesting is probably the most lucrative and widespread forest use. It can have large environmental impacts as logging affects many forest attributes such as structure, composition and function (Putz et al., 2000).

The trees which are felled are usually those with large crowns, which when felled can cause considerable damage to the lower storeys of the forest (Burgess, 1971). Theoretically it could be possible, that by logging a rare endemic tree species without natural regeneration at the time of cutting, the reproduction chain of other trees, pollinators and seed vectors for a number of other species may be interrupted causing some kind of domino effect (Schulte & Schone, 1996).

**Diversity in Mixed Dipterocarp Forest**

The co-existence of many tree species in tropical rain forests has been examined in various contexts (Kohyama et al., 2003). The differentiation between species along topographic and nutritional gradients has been investigated (Ashton, 1964) as have density-dependent regulation (Janzen, 1970), disturbance-mediated heterogeneity (Denslow, 1987) and dispersal limitation (Hubbell et al., 1999), all in a horizontal landscape. Because each tree must develop by growing up through the forest profile from the forest floor, the light resource gradient does not provide the basis for a simple niche differentiation among species (Kohyama et al., 2003). Using a size-structured model of population dynamics, in which upper foliage
density suppresses growth and recruitment, Kohyama 1993 showed that species with overlapping size distributions can coexist, even without the horizontal heterogeneity caused by tree fall gaps.

During the past 50 to over 100 million years, communities evolved in the tropics which attained an unprecedented level of biodiversity, strikingly represented by those lowland Dipterocarp forest ecosystems and other evergreen lowland rain forests offering home to more than 50% of all the world’s extant species (Linsenmair, 1990). In particular, the lowland mixed-dipterocarp forests in Borneo are thought to be among the forests highest in tree species diversity in the world (Whitmore, 1984).

The dominant element of the tropical rain forest tree flora throughout Southeast Asia are the *Dipterocarpaceae* family (Schulte & Schone, 1996). It is one of the major timber species group found in Malaysia and in South-East Asia. Usually the common tree genera found in this forest are *Dryobalanops*, *Dipterocarpus*, *Shorea*, *Hopea*, and *Parashorea*. According to Ashton (1982), in Asian phytogeographical areas, the corresponding Dipterocarp forest ecosystems manifest a more or less distinctive pattern of variation at around the tree species composition. It is also added that up to 10% of the species, and 80% of the emergent trees, are accounted for by various species of *Dipterocarpaceae*, which can reach 70m in height. Several dipterocarp species and genera usually grow together, so that a single species does not dominate (Sakai, 2002).

Because each tree must develop by growing up through the forest profile from the forest floor, the light resource gradient does not provide the basis for a simple niche differentiation among species (Kohyama et al., 2003). The extreme tree species diversity in
mixed dipterocarp forests makes it difficult to extract population-level traits of species, due to the relative rarity of each species (Kohyama et al., 2003).

Canopy openings create suitable light conditions for the growth of seedlings of dipterocarp species that grow well in gaps, but slower in the shade of young secondary forest species (Nguyen-The et al., 1998).

**Biomass Content of Mixed Dipterocarp Forest**

Changes in forest biomass density are brought about by natural succession; human activities such as silviculture, harvesting, and degradation; and natural impacts by wildfire and climate change (Brown, 1997). Many factors can influence the accuracy of biomass estimation in tropical forests and are known to vary with soil type (Tuomisto et al., 1995), soil nutrients (Laurance et al., 1999), climate (Gentry, 1982; Murphy & Lugo, 1986), disturbance regime (Lugo & Scatena, 1996), successional status (Saldarriaga et al., 1988), topographic position (Austin et al., 1996), landscape scale (Clark & Clark, 2000) and human impacts (Laurance et al., 1997; Gaston et al., 1998).

Variation in environmental factors such as topography, hydrology, and edaphic characteristics (e.g. soil nutrient availability) may also complicate attempts to generalize stand density and above-ground biomass over regional or landscape scale (Clark & Clark, 2000). Wood specific gravity is an important factor in converting forest volume data to biomass (Fearnside, 1997) and may also strongly depend on location, climate, and possibly management (Ketterings, 2001).
Variation in wood density has important consequences for the mechanical properties of wood, and hence for the mechanical safety of standing tree stems and branches (Niklas, 1993; Sterck & Bongers, 1998), which, in turn, determine the architecture (Sterck et al., 2001; Poorter et al., 2003), growth (King et al. 2005) and survival (Alvarez, 2005) of trees.

Growth rates may increase with decreasing wood density because (a) species with low-density wood tend to be less shade-tolerant and are therefore restricted than brighter-than-average microsites; (b) the thickness of the peripheral shell of stem wood corresponding to a given biomass increment is inversely proportional to wood density, so that diameter growth rates vary inversely with wood density, all else being equal; and/or (c) light-wooded species require less biomass to support their crowns, i.e. they have lower support costs, and are therefore able to achieve greater crown extension per unit of synthesized biomass, which enhances future light interception and growth (King et al., 2006).

Free-standing trees must, at a minimum, have stems that are rigid enough to prevent them from bending over under their own weight when displaced from the vertical (McMahon, 1973; King, 1981). Light-demanding species often have low-density wood and tend to be more susceptible to breakage and uprooting (Putz et al., 1983).

The model proposed by (Kohyama, 1993) suggested that the shorter species, where relative growth rate is strongly negative size-dependent, can coexist with taller species with less sensitive growth rates, providing shorter species have higher recruitment rates per unit species basal area than taller species. Species can then coexist along the gradient of trade-off constraints between vegetative growth and reproduction (Kohyama et al., 2003).
Biomass Content of Kerangas Forest

Kerangas forest, which was named heath forest by Richards (1957), is a particular vegetation of Sarawak. It occurs mainly in Borneo, where it is found on sandstone plateaus and cuesta formations; and it is usually found on dip slopes in hilly country in Sarawak, Sabah, and Brunei (Whitmore, 1984). Jordan (1985) points out that the nutrients content on such sites are in a critical condition in the tropical rainforest and the human impact of rapidly increased cutting and burning has influenced nutrient cycling.

Heath forest is easily degraded by felling and burning to an open savanna of shrubs and scattered trees over a sparse grass and sedge ground layer (Katagiri et al., 1991). It is also added that the leaf biomass in the forest was extremely low compared with other tropical, subtropical and temperate forests due to the soil conditions of poor nutrient accumulation and being leached.

According to Katagiri et al. (1991) again, the diversity of this forest was much smaller than those of mixed dipterocarp forests in the tropical zone. Kira (1983) points out that the species compositions of heath forests in Kalimantan are simple and are dominated by *Cratoxylon glaucum*.

The recovery of the logged stand to conditions similar to undisturbed forest is extremely slow, perhaps taking 150 years or more (Meijer, 1970; Riswan et al., 1986). Damaged poor sites, such as ‘kerangas’ (heath) forest on white sandy soil, recover very slowly and less vigorously (Riswan & Kartawinata, 1988b). Blocking of natural drainage leads to flooding, causing the death of trees and other species, with dipterocarp seedlings being
particularly vulnerable (Kartawinata et al., 2001). It is also added that climbers aggressively invade the bare ground and also overgrow residual trees, suppressing their growth.

In a heath forest, regeneration of a 0.5-ha gap took place by the re-sprouting of forest trees with insignificant percentage of regeneration by seedlings (Riswan & Kartawinata, 1988b, 1991).

**The Growth of Understory Plants in Mixed Dipterocarp Forest**

Most tropical rain forest tree species have strongly aggregated spatial distribution patterns (Hubbell, 1979). Neutral models of forest community assembly suggest that this aggregation is principally the result of limitations to seed dispersal (Bell, 2000). However, if communities are organized primarily by niche-assembly processes, aggregation is expected to be due to a high degree of species habitat specialization (Clark et al. 1999). Support for niche-assembly theory in tropical rain forests has mostly been sought through determination of differences in species distributions along gap-understory gradients of light availability and their consequent physiological specializations (Denslow, 1987).

Understory vegetation in forest ecosystems plays a crucial role in regulating succession (Royo & Carson, 2006). Canopy openings that result from treefalls are the predominant source of stand turnover in many mesic forests (Runkle, 1985; Brokaw, 1985; Veblen, 1992). In tropical rain forests, high light availability in gaps promotes growth and reproduction of seedlings of many, if not most, canopy trees as well as understorey species (Denslow, 1987).
Subsequent studies have indicated that, when light gradients are considered, only two major resource-response groups are found, namely high-light demanding and shade tolerant species (Swain & Whitmore, 1988; Denslow et al., 1990; Brokaw, 1985, 1987). Shade-tolerant dipterocarps can have seedlings established beneath closed canopied forest after >10 years (Appanah & Turnbull, 1998).

Surveys revealed that the abundance of regeneration was associated with certain dipterocarp species and sites (Appanah & Turnbull, 1998). In many circumstances regeneration was absent particularly on the slopes of hill forests and where competing understory palms, shrubs and herbs were present (Burgess, 1975; Wong, 1981; Kusneti, 1992).

According to Auffenberg (1994), herbaceous growth plays a much more important role in secondary forests than in most climax forests. It is also added that in mesic areas, giant herbs such as gingers and bananas are often common, as are sedges, shrubs, and viny tanglers (Auffenberg, 1994).