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FOREST LITTER ASSESSMENT IN DIFFERENT AGE STANDS OF REHABILITATED FOREST IN BINTULU, SARAWAK, MALAYSIA

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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October 2011

Chairman: Professor Japar Sidik bin Bujang, PhD

Faculty: Agriculture and Food Sciences

Forest degradation caused by mankind disrupts the availability of natural resources of economic, environmental, social and cultural importance. Rehabilitation has the potential to improve degraded sites and restore the ecological processes. Thus, research is needed to enhance the understanding of ecological process development after rehabilitation. The objectives of this study were to estimate the production, decomposition and quality of forest litter in rehabilitated forests at Bintulu, Sarawak.

Study plots of 20 m x 20 m were established in seven rehabilitated forest plots, P20 (20 years old, planted in 1991), P18 (18 years old, planted in 1993), P15 (15 years old), P12 (12 years old, planted in 1999), P9 (9 years old, planted in 2002), P6 (6 years old, planted in 2005), P3 (3 years old, planted in 2008), and PSF, an adjacent secondary forest. Litter production and decomposition was monitored in 4 plots, P20, P18, P12 and PSF. Using 1 m x 1 m litter traps placed randomly in the

plot, litter fall was collected biweekly for 6 months and weighed after oven-drying. Litter decomposition was determined by using 80 litter bags placed randomly in the plot (2 mm mesh) filled with fresh fallen litter and was retrieved weekly for sorting and weighing. Standing crop litter was sampled from all 8 plots, where litter of 1 m^2 area was carefully brushed, oven dried, weighed and then processed for litter quality analysis using standard procedures.

The estimated mean annual litter production of P20, P18, P12 and PSF was 6.81 t ha^{-1} $year^{-1}$, 3.09 t ha^{-1} $year^{-1}$, 2.40 t ha^{-1} $year^{-1}$ and 3.57 t ha^{-1} $year^{-1}$ respectively. By litter component, leaf was highest followed by branches and others.

Litter decomposition monitored revealed the decomposition followed the single-exponential model. The constant value (*k*) for litter decomposing in PSF has the lowest with 0.208 followed by both P12 and P18 at 0.216 while highest was P20 with 0.224.

Standing crop litter of the older rehabilitated plots was significantly different compared to the younger plots. P20 recorded 18.26 t ha^{-1}, P18 with 11.29 t ha^{-1}, PSF with 7.45 t ha^{-1} and P6 and P3 at 5.25 t ha^{-1} and 4.52 t ha^{-1} respectively. However, standing crop litter in P15, P12 and P9 were not significantly different by statistical treatment. Standing crop litter was found to be acidic with pH ranging from 4.4 to 5.1 when measured in water, with significant differences among different stand ages. Concentration of nutrients in litter were categorically in the order of C>N>Ca>K>Mg>P irrespective of plots, generally with older plots having higher

concentration of nutrients. Nitrogen ranged from 0.59 mg g^{-1} to 1.05 mg g^{-1}, phosphorus 0.05 mg g^{-1} to 0.20 mg g^{-1}, potassium 0.91 mg g^{-1} to 3.11 mg g^{-1}, calcium 0.31 mg g^{-1} to 7.92 mg g^{-1} and magnesium 0.39 mg g^{-1} to 1.64 mg g^{-1}.

The results of production, decomposition and quality of forest litter followed a trend where ecological process rates increase with stand age. Data of rehabilitated forest showed similarity to that of other tropical forests, suggesting that rehabilitation is beneficial importance on ecological processes.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

PENILAIAN SAMPAH HUTAN DALAM HUTAN DIPULIHARA BERLAINAN UMUR DI BINTULU, SARAWAK, MALAYSIA

Oleh

MELVIN KU KIN KIN

Oktober 2011

Pengerusi: Profesor Japar Sidik bin Bujang, PhD

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Kemusnahan hutan yang disebabkan oleh manusia mengganggu ketersediaan sumber-sumber asli hutan untuk kepentingan ekonomi, alam sekitar, sosial dan kebudayaan. Pemuliharaan hutan mempunyai potensi untuk meningkatkan laman dihina dan memulihkan proses ekologi. Oleh itu, penyelidikan yang diperlukan untuk meningkatkan pemahaman tentang proses pembangunan ekologi selepas pemulihan. Objektif penyelidikan ini adalah untuk menganggarkan pengeluaran, penguraian dan kualiti sarap hutan di kawasan hutan yang dipulihkan di Bintulu, Sarawak.

Plot penyelidikan 20 m x 20 m telah didirikan dalam 7 plot hutan yang dipulihkan, P20 (20 tahun), P18 (18 tahun), P15 (15 tahun), P12 (12 tahun), P9 (9 tahun), P6 (6 tahun), P3 (3 tahun), dan PSF, hutan sekunder bersebelahan. Pengeluaran dan penguraian sampah telah dipantau dalam 4 plot, P20, P18, P12 dan PSF selama

6 bulan. Menggunakan perangkap sampah berukuran 1 m x 1 m yang diletakkan secara rawak di dalam plot, kejatuhan sampah dari pokok-pokok dikumpul. Sekali dalam dua minggu, perangkap ini dikosongkan dan dibawa ke makmal untuk dikeringkan menggunakan ketuhar dan ditimbang. Penguraian sampah telah ditentukan dengan menggunakan 80 beg sampah yang diletakkan secara rawak di dalam plot (2 mm jejaring) yang dipenuhi dengan sampah jatuh segar dan yang dikutip setiap minggu untuk diasingkan, dikeringkan dan ditimbang. Sarap pada permukaan tanah hutan daripada semua 8 plot diambil dari kawasan 1 m^2 dengan berhati-hati, dikeringkan dengan ketuhar, ditimbang dan kemudian diproses untuk analisis kualiti sampah menggunakan prosedur standard.

Sampah pengeluaran tahunan untuk P20, P18, P12 dan PSF adalah dianggarkan sebanyak 6.81 t ha^{-1} $tahun^{-1}$, 3.09 t ha^{-1} $tahun^{-1}$, 2.40 t ha^{-1} $tahun^{-1}$ dan 3.57 t ha^{-1} $tahun^{-1}$ masing-masing. Apabila diasingkan mengikut komponen sampah, daun mencatatkan jumlah tertinggi diikuti oleh dahan dan komponen sampah lain-lain.

Penguraian sampah dipantau mendedahkan penguraian mengikuti model eksponen. Nilai malar (k) untuk penguraikan sampah di PSF terendah dengan 0.208 diikuti oleh kedua-dua P12 dan P18 dengan 0.216 manakala nilai tertinggi oleh P20 dengan 0.224.

Sarap pada permukaan tanah hutan di plot dipulihkan berumur lebih tua adalah jauh berbeza berbanding dengan plot berumur muda. P20 mencatatkan 18.26 t ha^{-1}, P18 dengan 11.29 t ha^{-1}, PSF dengan 7.45 t ha^{-1} dan P6 dan P3 pada 5.25 t ha^{-1} dan

4.52 t ha^{-1} masing-masing. Walau bagaimanapun, sarap lantai di P15, P12 dan P9 tidak jauh berbeza dengan rawatan statistik. Sarap pada permukaan tanah hutan didapati berasid dengan pH antara 4.4 hingga 5.1 apabila diukur dalam larutan air, dengan perbezaan yang signifikan di kalangan umur dirian yang berbeza. Konsentrasi nutrien dalam sampah berada dalam susunan C>N>Ca>K>Mg> P tanpa mengira plot, umumnya dengan plot yang lebih tua mempunyai konsentrasi nutrien yang lebih tinggi. Nitrogen adalah di antara julat 0.59 mg g^{-1} hingga 1.05 mg g^{-1}, fosforus 0.05 mg g^{-1} hingga 0.20 mg g^{-1}, kalium 0.91 mg g^{-1} hingga 3.11 mg g^{-1}, kalsium 0.31 mg g^{-1} hingga 7.92 mg g^{-1} dan magnesium 0.39 mg g^{-1} hingga 1.64 mg g^{-1}.

Keputusan dari penguraian pengeluaran dan kualiti sarap hutan didapati mengikuti satu trend di mana kadar proses ekologi meningkat dengan umur dirian. Data hutan dipulihkan menunjukkan persamaan dengan hutan tropika lain, menunjukkan bahawa pemulihan membawa kepada manfaat terhadap proses ekologi.

DEDICATION

"Give thanks to the Lord, for He is good;
His love endures forever".

1 Chronicles 16:34

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I certify that a Thesis Examination Committee has met on **25 October 2011** to conduct the final examination of Melvin Ku Kin Kin on his thesis entitled "**Forest Litter Assessment in Different Age Stands of Rehabilitated Forest in Bintulu, Sarawak, Malaysia**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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MELVIN KU KIN KIN

Date: 21 October 2011

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
AIS	Acid-Insoluble Lignin
ANOVA	Analysis of Variance
ASL	Acid-Soluble Lignin
C	Carbon
Ca	Calcium
CPOM	Coarse Particulate Organic Matter
DBH	Diameter at Breast Height
DMRT	Duncan Multiple Range Test
FAO	Food and Agriculture Organisation
FPOM	Fine Particulate Organic Matter
ITTO	International Timber Trade Organisation
K	Potassium
Mg	Magnesium
N	Nitrogen
P	Phosphorus
SF	Secondary Forest
UPM	Universiti Putra Malaysia
UV	Ultra-Violet
YNU	Yokohama National University

CHAPTER 1

INTRODUCTION

1.1 Background

Forests are multifunctional, differentiated by the needs of human and/or the functions of both economic and social simultaneously that provides natural resource products, both timber and non-timber (Führer, 2000). Concerning humans, forests are home to indigenous groups of people, sources of food, medicines and raw materials for industry and opportunities for recreation and tourism (Bruna, 2004). The various environmental effects of forests are countless, such as regulating the climate, landscape, maintaining hydrologic balance, supporting water and air quality, and sequestrating carbon in the air (Führer, 2000). It is available all over the world across a variety of sites, such as mountains, coastal plains, old highly weathered tropical soils, abandoned agricultural lands and reclaimed lands (Morris, 2004).

Healthy forests worldwide depends on the process of nutrient cycling as essential nutrients are absorbed and used in foliage production, followed by the return and recapturing in these forests, and producing subsequent growth (Morris, 2004). The nutrient cycle is made up of three individual but interconnected cycles, namely geochemical, biochemical and biogeochemical cycles (Kimmins, 2004).

The geochemical cycle is explained as the transfers of nutrients and energy into or out of the ecosystem (Kimmins, 2004; Morris, 2004). Conversion of non-plant available to plant available forms describe the geochemical cycles, such as weathering of parent material and nitrogen (N) addition to the ecosystem through nitrogen-fixing rhizobium, actinorrhiza or free-living organisms (Morris, 2004). Weathering of parent material contributes a significant amount of mineral based nutrients for reserves of forest ecosystems (Morris, 2000; Balogh-Brunstad *et al.*, 2008) such as phosphorus and base cations (calcium, magnesium, potassium and sodium) to ensure satisfactory plant growth (Morris, 2000).

The biochemical cycle, or known as the internal cycle involves the processes of transfer and retention of nutrients within an individual plant (Morris, 2004). Inorganic and organic foliar nutrients are retranslocated from senescing leaves to surviving tissue in the biochemical cycle to supply nutrient requirements for subsequent growing seasons (Nambiar and Fife, 1991; Aerts and Chapin, 2000; Morris, 2004).

Exchange of chemicals among different components within an ecosystem characterizes the biogeochemical cycle (Kimmins, 2004), or commonly referred to as uptake and return (Morris, 2004; Kimmins, 2004). Four major processes represent the biogeochemical cycle namely; plants uptake nutrient from the soil for growth, plants' retention of nutrients, leaf decay, leaching and root turnover returns nutrients to the soil and the dead plant material or

detritus decomposition (Attiwill and Adams, 1993). Species, stand age and site characteristics regulates the uptake and retention of nutrients (Attiwill and Adams, 1993; Morris 2000). Hobbie and Vitousek (2000) found that temperature, moisture, pH and litter quality (nutrient chemistry) influenced the return of nutrients where it regulars the quantity and process of decomposition of litter.

Litter, the layer of dead plant materials that are not attached to a living plant (Reshi and Tyub, 2007), is a fundamental component of the ecological integrity of a forested ecosystem. Primary production, regulation of energy flow and nutrient cycling in forest ecosystems is highly influenced by leaf litter and its ensuing decomposition (Waring and Schlesinger, 1985), therefore the transfer of energy and nutrients in a forest ecosystem is structured by leaf litter (Guo and Sims, 1999; Villela and Proctor, 1999).

Local and global environmental problems are the result of forest loss, such as timber production, flooding, erosion, landslides, desertification and other natural disasters (Kobayashi, 2004). Therefore, on regional and global scales, degraded forests and lands must be urgent and considerable to either compensation or enrichment of ecosystems and sustainability (Forestry Agency and ITTO, 1991).

The rehabilitation system based on Miyawaki's concept of integrating the concept of potential natural vegetation and the Japanese traditional idea of

ancient Shrine Forest (Chinju-no-Mori) was applied on abandoned shifting cultivation land in Bintulu, Sarawak. Since its establishment in 1991, the project now boasts of a rehabilitated forest with planted indigenous tree species (Miyawaki, 1999).

The rehabilitated forests with the primary goal of converting degraded lands into productive lands now require studies to enhance understanding on the ecosystem development, specifically the role of litter in nutrient cycling in ensuring a sustainable forest after planting with indigenous tree species. It is unknown about the characteristics of forest litter, its production, decomposition and nutrient concentration of rehabilitated forests with different age stands, as there is no research in this area. This research attempts to answer whether forest litter of rehabilitated forests is comparable with other tropical forests in this region.

As part of the objectives of the forest rehabilitation project, this study attempted to estimate the litter production, litter decomposition and nutrient concentration of standing crop litter at plots of rehabilitated forests with different establishment ages. The results obtained from analysis of the rehabilitation project are compared against a natural regenerating secondary forest to understand the status of rehabilitation with stand age.

1.2 Objective

The goal of this study was to investigate the dynamics of forest litter of different age stands of rehabilitated forests in Universiti Putra Malaysia Bintulu Sarawak Campus, Bintulu, Sarawak. The results of the rehabilitated forests are then compared against an adjacent secondary forest. Specifically, this study aimed to:

i. Estimate litter production (litterfall) in three rehabilitated forest plots and an adjacent secondary forest plot with closed canopies.
ii. Estimate standing crop litter mass and investigate litter decomposition in three rehabilitated forest plots and an adjacent secondary forest plot and,
iii. Determine the acidity and selected macronutrient concentration (litter quality) of standing crop litter in all seven plots of the selected age rehabilitated forest plots and an adjacent secondary forest plot.

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LIST OF PUBLICATIONS

Title:	Comparison of Carbon and Selected Macronutrients in Forest-Floor Litter of Rehabilitated and Secondary Forests
Journal:	American Journal of Applied Sciences
Authors:	Melvin Ku Kin Kin, Japar Sidik Bujang, Osumanu Haruna Ahmed, Nik Muhamad Nik Ab. Majid, Roland Kueh Jui Heng and Silvester Jemat
Year:	2011
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Journal:	American Journal of Agricultural and Biological Sciences
Authors:	Roland Kueh Jui Heng, Nik Muhamad Abd. Majid, Seca Gandaseca, Osumanu Haruna Ahmed, Silvester Jemat and Melvin Ku Kin Kin
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