UNIVERSITI PUTRA MALAYSIA

LITTER DECOMPOSITION IN THREE DIFFERENT FOREST TYPES IN UNIVERSITI PUTRA MALAYSIA BINTULU CAMPUS

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LITTER DECOMPOSITION IN THREE DIFFERENT FOREST TYPES IN UNIVERSITI PUTRA MALAYSIA BINTULU CAMPUS

By

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TO

Dad, WONG JU TIE

&

Mum, LING ING KIEW

ABSTRACT

Litter decomposition plays an important role in releasing nutrients back to the forest. The decomposition rate is affected by several factors, namely soil biota, climate, site condition, physiochemical properties and litter quality. The present study is conducted to compare the decomposition rate and nutrient release patterns in three different forest types in Universiti Putra Malaysia Bintulu Campus, namely Plantation Forest (PF), Rehabilitated Forest (RF) and Logged-over Forest (LF). Decomposition rates and nutrient release pattern were similar for all three study sites. The RF recorded the highest values of weight loss. Decay rates, *k* were recorded between 0.1050 and 0.1196 per annum. Nitrogen loss was slow initially and increased after four months while potassium was released more rapidly than phosphorus. Significant differences detected for nitrogen and potassium release rate suggested the microbial activity may be the main contributor influencing the rate of decomposition and nutrient release patterns.

ABSTRAK

Proses penguraian memainkan peranan yang penting dalam membebaskan nutrien-nutrien kembali ke hutan. Process penguraian dipengaruhi oleh beberapa faktor seperti organisma tanah, iklim, keadaan persekitaran, ciri-ciri fisiokimia, dan kuanliti sarap. Penyelidikan ini dijalankan dengan tujuan untuk membandingkan kadar penguraian dan menentukan pola pelepasan nutrien di tiga jenis hutan yang berbeza di Universiti Putra Malaysia Kampus Bintulu, iaitu hutan ladang (PF), hutan tanam semula (RF) dan hutan sekunder (LF). Kadar penguraian dan pola pelepasan nutrien adalah sama bagi ketiga-tiga jenis hutan. Hutan tanam semula mencatatkan kadar kehilangan berat yang paling tinggi. Kadar penguraian, k direkodkan di antara 0.1050 dan 0.1196 setahun. Kehilangan nitrogen pada awalnya adalah agak perlahan dan menunjukkan peningkatan pada bulan ke empat manakala pelepasan kalium adalah lebih cepat berbanding phosphorus. Kadar pelepasan nitrogen and kalium yang bererti mencadangkan bahawa aktiviti mikrob memainkan peranan yang besar dalam mempengaruhi kadar penguraian dan pola pembebasan nutrien.

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I certify that this research project report entitled "Litter Decomposition in Three Different Forest Types in Universiti Putra Malaysia Bintulu Campus" has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Bioindustry Science in the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Campus.

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ABBREVIATION

1	FOA	-	Food and Agriculture Organization
2	PF	-	Plantation Forest
3	RF	-	Rehabilitated Forest
4	LF	-	Logged Over Forest
5	SAS	-	Statistical Analysis System
6	ANOVA	-	Analysis of Variance
7	%	-	Percent
8	m	-	Metre
9	mm	-	Milimetre
10	km	-	Kilometre
11	cm	-	Centimetre
12	^{0}C	-	Degree Celcius

CHAPTER I

INTRODUCTION

Background

Litter decomposition plays an important role in releasing the nutrient back to the forest. The decomposition of leaf litter plays a crucial role in providing organic and inorganic elements for the nutrient recycling process (Mudrick *et al.*, 1994). Decomposition also refers to both the physical and chemical breakdown of litter and the mineralization of nutrients (Boulton and Boon, 1991). Leaf material returns annually to the forest floor in the form of litterfall. The annual return of material and bioelements to the soil, *via* litterfall, is one of the most important renewal factors of a forest ecosystem (Palma *et al.*, 1997). The decomposition of litterfall is well known to be a important ecosystem process which allows the maintenance of the soil nutrient status (Weerakkody and Parkinson, 2006).

Besides that, decomposition of leaf litter is an integral and significant part of biochemical (i.e., intrasystem) nutrient cycling and food web of forests. Decomposition is a fundamental process of ecosystem functioning because it is a major determinant of nutrient cycling (Moretto *et al.*, 2001). Nutrients such as nitrogen, phosphorus, potassium, magnesium and calcium are released and converted to plant available form, and is governed by the decomposition rate of litter. Nutrients are released into soil solution largely as by-products of microbial scavenging for energy.

Decomposition rate is affected by several factors, such as climate, litter quality, soil biota, micro-fauna, environmental site condition and physiochemical properties. During the process of decomposition, both the mass and biochemical characteristics of litter change through the influence of climate, litter quality and decomposer organisms (Swift *et al.*, 1979).

The micro and macro invertebrate, bacterial and fungal communities depend on these organic resources for food (Baker *et al.*, 2001). Gosz (1984) found that the addition of soil fauna increases that rate of available nutrients by as much as 25 % during the first year of litter decomposition. In Mulu National Park, Malaysia, Anderson *et al.* (1983) attributed the rapid weight losses of litter to invertebrates.

Objective

The present study focuses on the leaf litter decomposition of the forest. The objective of the study is to compare the decomposition rate and nutrient release patterns of leaf litter at different forest type.

CHAPTER II

LITERATURE REVIEW

Tropical Forest

The tropical forests cover only 6 % of the land surface, and harbour more than 50 % of the world's animal and plant species (Vikram Reddy, 2002). In Malaysia, majority of the forests are tropical rain forest. The rates of decomposition are more rapid in the tropical forests than in temperate forests (Anderson and Swift, 1983). The rates of decomposition showed wide variation in both tropical and temperate regions and can considerably overlap.

Plantation Forest

Plantation forests are defined as forest stand established by planting of seedlings in the process of afforestation or reforestation (FAO, 2001). Plantation forest is established for several purposes, such as production of pulp and paper or solid timber for a variety of end products, farm forests and agro forests, woodlots for fuel and environmental benefits land rehabilitation, bio-diversity conservation or catchment protection (Vikram Reddy, 2002).

Plantation forest is based mostly on a monoculture ecosystem where limitations exist especially those related to species richness, diversity and long-term maintenance of productivity when compared to the polyculture system and the natural forests (Vikram Reddy, 2002). Nutrient cycling in a plantation forest is not as efficient in the plantation forest as in the natural forest.

Rehabilitated forest

Rehabilitated forest is a forest which is established for an environmental purpose, either to enrich an ecosystem or maintain the sustainability of a forest. Tropical forests have been affected by human activities particularly logging which caused rapid reduction in size and quality of forests (Kobayashi *et al.*, 2001). Indirectly, local and global environments are affected and problems such as natural disaster, flooding, erosion, landslides, loss of biological diversity and global warming arise.

Forest rehabilitation is related to human intervention to counter the degradation of the forest such as the promotion of the recovery process in large gaps of dipterocarp forest or conversion of shrub forest to high storey plantation forest (Mori, 2001). In the rehabilitated forest of Universiti Putra Malaysia Bintulu Campus, six hundred seedlings (dipterocarp species) have been planted in 1990. These seedlings have reached 4 m after five years of planting, 8 m after 10 years and over 20 m after 25 years.

Logged-over forest

Logged-over forest is a forest which undergone logging activities. Forest harvesting caused negative impacts to biotic and abiotic environment by damaging residual large trees or other forest plant communities and their natural regeneration, causing surface soil erosion and change in physical soil characteristic (Sudarmadji, 2001).

Nutrient Cycling

Nutrient cycling is one of the most important processes in the forest to maintain the ecosystem. It is a process in which nutrients are released from the decomposed organic matter, through processes of nutrient uptake and use by plants, and back to the soil *via* litterfall (Binkley, 1986). Four components are involved in such processes, namely nutrient uptake, liter fall, litter accumulation and litter decomposition. Nutrient cycling within the ecosystem forms major source of nutrients for plant use (Binkley, 1986). Besides that, the nutrient cycling of litter also determined the nutrient status within the ecosystem (Binkley, 1986; Yang, 2006).

Biogeochemical cycling is a process where nutrients are transferred between plant and soil. It is important in nutrient requirement for growth and maintenance in the natural forests (Ong, 2004). The process includes the uptake by absorption of nutrients primarily through roots from soil and return to soil by leaching, litter and root turnover and by death of individuals (Switzer and Nelson, 1972).

Nutrient Uptake and Tree Growth

Once the nutrient is released into the soil system, the nutrient ion faced several possible fates: i) transport to roots for uptake, ii) absorption to ion exchange sites, iii) precipitation as an insoluble compound, or leaching from the soil (Binkley, 1986). Most nutrients reached roots in the form of a soil solution and absorbed by the roots.

After being taken up by trees, there nutrients would face several fates: i) incorporation into accumulating biomass, ii) recycled to the soil *via* litterfall or root death, iii) leached from leaves or roots or recycled from leaves or roots for the use of the following year (Binkley, 1986). Binkley (1986) observed that 40 % of nitrogen was incorporated into accumulating biomass and none was leached from leaves and about 3 % was resorted into the tree before the remaining 60 % was lost in litterfall. Three factors have been identified to affect nutrient uptake in the ecosystem, namely the quality needed by the plant, concentration in the soil and mobility through the soil (Binkley, 1986).

Litter Production

Litterfall includes leaf fall, shoot fall, bark fall and bud scale fall (Samra and Raizada, 2002). In the forest, litterfall is an important source of nutrient. Litterfall is also the formation and renewal of the forest floor, and litter mass on the forest floor is an important structural component of the ecosystem (Samra and Raizada, 2002). The quantity and composition of litterfall vary in a number of factors, such as tree species, stand age and development, and is affected by environmental conditions, particularly water and nutrient availability (Binkley, 1986).

Litterfall plays three main functions in the ecosystem, namely, i) energy input for soil microflora and fauna, ii) nutrient input for plant nutrition and iii) material input for soil organic matter building up (Bernhard-Reversat and Lourneto, 2002). All these functions are completed through mineralization, decomposition and humification process, and influenced by biological activity, nutrient cycling and soil structure (Bernhard-Reversat and Lourneto, 2002).

Litter Accumulation

The annual return of organic material and bio-elements to the soil, *via* litterfall, is a renewal factor of a forest ecosystem (Palma *et al*, 1997). Litter accumulation on the forest floor is a function of the amount of annual litterfall and the rate of decomposition (Pritchett, 1979). The accumulation of organic residue on the soil surface allows for the formation of humus that characterise of a particular ecosystem and is a permanent contribution of nutrients to the soil (Palma *et al*, 1997).

The slow rate of forest litter decomposition resulted in a transient accumulation of litter on the forest floor (Lin *et al.*, 2006). Lin *et al.* (2006) noted that the accumulation rate was different in a plantation forest, secondary forest and primitive forest, which followed the order: plantation > primitive forest > secondary forest.

Litter Decomposition

Decomposition refers to the mineralization of nutrients and both physical and chemical breakdowns of litter (Boulton and Boon, 1991). In a forest ecosystem, the decomposition of plant litter plays a crucial role in the process controlling nutrient cycling (Osono and Takeda, 2004). Leaf litter decomposition provided organic and inorganic elements for the nutrient cycling process (Mudrick *et al.*, 1994). Decomposition studies the nature and extent of the mineralization and immobilization of nutrient during leaf litter decomposition, and provides an understanding about certain nutrients whether they are immobilized biologically within a community, released to downstream system or mineralized (Baker *et al.*, 2001).

Leaf material returns annually to the forest ground in the form of litterfall. Decomposition of leaf litter is an integral part of biochemical nutrient cycling and food webs of forests (Baker *et al.*, 2001). The annual return of organic material and bio-elements to the forest ground, *via* litterfall, is one of the most important renewal factors of a forest ecosystem (Palma *et al.*, 1997). Nutrient is released by leaf litter and converted to plant available form and this process is governed by the rate of litter (Ong, 2004). Nutrients are released into the soil as byproducts of microbial for energy use. The micro and macro invertebrate, bacterial and fungal communities depended on decomposed leaf litter as food in order to survive (Baker *et al.*, 2001).

Temperature and precipitation are considered at a global or broad regional scale. These factors are largely responsible in affecting the rate of decomposition

(Swift *et al.*, 1979; Baker *et al.*, 2001). Warmer temperatures and higher precipitation provide higher rate of decomposition, and indirectly would get faster litter turnover and less organic matter accumulation (Baker *et al.*, 2001). The regional scale interacted with forest type, substrate quality, and nutrient availability, obscuring patterns within similar climatic and regional zones (Vogt *et al.*, 1986). At a local scale, the rate of decomposition and quantity of nutrients are influenced by some factors, such as (i) the quality of the samples (Baker *et al.*, 2001; Alhamd *et al.*, 2004), (ii) physicochemical properties such as pH, oxygen, temperature and moisture regime that affect decomposer *in situ* (Swift *et al.*, 1979; Heitz, 1992; Mudrick *et al.*, 1994; Baker *et al.*, 2001; Yang *et al.*, 2006)

Complexes of bacteria, fungi, and soil microorganisms also have important roles in leaf litter decomposition process (Alhamd *et al.*, 2004). The micro fauna can move freely through the litterbag net and this situation has shown to cause an increase in weight loss (Berg *et al.*, 1980; Berg and Staaf, 1981). The roles of soil microorganisms on nutrient cycle may change during the decomposition process (Hasegawa and Takeda, 1995).

Variation in Litter Decomposition Rates

The rate of decomposition can vary between species planted at the same site and this may be due to the differences in litter quality (Ong, 2004). Higher nitrogen content in leaf litter would cause litter to decay faster.

The *k* value is useful for comparing decomposability of various litter type, and for estimating the time required for a given percentage of the litter to be composed; as 0.6931/*k* estimates the time needed for 50 % disappearance, and 3/*k* estimates the 95 % point (Binkley, 1986). If the *k* value is greater than one, litter turnover is less than a year (Olson, 1963).

In their review, Hirobe *et al.* (2004) found that the decay rate constants, *k* to range from 0.38 year^{-1} to 2.36 year^{-1} with a mean value of 1.10 year^{-1} in a tropical lowland rain forest, Sarawak. In a tropical forest at Kodayar, India, Sundarapandian and Swamy (1999) reported the decay rate coefficients to range between 0.136 year^{-1} and 0.403 year^{-1}. In their study, Alhamd *et al.* (2004) reported 0.66 year^{-1} to 1.19 year^{-1} *k* value of between of four selected tree species during a 12 month period in a subtropical forest at Okinawa Island, Japan.

Litter Decomposition in Tropical Lowland Rainforest

For tropical forests, large amounts of small litter like leaves are produced and the majority of studies are carried out on the decomposition rates of specific types of leaf debris and nutrient dynamics (Weerakkody and Parkinson, 2006). Some studies have been carried out in different forests, for example lowland tropical rainforest (Hirobe *et al.*, 2004), cool temperate forest (Osono and Takeda, 2004) and floodplain forest (Baker *et al.*, 2001). In wet tropical regions, the litter decomposition is considered to be more rapid than the temperate regions, although the decomposition rates varied widely in both climatic regions (Anderson and Swift, 1983). The information on litter decomposition in lowland tropical rainforests is relatively poor than that of temperate forests (Hirobe *et al.*, 2004).

Hirobe *et al.* (2004) reported that the decomposition rate in the lowland rainforest in Sarawak is relatively slow and varied widely. For the nutrient dynamics, the general pattern of litter decomposition consisted of three phases; leaching, net immobilization and net mineralization (Swift *et al.*, 1979). This theory may be altered by both the mobility of the nutrients and limitations of the nutrient for decomposer organisms (Hiobe *et al.*, 2004).

Hirobe *et al.* (2004) also noted that the dynamics of carbon, nutrient, and organic constituents during decomposition in the lowland rainforest were generally similar to that in temperate regions and varied depending upon the initial litter quality. The phosphorus concentration and the biomass of soil macro-invertebrates in the forest are low. Besides that, the lowland rainforest in Sarawak is poor in nutrient. The ranges and means of litter nutrient concentration in such rainforest are similar or lower than temperate forest, especially for nitrogen and phosphorus (Hirobe *et al.*, 2004).

Nutrient Dynamic

Litter nutrient dynamic is related to the decomposition rates and determined the nutrient status directly (Yang *et al.*, 2006). In the forest, nutrient is released from litter decomposition and controlled the maintenance of fertility in the forest soil

(Weerakkody and Parkinson, 2006). This process involved initial leaching of nutrients followed by a phase of nutrient immobilization and nutrients released into the soil (Swift *et al.*, 1979).

In the forest, nitrogen and phosphorus are released through immobilization phase. During the decomposition process, immobilization of phosphorus by soil organisms or microbial suggested that this element is in short supply and lead to the competition for phosphorus between soil flora, flora and vegetation (Baker *et al.*, 2001). Phosphorus mainly existed in plant tissues thus easily leached out in the early stage of the decomposition phase (Wen *et al.*, 1998). Potassium on the other hand, is very mobile and easily leached out during the decomposition process. The remaining potassium showed a rapid decrease mostly during the first month of the experiment and was almost constant thereafter (Klemmedson, 1991; Hirobe *et al.*, 2004).

Initial nitrogen concentration is also important in nutrient release dynamics. There are several studies which showed that the initial nitrogen concentration and decomposition rate constant are positively related (Lin *et al.*, 2006). High level of nitrogen in litterfall is expected to accelerate the decomposition process (Alhamd *et al.*, 2002). Nitrogen dynamics in decomposing leaf litter involve three sequential phases: (i) initial release phase when the leaching process is predominated; (ii) the net phase when nitrogen is imported into residual material through the activity of microorganisms; and (iii) the net loss phase when nitrogen is decreased in the nutrient mass of decomposition process (Gosz *et al.*, 1973; Staff and berg, 1982). In the cycling of limiting nutrients such as nitrogen and phosphorus for plant growth in the terrestrial ecosystem, litter decomposition processes have a critical role to release the organically bound nutrients into plant available forms (Hirobe *et al.*, 2004).

CHAPTER III

METHODOLOGY

Background of Study Sites

The experiment was carried out at Universiti Putra Malaysia Bintulu Campus forests. It is located approximately 600 km northeast of Kuching with a latitude 3° 12' N, longitude 113° 05' E and 50 m above sea level. The annual mean rainfall is 2993 mm with the rainy season occurring in November till January during the northeast monsoon. The monthly relative humidity is usually above 80 % but slightly lower during the rainy season (Mohamad *et al*, 2001). Three different sites when chosen for this experimental namely rehabilitated forest (RF), plantation forest (PF) and logged-over forest (LF) (Figure 1).

The rehabilitated forest (RF) was established in 1990 through a joint project between Yokohama National University of Japan and Universiti Putra Malaysia to rehabilitate degraded land. This project has been supervised by Dr. Miyawaki. The plantation forest (PF) is planted with *Acacia mangium* and *Gmelina arborea.* It was published in the year of 1986. Trees are planted at a 3 m x 3 m and high mortality rate was recorded especially for *G. arborea.*

Logged-over forest (LF) of the campus was logged in the early in 1970 using the selective logging technique. The forest recovered well since then. However, the forest was illegally logged in 1994 when the campus was temporary closed. Most trees with a diameter of more than 30 cm were logged.

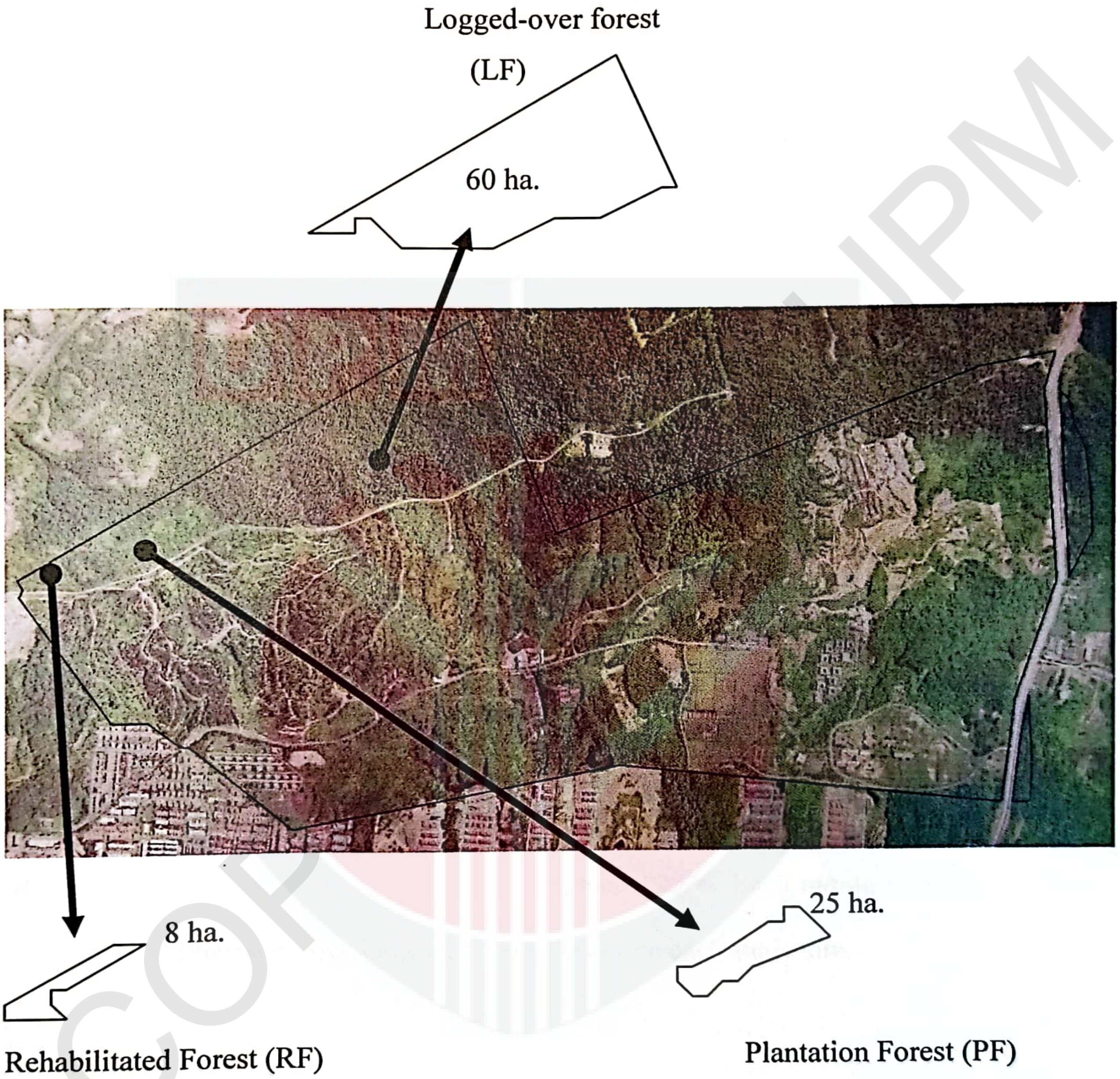

Figure 1: Location of three different study sites within Universiti Putra Malaysia Bintulu Campus, Bintulu, Sarawak, Malaysia.

Leaf Litter Collection and Preparation

Dipterocarps leaves were collected from the RF in August, 2006. Net traps were placed under the trees 30 cm above the ground. The freshly sensed leaves were collected for a period of two weeks.

Leaf samples were air dried for a week. Sub-samples were collected and divided into two groups and weighed before being oven dried at 70 °C, for 48 hours. Samples were weighed again after cooling to determine its moisture content.

Litterbag Preparation, Placement and Collection

Litterbags of 15 cm x 15 cm were prepared using nettings. Fifteen grams of leaves were inserted into each litterbag. In each study site, the forest floor was cleared until the mineral surface. Litterbags were placed on the surface of the floor and covered with existing litter in September, 2006. Each month after the placement of litterbags, five bags were collected from each study site.

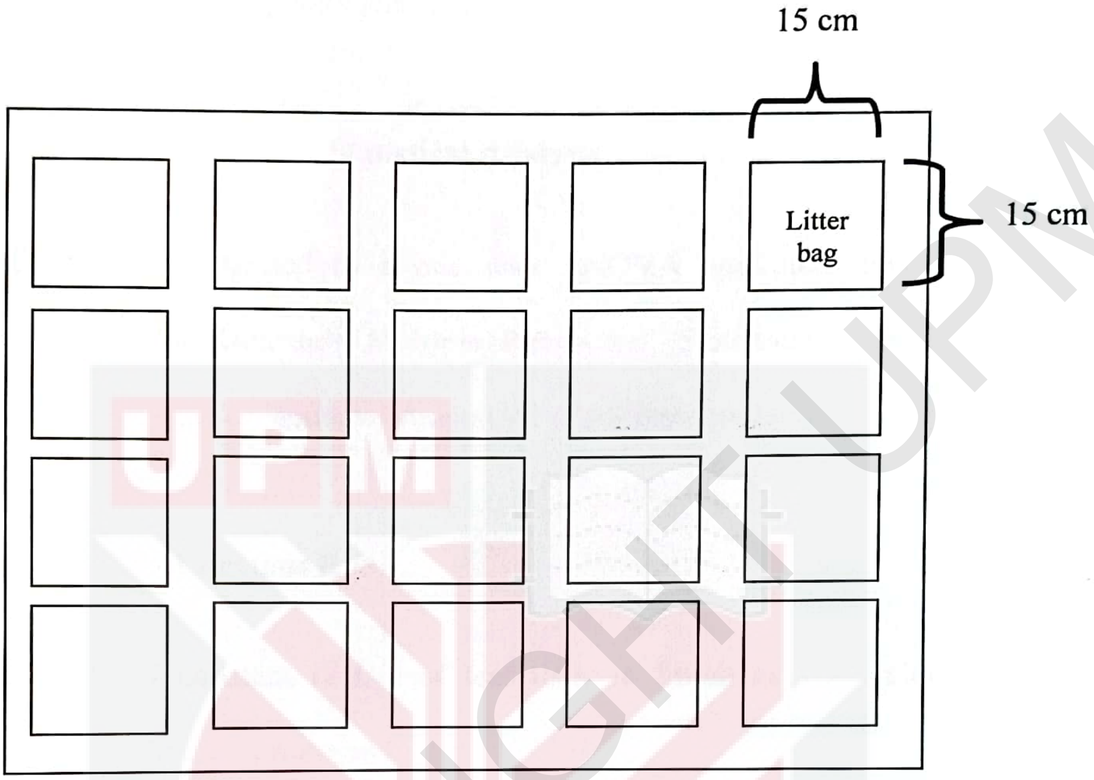

Figure 2: Layout of litterbags placement in a study site

Laboratory Procedures

Leaf samples were emptied from the litterbags and foreign materials such as roots, soil, sediments or woody materials were sorted out and removed. Leaf samples were then oven-dried at 70 °C for 48 hours and their weight determined.

Nutrient Analysis

Nitrogen was determined using the Kjeldahl method (Foster, 1995) while phosphorus was determined calorimetrically using the molybdenum-blue method (John, 1970). Potassium on the other hand, was determined using the atomic absorption spectrophotometer (AAS).

Statistical Analysis

Data were subjected to a one way ANOVA and their mean were compared using the Duncan's Multiple Range test. Statistical analysis was performed using SAS for Window Version 9.1 (SAS institute Inc.).

Analysis of Decay Constant Rate

The decay constant rate, k of leaf litter in litterbags was calculated according to the formula proposed by Olson (1963):

$$\text{In}\,(W_0/W_t) = -kt$$

where W_0 is the original mass, Wt is the mass remaining at the time t, and t is the time. The data used for the calculation of decay constant was the mean value of the weight remaining at each collection time.

CHAPTER IV

RESULTS

Biomass Dynamic

In the forest of Universiti Putra Malaysia Bintulu Campus, Bintulu, Sarawak, the rates of leaf-litter decomposition varied widely where the biomass ranged between 62.0 % and 64.0 % during the four months field experiment (Figure 3).

Similar trend was observed for all sites (Figure 3). The loss in dry weight in leaf litter over the four months varied amongst treatments although not significantly. The lowest decomposition rate among was observed on the third month for all sites whilst the highest decomposition rate was observed on the fourth month.

Decay Constant Rate, *k*

The *k* value of leaf litter among the treatment was not significant (Table 1). The decay rate ranged from 0.1050 year^{-1} to 0.1196 year^{-1}.

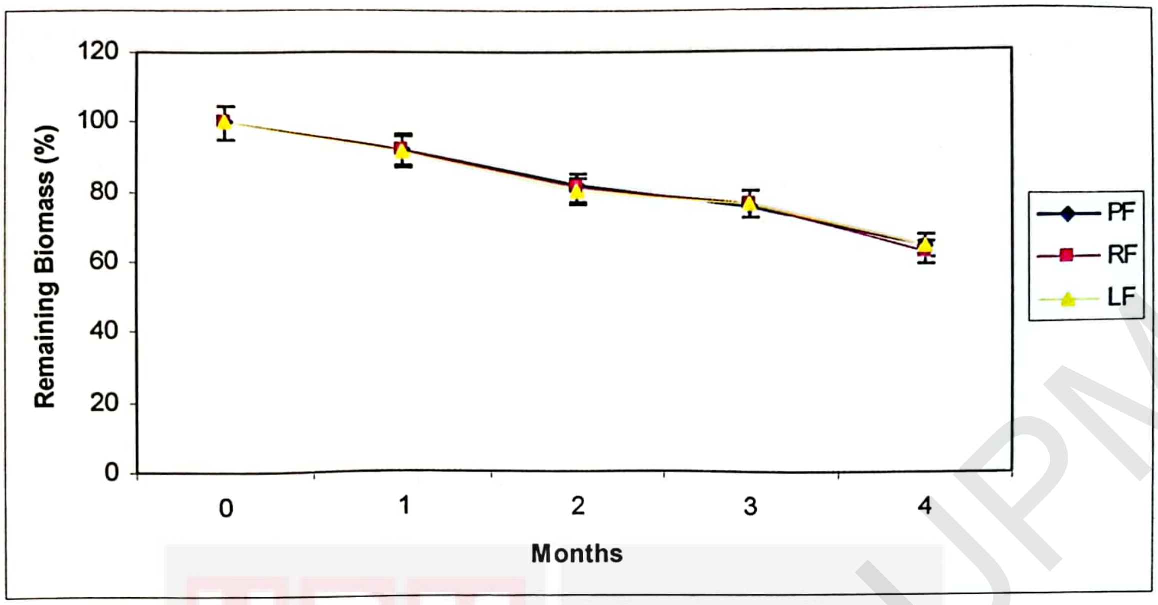

Figure 3: Changes in the weight of dipterocarps leaf litter.
(Each point represents the mean of five replicates ± SEM)

Table 1: The effect of treatment on decay constant of dipterocarps leaf litter after four months

	k (month)
Plantation Forest (PF)	0.1082^a
Rehabilitated Forest (RF)	0.1196^a
Logged over forest (LF)	0.1050^a

Mean value with similar letters in the same column are not significantly different at P=0.05 by Duncan New Multiple Range Test

Nutrients Dynamic

Nitrogen was released at a slower rate before rapidly disappearing during the second and third month of decomposition (Table 2). Concentration of nitrogen was higher at the end of the experiment than the initial stages. There was significant effect of treatment on nitrogen concentration after four months (Table 2) with RF recording the highest nitrogen concentration.

Table 2: Changes in nitrogen concentration of dipterocarps leaf litter (%)

	Month				
	0	1	2	3	4
Plantation Forest, PF	100.00	93.42^a	91.94^a	88.96^a	98.76^a
Rehabilitated Forest, RF	100.00	99.26^a	94.42^a	89.45^a	102.98^a
Logged-over Forest, LF	100.00	98.64^a	92.43^a	92.43^a	98.76^a

Mean value with similar letters in the same column are not significantly different at P=0.05 by Duncan New Multiple Range Test

Slower rate of release until the end of the experiment was observed for phosphorus (Table 3). Treatments had little effect on phosphorus concentration during decomposition. RF recorded the highest loss of phosphorus is compared to LF and PF.

Table 3: Changes in phosphorus concentration of dipterocarps leaf litter (%)

	Month				
	0	1	2	3	4
Plantation Forest, PF	100.00	92.74^a	90.76^a	90.43^a	86.47^a
Rehabilitated Forest, RF	100.00	92.74^a	93.40^a	87.46^a	80.86^a
Logged-over Forest, LF	100.00	96.37^a	91.75^a	84.49^a	85.48^a

Mean value with similar letters in the same column are not significantly different at P=0.05 by Duncan New Multiple Range Test

During the four months of experiment, lost of potassium was rapid especially on the third month, followed by a slower rate (Table 4). Potassium loss was more rapid rate if compared than nitrogen and phosphorus. Significant different was observed for potassium loss between sites on the fourth month.

Table 4: Changes in potassium concentration of dipterocarps leaf litter (%)

	Month				
	0	1	2	3	4
Plantation Forest, PF	100.00	90.56^a	79.44^a	52.22^a	40.56^a
Rehabilitated Forest, RF	100.00	92.22^a	76.11^a	45.56^a	28.33^b
Logged-over Forest, LF	100.00	90.00^a	80.00^a	43.33^a	37.78^a

Mean value with similar letters in the same column are not significantly different at P=0.05 by Duncan New Multiple Range Test

CHAPTER V

DISCUSSION

The weight of leaf litter decreased with increasing incubation time. Similar observations have been reported by many other authors; Binkley, 1986; Palma *et al.*, 1997; Sundarapandian and Swamy, 1999; Alhamd *et al.*, 2004; Ong, 2004. Results of the present study appeared to show an exponential pattern. Binkley (1986) found that litter disappearance rate generally follow an exponential decay curve. Biomass weight loss of leaf litter was around 36 % - 38 % of their initial weight. Hirobe *et al.* (2004) reported that the rates of leaf litter decomposition varied widely in the lowland tropical rain forest in Sarawak, and weight loss of litter samples was between 44% and 91 % after 13 months. Sundarapandian and Swamy (1999) reported that the percentage of litter mass remained between 38.96 % and 72.66 % at the end of 90 days in tropical forests of Kodayar in the Western Ghats, India. In his study, Ong (2004) found that the weight loss of *Azadirachta excelsa* litter under fertilizer treatment to range from 50.4 % to 58.2 % after eight months of observation in a plantation at Sungai Karas, Johore, Malaysia. In Okinawa, Japan, Alhamd *et al.* (2004) found that the remaining mass of four type species after 12 months of incubation on the forest floor was ranged from 54 % to 61 %. RF showed higher biomass loss as compared to LF and PF. Lin *et al.* (2006) reported that litter in the secondary forest showed faster mass loss rate than the plantation.

In the present study, no significant difference among the sites after four months experiment was observed. This might due to the fact that PF, RF and LF were under same climate. The highest decomposition rate was observed on the fourth month while the lowest was observed on the third month. Differences in the rate might be due to the rainfall factor. In November, Bintulu received less rainfall than December. The different physiochemical properties such as pH, oxygen, temperature and moisture content (Swift *et al.*, 1979; Heitz, 1992; Mudrick *et al.*, 1994; Baker *et al.*, 2001; Yang *et al.*, 2006) have been found to give great influence on decomposition rate. Different range of temperature and moisture content in November and December were largely responsible for the rate of decomposition. More rainfall resulted in higher moisture content and lower temperature which increased the activities of soil organisms. Thus, higher decomposition rate is expected.

In the present study, the calculated decay constant rate ranged from 0.1050 year^{-1} to 0.1196 year^{-1}. This result is within that reported by Sundarapandian and Swamy (1999) that the decay rate coefficients were ranged from 0.136 year^{-1} to 0.403 year^{-1} in a tropical forest at Kodayar, India. In their review, Hirobe *et al.* (2004) found that the decay rate constants, k ranged from 0.38 year^{-1} to 2.36 year^{-1} with a mean value of 1.10 year^{-1} in a tropical lowland rain forest, Sarawak. This range of k value was higher than the present study. Alhamd *et al.* (2004) reported k value of 0.66 year^{1} to 1.19 year^{-1} for four selected tree species in a subtropical forest at Okinawa Island, Japan. The present result suggested that the rate of decomposition is relatively fast as environmental conditions were suitable for microbial activities.

The release of nitrogen and phosphorus observed during the early stage of decomposition are consistent with other studies (Palm and Sanchez, 1990; Ribeiro *et al.*, 2002). An increase in nitrogen concentration in the later stage of the decomposition could be due to one or more of the following reasons: retention in microbial biomass, translocation from fungal hyphae and atmospheric deposition (Bocock, 1963; O'Connell and Grove, 1996).

In tropical lowland rain forest, Hirobe *et al.* (2004) found four to 96 % of the potassium still remained after 13 months. The rapid release of potassium during the early decomposition stages in the present study is consistent with the high mobility of potassium, as this element does not form part of the organic structure of the leaf litter (Marschner, 1995). Klemmedson (1991) also reported the loss of potassium to be higher and followed by phosphorus and magnesium in ponderosa pine forest of Arizona.

The rate of decomposition and nutrients release pattern of dipterocarps leaf litter in different sites may be due to meso- and microfauna on the forest floor. Higher loss of biomass, higher increase of nitrogen concentration and loss of phosphorus and potassium in RF as compared to LF and PF were probably due to microorganism activities in RF. Site characteristics and management could also affect litter fauna. The RF soil was ploughed to a one meter depth before the plantation was established. The media used to raise seedlings was collected from the natural forest around Bintulu. The condition of LF and PF were similar. These sites were subjected to a high degree of disturbance as the result of logging activity and site preparation. Thus, number and diversity of microorganism in RF may be higher than in LF and PF which resulted in higher loss of biomass and release of nutrients.

CHAPTER VI

CONCLUSION

Decomposition rates in LF, RF and LF were similar and showed similar trend of disappearance. The decomposition rates in the present study were in the order of RF > LF > PF. The decay rate constant, *k* ranged from 0.1050 year^{-1} to 0.1196 year^{-1} while the rate of loss was similar to other reported results.

Loss of nutrients such as nitrogen, phosphorus and potassium were recorded during the decomposition process. Nitrogen was initially released in a slower phase but increased towards the end of the experiment. Phosphorus loss was recorded to be the slowest while potassium loss was higher than phosphorus. Significant loss in potassium and increase in nitrogen is believed to be related to the microbial activities during the decomposition process.

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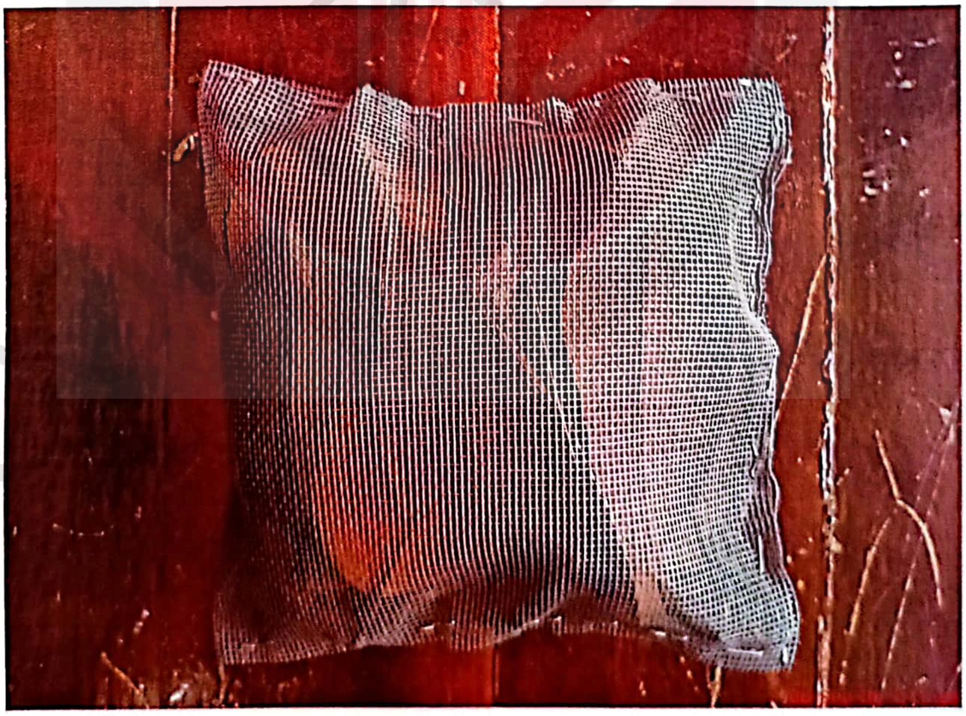
APPENDICES

APPENDIX A

Appendix A1: Leaf litter collection at RF



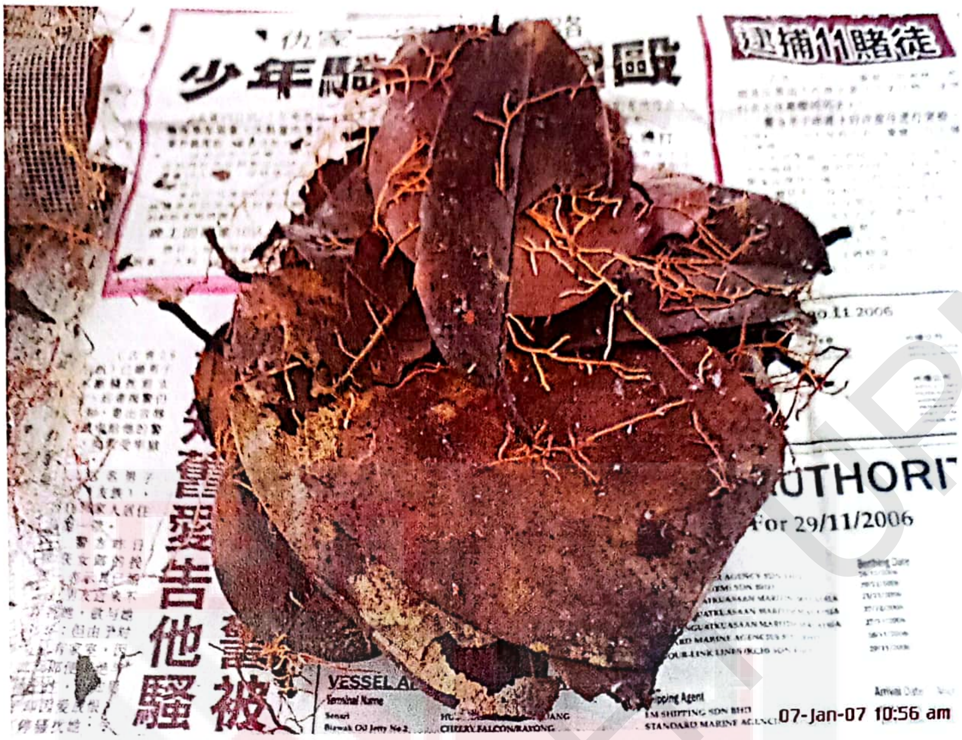
Appendix A2: Preparation of litterbag

Appendix A3: Placement of litterbags

Appendix A4: Litterbags were covered with litterfall after placement

Appendix A5: Soil condition in a study site

Appendix A6: Condition of collected litterbag



Appendix A7: Condition of leaf litter after being removed from litterbag

PUBLICATION OF THE PROJECT UNDERTAKING

This is to certify that I have no objection to publish the project entitled "Litter Decomposition in Three Different Forest Types in Universiti Putra Malaysia Bintulu Campus" by the supervisor in a joint authorship. However, it has to be evaluated by the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Campus and published in form approved by the Faculty.

Wong Siew Ming

Date: 07-05-2007