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Litterfall Production and Leaf-litter Decomposition at Natural Forest and Cacao Agroforestry in Central Sulawesi, Indonesia

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ABSTRACT

Litterfall production, litter decomposition and nutrient released were influenced by land use change from natural forest into cacao agroforestry. Cacao agroforestry is a traditional form of agriculture practiced by the people of Central Sulawesi. The study was carried out in the cacao was planted under forest covers (CF1), under planted trees (CF2) and between shade trees (CP). The Natural Forest (NF) was used as the undisturbed ecosystem compared to cacao agroforestry. This research was carried out since March 2005-February 2006. We recorded litterfall production by using litter trap and decomposition of leaf litter by nylon net bag technique. Litterfall production in relation to climate was analyzed by periodic curve. The result showed that NF had the higher annual litterfall (13.67 t/ha/year) than that of cacao agroforestry. Monthly litterfall in NF and cacao agroforestry were influenced by climate. Natural forest had the highest coefficient of decomposition (k = 3.07 in March-June 2005 and 1.85 in September-December 2005) and or the fastest rate of decomposition, whereas cacao agroforestry under CF2 had the lowest one (k = 1.23 in March-June 2005 and 1.14 in September-December 2005). Carbon released was higher in the NF (1.1% in March-June 2005 and 0.5% in September-December 2005) than that of cacao agroforestry. Nitrogen released was higher in the NF than that of cacao agroforestry in the first period (1.1% in March-June 2005).

Key words: Nutrient released, coefficient of decomposition, periodic curve, annual litterfall, *Theobroma cacao*

INTRODUCTION

Tropical land use change has important implications for biogeochemical cycles both regionally and globally. The conversion of the tropical forests to other land use (such as, agroforestry systems) generally ruptures ecosystem function (Scholes and Van Breeman, 1997).

The litter which is produced by a forest has different amount and different composition based on the structure and the species diversity of the plant which compiles it (Indriyanto, 2009). The litter on the forest floor acts as input-output system of nutrient and the rates at which forest litter falls and subsequently, decomposes contribute to the regulation of nutrient cycling and primary productivity and to the maintenance of soil fertility in forest ecosystems. Therefore, it is critical to understand the amount and pattern of litterfall in these forest ecosystems (Berg, 2000; Lebret *et al.*, 2001; Ranger *et al.*, 2003; Wang *et al.*, 2008). Litter production from plants, particularly trees, is a major source of organic matter and energy to soil and is important for nutrient cycling in ecosystem. Litterfall and litter decomposition from trees in agroforestry systems are considered to be an important factor contributing to soil quality. Litterfall has the biggest contribution in humus layer formation in the soil. It is releases mineral nutrients through litterfall decomposition process by soil organisms (Luizao and Schubart, 1987). Accumulation of litterfall layers on the topsoil depends on several factors i.e., plant species, climate, land use types, decomposers population and their activities (Fernandes *et al.*, 1997).

Decomposition in agroforestry systems differs from that of in the natural forest and in the agricultural system, because of differences in the types and quality of organic inputs (Mafongoya *et al.*, 1998). The leaf-litter deposition and decomposition are recognized as critical pathways of organic matter and nutrient flux in the tropical forest. The product of litterfall decomposition is facilitating the formation of soil organic matter and return of nutrient into soil (Fioretto *et al.*, 2003; Xuluc-Tolosa *et al.*, 2003). The relationship between nutrient storage and nutrient flow is a characteristic of ecosystems. A balance between litter deposition and decomposition regulates the accumulation of organic matter within an ecosystem (Singh *et al.*, 2004).

Decomposition of litterfall involves the chemical and physical processes that reduce litter to CO_2, water and mineral nutrients (Lambers *et al.*, 1998) and regulated by a number of abiotic and biotic factors (Lavelle *et al.*, 1993; Kavvadias *et al.*, 2001). These comprise: (1) microclimate, mainly temperature and humidity (Fioretto *et al.*, 2001), (2) vegetation type (Lambers *et al.*, 1998) and litter quality, in particular nitrogen, lignin and polyphenol concentrations (Sariyildiz and Anderson, 2003), (3) soil nutrient content (Verhoeven and Toth, 1995), (4) the qualitative and quantitative composition of decomposer communities (Knoepp *et al.*, 2000) and (5) soil nutrient availability (Fioretto *et al.*, 2005). These factors interact to determine decomposition rate (Dawoe *et al.*, 2010).

Mean annual decomposition rate constants or decay rate coefficient (k) for temperate and tropical forests have been estimated at k = 0.9 and k = 1.8, respectively (Torreta and Takeda, 1999). Within the tropics, there is some evidence of regionality in decay rates coefficient with k>2 (high) for most African forests and k = 1-2 (medium to high) for forests in Southeast Asia and the Neotropics (Anderson and Swift, 1983). Very high (k ~ 4) rates are observed mainly in African tropical forests (Olson, 1963), indicating rapid nutrient cycling. However, decay rates coefficient can be low (k<1) even in tropical areas, depending on litter type, season and altitude (Verhoef and Gunadi, 2001). The higher decomposition rates facilitate more rapid nutrient cycling in ecosystems (Sariyildiz *et al.*, 2005).

Although, there have been several studies on litterfall production (Kumar and Deepu, 1992; Sundarapandian and Swamy, 1999) and leaf-litter decomposition (Sundarapandian and Swamy, 1999) in tropical forest ecosystems, information on litterfall production and leaf-litter decomposition in natural forest and cacao agroforestry systems in Central Sulawesi is limited. Cacao agroforestry is a traditional form of agriculture practiced by the people of Central Sulawesi. The agroforestry systems vary from a simple system following selective cutting of forest trees, to more sophisticated planting design. The cacao agroforestry with different systems were predicted have a different nutrient cycling (Xu and Hirata, 2005). Conversion of natural forest into plantation affects the process of nutrient cycling due to management practices. Thus, it would be important to study the litterfall, litter decomposition and the factors regulating the rate of litter decay in these ecosystems to improve recommendations for their management and conservation (Pandey *et al*., 2007). The determination of cacao agroforestry system with nutrient cycling similar to natural forest is very important, therefore it can maintain natural ecosystem especially at the margin of Lore Lindu National Park, Central Sulawesi.

The objectives of this study were to investigate (1) litterfall production in relation to land use types and season, (2) leaf-litter decomposition associated with land use types and (3) nitrogen and carbon released during leaf-litter decomposition in the land use types.

MATERIALS AND METHODS

Study site description: The field studies were conducted in three different types of cacao agroforestry systems at the Northeastern margin of Lore Lindu National Park (LLNP), which is located in Central Sulawesi, Indonesia ca. 75 km southeast of Palu. The whole site is located between 120°1' - 120°3'30"E and 1°29'30"-1°32'S at an elevation of 800 m to 1100 m in Toro village, Kulawi district, Central Sulawesi, Indonesia. The average of relative humidity at Toro village is 87.2%, the mean of monthly temperature is 22.9°C, the average annual global radiation is 17.48 MJ m^{-2} and the total annual precipitation in 2005 recorded in the study sites was 2055.6 mm.

The three different cacao agroforestry systems and natural forest selected in the buffer zone of LLNP were (1) system under a remaining forest cover (CF1), (2) system under local shade trees (CF2), (3) system without forest cover, but with planted shade trees, *Glyricidia sepium* (CP) and (iv) natural forest. Environmental characteristics of study sites are presented in Table 1. Stand characteristics were measured for all trees with a diameter at breast height (dbh) of 10 cm or more, dbh and height were measured on 1500 m^{-2} plots. CF1 was dominated by *Theobroma cacao, Coffea robusta, Arthocarpus vrieseanus, Turpinia sphaerocarpa* and *Horsfieldia costulata*. The species that dominated CF2 were *Theobroma cacao, Erythrina subumbrans, Syzigium aromaticum, Arenga pinnata* and *Bischofia javanica,* while CP was dominated by *Erythrina subumbran, Theobroma cacao, Glyricidia sepium, Mellochia umbellate, Piper aduncum*. The species that dominate on the NF was *Palaquium quercifolium, Castanopsis accuminatisima, Ficus trachypison, Lithocarpus celebicus* and *Chionanthus laxiflorus*. Measurements of the canopy cover were done using a convex spherical densitometer at 10 randomly selected locations per stand with four readings per location in the four main aspects (N, E, S, W). Plot size was 30×50 m in every study site. The cacao trees in the study area were 5-15 years old.

Table 1: Environmental information in the Natural Forest (NF) and cacao agroforestry systems (CF1, CF2 and CP) in Toro village, Central Sulawesi

Parameters	NF	CF 1	CF 2	CP
Stem density-dbh>10 cm (n ha^{-1})	1184	608	488	625
Basal area (m^2)	58.4	31.5	6.6	13.2
Exposition	95°E	110°E	100°E	100°E
Air humidity (%)	95.7	92	91.4	86.3
Temperature (°C)	20.4	21.5	21.8	22.9
Canopy cover (%)	89.7	72.1	69.4	49.8
Altitude (m asl)	1006	832	802	799
Slope (%)	80	70	35	20

Litterfall production: Ten litter traps 1 m ×1 m, 50 cm high above the ground were installed at 20 subplots on each plot. Litter was collected monthly intervals from the traps for one year (March 2005-February 2006). The litter was taken to the laboratory and dried to a constant dry weight at 80°C. The total litterfall was weighed to obtain total dry weight.

Leaf-litter decomposition: The decomposition was evaluated by using the litter bag technique. The litter bags (10 cm ×20 cm) were constructed from nylonet (1 mm^2 opening screen). Five grams of dried fallen intact leaves was placed in each bags. The bags were pinned to the ground under the trees. One litter bag from each plot was collected each month during three months incubation, twice in 12 months. First period and second period were done from March to June 2005 and September to December 2005, respectively. After three months incubation in each period, the collected litter bags were taken to the laboratory and dried to a constant dry weight at 80°C to determine the percentage of the mass remaining. Nitrogen and organic carbon content in initial leaf-litter and mass remaining of leaf-litter were determined by the Kjeldahl and the Walkley and Black method, respectively.

The mass loss over time was fitted with a simple exponential curve. The decay-rate coefficient, k, for the rate of decomposition as outlined in Olson (1963).

$$\text{In}\left(\frac{X_t}{X_O}\right) = -kt$$

where, X_t is the amount of leaf-litter after time, (t), t is the time (month), X_O is the original mass leaf-litter and k is the decay rate coefficient.

The total amount of nutrient released in relation to total amount of litter produced at each study site was calculated from the amount of litter decomposed from time t_O to t and nutrient content associated with decomposed litter at t_O and t time, as follows (Sangha *et al*., 2006):

$$Y_0 = X_0 \text{ x initial nutrient concentration}$$

where, Y_O is amount of nutrients at time t_0 in litter, X_0 is amount of litter at time t_O.

$$\text{At time t, amount of remaining litter} = X_t$$

Thus, the nutrient content at time t in the remaining litter (Y_t):

$$Y_t = X_t \text{ x nutrient content at t}$$

$$\text{The amount of nutrient released during } t_O \text{ to t time} = Y_O\text{-}Y_t$$

Periodic curve fitting: Periodic curve fitting can be applied for periodic data when the observations are equally spaced a complete cycle (daily, weekly, monthly, or yearly cycles). Technically, periodic curve referred to as harmonics (Little and Hills, 1977). In this study, periodic curve fitting would be applied for data of monthly litterfall and climates (precipitation, temperature, air humidity and wind speed). Periodic curve consists of month (X-axis) and deviation of mean of litterfall and climate (Y-axis).

Data analysis: Data on litterfall production, leaf-litter decomposition and carbon and nitrogen released were analyzed using general linear models (GLMs). All post hoc tests were carried out using Tukey-tests. The standard level of significance was $p<0.05$. We used the software SPSS for windows for all statistical analysis. To investigate relationship between parameters were analyzed using regression and Pearson's correlation analysis.

RESULTS AND DISCUSSIONS

Litterfall production: Monthly litterfall production among study sites is depicted in Fig. 1. Monthly litterfall production in NF was significantly different, whereas in cacao agroforestry systems were not differ ($p<0.05$). Total annual litterfall varied significantly among land-use types ($p<0.05$). The greatest litterfall was recorded under the NF, that was 13.67 t/ha/year and the lowest litterfall production was 4.98 t/ha/year under CF2 (Fig. 2).

Periodic curve of the monthly litterfall and several recorded climatic factors (temperature, precipitation, air humidity and wind speed) are shown in Fig. 3. The y axis of this figure represents deviation mean of temperature, air humidity, wind speed, precipitation and litterfall. The values of deviation mean were obtained from the periodic curve equation by using those data.

In this study, periodic curve was used to analyze the influence of climate factors on litterfall production. When the periodic curves in a period of 12 months of monthly litterfall and recorded

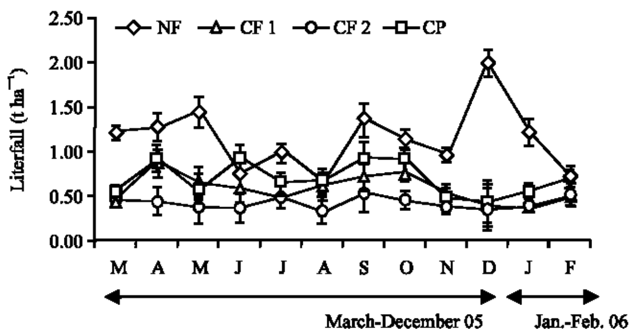

Fig. 1: Monthly litterfall (t ha^{-1}) in the Natural Forest (NF) and the cacao agroforestry systems (CF1, CF2 and CP) from March 2005 to February 2006. Value represent Mean±SE

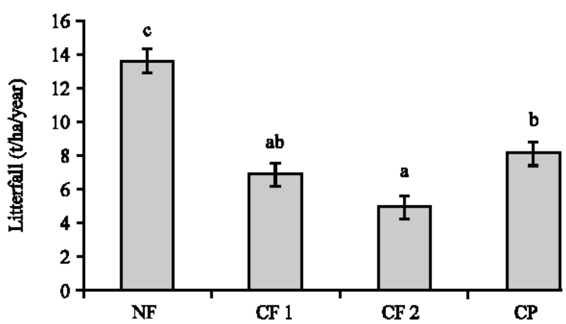

Fig. 2: Annual litterfall in the natural forest (NF) and cacao agroforestry systems (CF1, CF2 and CP). Data represent Mean±SE. Different letters indicate significantly different (Tukey-test, $p<0.05$)

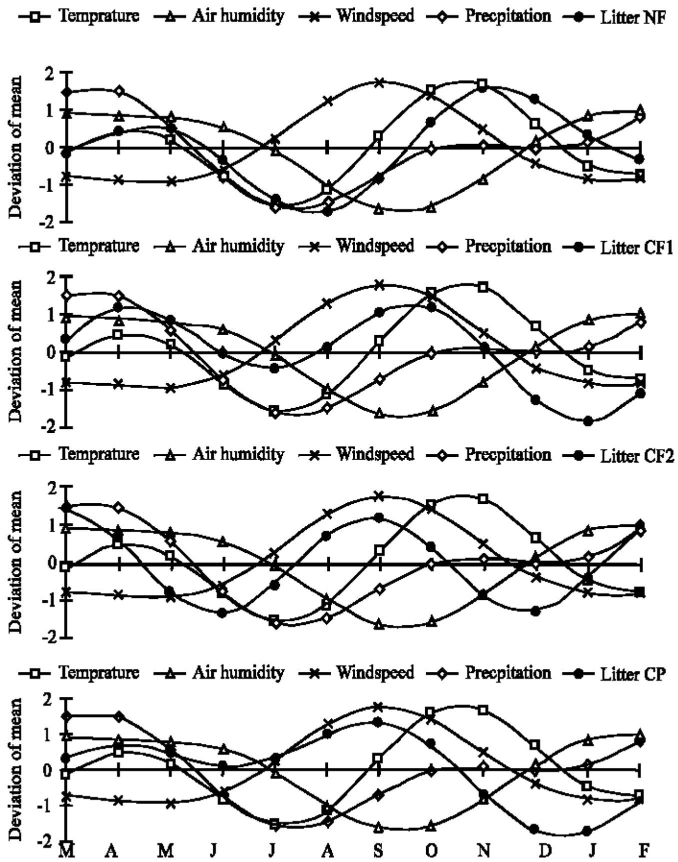

Fig. 3: Periodic curve of monthly litterfall and several recorded climatic factors (temperature, precipitation, air humidity and wind speed) in the natural forest (NF) and cacao agroforestry systems (CF1, CF2 and CP)

climatic factors (temperature, precipitation, air humidity and wind speed) were superimposed, the following analyses may be made: (1) the climatic factors (temperature, precipitation, air humidity and wind speed) modified each other producing a peculiar impacts on the litterfall, (2) during a year period may be differentiated into a period of high air humidity (January to July) and a period of low air humidity (July to October), (3) the dry period was characterized by cold and dry air with high wind speed and low rainfall (July to October), (4) the wet period was warm humid air with low wind speed and high rainfall, (5) high litterfall production occurred during low air humidity, high wind speed and high temperature and (6) cacao agroforestry system modified the time of maximum litterfall production. Another lower peak of litter occurred even during wet period maybe due to the leaf age.

Leaf-litter decomposition. Quantity of litter mass remaining in relation to time of decomposition was represented by an exponential function (Fig. 4a, b). The mass remaining during three months incubation in the first period revealed different pattern among study sites. The decrease rate of the mass remaining under NF was faster than those of cacao agroforestry systems during the first period. The decrease rate of the mass remaining of cacao agroforestry system under CP was faster than those of other cacao agroforestry systems, however, in the second period, the decrease rate of the mass remaining was not statistically different. We used original mass leaf-litter and the amount

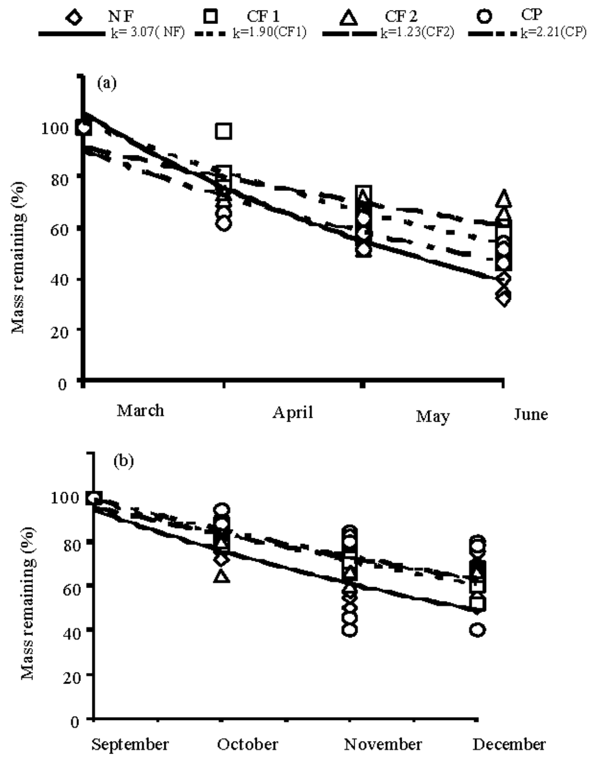

Fig. 4: Exponential curve of leaf-litter mass remaining (g) in two periods decomposition periods in the natural forest (NF) and cacao agroforestry systems (CF1, CF2 and CP), (a) first period: March to June 2005, (b) second period: September to December 2005

of leaf-litter after certain time to calculate decay-rate coefficient of leaf-litter. The decay-rate coefficient of leaf-litter during the first period, NF was the highest ($p<0.05$) among the land use system, the decay-rate coefficient of leaf-litter from CF1 and CP did not differ and CF2 showed the lowest value (1.23). On the other hand, the decay-rate coefficient of leaf-litter in the second period from all land use types did not differ significantly.

Nutrient released: Based upon the content of nutrient (carbon and nitrogen) remaining in the litter, there was a release of carbon and nitrogen as decomposition proceeded in all study sites (Fig. 5). The amount of carbon released in the first and second period was significantly different ($p<0.05$) in all land use types. In the first period, the carbon released under NF was similar to that under CP and the lowest under CF2. In the second period, carbon released under CF1 and CP was different significantly, but under NF and CF2 did not significantly. The nitrogen released in first period under NF differed significantly and higher than CF1, CF2 and CP. The nitrogen released in second period was quite similar in NF and cacao agroforestry systems.

Annual litterfall in this study (NF, CF1, CF2 and CP) were 13.67, 6.93, 4.98 and 8.23 t/ha/year, respectively (Fig. 2). The stem density (dbh>10 cm) in the study sites were 1184, 608, 488 and 625 n/ha, respectively (Table 1). Stem density in the cacao agroforestry systems under CF1 CF2 and CP were lower than those in the NF, therefore, their litterfall were also lower than those the NF. This result in line with study conducted by Owusu-Sekyere *et al.* (2006), which annual leaf

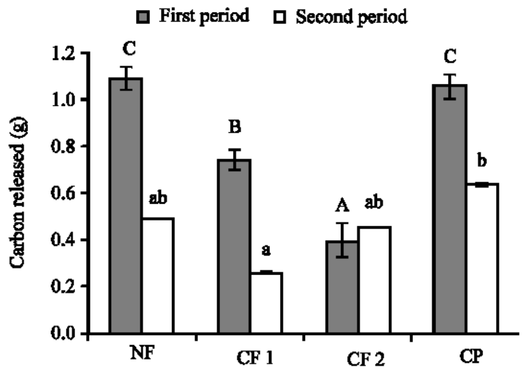

Fig. 5: The amount of carbon and nitrogen released (g) in two periods decomposition in natural forest (NF) and cacao agroforestry systems (CF1, CF2 and CP). First period (March-June 2005), second period (September-December 2005). Value represent Mean±SE. Different letters indicate significantly different (Tukey-test, $p<0.05$)

litter produced was higher in the primary and secondary forests than in the cacao plantation. In this study, increasing litterfall production was influenced by increasing of basal area, canopy cover and tree density. Basal area is reflected tree size, stand volume and biomass, therefore, NF had a higher litterfall production. This result was in line with study conducted by Starr *et al.* (2005); Goma-Tchimbakala and Bernhard-Reversat (2006) that litterfall production in natural forest strongly influenced by stand basal area, age structure, stem volume, latitude, season and climatic factor. Natural Forest (NF) in this study has litterfall production (13.67 t/ha/year) higher than that in primary forest in Ghana (8 t/ha/year) (Owusu-Sekyere *et al.*, 2006).

Litterfall production in cacao agroforestry system under CF1, CF2 and CP were lower than resulted by Indriyanto (2009). His study showed that litterfall production on agroforesty system in Lampung province dominated by *Theobroma cacao, Durio zibethinus* and *Coffea robusta* was 11.56 t/ha/year. Stand in CF2 and cacao agroforestry in Lampung province, Indonesia have high diversity and density, but they have different amount of litterfall production. Stands in fertile soil produced higher litterfall rates, due to biomass input via litterfall contributed high of nutrient (Dawoe *et al.*, 2010). With this reason, natural forest and cacao agroforestry systems in this study might be more fertile than natural forest in Ghana, but less fertile than cacao agroforestry in Lampung. Litterfall production in cacao agroforestry system under CP was 8.23 t/ha/year similar with cacao agroforestry systems in Ghana, West Africa (Dawoe *et al.*, 2010), because the both site have similar age of the cacao trees that were 15-year-old and cacao trees density.

Litterfall production fluctuated by month (Fig. 1) (Widyastuti *et al.*, 1998). This study showed that the monthly litterfall production at four studied sites was influenced by interactions of monthly climatic factors (Fig. 3). In the natural forest and cacao agroforestry systems high litterfall coincided with low air humidity and high temperature. Based on periodic curve (Fig. 3), dry season in this study occurred on July to October. A seasonal pattern of litterfall production in primary forest and cacao agroforestry in Ghana, which increase in the dry season, indicating that the physiological response to drought/reduced humidity plays a major role in this process (Dawoe *et al.*, 2010). These factors together with lower night temperatures which prevail during the dry season are known to stimulate abscisic acid synthesis in plant foliage which, in turn, stimulates leaf senescence (Yang *et al.*, 2003), particularly in species where bud break is suppressed by the presence of old leaves (Wright, 1996). Most litterfall studies in tropical forests have demonstrated strong seasonality of leaf litter, with the dry season being the peak of litterfall (Wieder and Wright, 1995; Lawrence and Foster, 2002). Seasonal pattern of litterfall largely depended on the factors responsible for leaf senescence and abscission (Lian and Zhang, 1998). This pattern of litterfall production in our study consistent with pattern of stands under climate with dry season, but different from those found in stands under climate without dry seasons, such as the Atlantic rain forest (Brazil), where the litter production peak occurs in the rainy season, indicating an effect of mechanical factors (De Moraes *et al.*, 1999).

In present study, the remaining mass of the leaf-litter during decomposition decreased with the increasing incubation time similar result was reported by Alhamd *et al.* (2004) and the breakdown of the leaf-litter varied among forest systems (Attignon *et al.*, 2004). Decomposition of leaf litter from Natural Forest (NF) was relatively faster than that of cacao leaf litter (CF1, CF2 and CP). This result similar with study was conducted by Owusu-Sekyere *et al.* (2006). They investigated decomposition rate in cacao plantation comparable with primary forest in Ghana, which decomposition rate coefficients tended to decrease from forest to cacao systems. Percentage of mass loss during three months in this study is higher than study conducted by Ngao *et al.* (2009) in eucalypt forest. This could be due to differences of environmental factors and physicochemical properties of the substrate in both sites. One of the predictor of decomposition rate is litter quality. This predictor which include ratios of carbon to nitrogen (C: N), polyphenol to nitrogen (PP:N), lignin to nitrogen (L: N) and polyphenol plus lignin to nitrogen (PP+L: N) (Mafongoya *et al.* 1998). Dawoe *et al.* (2010) stated that concentration of lignin, polyphenol, nitrogen of cacao leaf litter higher than forest leaf litter. Lower rates of decomposition in cacao agroforestry systems (CF1, CF2 and CP) compared to forest (NF), particularly in the first period (March to June), suggest the possible effect of litter quality dominating decomposition, nevertheless, interaction between litter quality, land-use systems and season also determine decomposition rate.

In this present study, during the first two months in each period of incubation decomposing rate was faster; thereafter, followed by slower rate. This could be due to a higher initial content of water-soluble materials, simple substrates that were easily decomposed by decomposers, especially microflora (Songwe *et al.*, 1995). The relatively slower rate may be due to the accumulation of more recalcitrant constituents in the residual litter mass (Sundarapandian and Swamy, 1999). The higher rate of mass loss during the first period than second period was due to environment factors. The first period (March to June) was wet period (low temperature, high precipitation and high air humidity), on the contrary, the rate of mass loss in second period was lower as this the dry period (September to December). Activity of decomposers were affected by environment factors particularly soil moisture, temperature and evapotranspiration (Facelli and Pickett, 1991; Zimmer, 2002).

The decomposition rate of leaf-litter is controlled by the interacting influences of the soil physicochemical environment, decomposers organisms and the quality of leaf-litter (Berg and McClaugherty, 2003; Pavao-Zuckerman and Coleman, 2005). Comparison of decay rate coefficient (k), however; may be confounded by differences in the length of the decomposition period. Extrapolation of decay rate coefficient from short decomposition period yields a higher k values than that the extrapolation from long period (Lisane and Michelsen, 1994). There were studies of short duration range from 98 days (Tian *et al.*, 1998) to 180 days (Yamashita and Takeda, 1998) and those of long duration usually extend over more one year (Loranger *et al.*, 2002). The decay rate coefficient, k, varied significantly among litter collected from different land use types, during the first period of incubation, ranging from 1.23 to 3.07. With the decomposition period of 90 days, present result was better compared to that from short-term studied by Sundarapandian and Swamy (1999) in tropical forest in India, but lower than reported by Attignon *et al.* (2004) in rainforest West African. According to Verhoef and Gunadi (2001) that the value of decay rate coefficient in this study was medium to high (k = 1 - 3). The annual decay rate coefficient of temperate hardwood species ranged from 0.08 to 0.47 (Melillo *et al.*, 1982), subtropical forest ranged from 0.66 to 1.09 (Alhamd *et al.*, 2004) and Mediterranean ecosystem ranged from 0.30 to 0.75 (Fioretto *et al.*, 2005). Alvarez *et al.* (1992) reported that in the tropical forest, k values were often greater than 1.0, indicating that leaf-litter turnover occurred in a year or less than a year. The varying k value seemed due to the nutrient content of leaves (Songwe *et al.*, 1995) and season. Based on periodic curve of precipitation, second period was wet season; on the contrary, first period was dry season. The enhanced litter decomposition rates in wet season showed a combined effect of higher precipitation and relative humidity (Pandey *et al.*, 2007). The large differences in k value could be attributed to decomposer population dynamics (Kumar and Deepu, 1992).

As decomposers, microbes are a key factor in nutrient cycling in ecosystems. The main source of energy for microbial life in soil is organic matter. The quantity and the quality of the organic matter in a certain ecosystem determine the population and activity of the soil microbes. Anas *et al.* (2005) reported that soil microbial population in the NF was rather low (18,180 cfu g^{-1}), but the soil microbial respiration was high (7.1 mg CO_2-C kg^{-1}). The highest soil microbial population occurred in CF1 (362,108 cfu g^{-1}) with soil microbial respiration quite similar to the NF, that was 7.3 mg CO_2-C kg^{-1}. This information supports the fact that leaf-litter decomposition in the NF was faster than those of cacao agroforestry systems.

Different species have different nutrient release patterns, which related to litter quality and seasonal environment factors (Kavvadias *et al.*, 2001). During litter decomposition, microbes convert organic carbon into total CO_2. This process also releases nutrient in various forms, for example NH_4^+, N_2 and PO_4^{3-} (Murray *et al.*, 2005).

Nutrient released from decomposing plant litter is vital for the maintenance of fertility in forest soils. The well-known general model for this process involves initial leaching of nutrients followed by a phase of nutrient immobilization and finally the release of nutrients into the soil (Weerakkody and Parkinson, 2006). The highest carbon and nitrogen released in the first period in the NF indicate that the microclimate in those site trigger litter decomposition and nutrient released. Decomposition of litter and release of nutrients not only depends upon litter composition but also upon soil type, microbial communities, incubation time and soil properties (Sangha *et al.*, 2006). Microbial and other decomposition processes depend upon the type of material available for decomposition and on other factors such as climate and water availability (Bardgett *et al.*, 1999). Thus, the quality of litter influences microbial processes and nutrient retention in a system. The effects of soil properties, for example water availability or pH, on litter decomposition or on growth of particular microbes and their activities responsible for litter decomposition, vary with seasons and can play an important role in moderating nutrient return to a system (Sangha *et al.*, 2006).

Land use change from natural forest into cacao agroforestry systems in Central Sulawesi, Indonesia decreasing the litterfall production, rates of decomposition and nutrient released and could impact on nutrient cycling in ecosystem. Therefore, land use change should be aware the conservation in global perspective.

It can be concluded that natural forest had the higher annual litterfall production than that of cacao agroforestry systems. Monthly litterfall production in natural forest and cacao agroforestry systems were influenced by climate. Natural forest had the highest coefficient of decomposition or the fastest rate of decomposition, whereas cacao agroforestry systems under local shade trees (CF2) had the lowest one. Cacao agroforestry system that can be developed in the margin of LLNP is cacao planted under forest cover. This system has the advantages, that it can maintain the ecological performance of resemble natural forest and local forest communities will gain income from the production of cacao, so that illegal logging can be avoided.

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