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Litterfall Production and Turnover in the Long-Term Ecological Research Sites in Southern Philippines

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ABSTRACT

Forest litter is an important aspect for healthy forest ecosystems. Hence, this study monitored the litterfall production and turnover in the established two-hectare permanent plots in the three Long Term Ecological Research (LTER) Sites in Mindanao, *viz*., Mt. Apo, Mt. Hamiguitan and Mt. Musuan. Litter samples were collected from 2w0 installed traps at each site and consequently sorted to components, processed and oven-dried. Data revealed that the estimated annual litter production was highest in Mt. Musuan with 11211.5 kg ha^{-1}, followed by Mt. Apo with 6648.0 kg ha^{-1} and Mt. Hamiguitan with 4919.5 kg ha^{-1}. *Agathis philippinensis* contributed the highest litterfall production in Mt. Apo, whereas *Barringtonia racemosa* and *Artocarpus blancoi* in Mt. Hamiguitan and Mt. Musuan, respectively. Highest litter turnover was observed in Mt. Musuan (5.35%/day). Litterfall production showed to have a positive correlation with temperature for Mt. Hamiguitan and Mt. Musuan. Among the studied sites, Mt. Musuan had the highest forest primary production. Results of this study support previous reports that lowland forests have high forest productivity. Further, there is a need to plant Philippine endemic and threatened trees, such as A. *philippinensis* since these prove to have high productivity as in the case of Mt. Apo and Mt. Hamiguitan.

Keywords: Mt. Apo, Mt. Hamiguitan, Mt. Musuan, oven-dry weight, tropical forests

INTRODUCTION

Forest litterfall refers to the plant materials such as fallen leaves, branches, twigs, flowers, fruits, seeds and root parts which are shed off from trees and the amount of litterfall may be indicative of the health status and the level of forest productivity (Clark et al., 2011). Almost 80% of the net primary production is supplied back to the ecosystem by means of litterfall (Meentemeyer et al., 1982; Kassnacht & Gower, 1997). The amount and quality of litter also provide information about the dynamics of nutrient cycling in which foliar litter constitutes the major proportion of ground litter (Celentano et al., 2011). The nutrient content in litterfall gives the functional state of the forest that can be used to improve its management and production (Higuera & Martinez, 2006).

The production and amount of litterfall is affected by seasonal fluctuations, which are regulated by biological and climatological processes and factors such as topography, edaphic condition, vegetal species, age and forest density (Higuera & Martinez, 2006). Since forests are climatic formation, the amount of litterfall can be used to indicate change of climate. It has become an important parameter recently in monitoring global climate change in addition to the plant flowering and foliation used for phenological observation (Hansen et al., 2009). Tropical forests tend to sustain the ecosystem processes but the fluctuating climatic conditions relatively affect the primary productivity of the forest (Celentano et al., 2011).

The establishment of the Mindanao Long Term Ecological Research (LTER) Sites is in response to the global campaign to move towards a more sustainable world in which the health of the ecosystem and human well-beings are improved and that its ecosystem services can serve the current and future generations. Assessments and biodiversity studies on the flora and fauna of Mindanao LTER Sites were conducted. Further, forest litterfall production in these LTER Sites was considered an important aspect to look into for it provides insights on the nutrient cycling process in this ecosystem. Among the five LTER Sites in Mindanao, three of which have been monitored in 2012–2013 and 2015. The three LTER Sites viz., Mt. Apo, Mt. Hamiguitan and Mt. Musuan were monitored in 2016–2017. This is necessary in order

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to monitor and obtain reliable data on the litterfall production and turnover of said sites. Data from this research serves as baseline information regarding the litterfall production in these sites. Hence, this study was conducted to obtain additional data on its third year from the established litter traps of these mountains.

METHODOLOGY

Study sites

The establishment of the two-hectare permanent plot in Mt. Apo (MAP), Mt. Hamiguitan (MHP) and Mt. Musuan (MMP) was based on the abundance of tree specis in the sites. The MAP is situated in upper montane vegetation, whereas MHP and MMP are located in lower montane and in lowland mixed dipterocarp/agroecosystem, respectively. Distribution of the litter traps were based on the location of the identified dominant tree species, in which MAP is characterized to have evergreen species in the forest which means that their leaves shed off not at the same time, but gradually, making the forests to remain green throughout the year and this include the gymnosperm species. MMP on the other hand, has tree species which are deciduous, which means that their leaves shed off at the same time leaving the tree temporarily bare for a certain time of the year. Deciduous species tend to give higher litter production to the forest ecosystem. The selected dominant and co-dominant tree species are shown in Table 1. Among

Table 1:
Selected dominant and co-dominant tree species tagged for litter collection in the three Mindanao LTER Sites (Quimpang et al., 2013, 2015, 2017).

Dominant Tree Species	Local Name	Family	Mindanao LTER Sites		
			MAP	MHA	MMU
1. *Agathis philippinensis* Warb	Almaciga	Araucariaceae	/	/	
2. *Alstonia scholaris* (L.) R. Br.	Dita	Apocynaceae			/
3. *Artocarpus blancoi* (Elmer) Merr.	Antipolo	Moraceae			/
4. *Barringtonia racemosa* (L.) Merr. ex DC	Malagubat	Lecythidaceae		/	
5. *Calophyllum blancoi* Planch & Triana	Bitanghol	Calophyllaceae		/	
6. *Cinnamomum mercadoi* S. Vidal	Kalingag	Lauraceae	/		
7. *Kleinhovia hospita* L.	Tan-ag	Malvaceae			/
8. *Lithocarpus apoensis (Elmer)* Rehder	Uwayan	Fagaceae	/		
9. *Melanolepis multiglandulosa (*Reinw. ex Blume) Rch. & Zoll	Alim	Euphorbiaceae			/
10. *Palaquium sp.*	Nato	Sapotaceae		/	
11. *Phyllocladus hypophyllus* Hook.f.	Tungog	Podocarpaceae	/		
12. *Senna spectabilis (D.C)* H.S. Irwin & Barnebt	Ansuan-dilaw	Leguminoseae			/
13. *Shorea polysperma* Merr.	Tangile	Dipterocarpaceae		/	
14. *Syzygium hulchinsonii* (Merr. ex C.B.Rob.) Merr.	Malatambis	Myrtaceae	/		

Lengend: (/)-Present MAP-Mt. Apo Plot MHA-Mt. Hamiguitan Plot MMP-Mt. Musuan Plot

Table 2:
Forest Characteristics of the three Mindanao LTER Sites (Quimpang et al., 2013, 2015, 2017).

LTER Sites	Province[1]	Elevation (masl)[2]	Climate Type[3]	Annual Rain-fall (mm)	Average Temperature[4]	Relative Hu-midity (%)[4]	Coordinates	Vegatation Type
Mt. Apo	North Cotabato	1,944	IV	1695	16°	90.57	6°59'47.05"N 125°15'12.18"E	Upper Montane
Mt. Hamiguitan	Davao Oriental	1,044	IV	1679	20°	95.13	6°43'58.02"N 126°9'58.32"E	Mid-montane
Mt. Musuan	Bukidnon	388	III	1887	24°	91.38	7°52'56.58"N 125°3'55.38"E	Lowland Mixed dipterocarp/ agroecosystem

1 - Google Earth 2 - GPS 3 - PAGASA (2011) 4 - HOBO ware Data Logger

the sites, MAP has the highest elevation (1,944 masl), followed by MHP (1,044 masl) and MMP (388 masl). The forest characteristics of the three Mindanao LTER Sites were recorded (Table 2). Temperature and relative humidity of the three sites were recorded using Hoboware Data Logger Pro v2 distributed by MicroDAQ.com, Ltd. USA.

Mt. Apo Natural Park is the highest mountain in the Philippines and can be seen in parts of Davao del Sur and Cotabato provinces. On the other hand, Mt. Hamiguitan Range Wildlife Sanctuary (MHRWS) in Davao Oriental is a protected area covering 6,834 ha and is identified as one of the Key Biodiversity Areas (KBAs) in the Philippines. It is both an ASEAN Heritage Park and a UNESCO World Heritage Site. It is located in the eastern coast of the Philippines and form the southern part of eastern Mindanao corridor (Villanueva & Mohagan, 2010). Mt. Musuan, also called Mt. Kalayo, is a prominent landmark of Central Mindanao University in Bukidnon province with a peak elevation of 646 masl.

In this study, only the dominant tree species in the three selected Mindanao LTER Sites were monitored. The most common is *Agathis philippinensis* (Almaciga) which is found in MAP and MHP. According to Higuera & Martinez (2006), litterfall of the trees that dominate the canopy has a great influence in the availability of nutrients in the ground under their tops. Five dominant and co-dominant tree species with four individuals were chosen based on the diversity of tree species. All tree species near the installed litter traps that may contribute to the collected samples were also identified.

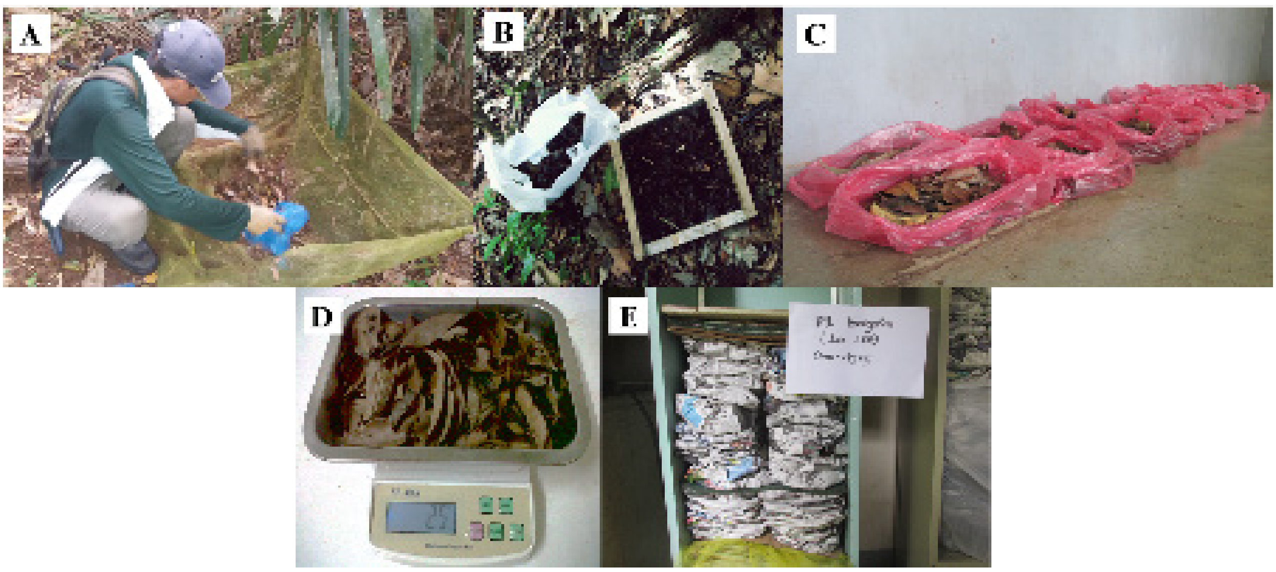

Figure 1. Litterfall collection and processing. A) Monthly collection; B) Collection of ground litter; C) Air-drying; D) Sorting and weighing of components; E) Oven-drying.

Litterfall Collection and Processing

Quimpang et al. (2013) tagged 20 dominant tree species in each site for litter collection in the five Mindanao LTER Sites. Litter were collected monthly from November 2016 to October 2017 from the 20 re-installed traps by handpicking and placed inside labeled collecting bags (Li et al., 2005). Following Quimpang et al. (2017), litter samples were weighed (fresh weight) using a digital weighing scale (1.0 g sensitivity), air-dried, weighed again (air dry weight) and sorted out into leaves, woody, reproductive and miscellaneous parts (i.e. dead insects, plants and others). Each sorted component was weighed again and placed in a labeled bag then oven-dried at a temperature of 70–80°C for three days or until the litter became brittle. After drying, oven-dried litter were weighed again (Fig. 1).

Analysis of Litter Turnover

Litter turnover rate was obtained by installing 0.25 m^2 wooden frame on the ground below the litter traps on which the ground litter (free of soil) enclosed within the wooden frame were collected. The fresh weight of collected ground litter samples were measured, air dried, weighed and oven dried. The litter turnover rate in percent per day (%/day) was calculated by dividing litterfall (g ODW/m^2/day) by litter standing crop multiplied by 100 and turnover time in days by dividing litter standing crop by litterfall (Zieman et al., 1979).

$$\text{Litter Turnover Rate: \% per day: } \frac{\text{LF g ODW/ m2/day}}{\text{LSC g ODW/m2}} \times 100$$

$$\text{Litter Turnover Time: \# of day: } \frac{\text{LSC g ODW/m2}}{\text{LF g ODW/m2/day}}$$

Where: LF = Litterfall
LSC = Litter standing crop

This is shown below:

Statistical Analysis

The monthly collected litter in oven-dry weight were expressed in kilograms per hectare per month (kg/ha^1/month). Descriptive analysis was used for litter quality, data comparison and determining relationship between variables. Percentage of litter component was determined by:

$$\text{Dry weight of Leaves (\%)} = \frac{\text{Total weight of dried leaves of Sp1}}{\text{Total weight of all litter components of Sp1}}$$

$$\text{Sp1 \% species Litter} = \frac{\text{All dry weight of Species 1}}{\text{Total dry weight of all itter of all tree species}} \times 100$$

% of Litter:
% of species litter:

RESULTS AND DISCUSSION

Litter Components

The leaves account for more than 50% of the total litterfall production and therefore had contributed the highest percentage of litter component, followed by woody parts, miscellaneous parts and reproductive parts in all study sites. These findings supported the report of Cuevas & Lugo (1998) and Liu et al. (2004) which stated that leaves account as a major and most important component of the total litter and respond rapidly to climatic changes. Additionally, the portion of leaf litter commonly varies between 60 to 90% (Lisanework & Michelsen, 1994; Schrumpf et al., 2006; Zhou et al., 2006; González-Rodríguez et al., 2011). In this study, the proportion of leaf litter in relation to woody, miscellaneous and reproductive structures was high in all months (Fig. 2). The proportions of the leaves in total above ground litterfall may also provide good indication on the successional stage of tropical forests. Older forests allocate more production to fruits, flowers and seeds, and have more branch production than younger forests. This implies that Mt. Hamiguitan is a younger ecosystem as its leaf component reaches 70% of the total litterfall which supports the earlier report of Quimpang et al. (2017), whereas Mt. Apo and Mt. Musuan are implied to be older forest ecosystems.

Species Litter Contribution

Percentage litterfall production of the dominant tree species at MAP showed that *A. philippinensis* (23.18%) had the highest percentage contribution of total litter production, followed by *C. mercadoi* (21.07%), *P. hypophyllus* (19.87%), *Syzygium hutchinsonii* (Merr. ex C.B.Rob.) Merr. (19.03%) and least by *Lithocarpus apoensis* (Elmer) Rehder (16.84%). For Mt. Hamiguitan, *Barringtonia racemosa* (L.) Merr. ex DC (21.83%) had the highest percentage contribution of total litterfall production, followed by *S. polysperma* (20.14%), *A. philippinensis* (19.75%), *Palaquium* sp. (19.50%) and *C. blancoi* (18.76%), while in Mt. Musuan, *K. hospita* (22.58%) and *A. blancoi* (22.88%) had the highest percentage contribution of total litterfall production, followed by *A. scholaris* (20.89%), *M. multiglandulosa* (18.50%) and *S. spectabilis* (15.14%).

These rates of litterfall are generally positively correlated with forest productivity (Adams & Attiwill, 1991; Thomas, 1992; Madeira et al., 1995; Moroni & Smethurst, 2003). According to the studies of Bray and Gorham (1964) and Vogt et al. (1986), there was

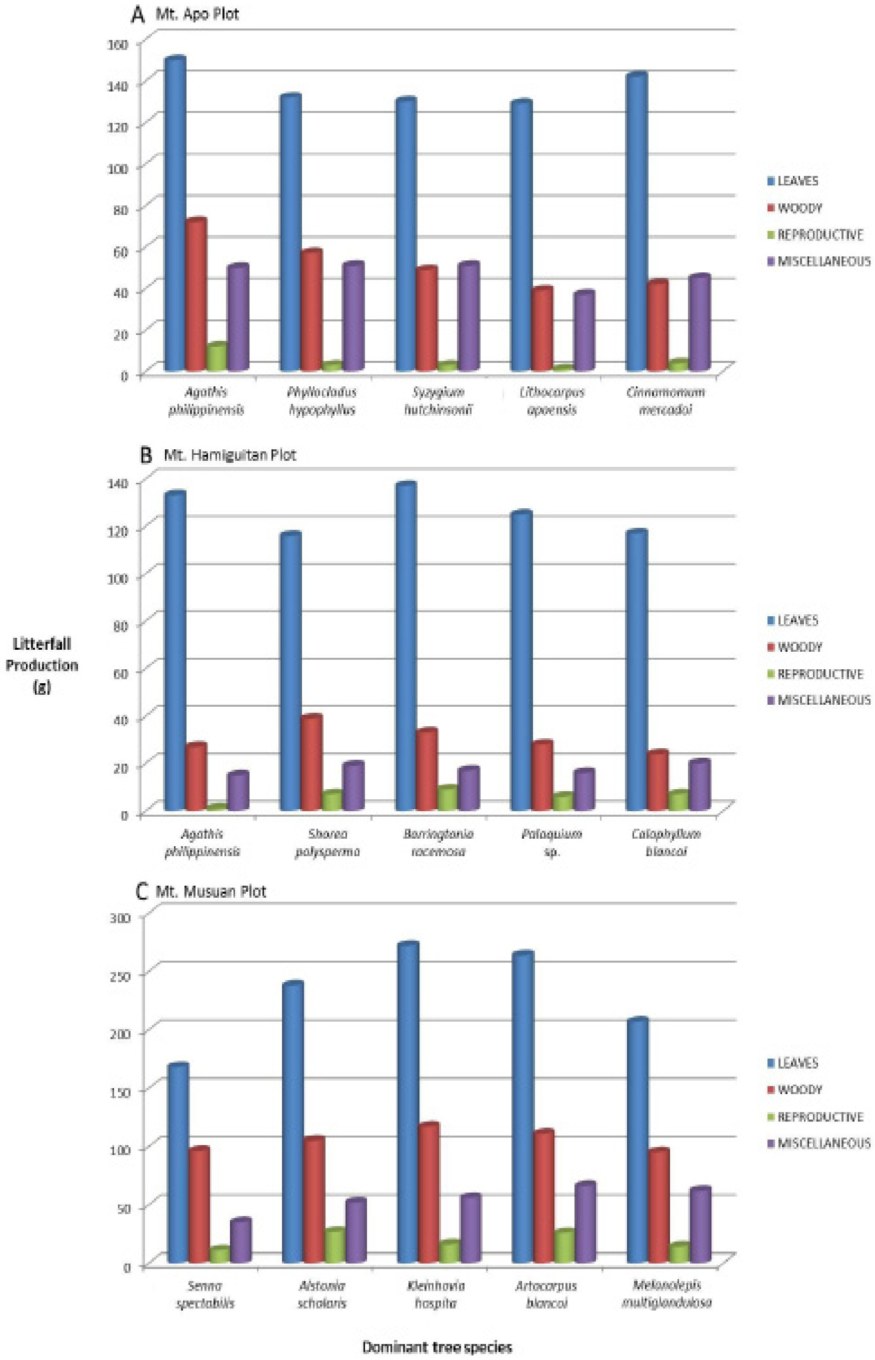

Figure 2. Litterfall production with its different components for the dominant tree species in A) Mt. Apo; B) Mt. Haimiguitan and C) Mt. Musuan plots.

not a major difference between the trees with respect to litterfall, the significant differences depends on the climate.

Litterfall Production

At MAP, the litter production peaked on October 2017 (78.50 g) and closely uniform from February 2017 (54.95 g) to June 2017 (54.45 g). The lowest production at MAP was in May 2017 (51.40 g). At MHP, litter production peaked on July 2017 (72.25 g) and closely uniform from December 2016 (57.80 g) to June 2017 (55.35 g). The lowest production at MHP was in March 2017 (51.40 g). At MMP, the litter production peaked on June 2017 (90.65 g) and closely uniform from November 2016 (80.30 g) to February 2017 (76.25 g) and March 2017 (89.7 g) to June 2017 (90.65 g). Lowest production at MHP was in February 2017 (76.25 g) (Fig. 3). Estimated annual litter production was highest at MMP with 11211.5 kg ha^{-1} which had an estimated mean daily litter production of 30.7 kg ha^{-1}, followed by MAP with 6648.0 kg ha^{-1} which had an estimated mean daily litter production of 18.2 kg ha^{-1} and MHP with 4919.5 kg ha^{-1} which had an estimated mean daily litter production of 13.5 kg ha^{-1}. These amounts of litter production closely fall within the values obtained in other tropical forests studies as reported by Gunadi (1992) with 900 g and 400 g in the 2 sites in Indonesia and the report of Pandey et al. (2007) with 419.9 g and 547.7 g in the two for-

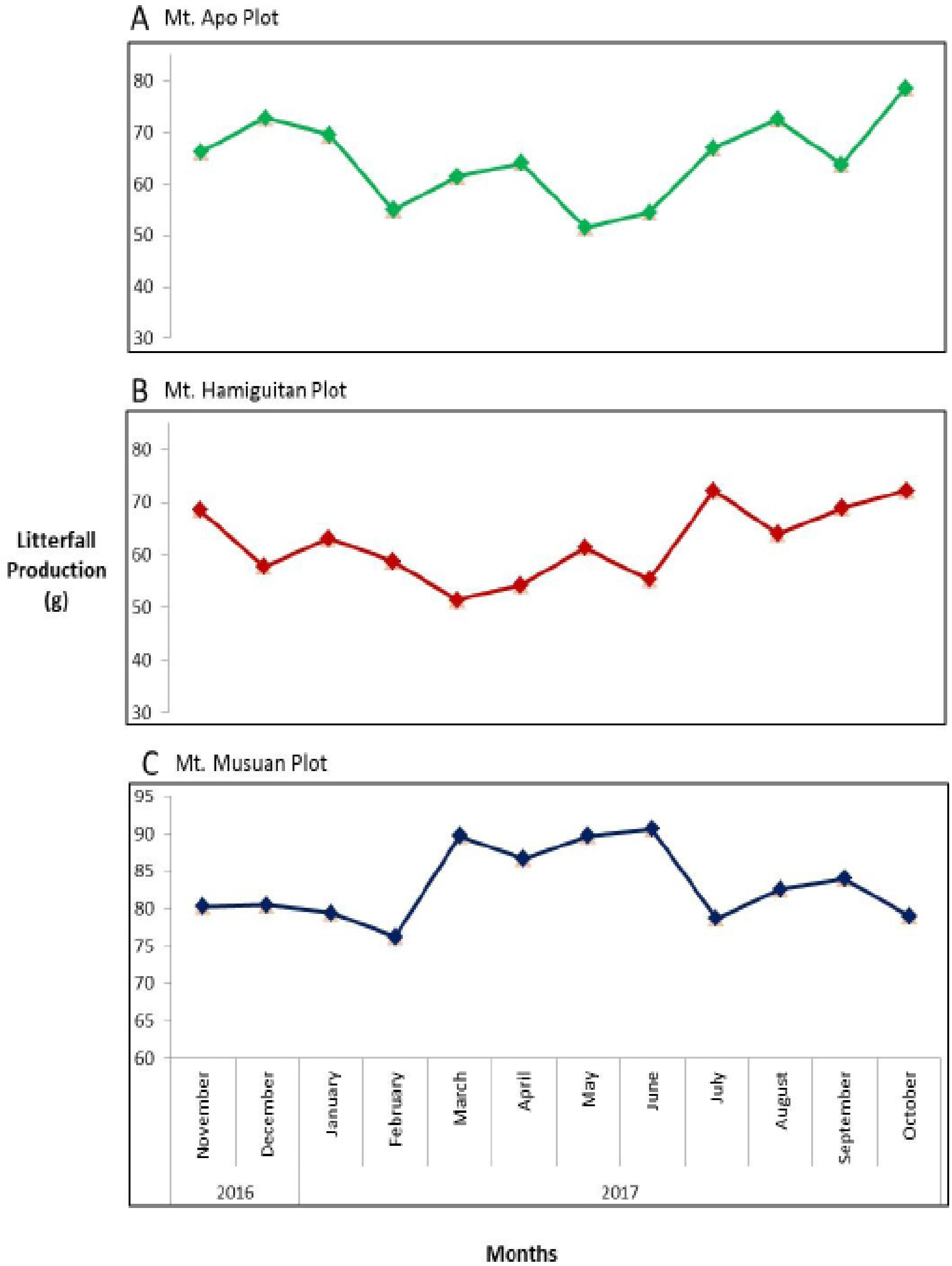

Figure 3. Patterns of monthly litterfall production of the dominant tree species in the three Mindanao LTER Sites

est types (plantation and forest) of northeastern India and in the study of Quimpang et al. (2013, 2015, 2017). Additionaly, these amounts of litter production might be due to the climatic type in which MAP and MHP have climatic type IV, while MMP has climatic type III (PAGASA, 2011).

As reported in several studies, the amount of litterfall may vary across different sites and biomes (Cakir & Akburak, 2017). Litterfall production was much higher in hot and wet months than the rest of the year for all studied forests by Chen et al. (1992), Tu et al. (1993), Weng *et al*. (1993) and Rawat et al. (2009). Pascal (1988) also reported that a heavy leaf litterfall occurred during the dry season in evergreen forests of Attappadi, Western Ghats, India and the generated data of Valenti et al. (2008) was affected by the season in tropical region, because litterfall production is greater during the dry season. However, Molles (2008) added that an agrosystem with the highest levels of primary production are those warm and receive large amount of precipitation, in which this present data supports this finding. In tropical montane forests, the seasonality of litterfall is generally low compared to that of tropical lowland forests (Chave et al., 2010). Recent studies supported that the litterfall production are in the peak either in dry and rainy season. Specifically, leaf aging, stomatal closure and subsequent leaf overheating, might lead to leaf shedding at the end of the dry season (Roderstein et al., 2005). As a side effect, trees are preparing for the upcoming season of highest net primary production. By contrast, the peaks during the rainy season are the result of strong winds and thunderstorms (Dawoe et al., 2010; Gonzalez-Rodriguez et al., 2011). This explains the observed increase in peaks of litter during wet months (Becker, 2015).

The tendency of litterfall to be concentrated in the cool and dry season is also related to a combination of decline in temperature and lowered soil moisture (Wang et al., 2008). However, monthly litterfall production pattern is still controlled mainly by community characteristics and environmental factors (Lu & Liu, 1988; Huebschmann et al., 1999; Pedersen & Hansen, 1999; Sundarapandian & Swamy, 1999; Kavvadias et al., 2001). Litterfall may also be affected by physical factors such as the mechanic action of wind and rain or physiological responses of the plants to environment changes (Delitti, 1998; Moraes & Prado, 1998; ICP Forests, 2004; Santiago & Mulkey, 2005) and some factors affecting litterfall amounts are also the succession stage, tree age and dominant plant or tree species (Barlow et al., 2007; Celentano et al., 2011). According to Holtgrieve et al. (1999) the annual quantity of litterfall is dependent on the proportion of foliage biomass that dies within a year, which ultimately depends on such factors as rate of leaf senescence, wind velocity, variation in canopy architecture and the tree species that make up the forest (Jackson et al., 1990).

Litter turnover

As cited by Raich et al. (2007), nutrient cycling in forestry systems is achieved when the fine litter is decomposed by soil biota, which determines forest primary productivity (Wang et al., 2008). Thus, the role of litter in plant nutrition is determined by its turnover time (Weerakkody & Parkinson, 2006). The mean average of standing litter in the five tree species in MAP was 182.72 g, in which the highest was observed in *L. apoensis* (202.29 g) and least in *S. hutchinsonii* (172.18 g). Mean average turnover rate among the five tree species was 1.00% which was highest in *A. philippinensis* (1.20%) which will decompose within 83.40 days and the least turnover rate was observed in *L. apoensis* (0.77%) which will decompose within 129.25 days. Mean turnover time for the five tree species in Mt. Hamiguitan is within 101.73 days which imply that litterfall will decompose in said number of days.

At MHP, the mean average of standing lit-

Table 3: Litter turnover of the dominant tree species in the three Mindanao LTER Sites

Five dominant tree species	Standing Litter (g ODW/m²)	Turnover Rate (%/day)	Turnover Time (Days)
1. Mt. Apo			
Agathis philippinensis	179.66	1.20	83.40
Phyllocladus hypophyllus	182.74	1.01	98.96
Syzygium hutchinsonii	172.18	1.03	97.40
Lithocarpus apoensis	202.29	0.77	129.25
Cinnamomum mercadoi	176.71	1.00	99.65
Mean	182.72	1.00	101.73
2. Mt. Hamiguitan			
Agathis philippinensis	53.00	2.51	39.80
Shorea polysperma	52.25	2.60	38.49
Barringtonia racemosa	53.00	2.78	36.02
Palaquium sp.	45.25	2.90	34.43
Calophyllum blancoi	53.25	2.37	42.12
Mean	51.35	2.63	38.17
3. Mt. Musuan			
Senna spectabilis	44.50	5.24	19.09
Alstonia scholaris	128.75	2.47	40.43
Kleinhovia hospital	51	6.81	14.68
Artocarpus blancoi	75.25	4.68	21.37
Melanolepis multiglandulosa	37.75	7.54	13.26
Mean	67.45	5.40	21.77

ter in the five tree species was 51.35 g, in which the highest was observed in *A. philippinensis* and *B. racemosa* (53.00 g) and least in *Palaquium* sp. (45.25 g). Mean average turnover rate among the five tree species was 2.63% which was highest in *Palaquium* sp. (2.90%) which will decompose within 34.43 days and the least in turnover rate was observed in *C. blancoi* (53.25%) which will decompose within 42.12 days. Mean turnover time for the five tree species in Mt. Hamiguitan is within 38.17 days which imply that litterfall will decompose in said number of days.

At MMP, the mean average of standing litter in the five tree species in Mt. Musuan was 67.45 g, in which the highest was observed in *A. scholaris* (128.75 g) and least in *S. spectabilis* (44.50 g). Mean average turnover rate among the five tree species was 5.40% which was highest in *M. multiglandulosa* (7.54%) which will decompose within 13.26 days and the least in turnover rate was observed in *A. scholaris* (2.47%) which will decompose within 40.43 days. Mean turnover time for the five tree species in Mt. Musuan is within 21.77 days which imply that litterfall will decompose in said number of days (Table 3).

Turnover rate is the percentage of litter standing crop to replace the litter fall every day. The higher the percentage of the turnover rate, the faster the decomposition and replacement of litterfall. Therefore, the faster the decomposition, the faster the productivity. The higher the rate of turnover time, the longer the litter turnover will stay on the ground (Quimpang et al., 2013, 2015, 2017). Litter decomposition rates are influenced by at least three general factors: the composition and activity of the decomposer community (O, organisms), the quality of the detritus (Q) and the physicochemical environment, P (Anderson and Swift, 1983). Some studies predict that lignin depresses litter turnover rates (e.g., Meentemeyer, 1978); however, Raich et al. (2007) contradicts the earlier result which found a highly significant, positive correlation between lignin contents and decay rates.

Litter decomposition has many factors to observe. As cited by Portillo-Estrada et al. (2016), soil characteristics, soil moisture (Bradford et al., 2016) and its microbial abundance and composition (Allison et al., 2013), and the species-related characteristics of litter also play an important role in the decomposition. The leaf litter may vary greatly in the leaf toughness (Gallardo & Merino, 1993), resistance to fracture (Wright & Illius, 1995), anatomical traits like leaf mass per area, and mechanical characteristics like leaf tensile strength (Cornelissen & Thompson, 1997), elemental composition (Berg & McClaugherty, 2008) and content of toxic chemicals such as terpenoids and alkaloids that are synthesized to protect against herbivory but also inhibiting soil microbes (Ormeño et al., 2009).

Relating Litter Production to Environmental Parameters

The correlations of litterfall production between temperature and relative humidity were also determined. In Mt. Apo, the patterns of litterfall production correlated with the relative humidity had a weak positive correlation of 0.13115. However, the temperature did not correlate with the litterfall production. In contrast to the correlation in MAP, the patterns of litterfall production in MHP correlated with the temperature had a weak positive correlation of 0.14617. However, the relative humidity did not correlate with the litterfall production. In MMP, the patterns of litterfall production correlated with the temperature had a strong positive correlation of 0.57478, whereas the temperature also correlated with the relative humidity had a strong positive cor-

Table 4: Correlation of litterfall production in the three Mindanao LTER Sites among the three parameters: A) Litterfall Production; B) Temperature; C) Relative Humidity

Parameter	Litterfall Production	Temperature	Relative Humidity
1. Mt. Apo			
Litterfall production	1		
Temperature	-0.31450	1	
Relative Humidity	0.13115	-0.25412	1
2. Mt. Hamiguitan			
Litterfall Production	1		
Temperature	0.14617	1	
Relative Humidity	-0.11849	-0.19558	1
3. Mt. Musuan			
Litterfall Production	1		
Temperature	0.57478	1	
Relative Humidity	-0.33507	0.85139	1

relation of 0.85139. However, the litterfall production did not correlate with the relative humidity (Table 4).

It was reported that positive correlation with maximum temperature in tropical species and changes in photoperiodicity can affect the flowering and bud break in plant (Cuevas & Lugo, 1998). In a regional scale, temperature and precipitation are the most important climatic factors controlling ecological processes (Liu et al., 2004) and are related to litterfall (Martins & Rodrigues, 1999; Liu et al., 2004; Cianciaruso et al., 2006). Litterfall production in this study had a positive correlation with temperature, but not with the relative humidity and rainfall. The data suggest that the climatic variables such as monthly mean and minimum temperatures and rainfall were not responsible for the patterns of monthly litterfall production in the three Mindanao LTER Sites. This supported Zhou et al. (2006) which indicated that their litterfall production in their five among the six studied communities were not significantly affected by precipitation in evergreen broadleaved forests.

A series of other studies from various ecosystems also showed no decrease with elevation (Roderstein et al., 2005; Kohler et al., 2008). However, the leaf litter production is considered dependent on temperature and thus decreases at higher elevations (Okeke and Omaliko, 1994; Zhou et al., 2006; Girardin et al., 2010). Elevation is also strongly affecting these parameters in montane ecosystems (Ensslin et al., 2015; Pabst et al., 2013; Becker et al., 2015) and is of particular importance regarding potential ecosystem shifts through climate change (Beniston, 2003). Therefore, the effect of elevation on litterfall is an important indicator for estimating future changes in ecosystem cycles (Becker et al., 2015). On the other hand, Vitousek and Sanford (1986), stated that litterfall varies considerably between ecosystems, depending on climate, tree species composition, stand structure and soil fertility.

CONCLUSIONS AND RECOMMENDATION

Majority of the litterfall is composed of leaves, followed by woody, reproductive and miscellaneous parts. Estimated annual litter production was highest at MMP with 11211.5 kg ha^{-1} which had an estimated mean daily litter production of 30.7 kg ha^{-1}, followed by MAP with 6648.0 kg ha^{-1} which had an estimated mean daily litter production of 18.2 kg ha^{-1} and MHP with 4919.5 kg ha^{-1} which had an estimated mean daily litter production of 13.5 kg ha^{-1}. At MAP, *A. philippinensis* (almaciga) conributed the highest litterfall production, whereas at MHP was *B. racemosa* (malagubat) and at MMP was *A. blancoi* (antipolo). It is noteworthy that *A. philippinensis* is a Philippine endemic and threatened species. Highest litter turnover was observed at MMP (5.35%/day), followed by MHP (2.63%/day) and MAP (1.00%/day).

Total and leaf litterall productions were not uniform throughout the year. Total litterfall production did not correlate with changes in temperature and relative humidity. This suggests that the litterfall production changed according to other environmental factors present in the forests, but temperature showed to have a positive correlation with litterfall production or forest productivity for MHP and MMP. Correlation was also noted between litterfall production and relative humidity in MAP. Furthermore, the results of the study have contributed to understanding in litter dynamics of the dominant tree species in the three sites and could be useful for the future studies in other tropical forests.

There is therefore the need to conserve our forests moreso those that are found in lower elevations like Mt. Musuan which revealed to have high forest productivity and fast litter turnover which imply fast soil nutrient cycling. Further, this study affirms the need to plant Philippine endemic tree species such as *A. philippinensis* in the sites since they prove to have high productivity.

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