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# FOREST LITTERFALL PRODUCTION IN MT. HAMIGUITAN, PHILIPPINES: A LONG TERM ECOLOGICAL RESEARCH (LTER) SITE

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## ABSTRACT

This study assessed the litterfall production, analyzed the leaf nitrogen (N), phosphorus (P) and potassium (K) contents and computed the litter turnover in the established two-hectare permanent plot of the Long Term Ecological Research (LTER) site in Mt. Hamiguitan, Davao Oriental, Philippines. Litter samples were collected from the traps installed below the dominant tree species and sorted to components, processed at the laboratory and oven-dried. Data revealed that leaves (88%) contributed the largest fraction of total litter, followed by woody parts (9%), reproductive parts (2%) and miscellaneous parts (1%). Estimated mean annual litter production was 571.84 g ODW $m^2$ which has an estimated mean daily litter production of 1.57 g ODW $m^2$. Nutrient content (% in 1.0g) in leaves was highest in N, followed by K and lowest in P. The highest content of N was observed in *Shorea polysperma* (1.25%) and lowest *in Calophyllum blancoi* (0.60%). Amount of K was highest in *Palaquium* sp. and *C. blancoi* (0.65%) but lowest in *Agathis philippinensis* (0.30%) and the highest amount of P was observed in *Palaquium* sp. (0.10%) and lowest in *C. blancoi* (0.05%). Litter turnover (g ODW/m2) among the five dominant tree species was highest in *C. blancoi* (53.25g) and lowest in *Palaquium* sp. (45.25g). Litter turnover rate (%/day) was faster in *Barringtonia racemosa* (3.11%) which will decompose within 32.12 days while lowest in *C. blancoi* (2.52%) which will decompose within 39.66 days. Data revealed that the litterfall production in Mt. Hamiguitan has a correlation coefficient in temperature at 1% level implying that the pattern of production in the forest is affected by said parameter. No correlation for humidity and rainfall against litterfall production was found. Further, this study implies that Mt. Hamiguitan is a younger ecosystem as its leaf component accounts for more than 70% of the total litter production.

**Keywords:** Litterfall production, litter turnover, leaf N, P and K analysis, Mindanao, Mt. Hamiguitan, tropical forest

## Introduction

Litterfall production can be perceived as an indicator of forest condition and reflects the interaction between biological heredity of trees and the influence of environmental fluctuations [57], [82]. A significant proportion of terrestrial net primary production is recycled from the trees as litterfall to the forest floor [71]. Nutrients taken up during the growing season are returned to the soil through litterfall and are then progressively released during decomposition [7]. Litterfall is related to primary production in terrestrial ecosystems and it is a principal pathway for return of organic matter, nutrients and energy from the vegetation to the soils in forest ecosystems [46]. It also represents one of the primary links between producers and decomposers [22]. The quantification of the foliage, flower and fruit amounts in litter allows direct measurements of year-to-year variation in phenology as a reaction to natural factors and anthropogenic actions, including global climate changes [30].

Mt. Hamiguitan is a protected area covering 6, 834 ha between 6 °40 ˈN to 6 °47 ˈN and 126 °09 ˈE to 126 °13 ˈE with the highest elevation of 1, 637 masl [33]. This mountain is considered as one of the thirteen (13) Long Term Ecological Research (LTER) sites in the Philippines. Leaf litters are abundant in this forest especially in the ground. Hence, this study was conducted to assess and monitor the forest primary productivity in Mt. Hamiguitan through litterfall production.

## Materials and Methods

### Site Description

Litterfall study was conducted within the established two-ha permanent plot at the Mindanao LTER mid-montane area of Mt. Hamiguitan (6°43'58.02"N 126° 9'58.32"E) with an elevation of 1,044 masl (Fig. 1). This forest falls within the Type IV climate of CORONAS classification (1951-2003) of the Philippine Atmospheric, Geophysical and Astronomical Services Administration [58] which is characterized by an even rainfall distribution throughout the year and an absence of a lengthy dry season. Five (5) dominant and co-dominant tree species with four (4) individuals were chosen based on the tree species' diversity. The diameter at breast height (DBH) for each species was measured using a measuring tape. The biggest among the five was *Agathis philippinensis* Warb. (49.82cm) and the smallest was *Palaquium* sp. (29.33cm) (Table 1). All tree species near the installed litter traps that may contribute to the collected samples were also identified.

**Climatological Features**

The Hobo ware Data Logger was employed to monitor the temperature and relative humidity and the SamSam Water Climate Tool for the rainfall in Mt. Hamiguitan.

**Installation of Litter Traps**

The 2-ha permanent plot was delineated in the forest with a total of 20 installed litter traps. The traps were made of 1mm nylon mesh with a dimension of 1x1 $m^2$ and 0.25 m depth and were elevated about 0.5 m above the ground. These litter traps were suspended using ropes and tied to neighbouring trees.

**Collection of Litterfall**

Litters shed by the trees; other vegetation and contributing tree species were collected monthly from the traps by handpicking and were placed inside the labeled collecting bags [41]. They 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 70-80°C for 3 days or until the litter becomes brittle. After drying, oven-dried litters were weighed again. Litter biomass was expressed in grams oven dry weight (g ODW).

**Analysis of Leaf N, P and K contents**

Fresh samples of green leaves were also taken from the five tree species and sealed inside zip-lock cellophane bags. These samples were submitted to the Soil and Plant Analysis Laboratory (SPAL) of the College of Agriculture, CMU, Musuan, Bukidnon for the nitrogen (N), phosphorus (P) and potassium (K) content analysis. To get the amount of nutrients contributed by the litter of the tree species to the soil/environment, the collected samples were oven-dried and those ground samples were burned at 500-550°C between 4-5 hours and followed by the addition of ashing aids (5N HCl).

**Analysis of Litter Turnover**

Litter turnover rate was obtained by installing 0.25 $cm^2$ wooden frame on the ground below the litter traps on which the ground litters (free of soil) enclosed within the wooden frame were collected. The fresh weight of collected ground litter samples was 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 [83].

This is shown below:

$$\text{Litter Turnover Rate: \% per day: } \frac{\text{LF g ODW/ m}^2\text{/day}}{\text{LSC g ODW/m}^2} \text{X100}$$

$$\text{Litter Turnover Time: \# of day: } \frac{\text{LSC g ODW/m}^2}{\text{LF g ODW/m}^2\text{/day}}$$

Where: LF = Litterfall

LSC = Litter standing crop

**Statistical Analysis**

All monthly collected litters in oven-dry weight were expressed in grams oven-dry weight per m2 per month (g ODW/m$^2$/month). Percentage of litter component was determined by:

% of Litter:

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

% of species litter:

$$\text{Sp1 \% species Litter} = \frac{\text{All dry weight of Species 1}}{\text{Total dry weight of all litter of all tree species}} \text{X100}$$

Two-way Analysis of Variance (ANOVA) was used to get the differences between the litterfall of all tree species and plant components [3]. Descriptive analysis was used for litter quality, data comparison and determining relationship between variables.

**Results**

**Litterfall Production**

The leaves (88%) contributed the highest percentage of litter component, followed by woody parts (9%), reproductive parts (2%) and miscellaneous parts (1%). Percentage contribution of the dominant tree species in the litter production showed *A. philippinensis* (26.13%) with the highest percentage contribution of total litterfall production while *Calophyllum blancoi* Planch and Triana (16.88%) has the least contribution to the total litterfall production (Table 2).

**Leaf N, P and K**

Nutrient analysis of leaves revealed that N was the highest followed by K and by P. The highest amount of N was observed in the leaves of *Shorea polysperma* (Blanco) Merr. (1.25%) and least was observed in the leaves of *C. blancoi* (0.60%). Meanwhile, the highest amount of K was observed in the leaves of both *Palaquium* sp. and *C. blancoi* (0.65%) and least in the leaves of *A. philippinensis* (0.30%) and the highest amount of P was observed in the leaves of *Palaquium* sp. (0.10%) and least in the leaves of *C. blancoi* (0.05%) (Table 3).

**Litter Turnover**

As shown in Table 4, the mean average of the 5 tree species in standing litter was 51.35 g, in which the highest was observed in *C. blancoi* (53.25 g) and least in *Palaquium* sp. (45.25 g). Mean average turnover rate among the 5 tree species was 2.08% which is highest in *Barringtonia racemosa* (L.) Blume ex DC (3.11%) which will decompose within 32.12 days and the least in turnover time was observed in *C. blancoi* (2.52%) which will decompose within 39.66 days. Turnover time for Mt. Hamiguitan is 24.62 days which imply that litterfall will decompose in said number of days.

**Multiple Correlations**

The correlations of litterfall production among temperature, relative humidity and rainfall were also determined. Data revealed that the correlation coefficient between litterfall production and temperature in Mt. Hamiguitan was significant at 1% level (R= 0.687**). However, litterfall production has no correlation in relative humidity and rainfall. As shown in Table 5, only the correlation coefficient between the total litterfall production and temperature had greater than 0.5 (>0.5).

**Discussion**

**Site Description**

Mt. Hamiguitan range is located in the eastern coast and form the southern part of eastern Mindanao corridor [74]. The area has a closed canopy brought by the foliar coverage of trees and shrubs that are growing close to each other. Foliar litters were also observed along the ground and individuals of fern were noticed to be thriving in the area. The soil substrate was also observed to be ultramafic. Ultramafic rocks form the predominant substrate and weather into soil with an unusually high concentration of iron and magnesium [4].

Mt. Hamiguitan range is also known for the largest pygmy “bonsai” forest in the Philippine archipelago. This unique ecosystem houses diverse flora and fauna that are currently threatened by agriculture, shifting cultivation and over-collection [5], [38]. The area is generally characterized by rough terrain with a very steep slope gradient ranging from 50-100%, starting from the edge of the forest at an elevation of 500 m [5]. The area also lies in a typhoon-free region of the Philippine archipelago. Some research studies have been conducted in this mountain site, such as flora [4], [5], [38], [34] and fauna [74].

**Litter Components**

The leaves (88%) comprised the highest percentage of litter component, followed by woody (9%), reproductive (2%) and miscellaneous (1%) parts. This finding supported the report of [16] which stated that leaves account as a major component of the total litterfall. Additionally, the portion of leaf litter commonly varies between 60 to 90% [42], [63], [82], [25]. The leaves are the most important component of litter and respond rapidly to climatic changes [43]. Leaves in older forests normally account for 70% or less in the aboveground litterfall [39]. In this study, the proportion of leaf litterfall in relation to woody, reproductive and miscellaneous structures was high in all months. The proportions of the leaves in total above ground litterfall may also provide good indication on the successional stage of tropical forests [8]. This is because 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 above 70% of the total litterfall.

**Litterfall Production**

The litter productions are closely uniform from November 2012 (75.3 g) and December 2015 (77.81) and January (61.33 g) to May 2013 (62.15 g), but showed a decrease from January 2015 (33.23 g) to May 2015 (26.3 g). The litterfall production also showed an increase in July 2015 (64.25 g) which could be due to tropical depressions that had affected the Mindanao region. Mean annual litter production was 571.84 g, in which this amount of production closely falls within the values obtained in other tropical forests studies [26] with 900 g and 400 g in the 2 sites in Indonesia and [55] with 419.9 g and 547.7 g in the two forest types (plantation and forest) of northeastern India.

As reported by several studies, litterfall production were much higher in hot and wet months (from April to September) than the rest of the year for all studied forests [15], [71], [79], [60]. A heavy litterfall of leaf occurred during the dry season in evergreen forests of Attappadi, Western Ghats, India [56] and the generated data of Valenti et al. [72] was affected by the season in tropical region, because litterfall production is greater in the dry season. However, agrosystem with the highest levels of primary production are those warm and receive large amount of precipitation [49], which this present data support the said study. In tropical montane forests, the seasonality of litterfall is generally low compared to that of tropical lowland forests [14]. Recent studies supported that the litterfall production are in the peak either in dry and rainy season. Specifically, leaf aging, caused by photo inhibition, stomatal closure and subsequent leaf overheating, might lead to leaf shedding at the end of the dry season [61]. 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 [18], [25]. This explains the observed increase in peaks of branch and rest deposition during wet months [10].

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 [77]. The increase in litter production may also be explained by a mechanism called the competitive production principle [35]. However, monthly litterfall production pattern is still controlled mainly by community characteristics and environmental factors [44], [29], [57], [65], [35]. 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 [19], [50], [30], [62] and some factors affecting litterfall amounts are also the succession stage, tree age and dominant plant or tree species [9], [13].

**Species Litter Contribution**

*A. philippinensis* contributed the biggest percentage of litter production, followed by *B. racemosa*, *S. polysperma*, *Palaquium* sp. and *C. blancoi* as the least contributing tree species. These rates of litterfall and leaf litterfall are generally positively correlated with forest productivity [2], [68], [45], [52]. However, based on the statistical analysis of the 5 dominant species, there was no significant difference in the litterfall production among the species.

DBH may also play a key role in the contribution of the litterfall production. *A. philippinensis* which have an average DBH measurement of 49.82 cm ranked 2$^{nd}$ among the 5 tree species and correlated with higher litter production and percentage contribution (26.13%). This is also true to *B. racemosa* with the biggest average DBH measurement of 53.95 and correlated with higher litter production which is 2$^{nd}$ among the 5 tree species (20.80%).

**Leaf N, P and K**

Most of the recent researches on nutrient cycling in tropical forest ecosystems has been conducted in the Neotropics and Southeast Asia [82], [73], [14], [13], [25], [21] and some in African forests, especially in montane rainforests in East Africa [63], [18]. However, this present study is limited only to leaf N, P and K analysis in the montane area of Mt. Hamiguitan. Old and recent studies have also suggested that initial N and P contents in leaf litter are good indicators of the decomposition rate [65], [81], [67]. Litter with low N concentration decayed faster than litter with high N concentration [32], [12]. Additionally, Martinez-Yrizar et al. [47] found that *Olneya tesota* had the lowest C/N ratio and the lowest mean decomposition rate. Litter decomposition rate was related to the initial litter phenolics concentration suggesting that polyphenols and lignin contents were the best indicators for predicting litter decomposition rate, probably because polyphenol and lignin bind strongly to organic N (e.g., amino acids and proteins) in litter [28] and thus protect organic N against microbial enzymatic attack [27], [31], [33], [78].

In contrast, the decomposition rate was positively correlated with N and P content and negatively correlated with C/N and C/P ratios [78]. Our results also contrasted the observations from studies on subtropical species [80], [69], [76], [78].

**Litter Turnover**

Turnover rate is the percentage of litter standing crop to replace the litter fall every day. The mean average percentage turnover rate per day was faster in *B. racemosa* which will decompose within 42.29 days. 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. Additionally, it is important to note that site conditions (e.g. soil moisture, temperature and fertility) also affect the litter decomposition [66], [64], [69], [55].

**Relating Litter Production to Environmental Parameters**

Positive correlation with maximum temperature in tropical species and changes in photoperiodicity can affect the flowering and bud break in plant [17]. Although in a regional scale, temperature and precipitation are the most important climatic factors controlling ecological processes [43] and are related to litterfall [48], [43], [16]. Litterfall production in this study has a positive correlation with temperature, but not with the relative humidity and rainfall.We found highest litter productions in November and December 2012 while lowest in January to May 2015. The decrease in temperature was also observed lowest from January to July 2015 compared to the following months while the relative humidity and rainfall are almost uniform throughout the study. This data suggests that the climatic variables such as monthly mean and minimum temperatures and rainfall were not responsible for the patterns of monthly litterfall production in Mt. Hamiguitan. This supported Zhou et al. [82] which indicated that their litterfall productions in their 5 among the 6 studied communities were not significantly affected by precipitation in evergreen broadleaved forests.

Leaf litter production is also considered dependent on temperature and thus decreases at higher elevations [52], [82], [24]. Nonetheless, a series of other studies from various ecosystems also showed no decrease with elevation [61], [37]. On the other hand, litterfall varies considerably between ecosystems, depending on climate, tree species composition, stand structure and soil fertility [75]. Elevation is also strongly affecting these parameters in montane ecosystems [19], [54], [10] and is of particular importance regarding potential ecosystem shifts through climate change [11]. Therefore, the effect of elevation on litterfall is an important indicator for estimating future changes in ecosystem cycles [10]. This might be the factor affecting the data in the present study; hence the 2 among the 3 parameters did not correlate with the total litter production.

## Conclusions

Leaves are the main contributor of the forest primary productivity in Mt. Hamiguitan, which comprised the highest percentage of total litter, followed by woody, reproductive and miscellaneous parts. Returns of N, P and K via leaf litter were significant for nutrient cycling. All tree species increase litter production and nutrient returns, and are helpful to restore soil fertility of the forest.

Total and leaf litterall productions were not uniform throughout the month. Total litterfall production correlated with changes in temperature, but not in relative humidity and rainfall. This study suggests that the litterfall production changed according to other environmental factors in Mt. Hamiguitan forest. Furthermore, the results of the study have contributed to understanding in litter dynamics of the 5 dominant tree species and could be useful for the future studies in other tropical forests.

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## References

[1] M.A. Adams, P.M. Attiwill, "Nutrient cycling and nitrogen mineralization in *Eucalyptus* forests of south-eastern Australia. I. Nutrient cycling and nitrogen turnover," Plant and Soil, 92, pp. 319–339, 1986.

[2] M.A. Adams, P.M. Attiwill, "Nutrient balance in forests of northern Tasmania. 1. Atmospheric inputs and within stand cycles," Forest Ecology and Management, 44, pp. 93–113, 1991.

[3] R. Aerts, "Nutrient use efficiency in evergreen and deciduous species from heathlands," Oecologia, 84, pp. 391-397, 1990.

[4] V.B. Amoroso, L. Obsioma, J. Arlalejo, R. Aspiras, D. Capili, J. Polizon, E.B. Sumile, "Inventory and conservation of endangered, endemic and economically important flora of Hamiguitan Range, southern Philippines," Blumea, 54, pp. 71–76, 2009.

[5] V.B. Amoroso, R.A. Aspiras, "Hamiguitan Range: A sanctuary for native flora," Saudi Journal of Biological Sciences, 18, pp. 7–15, 2011.

[6] M.C. Araujo, J.S. Pereira, H. Pereira, "Biomass production by *Eucalyptus globulus*. Effects of climate, mineral fertilization and irrigation. In: Biomass for Energy and Industry (eds G. Grassi, G. Gosse and G. dos Santos)," Elsevier Applied Science, London 1, pp. 446–452, 1989.

[7] P.M. Attiwill, M.A. Adams, "Tansley review No. 50. Nutrient cycling in forests," New Phytol., 124, pp. 561-582, 1993.

[8] Averti, I. and N. Dominique, "Litterfall Accumulation and Decomposition in Forest Groves Established on Savannah in the Plateau Teke, Central Africa," Journal of Environmental Science and Technology, 4, pp. 601-610, 2011.

[9] J. Barlow, T.A. Gardner, L.V. Ferreira, C.A. Peres, "Litterfall and decomposition in primary, secondary and plantation forests in the Brazilian Amazon," Forest Ecol. Manag., 247, pp. 91–97, 2007. doi:10.1016/j.foreco.2007.04.017.

[10] J. Becker, H. Pabst, J. Mnyonga, Y. Kuzyakov, "Annual litterfall dynamics and nutrient deposition depending on elevation and land use at Mt. Kilimanjaro," Biogeosciences, 12, pp. 5635–5646, 2015.

[11] M. Beniston, "Climatic Change in Mountain Regions: A Review of Possible Impacts, in: Climate Variability and Change in High Elevation Regions: Past, Present & Future," edited by: Beniston, M. and Diaz, H. F., Adv. in Glob. Change Res., Springer, the Netherlands, Dordrecht, pp. 5–31, 2003.

[12] B. Berg, "Litter decomposition and organic matter turnover in northern forest soils," For Ecol Manag., 133, pp.13–22, 2000.

[13] D. Celentano, R.A. Zahawi, B. Finegan, R. Ostertag, R.J. Cole, K.D. Holl, "Litterfall Dynamics Under Different Tropical Forest Restoration Strategies in Costa Rica," Biotropica, 43, pp. 279–287, 2011. doi:10.1111/j.1744-7429.2010.00688.x.

[14] J. Chave, D. Navarrete, S. Almeida, E. Alvarez, L.E.O.C. Aragão, D. Bonal, P. Chatelet, J.E. Silva-Espejo, J.Y. Goret, P. von Hildebrand, E. Jimenez, S. Patiño, M.C. Peñuela, O.L. Phillips, P. Stevenson, Y. Malhi, "Regional and seasonal patterns of litterfall in tropical South America," Biogeosciences, 7, pp. 43–55, 2010. doi:10.5194/bg-7-43-2010.

[15] Z.H. Chen, H.T. Zhang, B.S. Wang, "Studies on biomass and production of the lower subtropical evergreen broad-leaved forest in Heishiding natural reserve (VII): litterfall, litter standing crop and litter decomposition rate, "Bot. J. South China, 1(1), pp. 24–31 (Chinese with English abstract), 1992.

[16] M.V. Cianciaruso, J.S.R. Pires, W.C.B. Delitti, F.P. Silva, "Produção de serapilheira e decomposição do material foliar em um cerradão da Estação Ecológica de Jataí, Luiz Antônio, SP," Acta Bot. Bras., 20(1), pp. 49-59, 2006.

[17] E. Cuevas, A.E. Lugo, "Dynamics of organic matter and nutrient return from litterfall in stands of ten tropical tree plantation species. International Institute of Tropical Forestry," Forest Ecology Management, 112, pp. 263-279, 1998.

[18] E.K. Dawoe, M.E. Isaac, J. Quashie-Sam, "Litterfall and litter nutrient dynamics under cocoa ecosystems in lowland humid Ghana," Plant Soil, 330, pp. 55–64. 2010. doi:10.1007/s11104-009-0173-0.

[19] W.B.C. Delitti, "Ciclagem de nutrientes em cerrados". In Anais do VIII Seminário Regional de Ecologia. São Carlos: UFSCar. pp. 1031-1045, 1998.

[20] A. Ensslin, G. Rutten, U. Pommer, R. Zimmermann, A. Hemp, M. Fischer, "Effects of elevation and land use on the biomass of trees, shrubs and herbs at Mount Kilimanjaro," Ecosphere, 6, pp. 45, 2015. doi:10.1890/ES14-00492.1.

[21] A.G. Fontes, A.C. Gama-Rodrigues, E.F. Gama-Rodrigues, M.V.S. Sales, M.G. Costa, R.C.R. Machado, "Nutrient stocks in litterfall and litter in cocoa agroforests in Brazil," Plant Soil, 383, pp. 313–335, 2014. doi:10.1007/s11104-014-2175-9.

[22] J.W. Fyles, G.H. Laroi, R.A. Ellis, R.A, "Litter production in Pinus banksiana dominated in northern Albert," Can. J. For. Res., 16, pp. 772-777, 1986.

[23] M. George, G. Varghese, "Nutrient cycling in *Eucalyptus globulus* plantation. II. Litter production and nutrient return," Indian Forester, 116, pp. 287–295, 1990.

[24] C.A.J. Girardin, Y. Malhi, L.E.O.C. Aragão, M. Mamani, W. Huaraca Huasco, L. Durand, K.J. Feeley, J. Rapp, J.E. Silva-Espejo, M. Silman, N. Salinas, R.J. Whittaker, "Net primary productivity allocation and cycling of carbon along a tropical forest elevational transect in the Peruvian Andes," Glob. Change Biol., 16, pp. 3176–3192, 2010. doi:10.1111/j.1365-2486.2010.02235.x.

[25] H. Gonzalez-Rodriguez, T.G. Dominguez-Gomez, I. Cantu-Silva, M.V. Gomez-Meza, R.G. Ramirez-Lozano, M. Pando-Moreno, C.J. Fernandez, "Litterfall deposition and leaf litter nutrient return in different locations at Northeastern Mexico," Plant Ecol., 212, pp. 1747–1757, 2011. doi:10.1007/s11258-011-9952-9.

[26] B. Gunadi, "Litterfall, litter turnover and soil respiration in two pine forest plantations in Central Java, Indonesia," Journal of Tropical Forest Science, 6(3), pp. 310-322, 1992.

[27] G.X. He, "Degeneration of soil fertility in pure Chinese fir succession," J. Zhejiang For. Coll., 19, pp. 100–103, 2001.

[28] B. Hoorens, R. Aerts, M. Stroetenga, "Does initial litter chemistry explain litter mixture effects on decomposition," Oecologia, 137, pp. 578–586, 2003. doi: 10.1007/s00442-003-1365-6.

[29] M.M. Huebschmann, T.B. Lynch, R.F. Wittwer, "Needle litterfall prediction models for even-aged natural shortleaf pine (*Pinus echinata* Mill) stands," Forest Ecol. Manag., 117, pp. 179–186, 1999.

[30] ICP Forests, International Co-operative Programme on Assessment and Monitoring of air Pollution Effects on Forests, Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests-Part XI - Sampling and Analysis of Litterfall, United Nations Economic Commission for Europe, 2004. Available from: http://www.icpforests.org/pdf/Chapt11_compl2004.pdf.

[31] S.R. Isaac, M.A. Nair, "Biodegradation of leaf litter in the warm humid tropics of Kerala, India," Soil Biol Biochem, 37, pp. 1656–1664, 2005. doi:10.1016/j.soilbio.2005.02.002.

[32] N. Kaneko, E.F. Salamanca, "Mixed leaf litter effects on decomposition rates and soil microarthopod communities in an oak–pine stand in Japan," Ecol. Res., 14, pp. 131–138, 1999. doi:10.1046/ j.1440-1703.1999.00292.x.

[33] S. Kanerva, V. Kitunen, J. Loponen, A. Smolander, "Phenolic compounds and terpenes in soil organic horizon layers under silver birch, Norway spruce and Scots pine," Biol Fertil Soils, 44, pp. 547–556, 2008. doi:10.1007/s00374-007-0234-6.

[34] D.N. Karger, S. Lehtonen, V.B. Amoroso, M. Kessler, "A new species of *Lindsaea* (Lindsaeaceae, Polypodiopsida) from Mt. Hamiguitan, Mindanao, Philippines," Phytotaxa, 56, pp. 15–20, 2012. ISSN 1179-3155.

[35] V.A. Kavvadias, D. Alifragis, A. Tsiontsis, G. Brofas, G. Stamatelos, "Litterfall, litter accumulation and litter decomposition rates in four forest ecosystems in northern Greece," Forest Ecol. Manag., 144, pp. 113–127, 2001.

[36] M.J. Kelty, "The role of species mixtures in plantation forestry," Forest Ecol. Manage., 233, pp. 195–204, 2006.

[37] L. Kohler, D. Holscher, C. Leuschner, "High litterfall in oldgrowth and secondary upper montane forest of Costa Rica," Plant Ecol., 199, pp. 163–173, 2008. doi:10.1007/s11258-008-9421-2.

[38] F. Lasalita-Zapico, C.H. Aguilar, B. Lon, N. Bagay, "Phenotypic Variations of Extant Ferns in Mt. Hamiguitan Range, Mindanao Island, Philippines," World Applied Sciences Journal 12(7), pp. 979-987, 2011. ISSN 1818-4952.

[39] Lebret, M., C. Nys and N. Forgeard. 2001. Litter production in an Atlantic beech (*Fagus sylvatica* L.) time sequence. Ann. For. Sci., 58: 755-768.

[40] Y.K. Lee, S.Y. Woo, "Changes in litter, decomposition, nitrogen mineralization and microclimate in *Acacia mangium* and *Acacia auriculiformis* plantation in Mt. Makiling, Philippines," International Journal of Physical sciences, 7(12), pp. 1976-1985, 2012.

[41] Z.A. Li, B. Zou, H.-P. Xia, H. Ren, J.-M. Mo, H. Weng, "Litterfall Dynamics of and Evergreen Broadleaf Forest and a Pine Forest in the Subtropical Region of China," For. Sci., 51(6), pp. 608-615, 2005.

[42] N. Lisanework, A. Michelsen, "Litterfall and nutrient release by decomposition in three plantations compared with a natural forest in the Ethiopian highland," Forest Ecol. Manag., 65, pp. 149–164, 1994. doi:10.1016/0378-1127(94)90166-X.

[43] C. Liu, C.J. Westman, B. Berg, W. Kutsch, G.Z. Wang, R. Man, H. Ilvesniemi, "Variation in litterfall-climate relationships between coniferous and broadleaf forests in Eurasia," Global Ecol. and Biogeogr., 13(2), pp. 105-114, 2004.

[44] J.P. Lu, Q.H. Liu, "Litter-fall in tropical forest at Jianfengling mountains, Hainan island," Acta Phytoecologica et Geobotanica Sinica, 12, pp. 104–112, 1998. (Chinese with English abstract).

[45] M. Madeira, M.C. Araujo, J.S. Pereira, "Effect of water and nutrient supply on amount and on nutrient concentration of litterfall and forest floor litter in *Eucalyptus globulus* plantations," Plant and Soil, 168, pp. 287–295, 1995.

[46] D.A. Maguire, "Branch mortality and potential Litter fall from Douglas-fir trees in stands of varying density," For. Ecol. Manage., 70, pp. 41-53, 1994.

[47] A. Martinez-Yrizar, S. Núeñz, A. Burquez, "Leaf litter decomposition in a southern Sonoran Desert ecosystem, northwestern Mexico: effects of habitat and litter quality," Acta Oecol., 32, pp. 291–300, 2007. doi:10.1016/j.actao.2007.05.010.

[48] S.V. Martins, R.R. Rodrigues, "Produção de serapilheira em clareiras de uma floresta estacional semidecidual no município de Campinas, SP," Rev. Bras. Bot., 22(3), pp. 405-412, 1999.

[49] M.C. Molles, Ecology. Concepts and Apllications. 4th Edition, McGraw-Hills International Companies, Inc. Avenue of the Americas. New York, 2008.

[50] J.A.P.V. Moraes, C.H.B.A. Prado, "Photosynthesis and water relations in cerrado vegetation. In Scarano, FR. and FRANCO, AC. (Eds.). Ecophysiological strategies of xerophytic and amphibious plants in the neotrópicos. Rio de Janeiro," UFRJ. pp. 45-63, 1998.

[51] R.M. Moraes, W.B.C. Delitti, Y.S. Vuono, "Litterfall and litter nutrient content in two Brazilian tropical forests," Rev. Bras. Bot., 22(1), pp. 9-16, 1999.

[52] M.T. Moroni, P.J. Smethurst, "Litterfall nitrogen and phosphorus fluxes in two Tasmanian *Eucalyptus nitens* plantations," Tasforests, 14, pp. 53-64, 2003.

[53] A.I. Okeke, C. Omaliko, "Litterfall and seasonal patterns of nutrient accumulation in *Dactyladenia barteria* (Hook f ex. Oliv.) Engl. bush fallow at Ozala, Nigeria," Forest Ecol. Manag., 67, pp. 345–351, 1994. doi:10.1016/0378-1127(94)90029-9.

[54] H. Pabst, A. Kuhnel, Y. Kuzyakov, "Effect of land-use and elevation on microbial biomass and water extractable carbon in soils of Mt. Kilimanjaro ecosystems," Appl. Soil Ecol., 67, pp. 10–19, 2013. doi:10.1016/j.apsoil.2013.02.006.

[55] R.R. Pandey, G. Sharma, S.K. Tripathi, A.K. Singh, "Litterfall, litter decomposition and nutrient dynamics in a subtropical natural oak forest and managed plantation in northeastern India," Forest Ecol. Manage., 240(1-3), pp. 96–104, 2007.

[56] J.P. Pascal, "Wet Evergreen Forests of the Western Ghats of India. Institute Francais de Pondicherry, Pondicherry," pp. 343, 1988.

[57] L.B. Pedersen, J.B. Hansen, "A comparison of litterfall and element fluxes in even aged Norway spruce, sitka spruce and beech stands in Denmark," Forest Ecol. Manag. 114, pp. 55–70, 1999.

[58] Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Climate Change in the Philippines, 2011.

[59] J. Proctor, Tropical litterfall I. Problems of data comparison. In Sutton, SL., T.C. Whitmore and A.C. Chadwick (Eds.). Tropical rain forest: ecology and management. Oxford: Blackwell, pp. 267-273, 1983.

[60] N. Rawat, B.P. Nautiyal, M.C. Nautiyal, "Litter production pattern and nutrients discharge from decomposing litter in and Himalayan alpine ecosystem," New York Science Journal, 2(6), pp. 54-67, 2009. ISSN 1554-0200.

[61] M. Roderstein, D. Hertel, C. Leuschner, "Above- and below-ground litter production in three tropical montane forests in southern Ecuador," J. Trop. Ecol. 21, pp. 483–492, 2005. doi:10.1017/S026646740500249X.

[62] L.S. Santiago, S.S. Mulkey, "Leaf productivity along a precipitation gradient in lowland Panama: patterns from leaf to ecosystem," Structure and Function 19(3), pp. 349-356, 2005.

[63] M. Schrumpf, W. Zech, J.C. Axmacher, V.M. Lyaruu, V.M. Herbert," Biogeochemistry of an afrotropical montane rain forest on Mt. Kilimanjaro," Tanzania, J. Trop. Ecol., 22, pp. 77–89, 2006. doi:10.1017/S0266467405002907.

[64] K.P. Singh, P.K. Singh, S.K. Tripathi, "Litterall, litter decomposition and nutrient release patterns in four native tree species raised on coal mine spoil at Singrauli, India," Biol. Fertil. Soils, 29, pp. 371–378, 1999.

[65] S.M. Sundarapandian, P.S. Swamy, "Litter production and leaf-litter decomposition of selected tree species in tropical forests at Kodayar in the western Ghats, India," Forest Ecol. Manag., 123, pp. 231–244, 1999.

[66] M.J. Swift, O.W. Heal, J.M. Anderson, Decomposition in Terrestrial Ecosystems. Blackwell Scientific Publications, Oxford, 1979.

[67] R. Tateno, N. Tokuchi, N. Yamanaka, S. Du, K. Otsuki, T. Shimamura, Z. Xue, S. Wang, Q. Hou, "Comparison of litterfall production and leaf litter decomposition between an exotic

black locust plantation and an indigenous oak forest near Yan'an on the Loess Plateau, China," Forest Ecol. Manage., 241, pp. 84–90, 2007.

[68] H. Thomas, Canopy survival. In: Crop Photosynthesis: Spatial and Temporal Determinants (eds N.R. Baker and H. Thomas), pp. 11–41. Elsevier Sci. Publ. B. V., Amsterdam, 1992.

[69] S.K. Tripathi, A. Sumida, H. Shibata, K. Ono, S. Uemura, Y. Kodama, T. Hara, "Leaf litterfall and decomposition of different above- and belowground parts of birch (*Betula ermanii*) trees and dwarf bamboo (*Sasa kurilensis*) shrubs in a young secondary forest in Northern Japan," Biol Fertil Soils, 43, pp. 237–246, 2006. doi:10.1007/s00374-006-0100-y.

[70] M.Z. Tu, W.H. Yao, H. Weng, Z.A. Li, "Characteristics of litter in evergreen broadleaved forest of the Dinghu mountain," Acta Pedologica Sinica, 30, pp. 34–42, 1993. (Chinese with English abstract).

[71] L. Ukonmaanaho, P. Merila, P. Nojd, T.M. Nieminen, "Litterfall production and nutrient return to the forest floor in Scots pine and Norway spruce stands in Finland," Boreal Environment Research, 13 (suppl. B), pp. 67-91, 2008.

[72] M.W. Valenti, M.V. Cianciaruso, M.A. Batalha, "Seasonality of litterfall and leaf decomposition in a cerrado site," Brazilian Journal of Biology, 68(3), pp. 459-465, 2008.

[73] S.S. Vasconcelos, D.J. Zarin, M.M. Araujo, L.G.T. Rangel-Vasconcelos, C.J.R. de Carvalho, C.L. Staudhammer, F.A. Oliveira, "Effects of seasonality, litter removal and dry-season irrigation on litterfall quantity and quality in eastern Amazonian forest regrowth," Brazil, J. Trop. Ecol., 24, pp. 884–892, 2008. doi:10.1017/S0266467407004580.

[74] J.R. Villanueva, A.B. Mohagan, "Diversity and Status of Odonata across Vegetation Types in Mt. Hamiguitan Wildlife Sanctuary, Davao Oriental," Asian Journal of Biodiversity, Odonata Faunal Diversity Section 1(1): 25-35, 2010. ISSN: 2094-15019.

[75] P.M. Vitousek, R.L. Sanford, "Nutrient Cycling in Moist Tropical Forest," Annu. Rev. Ecol. Syst., 17, pp. 137–167, 1986.

[76] Q.K. Wang, S.L. Wang, B. Fan, X.J. Yu, "Litter production, leaf litter decomposition and nutrient return in *Cunninghamia lanceolata* plantations in south China: effect of planting conifers with broadleaved species," Plant Soil, 297, pp. 201–211, 2007. doi:10.1007/ s11104-007-9333-2.

[77] Q. Wang, S. Wang, Y. Huang, "Comparisons of litterfall, litter decomposition and nutrient return in a monoculture *Cunninghamia lanceolata* and a mixed stand in southern China," Forest Ecology and Management, 255, pp. 1210–1218, 2008.

[78] Q. Wang, S. Wang, Y. Huang, "Leaf litter decomposition in the pure and mixed plantations of *Cunninghamia lanceolata* and *Michelia macclurei* in subtropical China," Biol Fertil Soils, 45, pp. 371–377, 2009.

[79] H. Weng, Z.A. Li, M.Z. Tu, W.H. Yao, "The production and nutrient contents of litter in forests of Ding Hu Shan mountain," Acta Phytoecologica et Geobotanica Sinica, 17, pp. 299–304, 1993. (Chinese with English abstract).

[80] X. Xu, E. Hirata, T. Enoki, Y. Tokashiki, "Leaf litter decomposition and nutrient dynamics in a subtropical forest after typhoon disturbance," Plant Ecol., 173, pp. 161–170, 2004. doi: 10.1023/B:VEGE. 0000029319.05980.70.

[81] Y.S. Yang, Y.X. Chen, Z.M. He, J.F. Guo, "Comparatively study on litter properties between plantations of *Fokienia hodginsii* and *Cunninghamia lanceolata*," Sci. Sil. Sin. 40, pp. 2–9, 2004 (in Chinese).

[82] G. Zhou, L. Guan, X. Wei, D. Zhang, Q. Zhang, J. Yan, D. Wen, J. Liu, S. Liu, Z. Huang, G. Kong, J. Mo, Q. Yu, "Litterfall Production Along Successional and Altitudinal Gradients of Subtropical Monsoon Evergreen Broadleaved Forests in Guangdong, China," Plant Ecol., 188, pp. 77–89, 2006. doi:10.1007/s11258-006-9149-9.

[83] J.C. Zieman, G.W. Thayer, M.B. Robblee, R.T. Zeiman, "Production and export of sea grasses from tropical bay. In: Ecological Processes in Coastland Marine System," R.S. Livingston ed. pp. 21-31, 1979.

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**Table 1**: **Selected dominant and co-dominant tree species with characteristics and tagged for litter collection in Mt. Hamiguitan LTER mountain site.**

| Tree species | Local Name | Family | Mean DBH and ranges (cm) |
|---|---|---|---|
| *Agathis philippinensis* | Almaciga | Araucariaceae | 49.82 (36.29-57.30) |
| *Palaquium* sp. | Nato | Sapotaceae | 29.33 (12.40-40.10) |
| *Shorea polysperma* | Tangile | Dipterocarpaceae | 49.10 (37.80-55.30) |
| *Barringtonia racemosa* | Malagubat | Lecythidaceae | 53.95 (48.50-69.30) |
| *Calophyllum blancoi* | Bitanghol | Calophyllaceae | 31.18 (30.50-31.50) |

**Table 2: Percentage contribution of tree species in litter production of Mt. Hamiguitan.**

| Tree species | Total | Mean (■) | Percentage (%) |
|---|---|---|---|
| *Agathis philippinensis* | 249.08 | 49.82 | 26.13 |
| *Palaquium* sp. | 167.46 | 33.49 | 17.56 |
| *Shorea polysperma* | 177.67 | 35.53 | 18.63 |
| *Barringtonia racemosa* | 198.29 | 39.66 | 20.80 |
| *Calophyllum blancoi* | 160.92 | 32.18 | 16.88 |

**Table 3: Leaf N, P, K analysis on five selected tree species in Mt. Hamigutan.**

| Tree species | Total N (%) | Total P (%) | Total K (%) |
|---|---|---|---|
| *Agathis philippinensis* | 0.86 | 0.06 | 0.30 |
| *Palaquium* sp. | 1.12 | 0.10 | 0.65 |
| *Shorea polysperma* | 1.25 | 0.06 | 0.33 |
| *Barringtonia racemosa* | 0.93 | 0.07 | 0.43 |
| *Calophyllum blancoi* | 0.60 | 0.05 | 0.65 |

**Table 4: Turnover rate and time of litter standing crop in Mt. Hamiguitan.**

| Tree species | Standing litter (g ODW/$m^2$) | Turnover Rate (%/day) | Turnover Time (Days) |
|---|---|---|---|
| *Agathis philippinensis* | 53.00 | 3.02% | 33.16 |
| *Palaquium* sp. | 45.25 | 3.08% | 32.42 |
| *Shorea polysperma* | 52.25 | 2.86% | 35.01 |
| *Barringtonia racemosa* | 53.00 | 3.11% | 32.12 |
| *Calophyllum blancoi* | 53.25 | 2.52% | 39.66 |
| **Mean** | **51.35** | **2.08%** | **24.62** |

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**Table 5**: Correlation of litterfall production among the temperature, relative humidity and rainfall in Mt. Hamiguitan.

| PARAMETER | Litterfall Production | Temperature | Relative Humidity | Rainfall |
|---|---|---|---|---|
| Litterfall Production | 1 | | | |
| Temperature | 0.687440033** | 1 | | |
| Relative Humidity | -0.459137748 | -0.886834692 | 1 | |
| Rainfall | -0.384120522 | -0.281844324 | 0.245827798 | 1 |

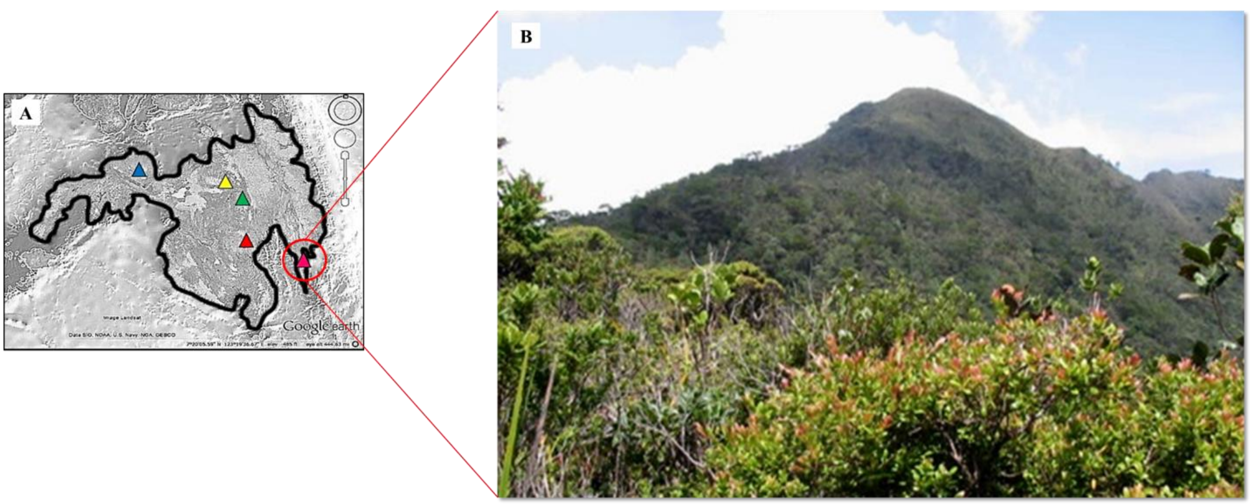


**Figure 1: Study site. A) Map of the Mindanao Island showing the 5 Mindanao LTER sites and B) Mt. Hamiguitan.**

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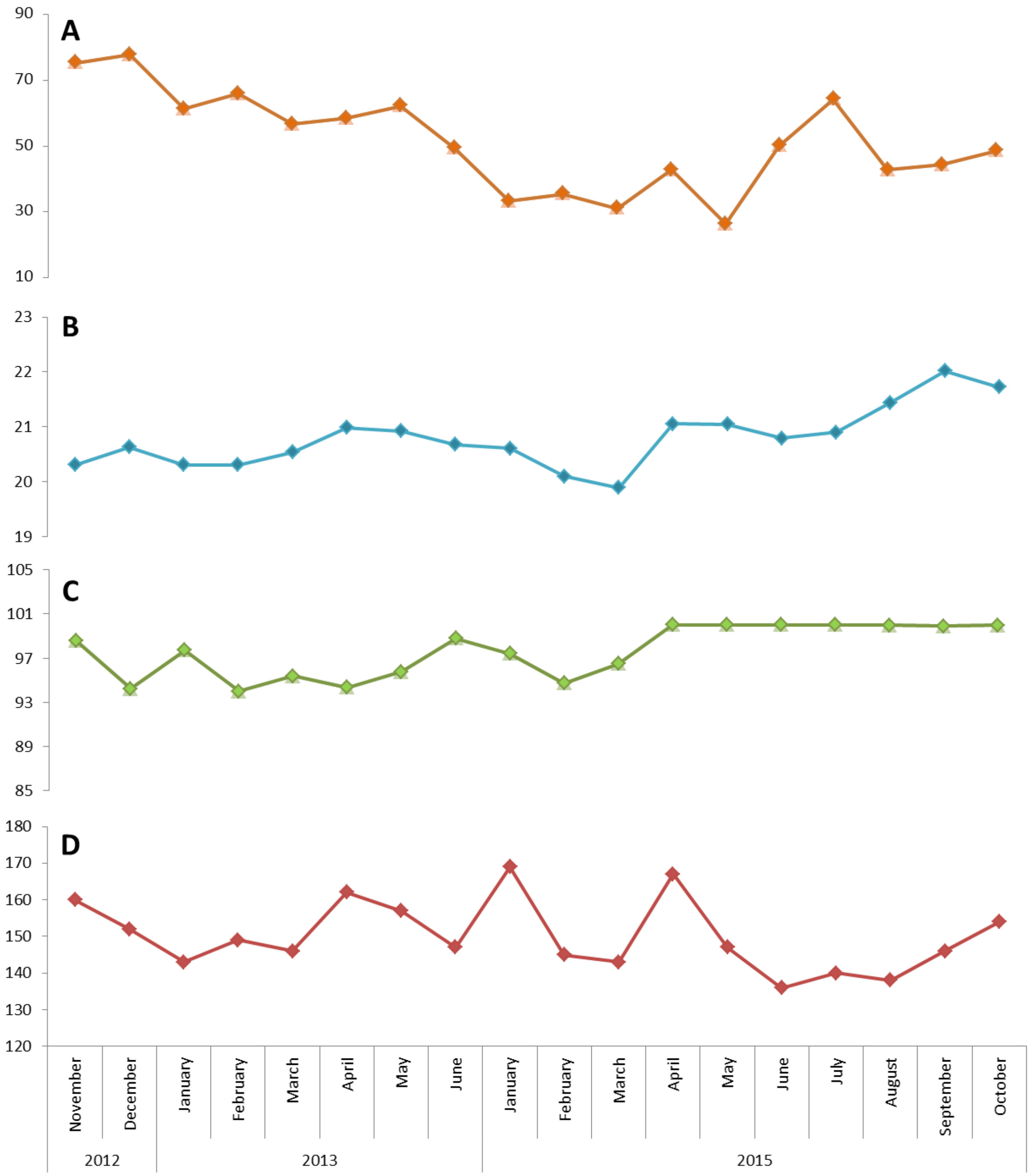


**Figure 2: Monthly variation of parameters in Mt. Hamiguitan. A) Litterfall Production, B) Temperature, C) Relative Humidity, D) Rainfall.**