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Research Article

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Litter Fall Production and Standing Crop Litter in a Natural Forest and Adjacent Cacao Plantation in Southwest Nigeria

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ABSTRACT

The study determined litter production in natural forest and cacao plantation. This was with a view to providing comprehensive understanding of nutrient cycling via mass-based litter fall and standing crop data due to their different management practices. The study was carried out in 0.0625 ha sample plots, three each in natural forests and cacao plantations adjacent to each other in Ile-Oluji, Ile-Oluji/Okeigbo Local Government Area of Ondo State. Litter fall was determined by 10 randomly laid litter traps and standing crop of litter by randomly laying 5 quadrats on the forest and cacao plantation floors of each plot to collect litter fall and standing crop of litter at monthly intervals for two years. The collected litter fall and litter standing crop were oven-dried at 800C and weighed. Significant difference between forest and cacao plantation monthly litter fall and litter standing crop were tested using two-way analyses of variance (ANOVA) with repeated measurement design with month and site as factors. The tests were performed using System Analysis Software version 9.2 (SAS 2010). Annual litter production (t ha^{-1} yr^{-1}) in the forest 24.32-35.094 was higher than 16.32-25.696 in cacao plantation. The annual standing crop of litter (t ha^{-1} yr^{-1}) in the forest 10.21- 19.337 was slightly higher than 10.16- 18.489. This study concluded that nutrient cycling via litter production and standing crop litter data in natural forests is more efficient than in cacao plantations and that clearing forests to establish cacao plantations adversely affects nutrient cycling.

INTRODUCTION

The conversion of the natural forests to agroforestry systems generally alter ecosystem function (Scholes and Van Breeman, 1997). Litter fall is the major input determining the nutrient accumulation within the forest soil ecosystem which goes a long way in determining forest stand productivity (Faboya *et al.*, 2015). Litter fall is an important component of forest function, and is inherently linked to net primary productivity (NPP) and global biogeochemical cycles (Aragão *et al.*, 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 (Fioretto *et al.*, 2003; Pandey *et al.*, 2007; Onyekwelu *et al.*, 2008). The processes of litter fall maintain nutrient pools in the soil, influence primary production and regulate energy flow and nutrient cycling in forest ecosystem (Oziegbe *et al.*, 2011).

Clearing of natural forests for the establishment of economic tree crops such as cocoa, coffee, kola nut, oranges, rubber and fast-growing timber trees (Eucalyp-

tus spp., Gmelina, Teak, etc.) has been on the increase recently, as such it has contributed to deforestation in tropical countries because of the continuing demand for these especially in developed countries. Plantation can be considered to 'mimic' natural forests they replaced when a 'steady-state' stage is reached and the consequent renewal of earlier immobilized nutrients take place (Grierson and Adams 1999).

Replacing natural forests with monoculture plantations decrease the forest species diversity, reduce the total litter fall and eventually change the pattern of nutrient release through decomposition (Wang *et al.* 2007, Pandey *et al.* 2007). In plantations, litter production might not be same as in the natural forest they replaced. Cacao agroforestry has been predicted to have different nutrient cycling from that of natural forests this is compounded by mono species nature of the plantation which affects the quantity and quality of litter produced (Xu and Hirata, 2005). Moreover, litter fall under some species also exhibits periodic characteristics. In sites with severe dry seasons, deposition of litter on the forest floor increases and reduces drastically at the onset of moist conditions during the wet season (Proctor 1983, Swift and Anderson 1989). Hence, it is vital to understand the nutrient cycling via litter fall product and standing crop litter in the plantation in relation to that of natural forest

MATERIALS AND METHODS

Study Area

The study was undertaken in Ile-Oluji, Ondo State, Southwest, Nigeria. Ondo State lies between longitudes 4° 31' and 6° 00' E of the Greenwich Meridian and latitudes 5° 15' and 8° 15' N of the equator while Ile-Oluji lies between latitudes 6° 40' N and 7° 14' N, and longitudes 4° 38' E and 4° 53' E (Fig 1). The tropical climate of the State is broadly rainy season (between April and October) and dry season (between November and March). Temperature throughout the year ranges between 21°C to 29°C and humidity is relatively high. The annual rainfall varies from 2, 000 mm in the southern areas to 1,150 mm in the northern areas (Ondo State Ministry of Environment, 2017). The monthly rainfall and temperature for the study area during study periods, 2016 and 2017, are presented in Figs 2. The State enjoys luxuriant vegetation with rain forest in the south and sub-savanna vegetation in the northern fringe (Falola *et al.*, 2013).

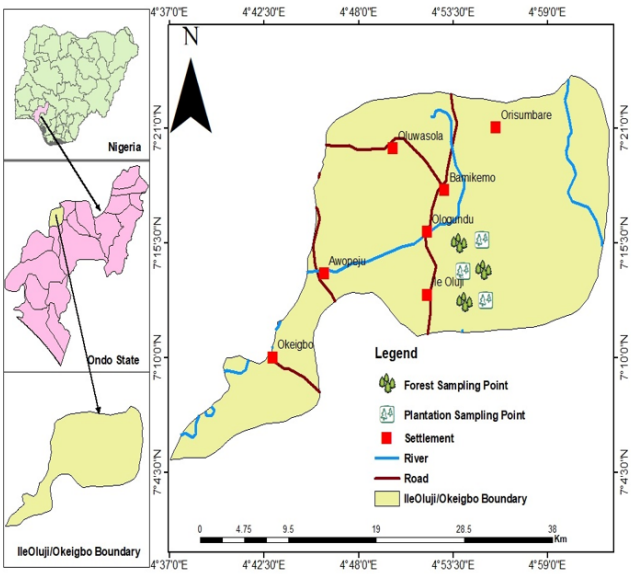

Figure 1: Map of the study area showing Nigeria, Ondo State, Ile-Oluji Local Government Area and Ile-Oluji town with the sampling sites.

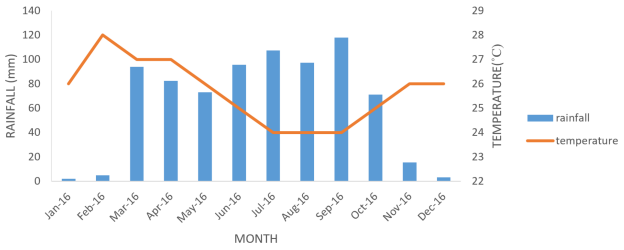

Figure 2: Rainfall and Temperature for Year 2016

Sampling Procedure

Three sample plots, 25 m x 25 m each were established in three different natural forests and three different cacao plantations in the study area. The natural forest and cacao sample plots were established close to each other in the same area. Litter fall and standing crop litter were measured at monthly intervals for two years in each of the plots.

Litter Fall

In each plot, ten 1 m x 1 m x 0.3 m nylon litter traps of 1-mm mesh size suspended 1 m above the ground were laid out at random to collect litter fall materials. The litter from these traps was collected every two weeks. The collected litter was sorted into (i) leaf, (ii) wood (iii) reproductive parts: flowers, fruits, and seeds, and (iv)finest litter/trash. These fractions were oven dried at 80° C to a constant weight and weighed. The fortnightly collections in each month were combined to obtain litter fall data per month.

Litter Standing Crop

Litter standing crop was sampled during the same period (January 2016 – December 2017). Five 1 m x 1 m quadrats were laid out randomly on the litter layer in each plot at monthly intervals. The standing crop of litter within each quadrat was collected and sorted into (i) leaf, (ii) wood, (iii) reproductive parts, and (iv) trash. These fractions were oven-dried at 80°C to a constant weight and weighed. The litter standing crop was collected the same day and at the same time that litter traps were emptied during the second litter fall collection each month. The location of a sample collection for estimating the litter standing crop was marked to avoid repeated collections from the same point. The first sampling period coincided with the installation of the litter traps.

Significant difference between forest and cacao plantation monthly litter fall, was tested using two-way analyses of variance (ANOVA) with repeated measurement design with month and site as factors. Monthly pattern of litter fall and litter standing crop in either cacao plantation or forest were analysed using 2-way ANOVA with month and plot as factors. Significant differences in the quantities of litter fall and standing crop of litter in cacao plantation or natural forest were tested using 2-way ANOVA with month and litter fraction (leaf, wood, reproductive part, trash) as factors. The probability level was set at 0.05, 0.01 and 0.001 to test for the significant difference.

Repeated measured design of analysis of variance was used to test significance differences in the monthly litter fall because the locations of sampling position for litter fall were random but monthly collections were not repositioned each month. The tests were performed using System Analysis Software version 9.2 (SAS 2010).

RESULTS

Litter Production in Forest and Cacao Plantation for 2016 and 2017

In the first year of sample collection (2016), the annual total litter fall in the moist forest and cacao plantation studied was 35.094 t/ha/yr and 25.696 t/ha/yr, respectively (Table 1). The contributions of different litter components to the annual total litter fall in natural forest were leaf 26.877 t/ha/yr (76.6%), wood 4.528 t/ha/yr (12.9 %), reproductive part 1.986 t/ha/yr (5.7 %) and Trash 1.703 t/ha/yr (4.8 %) while in cacao plantation, there were 23.594 t/ha/yr (91.8 %) leaf, 1.464 t/ha/yr (5.7 %) wood, 0.495 t/ha/yr (1.9 %) reproductive part and 0.143 t/ha/yr (0.6 %) trash (Table 1). The relative contribution of various litter components showed that for both ecosystem, leaf litter contributed the highest proportion in the moist forest (76.6%) and in cacao plantation (91.8%), followed by wood, reproductive parts and then trash (Table 1). Litter production was significantly higher ($F_{1,11}$=18.77; $p < 0.05$) in forest than cacao plantation (Table 1). Furthermore, the values of component parts of the litter produced in forest were significantly higher plantation ($F_{1,\ 11}$= 5.43 Leaf; $F_{1,\ 11}$= 10.22 wood; $F_{1,\ 11}$= 15.40 reproductive part and $F_{1,\ 11}$= 13.29 trash; $p < 0.05$) than those in cacao.

In the second year of sample collection (2017), the annual litter fall (t/ha/yr) was 24.32 (total) in the moist forest and 16.92 (total) in the cacao plantation. The leaf litter contributed 20.59 (84.7 %), 2.63 (10.8 %) wood, 0.53 (2.2 %) reproductive part and 0.58 (2.3 %) trash for moist forest while 15.34 (90.7 %) leaf, 0.89 (5.3 %) wood, 0.47 (2.7 %) reproductive part and 0.22 (1.3 %) trash for cacao plantation. The litter production in the natural forest was significantly higher ($F_{1,11}$= 3.89; $p <0.05$) than cacao plantation. Also, the litter fractions in the natural forest ecosystem were significantly higher ($F_{1,11}$= 286.96 Leaf; $F_{1,11}$= 52.25 wood; $F_{1,11}$= 17.81 reproductive part and $F_{1,11}$= 15.87 trash; $p < 0.05$) than cacao plantation (Table 1).

The relative contribution of various litter components to total showed that in both ecosystems, leaf litter contributed the highest proportion of 84.7% in the moist forest and 90.7% in the cacao plantation followed by wood, reproductive part and trash respectively (Table 1). The reproductive and trash made only a small contribution to total litter fall (Table 1). The order of litter production in the forest and cacao plantation was: leaf litter > wood litter > reproductive litter > trash litter in the two ecosystems (Table 1).

In the moist forest ecosystem, the annual litter fall as well as its component parts were significantly higher (($F_{1,11}$= 8.33 total; $F_{1,11}$= 12.35 leaf; $F_{1,11}$= 16.16 reproductive part and $F_{1,11}$= 6.66 trash; $p < 0.05$) in the year 2016 than in 2017 except the wood litter (Table 1).

However, the leaf litter in these ecosystems was highest while trash was lowest in the two years of study, 2016 and 2017 (Table 1).

In the cacao plantation ecosystem, the annual litter production as well as its component parts was significantly higher ($F_{1,11}$=78.6 total ; $F_{1,11}$= 18.33 leaf and $F_{1,11}$= 5.20 wood: $p < 0.05$) in the year 2016 than 2017 except the reproductive part and trash (Table 1). The leaf litter in this ecosystem was still highest while trash was the lowest (Table 1).

Table 1: Litter Production in the Forest and Cacao Plantation for 2016 and 2017

Component	Litter fall			
	Forest (%) (2016)	Forest (%) (2017)	Cacao plantation (%) 2016	Cacao plantation (%) 2017
Leaf (t/ha/yr)	26.877 (76.6)	20.59 (84.7)	23.594 (91.8)	15.34 (90.7)
Wood (t/ha/yr)	4.528 (12.9)	2.63 (10.8)	1.464 (5.7)	0.89 (5.3)
Reproductive part (t/ha/yr)	1.986 (5.7)	0.53 (2.2)	0.495 (1.9)	0.47 (2.7)
Trash (t/ha/yr)	1.703 (4.8)	0.58 (2.3)	0.143 (0.6)	0.22 (1.3)
Annual total (t/ha/yr)	35.094	24.32	25.696	16.92

Figures 4.2a - 4.2d showed the seasonal pattern of litter fall in the moist forest and cacao plantation in 2016 and 2017. In forest for year 2016, total litter production was highest in January, followed by April then February and the highest leaf litter production occurred in January followed by December (Fig. 3a). Wood and trash litter fall occurred most in April, reproductive part fall occurred most in May and August (Fig 3a). In cacao plantation, high total litter production was recorded in January, February and reaching peak in March. Highest leaf litter was recorded in March and least in June (Fig. 3b). There were significant monthly variations in litter fall($F_{1,11}$=4.35 total; $F_{1,11}$=10.07 leaf and $F_{1,11}$= 5.70 wood; $p < 0.05$) in the ecosystems and the component parts except reproductive parts and trash.

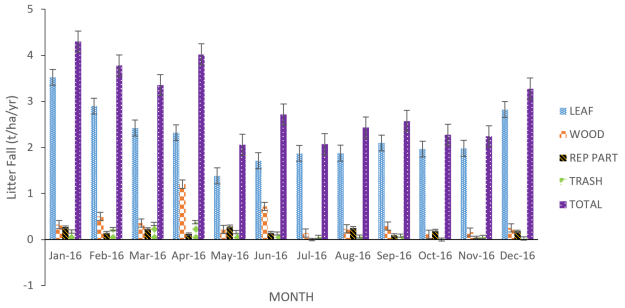

Figure 4: Monthly Litter Production in the Forest in 2016

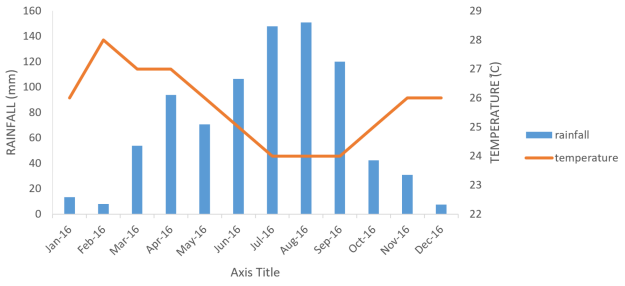

Figure 3: Rainfall and Temperature for Year 2017 Source – NiMet, 2018

In the year 2017, the highest production of litter in the forest was recorded in the month of February (Fig 3c). The leaf litter was at peak in January, wood in April while reproductive part and trash were at peak in September (Fig 3c). For cacao plantation in the year 2017, the month with highest production of litter was January (Fig 3d). Leaf litter also was at peak in January, wood in December, while reproductive part were at peak in the month of May (Fig 3d). There were no significant monthly variation in the litter fall between the two ecosystems and among its component parts except for total litter fall and leaf litter (total $F_{1,11}$= 10.90; leaf $F_{1,11}$= 7.84: $p < 0.05$).

Standing Crop Litter in the Moist Forest and Cacao Plantations for 2016 and 2017

In 2016, the annual total standing crop litter was 19.34 t/ha/yr in the forest and 18.49 t/ha/yr in the cacao plantation (Table 2). The composition of the annual total standing crop litter in forest was 12.43 t/ha/yr for leaf, 4.70 t/ha/yr for wood, 0.83 t/ha/yr for reproductive part and 1.39 t/ha/yr for trash while the composition was 14.21 t/ha/yr for leaf, 1.71 t/ha/yr for wood, 1.70 t/ha/yr for reproductive part and 0.87 t/ha/yr for trash in cacao plantation. The relative contribution of various components to total standing crop litter showed that leaf litter contributed the highest proportion of 64.3% in the forest and 76.9% in the cacao plantation, wood contributed 24.3% in the forest and 9.3% in the cacao plantation, reproductive part contributed 4.3% in the forest and 9.2% in the cacao plantation while trash contributed 7.1% in the forest and 4.6% in the cacao plantation (Table 2). The reproductive and trash made only a small contribution to total standing crop litter. In the two ecosystems, the order of standing crop litter component production was: leaf litter > wood litter > reproductive litter > trash litter (Table 2). There was no significant difference between

the litter standing crop in the forest and cacao plantation. The contributions of all the component parts to the total standing crop litter were not significantly higher except the wood (wood $F_{1,11}$= 49.85; $p < 0.05$) in forest than cacao plantation

Table 2: Standing Crop Litter in the Forest and Cacao Plantation for Years 2016 and 2017

Components	Standing crop litter			
	Forest (%) 2016	Forest (%) (2017)	Cacao plantation (%) 2016	Cacao plantation (%) 2017
Leaf	12.427 (64.3)	9.10 (89.1)	14.209 (76.9)	9.27 (91.1)
Wood	4.696 (24.3)	0.88 (8.6)	1.713 (9.3)	0.59 (5.9)
Reproductive Part	0.825 (4.3)	0.1 (1)	1.700 (9.2)	0.17 (1.7)
Trash	1.389 (7.1)	0.13 (1.3)	0.867 (4.6)	0.13 (1.3)
Total	19.337	10.21	18.489	10.16

In the second year (2017), the annual standing crop litter (t/ha/yr) was 10.21 (total) in the forest

and 10.16 (total) in the cacao plantation; and these were in the order 9.1 (leaf), 0.88 (wood), 0.1 (reproductive part) and 0.13 (trash) for forest while 9.27 (leaf), 0.59 (wood), 0.17 (reproductive part) and 0.13 (trash) in cacao plantation (Table 2). The standing crop litter in the forest was slightly higher than cacao plantation though not statistically significant (Table 2).

There was also no significant difference in the litter component parts of the forest and cacao plantation except reproductive part (reproductive part $F_{1,11}$= 9.05; p wood litter > trash litter > reproductive litter in the forest ecosystem and leaf litter > wood litter > reproductive litter > trash litter in the cacao plantation (Table 2)

However, the quantity of the leaf litter in the cacao ecosystem were higher than the forest ecosystem (Table 2).

In forest ecosystem, the annual standing crop litter and the component parts in the year 2016 were significantly higher (total $F_{1,11}$= 74.07; leaf $F_{1,11}$= 109.50; wood $F_{1,11}$= 52.04; reproductive part $F_{1,11}$= 5.7 and trash $F_{1,11}$= 13.6; p wood > trash > reproductive part (Table 2).

The annual standing crop of litter and its component parts in cacao plantation in the year 2016 was significantly higher ($F_{1,11}$= 53.73; p wood > reproductive part > trash (Table 2). Figures 4a - 4d show the seasonal patterns of standing crop litter in the forest and cacao plantation in 2016 and 2017. In the forest, the highest leaf litter standing crop occurred from December to March, while wood litter standing crop occurred most from December to March except for the month of June. Reproductive part occurred majorly in January, March, May and August while trash litter occurred most from April to June (Fig. 4a). In cacao plantation, leaf standing crop litter occurred most in March and least in June, wood litter occurred most in February and least in June, reproductive part occurred most in May and November and least in January, June, July, August and September. Trash litter occurred most in November, December and March and least in January, April, May, June, September and October (Fig. 4b). There were no significant monthly variations in the standing crop litter between the two ecosystems and among its component parts.

In the year 2017, the highest standing crop litter in the forest was recorded in January (Fig 4c). The leaf litter was highest in January, wood in December while reproductive part and trash were highest in September (Fig 4c). In cacao plantation in 2017, the month with highest standing crop litter was January (Fig 4d). Leaf litter was highest in January, wood in February, reproductive part in November and trash in February (Fig 4d).

DISCUSSION

The significantly higher litter fall production in the forest ecosystems than in cacao plantation observed in this study was similar to the findings of Nataro *et al.* (2013) for agroforestry and forest in the semi-arid region of Taquaritinga do Norte, in the State of Pernambuco, Brazil, Triadiati *et al.* (2011) for cacao agroforestry and forest ecosystem in Northeastern margin of Lore Lindu National Park (LLNP), which is located in Central Sulawesi, Indonesia and Dawoe (2010) for natural forest and cacao plantation in Ghana. The significantly higher litter production in the forest than cacao plantation was due to more diverse nature of tree biomass that produces not only more leaves but also more woody debris and reproductive parts and the deciduous nature of the tree species in the forest most especially in the tropics like Nigeria, encourages more litter production in the forest than any agroforest

The range of litter fall 24.32 - 35.094 t ha^{-1} yr^{-1}, in the study for forest ecosystem is higher than the 7.7 t ha^{-1} yr^{-1} reported by Daisy *et al.* (2006) for lowland tropical forest in East coast of Sabah, Malaysia; the range 7.0–14.1 t ha^{-1} yr^{-1} reported for other West African tropical lowland rainforests (Odiwe and Muoghalu, 2003); slightly higher than 20.3 t $ha^{-1}yr^{-1}$ reported by Neelu *et al.* (2002) for Shisham forest of Cen-

tral Himalaya but agrees with 30.20 t $ha^{-1}yr^{-1}$ reported for a lowland secondary rainforest in Ile-Ife (Nwosu, 2010) and the range of 29.50 - 40.40 t $ha^{-1}yr^{-1}$ reported by Vanod *et al.*, 2014 for central Himalayan forest. The higher litter production in this study might be as a result of aboveground biomass (determined as basal area) of tree species present in the study area, growth habit of the species in terms of deciduousness; spatial and temporal differences which include climatic condition of the study areas.

The contributions of the different litter fall fractions to total litter fall in this study in the forest ecosystem (Table 1) fall within the range reported for West African rain forests (leaf litter 63.6–77%; wood 10–28.3%, reproductive part 2.2-5.7% and trash 0.6 – 9%) (Odiwe and Muoghalu, 2003, Oziegbe *et al.*, 2011). The variation in the percentage contribution of various litter fall components might be as result of climate fluctuation, age of the forests and vegetative and reproductive phenologies of the species in the different forests.

Furthermore, litter fall occurred throughout the year but was highest during the dry season (January–March) the peak of the dry season. High litter fall during the dry season is a well-documented phenomenon in tropical forests which mainly re□ects drought stress during the season (Barlow *et al.*, 2007). This agrees with Chuyong (1994) and Odiwe and Muoghalu (2003) assertions that during the dry season litter fall is at peak because there is little or no rainfall with low humidity, therefore the high evapo-transpiration exceeds rainfall leading to water stress. A meta-analysis by Zhang *et al.* (2014) has shown that this connection is a characteristic feature of tropical ecosystems. Leaf aging, caused by photo inhibition, stomatal closure and subsequent leaf overheating, might lead to leaf shedding at the end of the dry season (Röderstein *et al.,* 2005). As a side effect, trees are preparing for the upcoming season of highest net primary production. Many deciduous species which occur in the forest completely shed their leaves between December and March, bring out new leaves (flush) with the onset of rain in March/April and attain full canopy leafiness between June and September (Odiwe and Muoghalu, 2003; Kohler *et al.*, 2008). Since leaves are the major constituent of total litter fall in most tropical forest, the seasonal pattern of litter fall is attributed to seasonal leaf shedding and the associated factor responsible for leaf senescence and abscission (Chuyong, 1994). ropical 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 higher litter production in the forest ecosystem during the first year (2016) compare to the second year (2017) might be attributed to climatic condition in the ecosystem during this period (Fig 3a and b)

In this study, the litter production in cacao plantation 16.92-25.69 t/ha/yr was higher than 4.73 t/ha/yr in cacao plantation and 7.34 t/ha/yr in Kolanut plantation reported by Muoghalu and Odiwe, 2011 in cacao plantation in Ile-Ife, Nigeria; 10.24 t/ha/yr reported by Dawoe, 2010 for cacao planation in Ghana, and slightly higher than 11.56 t/ha/yr by Indriyanto (2009) for cacao plantation in Lampung Province, Indonesia. The higher production of litter fall in the cacao plantation in this study might be attributed to spatial and temporal difference and ages of the plantations. The latter is in agreement with Dawoe (2010) assertion that there could be a significant increase in the amount of litter fall with increasing age of plantation.

The contributions of different litter fractions to total litter fall in cacao plantation (Table 2) for leaf litter 90.7%-91.8% falls within the range of 78%-92% reported by Dawoe (2010) for cacao planation in Ghana, while wood, reproductive part and trash were less than 10.8%, 3.9 % and 17.1 % respectively reported by Muoghalu and Odiwe (2011). The seasonal dynamics in litter fall in cacao plantation followed the same pattern as that of forest ecosystem, the litter production being higher in the dry season than in the rainy season. This is expected, because the cacao plantation is in the same tropical forest area as the forest. This agrees with Chuyong (1994) and Odiwe and Muoghalu (2003) assertions that during the dry season there is peak litter fall because there is little or no rainfall and a low humidity, therefore the high evapo-transpiration exceeds rainfall leading to water stress due to the seasonality of rainfall in the seasonal tropics.

Standing Crop Litter for the Forest and Cacao Plantation

The litter standing crop in this study was slightly higher in forest than in cacao plantation. Similar trend was reported by Owusu-Sekyere *et al.* (2006) for forest and cacao plantation in Ashanti, Ghana. The higher standing crop litter in the forest than cacao plantation might be as result of the deciduous nature of the woody species in the forest ecosystem than enhances accumulation of litter on the forest floor especially in the dry season.

In this study, quantity of leaf litter in the standing crop of litter were higher in cacao plantation than those of the forest ecosystem. This might be as a result of faster rate of decomposition of this component part

(leaf litter) in the forest ecosystem than cacao plantation this was in agreement with Triadiati *et al.* (2011) who reported a faster rate of decomposition of leaf litter in the forest ecosystem than cacao plantation

The standing crop litter range of 10.21-19.33 t $ha^{-1}yr^{-1}$ for the forest ecosystem in this study was higher than the range 8.3 – 9.4 t ha^{-1} yr^{-1} the reported by Odiwe and Muoghalu (2003) for a secondary rain forest in Ile-Ife, Nigeria. The higher value of standing crop litter in this study might be as a result of spatial and temporal differences, ages of the forests and density of the tree species in the forest and relative abundance of the decomposers.

In cacao plantation, the standing crop of litter range of 10.16 – 18.49 t ha^{-1} $yr^{-1}$was higher than 6.74- 7.64 t ha^{-1} yr^{-1}recorded in *T. cacao* plantations and 5.03- 6.79 t ha^{-1} yr^{-1}in *C. nitida plantations* reported by Muoghalu and Odiwe (2011) in Ile Ife Nigeria. The higher value of the standing crop litter might be as a result of the different ages of the plantation, climatic variability and higher level of management practices like application of chemical which might inhibit the performance of the decomposers.

There is also marked seasonality in the accumulation of litter on the floors of the forest and cacao plantations with higher standing crop litter during the dry season (January-March) and early rainy season (April-May) than during mid- and late rainy season. The monthly fluctuations in standing crop litter observed in these ecosystems reflect a response to two simultaneously operating processes: transfer of fresh litter into the system and decomposition of material. The high values for January-March correspond to the maximum fresh litter fall during the period and of the strong reductions in litter decomposition rates during the dry season, resulting in an accumulation of litter on the plantation floors. The lower amounts in subsequent months are due to lower inputs of fresh litter and higher rates of decomposition of old litter during the rainy season (April-October), due to availability of moisture needed by decomposers for the decomposition processes. Muoghalu *et al.* (1994) have reported that moisture availability is an important factor affecting litter decomposition in the tropics.

In this study, litter fall was higher than the standing crop litter in the two ecosystems. Similar trend was reported by Ibrahim *et al.* (2010) for tropical rainforest of Ebom southwest, Cameroon and a nearby plantation. The lower standing crop litter compared to litter fall in this study might be attributed to the decomposition of litter on the forest and cacao plantation floors (Oziegbe *et al.* 2011).

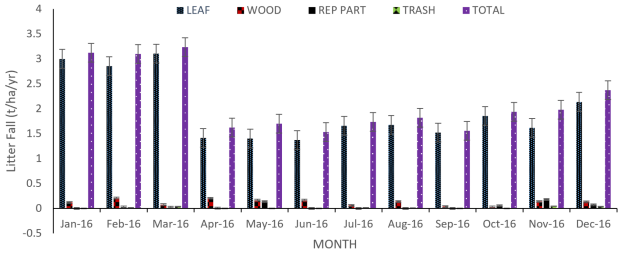

Figure 5: Monthly Litter Production in Cacao Plantation in 2016

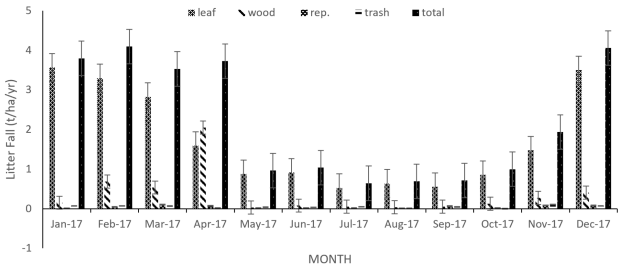

Figure 6: Monthly Litter Production in the Forest in 2017

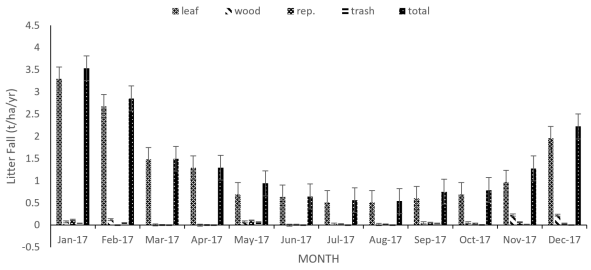

Figure 7: Monthly Litter Production in Cacao Plantation in 2017

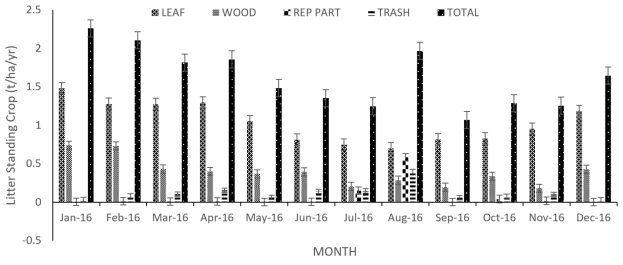

Figure 8: Monthly Litter Standing Crop in the Forest in 2016

Figure 9: Monthly Litter Standing Crop in the Cacao Plantation in 2016

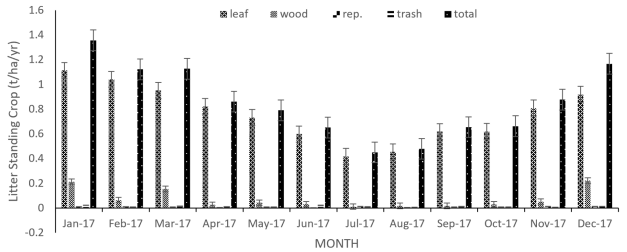

Figure 10: Monthly Litter Standing Crop in the Forest for 2017

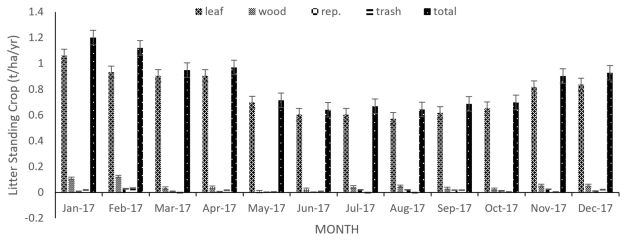

Figure 11: Monthly Litter Standing Crop in the Cacao Plantation for 2017

CONCLUSION

The study concluded that clearing of natural forest for establishing cacao plantation adversely affects litter fall and standing crop litter quantity affecting which might in turn disrupt nutrient cycling dynamics

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