CHANGES IN LITTER PRODUCTION IN A SECONDARY RAIN FOREST 29 YEARS AFTER FIRE INDUCED SUCCESSION

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ABSTRACT: This study investigated dynamics in litter production after a fire induced succession, with a view to assessing the changes in litter fall deposition in the forest as it recovered from fire disturbance. Litter traps were randomly positioned for litter fall collection for a period of one year in 25×25 m sample plot in the burnt area of the forest. The collected litter was sorted into leaf, wood, reproductive parts and trash and oven dried at 80 °C, weighed. The results from this study were compared with those of previous studies on the litter production in the forest in 1990, 1997 and 2008. The results showed that the annual litter fall production ($t \cdot ha^{-1} \cdot yr^{-1}$) was 77.36 (total), 57.31 (73.7 %) (leaf); 14.79 (19.4 %) (wood); 2.02 (2.7 %) (reproductive parts) and 3.24 (4.3 %) (trash). There was *significant ($p < 0.05$) differences in litter fall between the litter components.* Litter fall has increased from 4.60 $t \cdot ha^{-1} \cdot yr^{-1}$ in 1990 to 77.36 $t \cdot ha^{-1} \cdot yr^{-1}$ in 2013. It was concluded that there had been changes in litter production in the forest 29 years after fire.

Keywords: disturbance, ecosystem, fire, forest, litter fall, succession**.**

Introduction

Disturbances are natural and integral part of forest ecosystems, which influence forest structure, composition and functioning and are important for maintaining biological diversity and facilitating regeneration (Moore and Allard, 2011). It plays a key role in shaping the structure, dynamics and species composition of tropical tree communities by causing environmental heterogeneity over space and time and various scales (Sheil and Burslem, 2003). Some researchers have reported disturbances as a factor that can greatly affect annual or monthly litter fall rates (Horng *et al*., 1995; Vitousek *et al.*, 1995).

Physical disturbances, such as fire, wind and hurricane (Bruederle and Streans, 1985) storm and cyclone activity combined with strong winds and heavy rainfall (Congdon, 1993), difference in biomass as may be deduced from the differences in tree basal area of the sites, their degree of exposure (Muoghalu *et al*., 1993) and effect of temperature and light regime (Spain, 1984) may increase the rate of litter fall in a forest.

The amount and seasonal pattern of litter fall are important determinants of overall recycling of nutrient and maintenance of soil fertility in different ecosystems (Tripathi and Singh 1995, Campo *et al*., 2001). The seasonal variation of litter component that falls, constitutes an important aspect of nutrient cycling (Campo *et al*., 2001).

Quantitative and qualitative variations in fine litter fall influenced the amount of nutrients returned to the soil, as well as their stock on the forest floor (Arunachalam *et al.*, 1998). Nutrient flux has been reported to correspond with litter fall, as well as correlate positively with tree population and number of tree species (Hermansah *et al.*, 2002). The amounts of various nutrients returned to the forest floor annually is determined not only by the amount of litter produced but also by the chemical composition of the species present on the site particularly the dominant ones and nutrients returned is not limited only to the enrichment of the soil but also the choice of species for regeneration and maintenance of the productivity of the site (Songwe *et al.*, 1997).

The secondary rainforest of Obafemi Awolowo University's Biological Gardens in Ile-Ife, Nigeria, was burnt by fire at the beginning of 1983. A portion of the secondary rain forest at Obafemi Awolowo University's Biological Gardens in Ile-Ife, Nigeria, was destroyed by fire at the beginning of 1983. After a 50 m × 50 m section of the forest was delineated in January 1983 for a baseline study of tree girth increases and litter deposition patterns, species listing and girth measurements for woody species were finished, and the fire broke out. Following the fire incident, research was conducted (Isichei et al., 1986; Odiwe and Muoghalu, 2001). Muoghalu *et al*. (1993) and Odiwe and Muoghalu (2003) have also reported on the litter fall and nutrient dynamics in this forest 7 and 14 years after the fire. Disturbances could have deleterious effects on litter production. It is hypothesized that as disturbance, in this case fire, deters canopy structure, stem density and floristic composition, it would therefore also affect other functional aspects of the forest, such as soil chemistry and litter production in regenerating vegetation from fire disturbance.

This study, therefore, established changes in litter production in a secondary rainforest, after 29 years of fire induced succession.

Materials and methods

Study area

The research was conducted in a forest that was burnt in 1983 within Obafemi Awolowo University's Biological Gardens in Ile-Ife, Nigeria. Ile-Ife lies within latitudes 7°30' N to 7°35' N and longitudes 4°30'

to 4°35' E. The latitude of the study area is 7°31' N and longitude is 4°31' E. The elevation of the area is 306 m a.s.l. There are two prominent seasons in the Ife area, the rainy season (April-October) and the dry season (November-March). In a five-year survey, the average annual rainfall was 1413 mm, with two maxima occurring in July and September. At 10:00 a.m., the monthly humidity is 58.1% and relative humidity is 82.8%. The temperature ranges between 22.5–31.4 °C (Duncan, 1974). The annual rainfall, mean monthly relative humidity and temperature from July 2012 to June 2013 during the study were 3663 mm, 79.5% and 25.7 °C, respectively.

Onochie (1979) reported that Ile-Ife area lies in a dry deciduous forest zone. White (1983) also described the vegetation as Guineo-Congolian drier type. The basal area of trees in the forest was 32.2 $m^2 \cdot ha^{-1}$ and stem density of woody plants less than 2 m in height was 798 plants per 0.25 ha (Isichei *et al*., 1986). The eleven most abundant species are *Albizia zygia* (DC.) J.F.Macbr., *Blighia unijugata* Bak., *Bombax buonopozense* P.Beauv., *Trilepsium madagascariense* DC., *Commiphora kerstingii* Engl., *Elaeis guineensis* Jacq., *Ficus mucuso* Welw. ex Ficalho, *Funtumia elastica* (Preuss) Stapf, *Holarrhena floribunda (G. Don) Dur. & Schinz*, *Manihot glaziovii* Müll.Arg. and *Pycnanthus angolensis* (Welw.) Warb. (Isichei *et al*., 1986).

Families, Apocynaceae, Euphorbiaceae, Mimosaceae, Moraceae, Rubiaceae and Sapindaceae were the most frequently occurring plant. The percentage canopy cover in the study plot is 88.8 ±0.8%.

The area is underlain by rocks of the Basement Complex, which are of Precambrian age (Wilson, 1922). The Basement complex consists of heterogeneous group of rocks (gneisses, schists, granites and minor rocks types, such as pegmatites). The soils are Lixisols (FAO/UNESCO, 1974) and Ultisols (USDA, 1975). The soil temperature regime is isohyperthermic, the soil moisture is ustic and clay minerals are mostly kaolinite. The soils of the area are moderately to strongly leached and have low to medium humus content, weakly acid to neutral surface layers and moderately to strong acid subsoils (Ayodele, 1986).

Data collection

Sampling procedure

A sample plot of 25×25 m was marked out in the burnt area of the forest using measuring tape and twenty 1×1×0.3 m litter traps raised 1 m above the ground were randomly located. Litter fall was collected every two weeks (14 days) for a period of one year (July 2012 – June 2013) and sorted into leaf, wood, reproductive parts (flower, fruits and seeds) and trash and oven-dried at 80 °C to a constant weight and weighed.

Data and statistical analysis

The monthly weight of litter fall was determined by adding the oven-dry weight of the two weekly collections in each month. The data was subjected to descriptive statistical analysis using SPSS 26.0 version. The data from this study were compared with those of studies carried out in the forest 7 years (1990), 12 years (1995), 14 years (1997) and 25 years (2008) after the fire to assess changes in litter fall in the forest over the years.

Results

Litter production

Litter fall

The annual litter fall ($t \cdot ha^{-1} \cdot yr^{-1}$) in the plot was 77.36 (total); 57.31 (leaf); 14.79 (wood); 2.02 (reproductive parts) and 3.24 (trash) (Table 1). There was significant ($p < 0.05$) difference among the litter fall components. The relative contributions of various litter components to the total litter fall in the study

area show that the leaf litter fall contributed the highest proportion (73.7 %) followed by wood (19.4 %), trash (4.3 %) and reproductive parts (2.6 %) respectively (Table 1).

Table 1. Different litter components' contributions in a secondary lowland forest.

Litter component	Litter fall	
	$t \cdot ha^{-1} \cdot yr^{-1}$	%
Leaf	57.31±16.96*	73.7
Wood	14.79±5.25*	19.4
Reproductive part	2.02±0.56*	2.6
Trash	3.24±0.62*	4.3
Total	77.36±23.42	100

*Mean differs significantly at the 0.05 level

Figure 1 reveals litter fall seasonal pattern in the plot from July, 2012 – June, 2013.
There was continuous litter fall all year, the highest quantity of leaf component of the litter was recorded in January during dry season and the least – in May (one of the wettest months of the year). The highest quantity of wood component was in March (peak of dry season). Other periods of high wood component were in September and October (peak of wet season), the lowest wood litter fall was in August. Highest reproductive component was in February and highest trash litter fall was in March (peak of dry season) (Fig. 1).

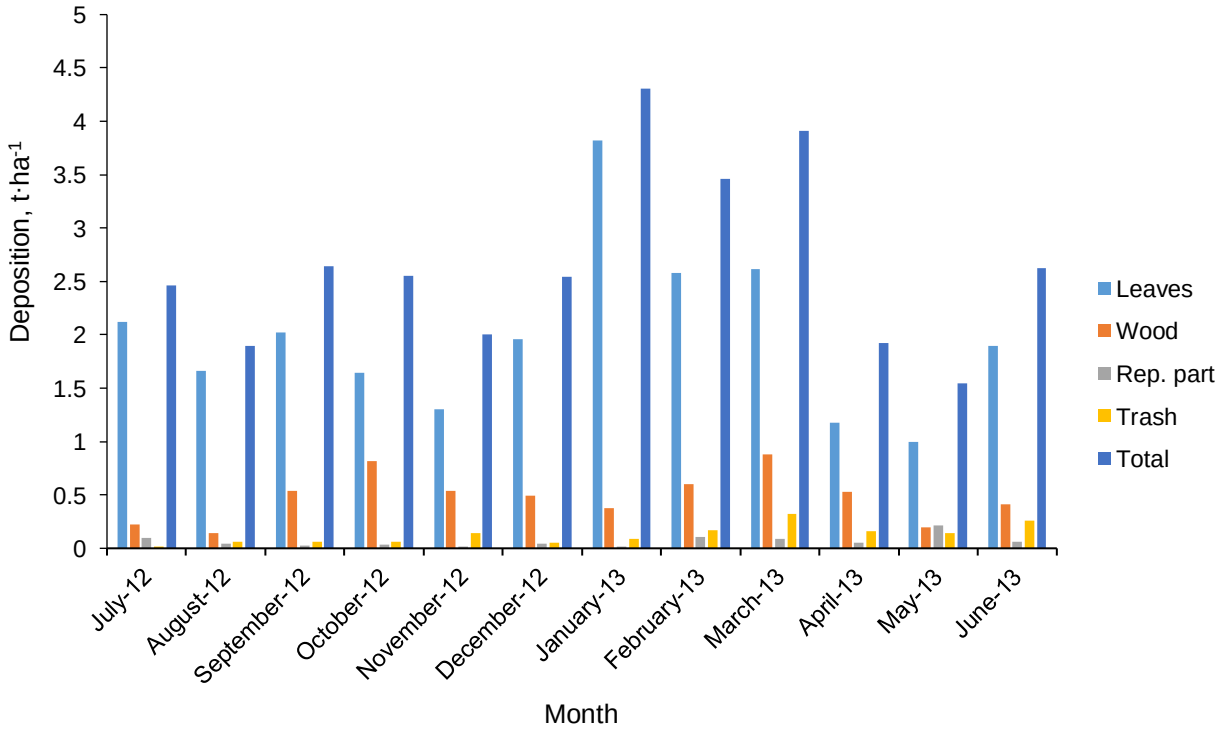

Fig. 1. Litter fall seasonal pattern from July 2012 to June 2013 in a secondary lowland forest.

Changes in litter production through the years

Litter produced twenty nine years (2013) after the fire (77.3 $t \cdot ha^{-1} \cdot yr^{-1}$) was higher than 4.6 $t \cdot ha^{-1} \cdot yr^{-1}$ produced in 1990, seven years later; 11.8 t·ha-1·yr-1 in 1997, fourteen years later; and 30.20 $t \cdot ha^{-1} \cdot yr^{-1}$ in 2008 twenty-five years later. Additionally, there were variations in how much each component of the litter fall contributed in relation to the total amount of litter fall during the various periods. The percentage of leaf component of the litterfall contribution decreased from 91.3% in 1990 to 65.6% in 1997 and increased to 67.9% and 73.7% in 2008 and 2013, respectively; wood component and reproductive part component increased from 6.5% for wood litter fall and 2.2% for reproductive part in 1990 to 22.4% for wood component, 7.2% for reproductive litter in 1997 and decreased to 20.2% for wood component, 3.0% reproductive part litter fall in 2008 and further decreased in 2013 to 19.4% for wood component of litter fall and 2.6% for reproductive part litter fall in 2013 and trash litter fall component fluctuated over the years (Table 2).

Table 2. Variation in litter production in the secondary forest, after 29 years of ground fire.

Litter component	1990[a)]	1997[b)]	2008[c]	2013
Leaf, $t \cdot ha^{-1} \cdot yr^{-1}$	4.2 (91.3)	8.2 (65.6)	20.5 (67.9)	57.3 (73.7)
Wood, $t \cdot ha^{-1} \cdot yr^{-1}$	0.3 (6.5)	2.8 (22.4)	6.09 (20.2)	14.8 (19.4)
Reproductive part, $t \cdot ha^{-1} \cdot yr^{-1}$	0.1 (2.2)	0.9 (7.2)	0.91 (3.0)	2.0 (2.6)
Miscellaneous, $t \cdot ha^{-1} \cdot yr^{-1}$	-	0.6 (4.8)	2.7 (8.9)	3.2 (4.3)
Annual total, $t \cdot ha^{-1} \cdot yr^{-1}$	4.6	12.5	30.20	77.3

Note: [a)]Muoghalu *et al*. (1993), [b)]Odiwe and Muoghalu (2003), [c)] Nwosu (2010)

The component of leaf litter fall's percentage contribution was the highest through the years, while the least was reproductive part litter except in 1997 (Table 4).

Discussion

The total annual litterfall in this research was 77.3 $t \cdot ha^{-1} \cdot yr^{-1}$ from July 2012 to June 2013. This value is greater than 7.7 $t \cdot ha^{-1} \cdot yr^{-1}$ reported by Dent *et al*. (2006) for lowland tropical forest in East coast of Sabah, Malaysia; the range 7.0 –14.1 $t \cdot ha^{-1} \cdot yr^{-1}$ reported for this very forest in 1997 (Odiwe and Muoghalu, 2003); 20.3 $t \cdot ha^{-1} \cdot yr^{-1}$ reported by Lodhiyal *et al*. (2002) for Shisham forest of Central Himalaya and also greater than 30.20 $t \cdot ha^{-1} \cdot yr^{-1}$ reported for this Ile-Ife secondary lowland rainforest. The higher significant litter fall indicates an increase in the production of above ground biomass in the forest as it recovers from disturbance. This is consistent with Ewel's (1976) assertion that increase in litterfall annually is a function of biomass function of increase biomass and canopy development, and climate fluctuation throughout the study. The different fractions of litterfall except the reproductive part contribution to the overall litter fall is comparable with the range documented for West African rainforests (leaf litter 63.6–77%; wood 10–28.3%, trash 0.6 – 9%) (Odiwe and Muoghalu, 2003; Oziegbe *et al.*, 2011). 73.7% contributed by leaf fraction falls within 54–87% range reported by Singh and Singh (1992) for natural forests of central Himalaya; the result of 19.4% of wood is found in the range (10–36%) reported for various forests around the world (Singh and Singh, 1992); 4.3% of trash was less than the range 6–10% reported for Bornean rainforest (Burghouts *et al*., 1998). The variation in the different litterfall fractions' percentage contribution might be as result of the relative abundance of each component part, tree species age species and reproductive phenology of the species in the study area during the period of study. In addition, there was a continuous litter fall all year but was highest during the dry season (January–March), although there

were no significant differences in the monthly litter production when the study was conducted. This agrees with Chuyong (1994), Odiwe and Muoghalu (2003) assertion that there is peak litter fall during the dry season due to low humidity, little to no rainfall, and high evapo-transpiration, which causes water stress. Many of the forest's deciduous species lose all of their leaves between December and March, sprout new leaves (flush) when the rainy season begins in March or April, and reach full canopy leafiness between June and September (Odiwe and Muoghalu, 2003). Since leaves are the major constituent of overall litter fall in most tropical forests, litter fall seasonal pattern is attributed to seasonal leaf shedding and the associated factor responsible for leaf senescence and abscission (Chuyong, 1994).

There has been increase in the forest's total litter fall with the standing age of the vegetation as the forest recovers from fire disturbance, 77.3 $t \cdot ha^{-1} \cdot yr^{-1}$ 29 years after disturbance being higher than 30.2 $t \cdot ha^{-1} \cdot yr^{-1}$, 25 years after disturbance, 12.5 $t \cdot ha^{-1} \cdot yr^{-1}$ reported by Odiwe and Muoghalu (2003), 14 year after disturbance and 4.6 $t \cdot ha^{-1} \cdot yr^{-1}$ reported by Muoghalu *et al.* (1993), 7 years after the disturbance. Similar increasing trend was also reported for Shisham forest of Central Himalaya from 12.6 $t \cdot ha^{-1} \cdot yr^{-1}$ (5 years after disturbance) to 20.3 $t \cdot ha^{-1} \cdot yr^{-1}$ (15 years after disturbance) by Lodhiyal *et al.* (2002). The significantly higher litter fall in the forest over the years indicates increase in above ground biomass production, nature and tree species age as it recovers from the disturbance. The variations in the percentage that each fraction of litter contributes to the overall amount over the years might be due to climate fluctuation, relative abundance of each component part, trees age and reproductive phenology of the species in the study area after ground fire.

Conclusion

The study has shown that there has been increasing litter production over the years as the forest recovered from disturbance. Additionally, there were variations in how much trash, leaf, wood, and reproductive parts contributed to the overall amount of litter fall.

Understanding these changes in litter production in a forest during succession after fire disturbance provides information on available litter fall after recovery from such natural disturbance in tropical forest ecosystem. This is important in the management of tropical moist forest growing on tropical soils of low fertility, which have suffered from such disturbance. This study and the previous studies in the forest (1990, 1997 and 2008) on litter fall with increasing age after disturbance have shown the need for long-term studies of disturbed forests to understand the changes in litter fall of tropical forests after disturbance, especially for their effective management.

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