THE IMPACT OF HUMAN ACTIVITIES ON LITTERFALL PRODUCTION, TREE DIVERSITY AND STRUCTURAL CHANGES IN TROPICAL RAINFOREST

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Abstract: Homo sapiens greatly depend on food, shelter and cloth which forest produces majorly. The impact of anthropogenic activities on the changes of forest quality and quantity is increasing overtime which as negative effect on ecological services. Therefore, study was investigated on the impact of human activities on litter fall production, tree diversity and structural changes in tropical rainforest. Sixteen (16) sampling plots of 25 x 25 m in size were laid at line transect of 1 km at an interval of 100 m. Also, sixteen (16) quadrants of 1 x 1 m were also laid within each plot for collection of litterfall. The parameters examined were Dbh and total height while volume and basal area were extrapolated. Shannon Weiner and evenness were also assessed. Data collected were analysed using Shannon Weiner, Analysis of variance and descriptive statistic i.e. percentage and frequency. The result from the study showed that litter fall in 2010 was higher than 2015 with value of 5412.84±96 and 4284.65±43, respectively. The total number of tree and species were higher in 2010 than 2015 with values of (1404, 864) and (79, 78), respectively. Total basal area was found to be higher in 2010 than 2015 with values 27.61 and 17.09 m^2ha^{-1}, respectively. The total volume was found to be 162.47 m^3ha^{-1} in 2010 and 107.28 m^3ha^{-1} in 2015. The Shannon Weiner index (H') reduced from 4.13 to 3.28 but increased from 0.60 to 0.69 in 2010 and 2015, respectively. The biological resources available in the study site would therefore demands for good management of the area for the conservation, ecological balance and sustainability of the constituent resource.

Keywords: Human activities, litterfall production, tree diversity, tropical rainforest

Introduction

Forests are often known as one of the most species diverse terrestrial ecosystems, and generate a variety of natural resources to help sustain the livelihood of local communities (Nirmal *et al*., 2011; Salami *et al.,* 2016). Tropical forests provide a wide variety of highly valuable ecological and social services including the conservation of biological diversity, carbon storage, soil and water conservation, provision of employment and enhanced livelihood, agricultural production systems, and improvement of urban living conditions (Dagba *et al*., 2007). Trees form the major structural and functional basis of tropical forest ecosystems and can serve as robust indicators of changes and stresses at the landscape scale. In terms of tree composition and species diversity, tropical rain forests are Earth's most complex ecosystems (Humphrey, 2015; Salami *et al.*, 2016).

Deforestation results from a mixture of economic, social and political causes that vary from site to site. The primary causes of deforestation in the tropics are logging and its conversion to agricultural production or grazing (Rowe *et al.,* 1992; Salami *et al.,* 2018). Pressures of forests, especially in the tropical world are to provide economic resources have been increasing rapidly as a result of geometric increase of human population in the region (Salami, 2006). In Nigeria, the country is said to have lost large parcels of her forestlands to human encroachment. According to (Mbakwe 1986), the Nigerian Forest was estimated at 36 million hectares as at 1951 had depleted to 15.5 million hectares by 1979. While Umeh (2005), attributed annual forest loss of about 3% to human activities, Ladipo (2010), put the rate of deforestation in the Country at between 250,000-350,000 ha or 3.5% per annum. He said that forests are degraded through selective logging, industrial uses, grazing, land clearing, bush burning, deforestation and urbanization. Alao (2008) reported that Sahara desert has taken over more than 50% of arable land cultivated 50 years ago in eleven states. Adelusi (2002) and the Nigeria Environmental Study Team NEST (1991) had earlier attributed the wide scale deforestation in Nigeria to increase in demand for agricultural land and urbanization. The destruction of the forest and its resources has been intensified through the use of effective tools and machines and more importantly, as a result of population growth. Urbanization and agriculture are two of the most important threat to biodiversity worldwide (Ricketts and Imhoff, 2003). The problem of deforestation in the country today is being aggravated by desertification especially in Northern Nigeria.

Human activities have been widely reported to contribute more to this problem compared to natural factors (Putz *et al.*, 2000). Habitat loss, fragmentation, and degradation are currently the most important threats to biodiversity conservation worldwide (Cannon *et al.,* 1998). Tropical forests especially those located in developing countries are more vulnerable following the fact that the majority of forest adjacent communities are poor and depend directly on the forest resources to sustain their livelihood (Shackleton and Shackleton, 2004). Unsustainable use of forest resources, for example, through logging and shifting cultivation, has potential impact on its ecological functioning due to sudden changes on their structure and composition (Denslow, 1995). Emergence of invasive species and loss of ecosystem services resulting from the occurrence of many woody pioneers and herbaceous species have been observed in several disturbed forest ecosystems (Cannon *et al.,* 1998; Eichhorn, 2006). Opening of forest canopies in the logged or burnt forests increases light levels which in some cases positively influences diversity indices (Pinard, 2000). Understanding the factors related to human disturbance that affect the tree biodiversity and forest vegetation structure can help conservation managers to suggest best forest management practices in ways that can best protect these values (Pickett, 1995).

Groombridge (1992) observed significant pressures on biodiversity of forest reserves through anthropogenic activities such as over exploitation of forest resources, grazing in forest reserve and conversation of forest areas to other forms of use such as residential, schools, industries, road construction and unstable climate conditions. This has led to unabated deforestation, which has been recognized as one of the major drivers of biodiversity loss (Ojonigu *et al.,* 2010). According to FAO (2005), each year about 13 million hectares of world's forest are lost due to deforestation. The overall impacts are reduction, fragmentation and impaired natural ecosystem functions. Forest conversion may have far reaching environmental, economic and social effects. Environmental consequence can include the disruption of natural hydrological process. Soil erosion and degradation, nutrient depletion, loss of biological

The degradation, fragmentation and conversion of the forests to other forms of land uses in Nigeria, are currently progressing at alarming rates. Between 1990 and 2000, Nigeria lost about 2.7% of its natural forests to deforestation which increased to about 18.56% (about 2.06 million ha) between 2000 and 2010 (FRA, 2010; FAO, 2011). A cumulative 47.5% of Nigeria's natural forests were lost to deforestation between 1990 and 2010 (FRA, 2010). Recent global forest resources assessment revealed that Nigeria is one of the five countries in the world with the highest annual rate of deforestation for the period 2000 –2010 (FAO, 2010). These changes have caused the loss of some plant species and a decline in the biodiversity conservation status of the forest and environmental quality. The sustainable management and use of these resources are essential for the nation's economic and environmental security (Akinsanmi, 1999). This study therefore investigated on the impact of human activities on the litter fall production, tree diversity, structural changes in tropical rainforest by provided baseline and impact data on species composition and diversity to guide forest owners and managers.

Materials and Methods

Site descriptions

The Study area is located in Ondo State between latitudes 6°57' and 6°59' and longitudes 5° 34' and 5° 38' in the Northern part of the State which is found in Southwestern lowland rainforest zone of Nigeria (Plate 1) (Salami and Jibo, 2019; Haastrup *et al.*, 2019). It covers a total land area of 24061ha, FAO, (2010). The most practising profession in the state is agriculture which contributes to farmer's encroachment into the reserve. The climate is humidsub-tropical indicating that it is basically within the tropical rainforest zone which is dominated by broadleaved hardwood trees that form dense layered stands. Characteristic of the study site is two distinct seasons (rainy and dry seasons), with frequent rainfall that normally starts in March and ends in November. The annual rainfall ranges from 1,700 to 2,200 mm. The dry season is experienced from December to February. Mean annual temperature fall between 26 and 28^{0}C while the average daily humidity is 80%. The most common type of soils are ferruginous tropical soils and are typical of the variety found in the intensively weathered areas of basement complex formations in the rainforest zone of Southwest in Nigeria (Onyekwelu *et al.*, 2005; Salami and Jibo, 2019).

Plate 1: Map of Owo Forest Reserve

Leaf litter collection

To determine the amount of litters in the litter layer, a sub-plot (1 × 1 m) was established in each plot during inventory period. Samples from sixteen plots were collected, pooled together into leaves, small branches (<2 cm in diameter), flowers, fruits, and miscellaneous material (insect fecal, unidentified plant parts) (Yang, 2003), air-dried and weighed with the aid of weighing balance in the College Laboratory of Department of Forestry and Wildlife Management, Federal University Dutse, Jigawa State. The collected litter at each time was oven-dried at 80℃ to constant weight (Yang, 2003). Thus, the minimal sampling unit for litter fall was the plot. Species relative abundances in litterfall were calculated as % of litterfall per plot. Data for plots were then pooled to calculate % contribution of each species to total annual litter fall for each plot and for the whole forest

Measurements of tree growth variables

Trees measured were woody plant with Diameter Breast at Height (Dbh) between ten (10 cm) and above. The tree growth variable measured include: Diameter at breast height measured with the aid of Girth tape while Basal area and volume was evaluated. Data collected were classified and analysed to calculate volume (m^3), basal area (m^2), species diversity and abundance.

Sampling design

One hectare was selected in a well-stocked portion of the forest while complete enumeration method was adopted. Sampling plot of 25 x 25 m in size was laid resulting to 16 plots in all. Also, sixteen (16) quadrants of 1 x 1 m were also laid within each plot for collection of litter fall. Total area of land surveyed was 24061ha and sampling intensity was 0.0042%. Data were collected on Diameter at breast height (Dbh) cm, total height (m) and these were used to compute basal area (m^2) and volume (m^2). Tree height of each tree species was measured at 20 m from the base of the tree for easy access to the crown of the tree using Haga altimeter. Diameter at breast height of each tree species was measured using girthing tape from the ground level to where 1.3 m is located at the tree and it was recorded. The botanical name of every living plant species that were encountered during the study was recorded in each plot in the field book.

Data analysis

Community structure analysis

The following community assessment variables were determined to analyse the Owo Forest Reserve Structure:

The basal area of all trees in the sample plots was calculated using the formula:

$$BA = \pi D^2 \text{.. } (eqn\ 1)$$

Where: BA = Basal area (m^2), D = Diameter at breast height (cm) and π = (3.142)

The total basal area for each of the sample plots were obtained by adding the BA of all trees in the plot while mean BA for the plot (*BAp*) was obtained by dividing the total BA by the number of sample plots. Basal area per hectare was obtained by multiplying mean basal per plot with the number of 25 × 25 m plots in a hectare (4).

$$BA/ha = BAP \times 16 \text{..........................} (eqn2)$$

Where: *ha BA* = Basal area per hectare

Volume estimation

Volume of individual trees encountered in the plots. Mean volume for sample plots was calculated by dividing the total plot by the number of sample plots. Volume per hectare was obtained by multiplying mean volume per plot (VP) with the number of 25 × 25 m plots;

$$VP = MV*N$$

Where: VP= volume per plot,

MV= mean volume of 10 trees in each plot

N= total number of trees in each plot

The volume of all trees in the sample plots were calculated using this formula:

$$V = B.A \times H \text{..} (eqn\ 3).$$

Diversity index analysis

The species diversity index and evenness were calculated using Shannon-Wiener index. Species relative density, frequency and relative frequency were calculated. The following biodiversity indices were used to obtain: Species relative density (RD) number of individual per hectare was obtained using the formula given by Oduwaiye *et al.*, (2002):

$$RD = \left[\frac{n_i}{N}\right] \times 100 \text{.........................} (eqn4)$$

Where RD = relative density, n_i = number of individuals of species i and N = total number of individuals in the entire population. Species diversity is the number of different species in a particular area. This was obtained using a mathematical formula that takes into account the species richness and abundance of each species in the ecological community. The equation for the Shannon-Wiener diversity index given by Price (1997) that was used is:

$$H^1 = \sum_{i=1}^{S} p_i Lnp_i \text{....................................} (eqn5)$$

H^1 is the Shannon diversity index, S is the total number of species in the community, p_i is the proportion of a species to the total number of plants in the community and Ln is the natural logarithm.

Species evenness (E) measures the distribution of the number of individual species. It was determined using Shannon's equitability (E_H) as stated by Kent and Coker (1992):

$$E = \frac{H^1}{Ln(S)} \text{..} (eqn6)$$

S is the total number of species in each community.

H^1 is Shannon index

Ln is natural logarithm

Knowledge of the biodiversity in different ecosystems in tropical rainforest is urgently needed, given the high rate of deforestation and species loss as a result of anthropogenic activities

Litter fall

Data collected on litter fall amount, percentage of leaf litter mass remaining during the study was analysed using one-way ANOVA. The multiple comparisons were determined with SSR test at a significance level of 0.05 (SAS Institute 1998).

$$\text{Litterfall} = \frac{T2 - T1}{T2}.\% \text{..} (eqn7)$$

T2: Fresh weight, **T1:** dried weight

Results and Discussion

The distribution, composition, species diversity and evenness of plant species per hectare in the study area are shown in Table 1.

Table 2 displays the tree families and abundance in the study area. The family with the highest number of species is *Caesalpiniaceae* with 120 species, followed by *Ebenaceae* (109) and the least *Samydaceae* with 3 species. Other dominating families were *Sterculiaceae* (93), *Euphorbiaceae*(85), *Rubiaceae*(72), *Sapindaceae*(57), *Annonaceae*(45), and *Papilionaceae* with 36 species. Trees belonging to the families of *Araceae, Boraginaceae, Celastraceae, Fabaceae, Meliaceae* and *Verbalaceae* had 5 species each (Table 2).

Table 1: Distribution, composition, species diversity and evenness of plant species per hectare in the study area

Variables	Year 2010	Year 2015
Total basal area (m^2ha^{-1})	27.61	17.09
Mean Dbh (m/ha^{-1})	0.36	0.25
Total Volume (m^3/ha^{-1})	162.47	107.28
Mean basal area (m^2ha^{-1})	0.35	0.22
Mean Volume (m^3/ha^{-1})	2.06	1.38
Number of stem per hectare	1404	864
Number of species	79	78
Number of family	31	31
Shannon Weiner	4.13	3.28
Species evenness	0.60	0.69

Source: Author's Computation (2020)

Table 2: Family distribution and species abundance encountered per hectare within the study period

Family	Abundance	
	2010	**2015**
Anacardiaceae	18	18
Annonaceae	73	45
Apocynaceae	54	07
Araceae	68	05
Bignonaceae	21	21
Bombacaceae	18	12
Boraginaceae	05	05
Caesalpiniaceae	189	120
Celastraceae	28	05
Connaraceae	17	06
Dichaptaliaceae	29	16
Ebenaceae	109	109
Euphorbiaceae	98	85
Fabaceae	05	05
Lauraceae	20	11
Lecythidaceae	26	26
Letheraceae	08	08
Melastomataceae	15	15
Meliaceae	20	05
Menispermaceae	30	11
Moraceae	12	12
Myristicaceae	07	07
Papilionaceae	87	36
Rubiaceae	179	72
Samydaceae	05	03
Sapindaceae	57	57
Sapotaceae	20	20
Sterculiaceae	142	93
Ulmaceae	21	17
Verbalaceae	11	5
Violaceae	12	07
Total	**1404**	**864**

Field survey: Salami (2010; 2015)

The diameter class distribution of Owo Forest Reserve showed a U-shape (Fig. 1). This relates a pattern where frequency of species distribution had the highest frequency in the larger diameter and height classes, moderate at lower diameters and a decrease towards the middle classes. The forest structure in 2015 which depicts a more open canopy can be attributed to have prime influence on the species composition and increase in plants with lower class diameter. This is in line with Salami *et al.* (2016) who recorded that reduced canopy closure increases the number of wildlings as it enables light demanding plants and organisms to utilize the improved light influx optimally. This result contradicts the findings of Oduwaiye and Ajibode (2005) which stated that majority of the trees observed in Onigambari Forest Reserve were between 11 – 30 cm followed by less than 10 cm diameter classes.

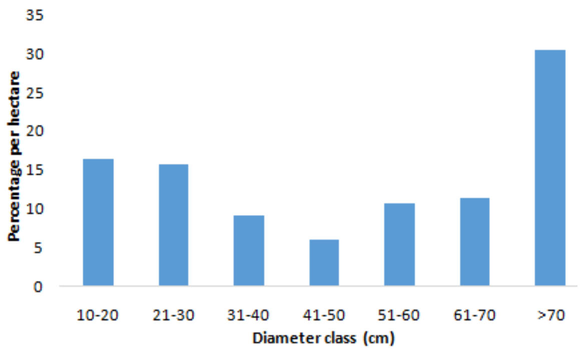

Fig. 1: Diameter class distribution of tree species

Floristic composition and Plant species diversity

The plant distribution, richness and species diversity in Owo Forest Reserve as at the time of the study were presented in Table 1. Species richness and composition are vital pointers for biodiversity assessment (Husch *et al.,* 2002); and an important measure of number of species in a distinct sample unit as well as the basic component ofdiversity in any community (Bello *et al.,* 2013).In 2010, a total of1404 trees were found, which were classified to 79 specieswhereas in 2015, the number of trees reduced to 864 with 78 species and the number of familiesfor both years remained the same (31) (Table 1).

The plant diversity is closely relatedto many other tropical rainforests in Africa. Ihenyen *et al.* (2009), recorded similar result in Ehor forest reserve with 99 species and 36 families. Total basal area was found to be higher in 2010 than 2015 with values 27.61 and 17.09 m^2ha^{-1}, respectively (Table 1). According to Lamprecht (1989) basal area gives the measure of the relative importance of the species when compared to simple stem count. Our findings suggest that the significant reduction in tree species and the resultant effect on basal was due to unrestricted tree felling and not due to environmental factors.

Mean values of diameter at breast height (Dbh), basal area and volume were optimum in 2010 and dropped rapidly in 2015 (Table 1). It was also recorded that Shannon-Weiner index and species evenness decreased as tree numbers reduced. In 2015 the Shannon-Weiner index dropped from 4.13 in 2010 to 3.28 while the species evenness increased from 0.60 (2010) to 0.69 in 2015 (Table 1). This implies that the forest is with very high diversity as well as even representation of individuals of all species in the studied quadrants for both years. Accessibility and unguided extraction of resources (both timber and non-timber) from forests with rich biodiversity attributes to lower species diversity (Kumar and Ram 2005); hence, the drop of the index from 4.13 to 3.28. Sarvade *et al.* (2016) asserted that species evenness is higher in mixed forest than in plantation forests, as such Owo Forest reserve. Species evenness is the relative abundance or proportion of individual trees within the species (Bello, *et al.,* 2013). In all ecosystems, forest has the largest diversity as regards genetic components, ecological processes and species (Adekunle *et al.,* 2013). According to Cavalcanti and Larrazabal (2004), Shannon diversity index is classified high when the value is greater than 3.0, medium when it is between 2.0 and 3.0, termed low when the values are between 1.0 and 2.0 and very low at values less than 1.0. The number of stems per hectare was 864 in 2010 and 490 in 2015. This implies that there is high level of deforestation taking place in the area without proportional reforestation plans, hence, disappearance of 374 stems only in 5 years. The total volume was found to be 162.47 m^3ha^{-1} in 2010 and 107.28 m^3ha^{-1} in 2015 (Table 1).

Leaf litterfall

Litterfall production in forest ecosystem is determined by climatic condition, species composition and successional stage in its development (Haase 1999). In this study, the total observed litterfall in 2010 was higher than 2015 with value of 5412.84±96 and 4284.65±43, respectively (Table 3). There is a significant difference between the years of studies. Also, there is a significance difference for flower, fruit but no significant difference for leave and small branches in the two different years of studies. Xu and Hirata (2002) observed that significant differences among *Castanopsis kawakamii* (NF) and adjacent monoculture plantations of *C. kawakamii* (CK) and Chinese fir (*Cunninghamia lanceolata*, CF) could be attributed to tree behavior. Weng *et al.* (1993) also reported that the litter production in the CK and CF was lower than NF likewise (Zheng *et al.,* 1995) and also coincide with subtropical rain forest of Hexi.

Table 3: Quantity (Kg $^{-1}$ ha $^{-1}$ Yr $^{-1}$) and composition (%) of litter fall in the study site

Year	Leaves	Small branches	Flower	Fruit	Miscellaneous	Total
2010	2700.23±45a (67.43)	1148.19±96a (13.10)	200.65±96a (0.96)	507.05±96a (6.5)	856.72±96a (12.01)	5412.84±96a(100)
2015	2269.18±12a (56.86)	1005.34±34a (15.74)	100.74±43b (1.56)	345.52±96b (7.40)	564.12±54b (9.50)	4284.65±43b (100)

Notes: Values are means ±s.d. of 16 plots at each year. Means followed by different letters on the same column indicate significant differences at P<0.05

Conclusion and Recommendations

The study area is considered to be high in biodiversity of tree species with individual tree species increasing with fallow age. However, deforestation is highly eroding this forest reserve which has the potentials of being a good bank of genetic resources as it has very high species diversity. Thus, the prospect of Owo Forest Reserve is highly dependent on conservation and proper management to ensure sustainable felling and regeneration of species. As the recovery process of this reserve will take many years to be restored to its initial state. The finding of this study on the disappearance of 374 stems within 5 years provides an insight on the degrading state of the reserve.

Conflict of Interest

Authors have declared that there is no conflict of interest reported in this work.

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