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Effects of Industrial Activities on the Structure and Floristic Pattern of Vegetation within the Calabar Port Authority, South-Southern Nigeria

[1]R.A. Offiong, [2]A.I. Iwara, [1]A.O. Alade and [1]G.N. Njar

[1]Department of Geog. and Reg. Planning, University of Calabar, Calabar, Nigeria
[2]Department of Geography, University of Ibadan, Nigeria

Absract: The paper evaluated the effects of industrial activities on the phytogeography of woody tree species in the Calabar Port Authority. Data were obtained from vegetation parameters (structure and floristic) adjoining highly impacted site (HIS) with those of less impacted site (LIS). Two belt transects of 80m x 40m with distance of 5m in between were laid in the study sites and in each transect, two quadrats measuring 40m x 40m were established, out of which 3 were randomly selected. Shannon-Wiener's index showed that vegetation in the LIS was more diverse and heterogeneous than those in the HIS with species diversity indices of 2.29 and 2.26 respectively; whereas, the index of evenness for HIS (0.53) revealed what tree species encountered at the site were fairly equally abundant compared to those in the LIS (0.44). Vegetation in the LIS was more diverse and richer at spatial scale and taxonomic levels than their counterpart in the HIS, as a result of favourable edaphic and substrate conditions. Therefore, to preserve the threatened diversity of available tree species in the area, government was encouraged to enact laws to stop the destruction and transformation of remaining hectare of vegetation into industrial and residential estates.

Key words: Industrial activities · Calabar port authority · Floristic composition · Structural composition · Adaptive capacity

INTRODUCTION

Biodiversity represents an important renewable natural resource with scientific, agricultural, medicinal, pharmaceutical, educational, cultural and ecological values. The development activities which may affect biodiversity include, over exploitation, pollution, industrialization, habitat destruction and degradation by physical and chemical means are causing significant and often irreversible loss [1]. The landscape, vegetation and flora of the Calabar port environment have been subjected the past three decades to irreversible change. Urban and industrial development, deforestation, agriculture, tourism and population growth have dramatically altered the face of the Calabar Port ecosystem. The Southwestern part of Calabar contributes immensely to the economic development and environmental security of the state and country as a whole. It is noted to contain some virgin forest in the country with its abundant resources [2]. The effects of industrial development and urbanization in this region are immensely affecting forest and forest resources available. Indeed, the developmental efforts of the government and entrepreneurs in opening up areas for access to basic necessities of life and increase industries have resulted in the removal of vegetation and the degradation of the environment.

The operations and effluent management of industries in the Calabar Port Authority in relation to other municipal wastes negatively impact on the wetlands, coastal and terrestrial ecosystem of the port environment. The industrial activity in the area includes food processing, fuel bunkering, tanneries, corrugated iron sheets, logging, shipping as well as municipal waste disposal. There is however urgent need to address the depletion of the area's rich biodiversity to avoid the inherent impact on the survival of man especially on the coming generations. Perhaps, the most serious risks of industrial production activities in include air pollution and water pollution mostly from the discharge of without prior treatment into rivers, estuaries, lagoons and vegetated areas. Many of these effluents are toxic because they contain heavy metals such as mercury, aluminum and

Corresponding Author: Mr. Anthony Inah Iwara, Department of Geography, University of Ibadan, Ibadan, Nigeria.
Tel: +2348039451970.

bromide among others. This is of course is of great concern to the general environment (terrestrial and coastal) due to the discharge of industrial waste in mostly untreated forms. The danger of these heavy metals into the environments stems from the fact that they are not only toxic, but some have cumulative or synergistic effects on terrestrial and aquatic resources when combined [2, 3].

The continuous growth and expansion of industries in the area is causing an enormous environmental pollution affecting plants growth. Vegetation in the area differs from area to area depending on the soil characteristics. Polluted soil is noted [4, 5] to alter plant growth and quality and the effects are often destructive. However, with the daily industrial activities and expansion of the work environments like the tank farm that is ongoing, the natural vegetation of the Calabar Port environment is modified and altered resulting in structure and floristic changes, loss of habitat and pollution of streams and disappearance of watersheds. Information on floral composition, diversity and biomass is absolutely essential in understanding forest ecosystem dynamics and conservation; as it may be a tool to estimate the level of adaptation to the environment and their ecological significance [6]. However, for sustainable development, management and conservation of the remaining vegetation in the area in line with the global call for forest protection as sequester of CO_2, it becomes imperative to evaluate the impacts industrial activities have on woody tree species in order to ascertain the ecological status of vegetation in the area and to call for its protection. This study is also relevant because it would contribute to the existing gap in knowledge; as no study so far has examined this in the area.

Study Area: The study area is Calabar Port Authority (NPA) which lies between latitude 05 00'40"N and longitude 008 19'04"E (GPS readings). The area has temperature of 27°C and rainfall ranges between 2000mm-3000mm reaching its peak within the month of July and August; with a relative humidity of about 80%. It has a luxuriant topography which heads seaward; the soils of the area are ferrasols with dominant colour of red -yellow [7]; and are generally made up of loose sandy sediments. It also has luxuriant vegetation dominantly occupied by oil palms, grasses, herbs, *Alstonia boonei*, *Anthocleista vogelii*, *Terminelia spp,* nypa palms and cultivated crops. The area is basically an industrial zone comprising of primary, secondary and tertiary industries. The industries in the area include food processing industries, fuel bunkering activities, tanneries, metal works, building materials and engineering industries, logging activities, shipping services and financial institutions among others. These industries through their numerous production activities have impacted tremendously on the biophysical components of the environment mostly soil and vegetation. The vegetation of the area has been seriously modified due to the continuous expansion of industrial units and the indiscriminate disposal of toxic substances.

MATERIALS AND METHODS

Vegetation Sampling and Data Collection: This study assesses the impact of industrial activities on the phytogeography of woody tree species around Calabar Port Authority, by comparing vegetation parameters (structure and floristic) adjoining highly impacted area (Calabar Port otherwise referred to as Nigeria Port Authority) with those of less impacted site (in Odukpani as control). The study sites have similar climate, but have different anthropogenic activities. The highly impacted site (Calabar Port Authority) is completely an industrial estate with patches of farmlands, as such is mostly polluted with industrial effluents. The heavy metal found in the highly impacted site includes caustic soda, dye, hydrocarbons, lead and fecal coliform. On the other hand, the less impacted site is characterized by fallows as a result of farming activities and sporadic logging as well as fuel wood harvesting activities. The vegetation of both communities is purely fallow with patches of woodland. Two belt transects of 80m with interval of 5m in-between was laid in the two study sites. In each site, four quadrats measuring 40x40m were laid and six quadrats (three in the highly impacted site and another in the less impacted site) were randomly selected and studied. However, in each quadrat, all woody stems $\geq$10 centimeters (cm) diameter at breast height (DBH 137cm from the ground) were counted regardless of trees or shrubs species, number of tree species, family composition, tree height, crown and basal cover were examined. Basal cover and crown cover were examined using a line transect method [8, 9]; tree diameter was obtained using measurement at breast height of 137cm; tree height was measured using the trigonometry approach (in each quadrat, only tree species with the highest canopy was measured) [10].

Data Analysis: The vegetation data were quantitatively analysed for species diversity, relative density, relative frequency, relative dominance, basal area, Importance Value Index (IVI) and species evenness. The Importance

Value Index (used to determine dominance) for the enumerated tree species was determined as the sum of the relative density, relative frequency and relative dominance following Cintron and Novelii [11].

- Basal Area (BA) for each plot was calculated using the formula given by Cintron and Novelii [11] cited by Adams *et al.* [12] as:

  Basal Area (BA) = 0.7857 X D^2 (cm)

Where: D = Diameter at breast height taken at 137cm

- Importance Value Index (IVI) for every species in each plot was calculated using the equation given by Cintron and Novelii [11] and Adams *et al.* [12] as:

IVI = Relative density (R_d) + Relative frequency (R_f) +Relative dominance (R_D)

Where:

$$R_d = \frac{\text{No. of trees of species A}}{\text{Total No. of all tree species}} \times 100$$

$$R_f = \frac{\text{Frequency of occurrence of species A}}{\text{Total frequency of all species}} \times 100$$

$$R_D = \frac{\text{BA of all trees of species A}}{\text{Total BA of all species}} \times 100$$

- Species Diversity Index for the two communities was calculated using Shannon-Wiener's Index given by Price [11] as:

$$H^1 = -\sum_{I=1}^{S} pi \log_e Pi$$

Where:

H^1 = Shannon-Diversity Index;
S = Total no. of species in each community;
Pi = The proportion or relative abundance of individual species;
Log_e = Natural logarithm.

- Species Evenness Index for the two communities was calculated using Shannon-Wiener's Index given also by Price [13] as:

$$E = H^1 / \log_e S$$

Where:

E = Shannon-Wiener's Evenness Index;
H^1 = Shannon-Diversity Index for each study community;
S = Total no. of species in each community and
Log_e = Natural logarithm.

Test of Significance: Independent T-test statistical technique was used to determine differences in tree growth variables (crown cover, basal cover and tree size or DBH as well as tree height) between the two study communities. The analysis was done using statistical package for social sciences (SPSS) 17.0 for Windows.

RESULTS AND DISCUSSION

Floristic Composition of Woody Tree Species: In the highly impacted site (HIS), 67 woody stems of 11 tree species belonging to 9 families were encountered, while 191 woody stems of 14 tree species belonging to 12 families were recorded in the less impacted site (LIS) or control vegetation plot (Table 1). Mean stem density was 55 trees per plot or 0.04 ha for vegetation in the LIS, while that for the HIS was 23 trees/ha. The Vegetation in the LIS was more diverse, richer and heterogeneous at both spatial scale and taxonomic levels than those in the HIS. This variation in the composition of woody tree species could be attributed to the industrial activities prominent in vegetation adjoining NPA work environment which made it unfavourable for of trees to adapt to the area as a result of the discharge of toxic substances, consequent site disturbance and poor substrate condition (unfavourable edaphic condition) making it impossible for the establishment of roots. Indeed, the retention and presence of toxic pollutants in the area greatly decreased the habitat potential for flora of the region [14, 5]. In the HIS, Apocynaceae, *Arecaceae* and *Fabaceae* were the most abundant families with 19, 19 and 9 tree species respectively; whereas, in the LIS, only *Fabaceae* was the most abundant family with 26 tree species. The density of trees in the two communities differed significantly ($t_{cal} = 11.085$, $t_{crit} = 2.776$).

Also, results in Table 1 showed that vegetation in the less impacted site was richer, more diverse and heterogeneous than vegetation adjoining Calabar Port Authority (HIS) with species diversity indices of 2.29 and 2.26 respectively; whereas, the index of evenness obtained for vegetation in the highly impacted site (vegetation adjoining Calabar Port Authority) (0.53) revealed what tree species encountered along at the site were fairly equally abundant compared to those in the less impacted site (0.44) that showed some pattern of dominance in occurrence and distribution by tree species like *Elaeis guineensis*, *Alstonia boonei, Musanga cecropioides*, *Anthocleistra vogelii* and *Terminelia superb*. The presumably reason for the moderate species diversity obtained for vegetation adjoining Calabar Port Authority could be that either that the impact of disturbance was not enough to eradicate all the tree species from the area or that tree species might have survived the disturbance due to their adaptive capacity [1].

Structural Composition of Woody Tree Species: Information on the structure of vegetation in the study communities is shown in Table 1. Total basal area for woody stems with ≥10 centimeters (cm) diameter at breast height measured across the 3 plots for vegetation in LIS was 28016.72cm^2 with mean value of 9338.91cm^2 per plot, those in the HIS was 4538.46 cm^2 with mean value of 1512.0 cm^2. However, the distribution of tree size across the 0.04 ha plots using DBH interval classes, revealed the dominance of big stemmed individuals in the less impacted site (LIS), tree species increased with increasing girth and girth class of 91 - 120cm recorded the highest number of individuals or stems of 86; while the DBH interval classes for vegetation in the highly impacted site (HIS) was dominated by small stemmed individuals with girth class of 31 - 60cm having the highest number of stems of 25 (Fig. 1). The low tree growth variables in terms of basal cover, crown cover, tree size (DBH) and tree height recorded in the highly impacted site compared to those in the less impacted site was attributed to the varying site disturbances such as gravel deposition, farming activities and the discharged of toxic substances [1, 5]. These series of disturbances significantly affected the vegetation growth rate. The high structural distribution of vegetation parameters in the less impacted site was due to the relatively low rate of disturbances, as the ecological status of the vegetation was near stable. The result of independent samples test showed that basal area and tree size varied significantly between the two vegetation communities ($t_{cal} = 12.00$, $t_{crit} = 2.776$ and $t_{cal} = 14.623$, $t_{crit} = 2.776$).

Table 1: Consolidated details of vegetation inventory in the two communities

Description	Less Impacted Site (LIS)	Highly Impacted Site (HIS)
No. of tree species	14	11
No. of families	12	9
Density (no. of stems)*	191 (55±2.3)	69 (23±1.7)
Species diversity index	2.29	2.26
Species evenness index	0.44	0.53
Basal area (cm^2)	28016.72 (9338.91±627.09)	4538.46 (1512±179.14)
Height (m)*	84.74 (28.25±3.68)	47.46 (15.82±1.69)
Crown cover (%)*	262.7 (87.6±3.7)	147.6 (49.2±3.1)
Basal cover (%)*	31.1 (10.4±0.3)	16.9 (5.6±1.4)
Tree size (cm)*	326.70 (108.9±3.7)	131.2 (43.7±2.5)

*Difference between means is significant at 5% alpha level

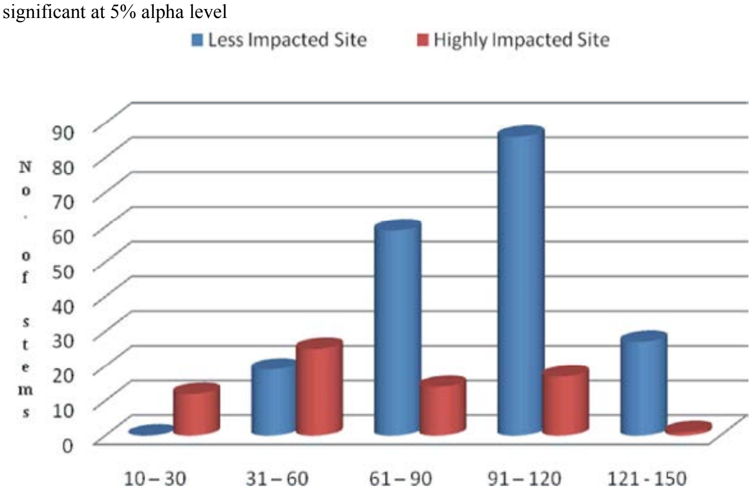

Fig. 1: Stem diameter distribution of treespecies

Table 2: Ecological dominance of top 5 woody tree species

Species	Family	BA (cm^2)	R_D %	D	R_d %	F	R_f %	IVI %
LIS								
Elaeis guineensis	Arecaceae	7091	24.79	21	22.10	3	21.43	68.32
Alstonia boonei	*Apocynaceae*	4538	15.86	28	29.47	3	21.43	66.76
Musanga cecropioides	*Moraceae*	6506	22.74	20	21.05	3	21.43	65.22
Terminelia superba	*Combretaceae*	7546	26.38	11	11.58	2	14.29	52.25
Anthocleistra vogelii	*Potaliaceae*	2924	10.22	15	15.79	3	21.43	47.44
Σ 5 species	Σ 5 families	28605	100.00	95	100.00	14	100.00	300.00
HIS								
Alstonia boonei	*Apocynaceae*	5028	22.79	11	36.67	3	25.00	84.46
Elaeis guineensis	*Arecaceae*	6942	31.47	6	20.00	3	25.00	76.47
Anthocleistra vogelii	*Potaliaceae*	3850	17.45	8	26.67	3	25.00	69.12
Harungana madagascariensis	*Hyperiaceae*	3218	14.59	3	10.00	2	16.67	41.26
Pandanus candelabrum	*Pandanaceae*	3020	13.69	2	6.67	1	8.33	28.69
Σ 5 species	Σ 5 families	22058	100.00	30	100.00	12	100.00	300.00

R_d = relative density; R_f = relative frequency, R_D = relative dominance; BA = basal area; LIS = less impacted site; HIS = highly impacted site

Tree distribution by height indicated that a total of 84.74m was measured across the 3 plots in the less impacted site with a mean value of 28.25m per 0.04 ha plot (Table 1); the tallest tree species in this site were *Albizia zygia* (35.12m), *Alstonia boonei* (27.08m) and *Musanga cecropioides* (22.54m); while in the highly impacted site, a total of 47.46m was measured across the 3 plots with a mean value of 15.82m per plot. The tallest tree species in this site were *Terminelia superb* (18.96m), *Elaeis guineensis* (15.34m) and *Alstonia boonei* (13.16m). The height of trees in the two communities differed significantly ($t_{cal} =$ 3.070, t_{crit} = 2.776) with trees in the less impacted site showing better canopy structure, this characteristic was attributed to favourable site conditions like richness of nutrients, abundance of sapling and absence of industrial effluents [6]. Total basal and crown cover for woody stems with $\geq$10 centimeters (cm) diameter at breast height measured across the 3 plots for vegetation in LIS were 31.1% and 262.7% with mean values 10.4% and 87.6% respectively per plot, while those in the HIS were 16.9% and 147.6% with mean values of 5.6% and 49.2% respectively per 0.04 ha plot. The reason for this apparent variation ($t_{cal} =$ 3.342, t_{crit} = 2.776 and $t_{cal} =$ 7.913, t_{crit} = 2.776) as noted above was as a result of the differences in nutrients and substrate condition as well as industrial activities characterized by the discharge of toxic substances between the two sites.

Ecological Dominance of Woody Tree Species: Dominance which is calculated as the Importance Value Index (IVI) for different tree species varied in relation to species adaptive and tolerant capacity. For this study, the IVI for five (5) tree species with the highest number of stems or individuals enumerated across the 3 plot was calculated for (Table 2). The table depicts that in the LIS, *Elaeis guineensis* was the most ecologically dominant and adaptive tree species with relative density of 22.10%, relative frequency of 21.43% and relative dominance of 24.79%; it was closely followed by *Alstonia boonei* with relative density of 29.47%, relative frequency of 21.43% and relative dominance 15.86%. The third adaptive tree species in the area was *Musanga cecropioides* with relative density of 21.605%, relative frequency of 21.43% and relative dominance of 22.74%. *Elaeis guineensis*, *Musanga cecropioides*, *Alstonia boonei* and *Anthocleistra vogelii* were the most frequently occurring tree species in this site. However, other tree species with wide spatial distribution and speciation were *Terminelia superb* and *Anthocleistra vogelii* with IVI of 52.25 and 47.44 respectively. The presence of large quantities of these ecologically dominant and adaptive tree species revealed a high level of floristic overlap in the forest vegetation due to its moderate stable state and favourable edaphic conditions.

Table 2 also shows information on the dominance of tree species in the HIS. It thus revealed that Alstonia boonei was the most ecologically dominant and adaptive tree species despite the site disturbance associated with the area. It had relative density of 36.67%, relative frequency of 25% and relative dominance of 22.79%; the second ecologically dominant species in the disturbed zone was *Elaeis guineensis* with relative density of 20%, relative frequency of 25% and relative dominance of 31.47%. The third dominant and ecologically adaptive species was *Anthocleistra vogelii* with relative density of 26.67%, relative frequency of 25% and relative dominance of 17.45%. The low level of floristic overlap noticed in here could be attributed to the various disturbance regimes of site expansion, discharge of toxic substances and poor edaphic condition that characterize the area. In addition, *Nypa fruiticans* with immeasurable cover and girth dominated the ocean margins and constituted the major riparian trees species in the HIS, while *Alstonia Boonei, Elaeis guineensis*, *Anthocleistra vogelii*, *Harungana madagascariensis* and *Pandanus candelabrum* dominated the hinterland.

CONCLUSION AND RECOMMENDATIONS

This study has shown that flora and their environment provide a better understanding of ecological consequences of disturbance, as depicted in the result obtained above. The vegetation in the LIS was more diverse and heterogeneous at spatial scale and taxonomic levels than those in the HIS. The variation in the composition of woody tree species was attributed to the industrial activities prominent in vegetation adjoining NPA work environment which made it unfavourable for trees to adapt to the area as a result of the discharge of toxic substances, poor substrate condition (unfavourable edaphic condition) making it impossible for the establishment of roots and consequent site disturbance like dumping of sand and granite as well as the disposing of hydrocarbons. This result agrees with earlier studies, such as those of [4, 5] that heavy metal toxicity in the environment is of great concern because of its effects on plants growth. In that plants under stressed conditions are most likely to be adversely affected by high concentration of heavy metals.

Lead exerts deleterious effects on morphology, growth and photosynthetic processes of plants and causes inhibition of enzyme activities, water imbalance, alterations in membrane permeability and disturbs mineral nutrition. The results obtained for HIS (Calabar Port Environment) indicated two important observations. One, it was either that the impact of disturbance (discharge of toxic substances, oil spills, farming activities, poaching, concrete works, air pollution amongst others) was not enough to eradicate all the species from the area or that plant species might have survived the series disturbances due to their adaptive capacity. Secondly, the LIS with abundant diversity showed a fascinating sensitivity of plant species to disturbance; hence the spatial distribution, ecological dominance, adaptation and composition of vegetation (structure and floristic) depended greatly on the rate of disturbance. The retention and presence of toxic substances in the Calabar Port Authority greatly decreased the habitat potential for flora of the region. The study revealed that industrialization activities strongly influenced the plant communities. Numbers of species increased, while others were unable to survive. Similar result was reported by [1, 14, 4].

However, transformation and fragmentation are not the only results of unplanned and intended developments, as the loss of ecosystem functioning and the local extinction of species also frequently result. Though, the vegetation of Calabar Port Authority is highly threatened, the diversity of available tree species can be protected to facilitate rapid regeneration. On this note, government is encouraged to enact laws to stop the destruction and transformation of remaining hectare of vegetation into industrial estate. If this is urgently implemented, it would not only preserve rare and endemic flora, but also the ecological integrity of ecosystems of the landscape level which is imperative for the continuation of natural resources such as fossil fuels, water and soil with high environmental potentials mostly in the era of climate change.

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