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Crude-Oil-Spill-Induced Spatial Variation in Woody Species Populations of an Oil-Rich Community in Rivers State, Nigeria

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Abstract

We used the spatial analogue technique of studying ecosystem dynamics to evaluate the impact of crude oil pollution on species composition and populations of woody plants in an oil-producing community in Ogoniland located within the Niger Delta Region of Nigeria. Three sites – Unpolluted Site (US), Polluted/Treated Site (PTS) and Polluted/Untreated Site (PUS), were purposively selected for the study. Five 35m x 35m quadrats were randomly laid in each of the sites for woody species enumeration. Woody species diversity was measured using Shannon-Wiener diversity index (H'). Species richness was calculated using Margalef index (R); while similarity in species between sites was measured using Sorensen index (SI). A total of 2166 individuals belonging to 28 species and 16 families were recorded in US; 149 individuals belonging to 14 species and 11 families were recorded in PTS; while 72 individuals belonging to 7 species and 7 families were recorded in PUS. Species diversity was higher in US (H' = 2.917) than in PTS (H' = 2.406) and PUS (H' = 1.801). Species richness was also higher in US (R = 3.515) than in PTS (R = 2.598) and PUS (R = 1.403).

Similarity in species composition was higher between US and PTS (SI = 0.48) than between US and PUS (SI = 0.34), and highest between PTS and PUS (SI = 0.67). The results showed that crude oil pollution has impacted negatively on woody species of the community. However, higher species richness and diversity in PTS than in PUS, and higher similarity in species composition between US and PTS than between US and PUS, underscores the relevance of proper remediation for the regeneration and restoration of the woody species of the area.

Keywords: Ogoniland, Crude oil spillage, Remediation, woody species, Abundance, Diversity

1. Introduction

The Nigerian economy to a very large extent depends on crude oil sales. In Nigeria, the Oil and Gas sector plays a very dominant role to the economy in that 90 percent of the total revenue comes from Oil and Gas production while over 90 percent of the nation's foreign exchange earnings comes from the sales of crude oil (http://www.nnpcgroup.com). This oil is mainly found within the Niger Delta Region of Nigeria – a region that is made up of nine States including Rivers State. In Rivers State is found the Ogoniland – an area endowed with immense crude oil reserves, first discovered at Bomu, Kegbara- Dere, in Gokana Local Government Area in 1958 after Oloibiri, by Shell Petroleum Development Company (SPDC) (Tanee and Albert, 2011). Although, SPDC has not produced oil or gas from Ogoni fields since 1993, major oil pipelines still pass through Ogoniland and oil spills continue to affect the region, due to lack of maintenance and vandalisation of oil infrastructure and facilities.

Evidences of oil spills are apparent in Ogoniland. Between 1993 and mid- 2007, 35 incidences of oil spills were recorded, outside unnoticed slicks and unreported cases (Pyagbara, 2007). Tanee and Albert (2011) reported that popular cases of crude oil spills in Ogoniland include the Bomu Oil Well 2 of 1970 which polluted over 607 hectares of farmland belonging to Kegbara- Dere, and Kegbara-Dere crude oil seepage of 2008 from one of Trans-Niger crude oil pipelines that cross the community.

It is well known that hydrocarbons are harmful to animals and plants (Dorn and Salanitro, 2000). Many workers have reported the impact of crude oil pollution on plants. Michel *et al*. (2002, 2005) observed that petroleum constitutes a pollutant that can persist in the environment for a long period until the vegetation recovers completely, and that its persistence can be explained by the slow biodegradation of hydrocarbons. Oil contamination causes slow rate of germination in plants (Ogbo *et al*, 2009); and this has been attributed to the prevention or reduction of the seeds' access to water and oxygen due to the physical barrier caused by oil (Adam and Duncan, 2002). Crude oil spill has also been reported to reduce species number and live standing herbaceous crop biomass (Debojit and Sarma, 1996); retard and reduce percentage seed germination, plant height, stem density, photosynthetic rate and biomass, and in most cases cause outright death of plants (Qianxin and Mendelssohn, 1996; Pezeshki *et al*., 2000; Ekundayo *et al*., 2001; Tanee and Anyanwu, 2007; Anyanwu and Tanee, 2008).

Environmental pollution in Ogoniland from oil spills remains largely untreated or partially remediated. Despite the bogus claims by the oil companies with regards to remediation, recent UNEP report found 10 of the 15 sites investigated, which SPDC claimed remediated, to contain pollutants exceeding SPDC and government standards. As aptly observed by Adeyemo (2008), "it is uncontroversial to conclude that the Niger Delta Region is environmentally degraded by oil and gas exploration and exploitation activities but our conclusions could not be supported quantitatively because of shortage of relevant data". Therefore, this study was undertaken to quantitatively ascertain the impact of crude oil pollution on populations of woody species in Kegbara-Dere community within Ogoniland, and the effectiveness of the remediation carried out with respect to woody plant species

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regeneration. Specifically, it examined and compared woody plant species in unpolluted, polluted/treated, and polluted/untreated sites.

2. Materials and Methods

2.1 Study Area

Kegbara-Dere is located in Gokana Local Government Area of Rivers State. The town is basically linear. This pattern is as a result of the direction of expansion of the town northwards and southwards. It lies in the humid tropical zone with annual rainfall that ranges from 2000 – 2470 mm, and an annual temperature ranging from 23^{0}C minimum to 32^{0}C maximum (NDES, 2001). Generally, the vegetation of the area is made up of an intricate mixture of plants which belong to different plant families, genera, and species. A Port Harcourt Appeal Court Report (1994) observed that the soils in the polluted areas are acidic, poor in total nitrogen, available phosphorous, organic carbon; have high bulk densities, high level of manganese, low levels of exchangeable cations, low hydraulic conductivities and infiltration capacities; and consequently, very poor plant growth.

2.2 Selection of Study Sites

Three sites were used for the study. The first site which served as the reference ecosystem (4^0 39$^'$ 8" N and 7^0 14$^'$ 26"E) was selected from an unpolluted area (about 5km away from the Kegbara-Dere/Bomu Oil Field). The second site (4^0 39$^'$ 37"N and 7^0 15$^'$ 8"E) was selected from a polluted but treated or remediated area; while the third site (4^0 39$^'$ 41"N and 7^0 15$^'$ 6"E) was selected from a polluted and untreated area. The remediation carried out at the polluted/treated site included manual tillage and bulking of soil; and this was done in 2007 - 2008. These sites were chosen to ascertain the impact of crude oil pollution on the woody species, and the effectiveness of the remediation exercise carried out. Figure 1 is the map of Rivers State showing the study sites.

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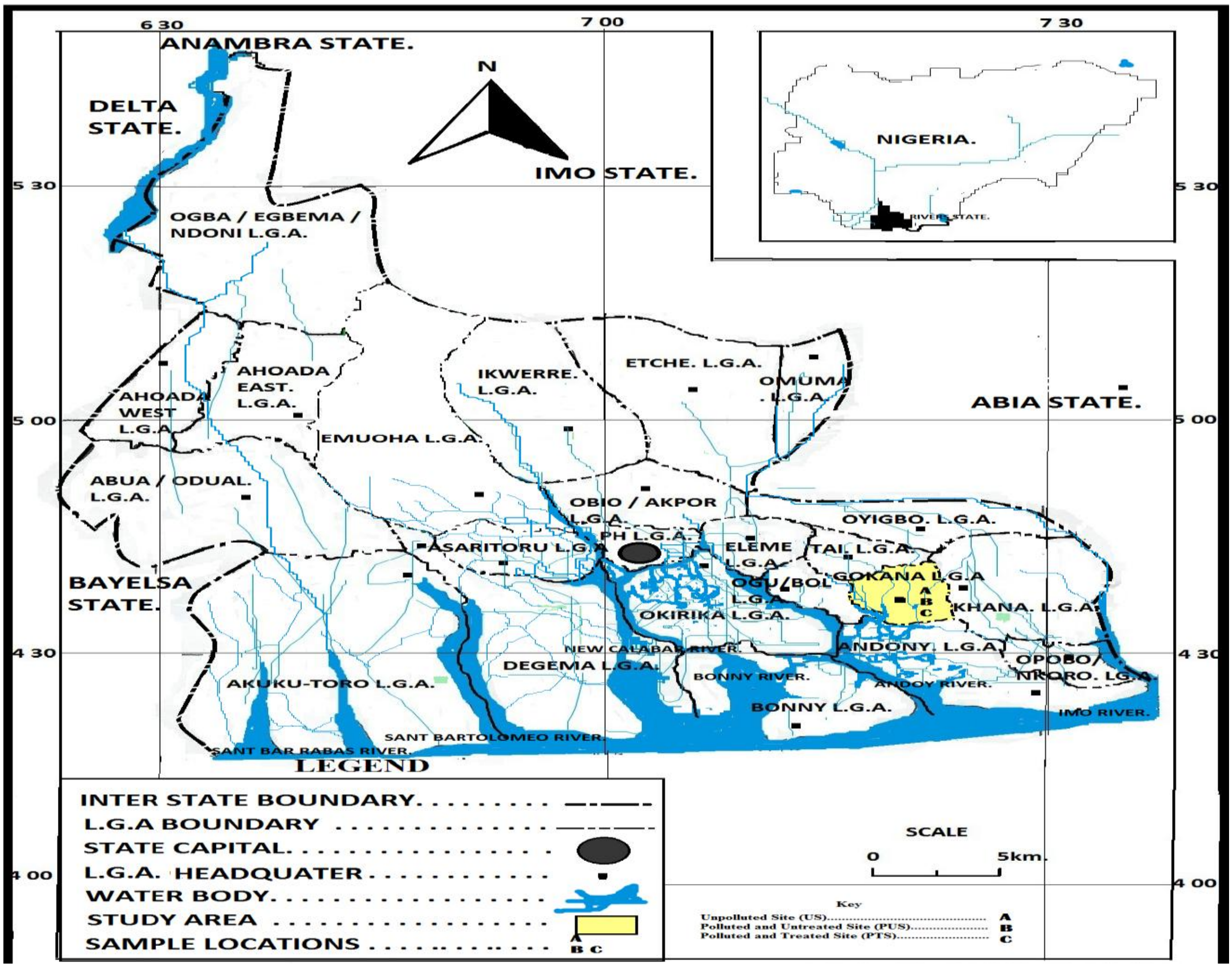

Figure 1. Map of Rivers State showing the Study Sites

Source: Rivers State Ministry of Land and Urban Planning

2.3 Woody Species Enumeration

Five 35m x 35m quadrats were randomly laid in each of the sites for woody species enumeration. This quadrat size falls within the range specified in literature for ecological studies in the humid tropics (Salami 2006). Narrow cut lines, ropes and pegs, were used to demarcate plot boundaries. Species identification was done with the aid of the keys provided by Keay (1989), and Hutchinson and Dalziel (1954). All woody species with a minimum height of 1.5m were identified to species level and the number of individuals counted for each site.

2.4 Data Analysis

2.4.1 Woody Species Diversity

Woody species diversity was calculated for each site using the Shannon- Wiener Diversity Index as described by Kent and Coker (1992).

$$H' = -\sum_{i=1}^{s} pi \ln pi \qquad \text{.......................................} (1)$$

Where:

pi = ni / N

ni = Total number of individuals belonging to ith species

N= Total number of individuals for all species enumerated

s = Total number of species

2.4.2 Woody Species Richness

Species richness index was calculated using Margalef's Richness Index as described by Clifford and Stephenson (1975).

R = S -1 / ln N .... (2)

Where: S = Total number of species

N = Total number of individuals for all species

2.4.3 Similarity in Species Composition between Sites

Similarity in woody species composition between sites was calculated after Margurran (2004) using Sorensen's index.

SI = 2a / (2a + b + c) .... (3)

Where:

a = number of species present in both Sites

b = number of species present in Site 1 but absent in Site 2

c = number of species present in Site 2 and absent in Site 1

3. Results and Discussion

The woody species encountered at the various sites, their habits, abundance and relative abundance, are shown in Tables 1, 2 and 3 for the Unpolluted Site, Polluted/Treated Site, and the Polluted/Untreated Site, respectively. A total of 2166 individuals belonging to 28 species and 16 families were found in the Unpolluted Site; 149 individuals belonging to 14 species and 11 families were found in the Polluted/Treated Site; while 72 individuals belonging to 7 species and 7 families were found in the Polluted/Untreated Site. *Bambusa vulgaris* had the highest relative abundance (11.87%) in the Unpolluted Site while *Chromolaena odorata* had the highest relative abundance in both the Polluted/Treated Site (15.44%) and Polluted/Untreated Site (23.61%).

Tree species dominated in all the sites (Figure 2). Woody species diversity as revealed by the Shannon-Wiener index (Figure 3) was 17.52% and 38.26% higher in the Unpolluted Site than in the Polluted/Treated Site, and the Polluted/Untreated Site, respectively. Also, species richness as shown by Margalef's index (Figure 3) was 26.09% and 60.09% higher in the Unpolluted Site than in the Polluted/Treated Site, and the Polluted/Untreated Site,

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respectively. Similarity in woody species composition (Table 4) was higher between the Unpolluted Site and the Polluted/Treated Site than between the Unpolluted Site and the Polluted/Untreated Site.

Table 1. Checklist of woody plants encountered at the unpolluted site (US)

S/No.	Species	Family	Habit	Abundance	Relative abundance (%)
1	*Albizia zygia*	Leguminosae-Mimosoideae	Tree	55	2.539243
2	*Alchornea cordifolia*	Euphorbiaceae	Shrub	170	7.848569
3	*Anthonotha macrophylla*	Leguminosae-Caesalpinioideae	Tree	17	0.784857
4	*Bambusa vulgaris*	Gramineae	Tree-grass	257	11.86519
5	*Baphia nitida*	Leguminosae-Papilionoideae	Tree	235	10.84949
6	*Cocos nucifera*	Palmae	Tree	4	0.184672
7	*Dactyladenia barteri*	Chrysobalanaceae	Shrub	120	5.540166
8	*Dialium guineense*	Leguminosae-Caesalpinioideae	Tree	120	5.540166
9	*Elaeis guineensis*	Palmae	Tree	56	2.585411
10	*Euphorbia sp.*	Euphorbiaceae	Tree	171	7.894737
11	*Ficus exasperata*	Moraceae	Tree	8	0.369344
12	*Ficus mucuso*	Moraceae	Tree	83	3.831948
13	*Ficus trichopoda*	Moraceae	Tree	175	8.079409
14	*Millettia macrophylla*	Leguminosae-Papilionoideae	Tree	117	5.401662
15	*Musanga cecropioides*	Moraceae	Tree	4	0.184672
16	*Nauclea latifolia*	Rubiaceae	Shrub	4	0.184672
17	*Newbouldia laevis*	Bignoniaceae	Tree	7	0.323176
18	*Olax subscorpioidea*	Olacaceae	Tree	24	1.108033
19	*Pentaclethra macrophylla*	Leguminosae-Mimosoideae	Tree	81	3.739612
20	*Polyalthia sp.*	Annonaceae	Tree	26	1.200369
21	*Pterocarpus sp.*	Leguminosae- Papilionoideae	Tree	41	1.892890
22	*Pycnanthus angolensis*	Myristicaceae	Tree	41	1.892890
23	*Syzygium sp.*	Myrtaceae	Tree	14	0.646353
24	*Treculia africana*	Moraceae	Tree	56	2.585411
25	*Uapaca heudelotii*	Euphorbiaceae	Tree	35	1.615882
26	*Uapaca sp.*	Euphorbiaceae	Tree	20	0.923361
27	*Vitex grandifolia*	Verbenaceae	Tree	143	6.602031
28	*Vitex sp.*	Verbenaceae	Tree	82	3.785780
			Total	**2166**	**100**

Table 2. Checklist of woody plants encountered at the polluted and treated site (PTS)

S/No.	Species	Family	Habit	Abundance	Relative abundance (%)
1	*Alchornea cordifolia*	Euphorbiaceae	Shrub	6	4.026846
2	*Bambusa vulgaris*	Gramineae	Tree-grass	17	11.4094
3	*Baphia nitida*	Leguminosae-Papilionoideae	Tree	19	12.75168
4	*Chromolaena odorata*	Asteraceae	Shrub	23	15.43624
5	*Dacryodes edulis*	Burseraceae	Tree	5	3.355705
6	*Dialium guineense*	Leguminosae-Caesalpinioideae	Tree	11	7.38255
7	*Elaeis guineensis*	Palmae	Tree	7	4.697987
8	*Euphorbia sp.*	Euphorbiaceae	Tree	3	2.013423
9	*Ficus exasparata*	Moraceae	Tree	13	8.724832
10	*Mangifera indica*	Anacardiaceae	Tree	5	3.355705
11	*Musanga cecropioides*	Moraceae	Tree	1	0.671141
12	*Newbouldia laevis*	Bignoniaceae	Tree	17	11.4094
13	*Polyalthia sp.*	Annonaceae	Tree	3	2.013423
14	*Vernonia amygdalina*	Asteraceae	Shrub	19	12.75168
			Total	**149**	**100**

Table 3. Checklist of woody plants encountered at the polluted and untreated site (PUS)

S/No.	Species	Family	Habit	Abundance	Relative abundance (%)
1	*Alchornea cordifolia*	Euphorbiaceae	Shrub	1	1.388889
2	*Bambusa vulgaris*	Gramineae	Tree-grass	9	12.50000
3	*Baphia nitida*	Leguminosae-Papilionoideae	Tree	14	19.44444
4	*Chromolaena odorata*	Asteraceae	Shrub	17	23.61111
5	*Dialium guineense*	Leguminosae-Caesalpinioideae	Tree	11	15.27778
6	*Elaeis guineensis*	Palmae	Tree	13	18.05556
7	*Ficus exasparata*	Moraceae	Tree	7	9.722222
			Total	**72**	**100**

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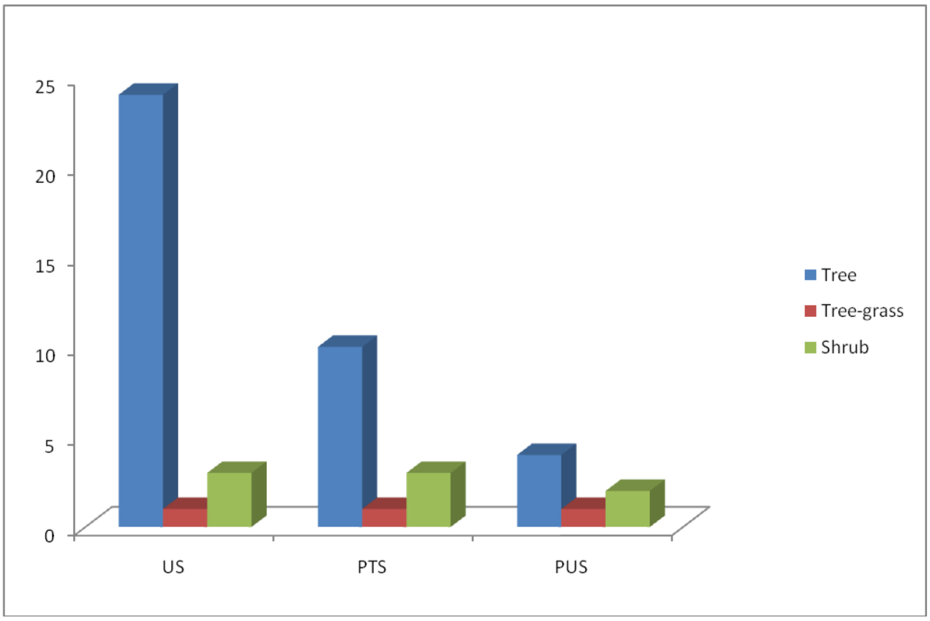

Figure 2. Habits of woody plants at different sites

US = Unpolluted Site; PTS = Polluted and Treated Site; PUS = Polluted and Untreated Site

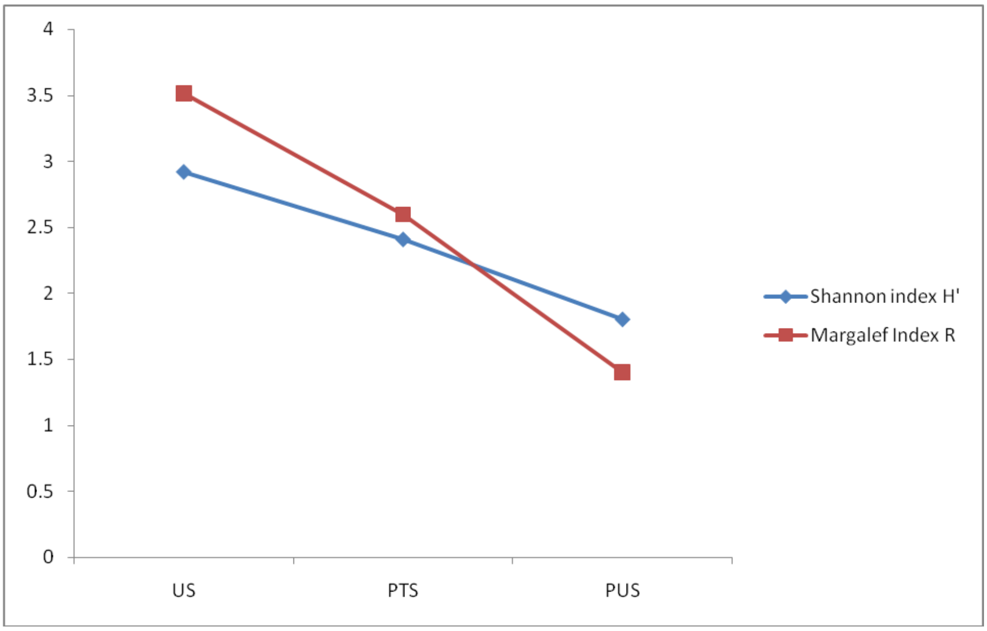

Figure 3. Woody species diversity and richness indices for different sites

US = Unpolluted Site; PTS = Polluted and Treated Site; PUS = Polluted and Untreated Site

Table 4. Sorensen Similarity indices for different sites

	US	PTS	PUS
US	*	0.48	0.34
PTS		*	0.67
PUS			*

US = Unpolluted Site; PTS = Polluted and Treated Site; PUS = Polluted and Untreated Site

Lower species richness, diversity and abundance of woody plants in the polluted sites could be attributed to the harmful effects of crude oil. Crude oil spill has been reported to reduce species number and live standing herbaceous crop biomass (Debojit and Sarma, 1996); retard and reduce percentage seed germination, plant height, stem density, photosynthetic rate and biomass, and in most cases cause outright death of plants (Qianxin and Mendelssohn, 1996; Pezeshki *et al*., 2000; Ekundayo *et al*., 2001; Tanee and Anyanwu, 2007; Anyanwu and Tanee, 2008). However, higher species richness, abundance and diversity of woody plants in the Polluted/Treated Site than in the Polluted/Untreated Site could be attributed to improved soil and growth conditions in the former. Tanee and Albert (2011) reported a drastic reduction in soil total hydrocarbon content and significant improvement in soil conductivity, nitrate and phosphate levels, in remediated soils within the study area.

4. Conclusion

The study has shown that crude oil pollution has impacted negatively on woody species of the community. However, higher species richness and diversity in PTS than in PUS, and higher similarity in species composition between US and PTS, than between US and PUS, underscores the relevance of proper remediation for the regeneration and restoration of the woody species of the area.

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