

## Relationship between Soil and Vegetation in an Oil and Gas Polluted Environment as Revealed by Regression Analysis

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### Abstract

The relationship between soil and vegetation in an oil and gas polluted environment as revealed by regression analysis was investigated. This study was carried out in four different sites in Rivers State purposively selected for ease of accessibility. The study adopted field measurement for data collection. In each experimental sites, soils and vegetation samples were obtain from transects establish from the centre of the polluted area outward. The data was obtained in a 10 m by 10 m quadrats placed at regular of 50 m along the transect from the hydrocarbon-impacted area. A total of six Quadrat areas were sampled along each transect of 300 m in length making a total of 24 Quadrats. The soil and vegetation data were analyzed using multiple regression equation. The relationship between soil and vegetation around the polluted area was achieved through the multiple regression analysis. The technique was selected from the four basic soil nutrients as determinants of vegetation productivity in the polluted area. They include electrical conductivity (EC), sodium (Na), exchange cation capacity (ECC) and magnesium (Mg). They were found to correlate positively with all the species of the vegetation strata of the study area. On the basis of these findings, it was strongly recommended among others that bioremediation, environmental certification and monitoring and environmental education in the area be urgently carried out.

**Keywords:** Environmental education; Bioremediation; Environmental certification; Oil; Gas

### Introduction

Oil and gas exploration began in Nigeria in the late 1950s. When exploitation started in the late 1950s, crude oil which was the target was discovered alongside natural gas. The cheapest way to separate the identified product, crude oil, from the associated natural gas was to burn the gas. A gas flare, alternatively known as gas flare stack; is an elevated vertical found accompanying the presence of oil wells, gas wells, rigs, refineries, chemical plants, natural gas plants and landfills.

They are used to eliminate waste gas which is otherwise not feasible to use or transport. According to Kadana [1], Nigeria gas reserves are estimated at over 100 trillion cubic meters, qualifying Nigeria to be one of the top fifteen (15) countries with proven gas reserves. He explained further that petroleum experts describe Nigeria as a natural gas province with oil in it. A gas flare site may have a number of stacks depending on the size of the flow station. Some of the stacks are vertical, while others horizontal, all of them flaring gas into the atmosphere. Because of its composition, flaring of association gas could results in the release of emissions rich in carbon dioxides, nitrogen oxides, sulphur oxides and soot.

These acid gases are carried down ward as acid deposition (wet and dry deposition) on vegetation, soil and water bodies in communities close to the flare sites. Considering the grave danger posed by oil activities in the Niger Delta region of Nigeria, studies have been carried out by researchers [2,3]. Odu, Adedipe and Spiff [2] examined the environmental effects of Agip oil company flares on soils and crop production. Free-Smith and Taylor [3] reported that damage to crops by high levels of air pollutant in industrial areas has often been reported but that evidence has shown that lower levels of pollutant may reduce yields without causing recognizable lesions to the plants. Research and Monitoring Coordinating Committee (RMCC) of Canada [4] in their long-range transport of air pollutants and acid deposition assessment report stated that nine hard wood trees species in Ontario (Canada) differed in susceptibility to pollutants.

Air pollutants from oil and gas have been reported to reduce environmental quality (soil and vegetation) through pollutants like carbon (C), nitrogen dioxide (NO<sub>2</sub>), sulphur-dioxide (SO<sub>2</sub>) and lead (Pb) among others into the atmosphere [5-7]. Considering the threat of air pollution on an ecosystem of petroleum exploration, there is need for further investigation into the dangers posed by the activities of oil companies. Due to many forms of oil generating environmental pollution evident throughout the Niger Delta region of Nigeria, plants and agricultural soils have been destroyed [8].

Oil extraction and the related operations of multinational oil corporation pose a serious threat to the livelihood of the people in the region as the area is being threatened with oil spills, gas flaring, vegetation and soil degradation [9-12]. An understanding of the problem of soil and vegetation decay especially in the third world countries and Nigeria in particular can only be reliably examined when the complimentary issue of air pollution is allowed to offer a preliminary assessment of its importance relative to the other short-term process.

This has become necessary in the light of the fact that the ecosystem of Nigeria is threatened by the worst form of degradation [13,14], a situation which is complimented by observations that Nigeria's air pollution (gas flare) is the highest in the world [15,16]. It is in the light of the above that this paper is going to investigate the relationship between soil and vegetation in air polluted environment.

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## Study area

Rivers State of Nigeria is a state located in the Niger Delta region of the country. The state is located between latitude 4°30"-5°40"N and longitude 6°40"-7°20"E. The total land area is approximately 10378 km<sup>2</sup>. The topography of the area is a predominant sequence of alluvial deposition in the Delta basin of Massive continental sandstones overlying marginally on marine sandstones shale [17]. Generally, the economically exploitable petroleum deposits, being lighter and more gaseous, occur within the sandstone and shale sequence.

The drainage of the state is synonymous with the drainage of the Niger Delta characterized by a maze of waterways, creeks and swamps criss-crossing the drainage pattern or system. Water is discharged through mostly large and medium-sized natural channels. The larger rivers such as Orashi, Otamiri/Imo rivers system, the Sombreiro, new Calabar River and the coastal creeks often have widths above 100 meters, especially at the middle of the lower courses [17]. Other drainage system includes the Niger which divides into River Nun and Forcados tributaries, which flow south-west and west respectively.

The temperature of the state averages 27°C. The annual range varies from 1°C to 3°C. Rainfall in the state could be described as seasonally variable and energetic in down power. Rain occurs every month of the year; a consistent amount of about 3000 mm. The soil of Rivers State is formed by the accumulation of sedimentary deposit transported by the Niger and Benue. By extension the soils are formed from un-solidated younger sands, highly ferrallitic in nature and experience considerable leaching and erosion respectively. Soils of Rivers State have spatial characteristics. Therefore they are grouped into six main classes: soils of the coastal plain terrace; soils of the sub-recent Niger Terrace; soils of the fresh water alluvial zone; soils of the fresh/salt water Transition zone; soils of the mangrove zone (Tidal mud flats) and soils of the Beach-ridge zone.

The vegetation of Rivers State falls into three principal types of vegetation; mangrove swamp forest which is a specialized type of vegetation which developed very extensively in the Delta of the River

Niger and grow best under brackish water conditions. Fresh water swamp forest found in the fresh water areas and the moist rain forest. This is also known as the rainforest wet or dry evergreen forest. Different species of tree, grasses and shrubs exist in this forest. The forest is characterized by three layers of top, middle and bottom. A great deal of the forest areas has been disturbed at some time or the other, usually by farming or felling for timber. There is therefore, hardly any forest in the study area which is truly primary in the sense that it has never been disturbed by man through his numerous activities. Figure 1 shows the map of the study area in the map of Rivers State.

## Study Methodology

Four different oil and gas polluted sites in Rivers State were purposively selected for this study. The sites are located at Ebocha in Ogba/Egbema/Ndoni Local Government Area, owned by Agip Oil Company (NAOC), Oyigbo North, in Oyigbo Local Government Area owned by Shell Petroleum Development Company (SPDC), Bomu Flow Station (K. Dere) in Gokana Local Government Area owned by SPDC. These sites were selected because of ease of accessibility.

## Soil and vegetation sampling

In each experimental site, Soil and vegetation samples were obtained along transects established from the polluted points outwards. The direction of the transects were determined by the direction of spill. Data were obtained in a 10 m × 10 m quadrat placed at regular interval of 50 m along the transects from the impacted points. A total of six (6) quadrats were sampled along each transects of 300 m in length. Therefore, 24 quadrats were sampled.

## Soil sampling

The soil samples were taken from the quadrat along the transects from the centre of the impacted points. A total of 24 soil samples were collected from 24 quadrats. In each quadrat, two soil samples were taken from the depth of 0-30 cm (0-15, 15-30 cm) with an auger. The T-shaped screw auger was twisted into the soil to the required depth

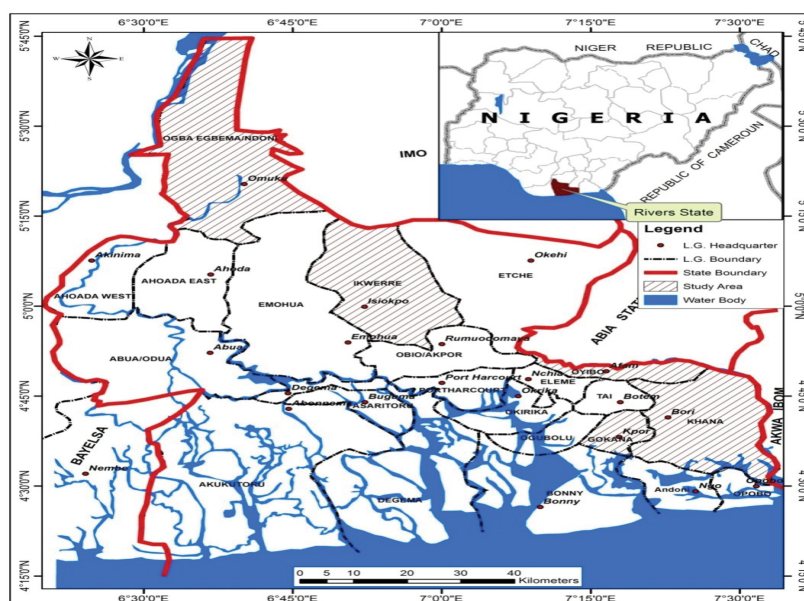


Figure 1: Study area in the map of Rivers State.

and then pulled out. The soil samples that stick to the screw were collected and labelled for laboratory analysis.

In the laboratory, the soil samples were air-dried under room temperature gently crushed and sieved using 2 mm sieve. The sieved samples were properly stored and sub-sampled for the determination of the various soil parameters required for the study. Table 1 shows the list of soil parameters (independent variable and unit of measurement).

### Vegetation sampling

The vegetation samples were carried out in the 10 × 10 m quadrant was the oil samples were collected. The vegetation was divided into three vertical strata for the purpose of structural description. Plants that were 3 meters tall and above description were used. Plants that were 3 meters tall and above were classified “A” stratum. Plant species that were between 1-3 meters were classified as “B” stratum while plants less than 1 meter in height were classified as “C” stratum or ground layer. The vegetation parameters measured includes Height, Diameter and Breast Height (DBH), species density, Basal area, and dominance. Table 2 shows the list of vegetation degradation indices.

### Multiple regression

Multiple regression was used to test the relationship between soil and vegetation in the oil and gas polluted sites. The multiple regression measures the effect of numerous independent variables  $X_1, X_2, X_3, \dots, X_n$  on a single dependent variable  $y$ . The value of  $y$  in a multiple regression problem is given as follows:

$$Y = a + b_{1x_1} + b_{2x_2} + b_{3x_3} + \dots + b_{n x_n} + e$$

Where:

$Y$  = Estimated value of the dependent variable.

$a$  =  $y$  intercept.

S. No	Soil indices	Units of measurement
1	Soil pH	%
2	Electrical Conductivity (EC)	dS/m
3	Organic Matter (OM)	%
4	Total Nitrogen (TN)	%
5	Available Phosphorus (AP)	Mg/kg
6	Calcium (Ca)	cmo/Kg
7	Sodium (Na)	cmo/Kg
8	Magnesium (Mg)	cmo/Kg
9	Potassium (K)	cmo/Kg
10	Exchange Cation Capacity (ECC)	cmo/Kg
11	Base Saturation (BS)	%
12	Exchangeable Acidity (EA)	cmo/Kg

Table 1: List of soil parameters (independent variable and unit of measurement).

S. No	Vegetation indices	Unit of measurement
1	<i>Allanblackia floribunda</i>	s/ha
2	<i>Elaeis guineensis</i>	s/ha
3	<i>Harungana madagascariensis</i>	s/ha
4	<i>Astonia boonei</i>	s/ha
5	<i>Upaca species</i>	s/ha
6	<i>Chromolinae odorata</i>	s/ha
7	<i>Costus afer</i>	s/ha
8	<i>Baphia nitida</i>	s/ha
9	<i>Aspilia africana</i>	s/ha
10	<i>Sida acuta</i>	s/ha

Table 2: List of vegetation degradation indices.

In this study,  $y$ =Vegetation parameters,  $x$ =Soil parameters,  $X_1$ =pH,  $X_2$ =EC,  $X_3$ =OM,  $X_4$ =TN,  $X_5$ =AP,  $X_6$ =Ca,  $X_7$ =Mg,  $X_8$ =Na,  $X_9$ =K,  $X_{10}$ =ECC,  $X_{11}$ =BS,  $X_{12}$ =EA.

### Results and Discussion

The result of the correlation derived from the multiple regression analysis revealed that there is a strong relationship between vegetation diversity and soil nutrient status. For instance, while some basic nutrients such as Mg, OM, Na, K, ECC, BS, EA, Ca, where found to be positively correlated with vegetation species under investigation, pH, EC, TN and AP were found to be significant in accounting for the variation in vegetation diversity in the study area.

Organic Matter (OM) show significant positive correlation with all the species in different stratum, but was particularly relevant with respect to *Allanblackia floribunda*, *Elaeis guineensis*, *Astonia boonei*, *upaca species*, *costusafer*, *Aspilia Africana* and *Sidaacuta*. This result further affirms the significance of organic matter in vegetation growth as asserted by Knapp (1974). Thus it could be said that organic matter are primary nutrient source because is through it that nutrient cations are initially held before they are released for uptake by plants.

Calcium (Ca) was positively correlated with all the species in their various levels, except *Harungana Madascariensis* and *upaca species* in the top layer ‘A’ stratum. Total Nitrogen (TN) was positively correlated with the species in their stratum at a low level of statistical significance. Available phosphorus (AP) also showed positive correlation with all the species. Sodium (Na) also showed positive correlation with all the species in their different stratum. Other soil parameters, potassium, exchange cation capacity (ECC), Base Saturation (BS) and Exchange acidity all showed positive correlation with all the species in their different stratum. The soil parameters that showed negative or low level of correlation with the species are doubtful value for establishing nutrient gradient relationships. This has been noted by Wikum et al. [18].

The positive correlations are indications that the structural development of the species are enhance at the level of nutrient occurring in the soil around the polluted sites while the negative or low correlation are a reverse of this relationship. From the aforementioned, it could be concluded that the nutrients status of the soils around oil and gas polluted may be defined in terms of organic matter, magnesium, sodium, potassium, exchange cation capacity (ECC), base saturation, exchangeable acidity, electrical conductivity, total nitrogen and available phosphorus.

Soil pH with very low and negatively correlation with most of the species could not be considered as a nutrient status indicator in polluted sites. This could possibly be due to the fact that soils in polluted sites have acid deposition. This was further confirmed by Akpojivi et al. [19]. The summary of the relationship between soil and vegetation in the polluted sites clearly emphasized the importance of electrical conductivity, sodium, exchange cation capacity (ECC), magnesium, calcium and a lesser extent potassium, available phosphorus, soil ph and total nitrogen as a strong determinant of species performance around the oil and gas polluted sites.

The multiple regression analyses have selected four strong nutrients determinants out of Twelve (12) determinant variables used in the analysis. These include; EC, Na, Mg, ECC. The presence of these soil variables in the polluted sites could be attributed to their high level of electrical conductivity since they are metals and also macro-nutrients required in large quantities by plants to survive. Overlapping

occurrences of species and the ecological optima or points at which maximum population densities occur can be attributed to functional relationship between nutrients and vegetation measures [18,20]. The available of these nutrients will affect the distribution of the plant species. Hence the absence of the nutrient will ring about the development of an acetone.

## Conclusion

The study revealed that multiple regression analysis led to the selection of some soil variables that contributed to the survival of plants in the oil and gas polluted sites. The presence of nutrients determines the structural development of the plants as well as the relative abundance of the species. The soils and vegetation of the study area are fast losing their fertility and capacity for sustainable agriculture due to the edification of the soils. If what obtains in the study area are extrapolated and generalized for all other oil producing areas in the Niger Delta region of Nigeria, it will be pertinent to say that the physical environment should be sustained for life.

## Recommendations

In view of the various challenges facing the environment and the results obtained, it is recommends as follows:

- This study strongly recommends the use of biological remediation to restore the contaminated soils. This should involve the use of plants such as *Vetiveria zizanioides*, a perennial grass species with deep vibrous root network that can both tolerate chemicals in the soil and can also detoxify soils through time requiring little maintenance.
- Secondly, the application of appropriate and sufficient organic NPK fertilizer to restore the carbon to nutrient ratios to the optimum required to stimulate and sustain microbial activity is required.
- The study also recommends environmental education in the area. This will enable all and sundry to know the need to protect and preserve the environment for the future.
- There is need for environmental monitoring in Nigeria. This is very paramount in view of the fact that since the discovery of petroleum oil in Nigeria in the 1950s, the country has continued to suffer the negative consequences of oil exploitation.
- Finally, the study recommends environmental audit which is a systematic, documented periodic and objective process in assessing an organizations activities and services.

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The authors declare that there is no conflict of interest related to this research work.

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