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Impact Assessment of Oil Exploration Activities on Soil Fertility in Delta State, Nigeria

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ABSTRACT

Background: Limited information on impact of oil exploration on soil fertility in Nigeria is hindering the efforts toward soil improvement. Hence, the impact of oil exploration on soil fertility in four local government areas (LGA), Delta State, Nigeria was evaluated in 2020.
Methods: Two LGAs in oil producing (Ukwani, Ndokwa) and non oil producing (Aniocha South, Ika South) and three communities in each LGA and one crop largely cultivated was purposely chosen. Soil samples were taken from 0-30 cm depth at 10 meters intervals along transverses cut at 100 m apart. The samples were air-dried at room temperature, crushed and made to pass 2 mm sieve. Soil pH, organic matter, nitrogen, phosphorus, calcium, magnesium, potassium and sodium were measured. Data were statistical analyzed and least significance difference at $\alpha_{0.05}$ was used to separate means while Parker's nutrient index was used to rate the fertility.
Result: Ukwani soil was strongly acidity (5.30), Ndokwa was moderately acidity (5.83) while Ika (6.61) and Aniocha (6.27) were slightly acidity. Organic matter (2.54 and 2.48%) and phosphorus (16.98 and 14.51 mg/kg) were medium in Ika and Aniocha whereas, both were low in Ukwani (1.49%, 10.14 mg/kg) and Ndokwa (1.74%, 12.52 mg/kg), respectively. Nitrogen was high in Ika (0.27%) and Aniocha (0.42%), medium in Ndokwa (0.18%) and low in Ukwani (0.15%). Potassium and sodium were high in Ika, Aniocha and Ukwani but medium in Ndokwa. Calcium was high in Ika, medium in Aniocha but low in Ndokwa and Ukwani. Magnesium was high in Ika, Aniocha and Ndokwa but was medium in Ukwani.

Key words: Delta state, Farming communities, Impact assessment, Oil exploration, Soil fertility.

INTRODUCTION

Soil is one of the most critical natural components used for cultivation but worst affected by human activities. Human utilization of land negatively affects the quality by changing its biological, chemical and physical properties. Fertile lands used to produce enough food crops have become infertile due to the oil exploration and this had made farming to be very difficult (Godson-ibeji *et al*., 2016), threatened the communities' potential for sustainable production of food (O Rourke and Connolly, 2003). Large quantities of oil are transported by pipelines that pass through farming communities and there are oil leakages. The oil can clogged soil particles thereby reducing water infiltration and increasing bulk density which hinder root penetration (Ewetola, 2013). It can form film on planting materials which retard water and oxygen absorption and also inhibit the activities of starch phosphorylase that reduces assimilation of starch (Oyem and Oyem, 2013).

Gas flaring, one of the stages in oil exploration generates enormous heat that make the surrounding soils to get scorched and the vegetation looking parched (Giwa *et al*., 2014). Crops grown in this type of environment will definitely show symptoms of leaves chlorosis and plant dehydration. According to Ukegbu and Okeke (2007), growth and yield of crops reduced due to flow station located in the areas. Substances that are introduced into the surrounding environment during oil exploration can change soil compositions and this can drastically reduce its productive capability (Achi, 2003). Crude oil can impair metabolic processes by reducing carbon-mineralizing capacity of micro-organisms. It can alter soil chemical properties by increasing acidity and in this condition, nitrogen fixation and organic matter decomposition are hindered (Osuji and Nwoye, 2007).

The revenue generated from crude oil had improves the nation economy and this had increased budgetary allocations (Nwilo, 1998). The dwindling prices recently made the government to look at how agricultural productivity can be improve to eradicate hunger in Nigeria. Efforts made so far are in areas of provision of improve varieties, fertilizers and training of Agricultural Extension Agent (Irhivben and Omonona, 2013). However, not much work has been done on soil fertility assessment in spite of fact that it is the bed rock of agriculture. It is now pertinent to evaluate the soil fertility status in oil producing

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communities. The finding will give an insight to the extent oil exploration has depletion the soil for remedial action to be taken. Hence this study, investigated the impact of oil exploration on soil fertility in some farming communities in Delta State, Nigeria.

MATERIALS AND METHODS

Study site

The study was conducted in four local government areas [Aniocha South, Ika South (non oil producing), Ukwani and Ndokwa (oil producing)], Delta State in 2020. Oil producing State in Nigeria with estimated population of 193,392,500 and land area of 17,698 sq. kilometers (NPC, 2006). It lies within latitude 5°00 and 6°30[1] North and longitude 5°00 and 6°45[1] East and characterized by two seasons: Dry season (November - April) and rainy season (May - October). Annual mean rain fall ranged from 1850 - 2250 mm, temperature ranges between 25.7 and 28.3°C. Daily relative humidity varied from 63 to 76% with evaporation of about 1450 mm/y (NIMET, 2017). The soils generally were Entisols and of the Suborder Eutric Tropofluvent (FDALR, 1985). The vegetation is unique characterized by grasses, shrubs, timber species and oil palm and rubber plantations were the major cash crops. The relief is gentle undulating plain to nearly level topography in some cases. The drainage could be well drained or poorly drained depending on the time of the year. Land use is based on rain fed agriculture and crops cultivated include cassava, yam, maize, plantain including okra, pepper in large quantities.

Soil sampling and parameters measured

Three communities in each local government area were selected and cassava farm that was largely cultivated was assessed. Auger point investigation was carried out at 10 meters intervals along transverses cut at 100 m apart. Mini soil profile at depth of 30 cm was dug randomly for soil samples collection. Soil pH, organic matter (OM), total nitrogen (TN), available phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) in the soil were measured.

Table 1: Nutrient index rating.

Nutrient index	Range	Remarks
1	< 1.67	L
2	1.67 – 2.33	M
3	>2.33	H

Source: Parker *et al*. (1951)

Laboratory procedures

Soil pH was on a ratio of 1:2 soil/water suspensions. Soil organic matter was analyzed by Walkley and Black method (Nelson and Sommers, 1982). Total nitrogen was determined by micro - kjeldahl digestion method (Jackson, 1962). Available phosphorus was measured with Bray (II) (Olsen and Sommers, 1982). Exchangeable bases were extracted with 1N NH_4OAC, Ca and Mg were read with ethylene diamine tetra-acetic acid titration method while K and Na were read with flame photometry (Jackson, 1964).

Statistical analyses

Data generated were subjected to descriptive statistics and analysis of variance (ANOVA) while least significance difference (LSD) at 5% probability level was used to separate means. Correlation analysis was used to show relationship among nutrient parameters with SAS software version 9.0.

Nutrient index determination

Parker's nutrient index (Table 1) modifies by Kumar *et al*. (2013) was used to rate soil fertility level in the LGAs with reference to Chude *et al*. (2011) soil fertility chart (Table 2).

Nutrient index = {(1x a) + (2 x b) + (3 x c)}/ns

Where:
a stand for number of samples in lower category, b = number of samples in medium category and c = number of samples in higher category and ns = number of samples.

RESULTS AND DISCUSSION

Soil fertility status of the farming communities in Ukwani and Ndokwa West

Soil fertility indices in the oil producing communities are presented in Table 3. All the parameters measured were not significantly different except available P in Ukwani whereas, organic matter, total N and exchangeable K were significantly different in Ndokwa. Soil pH ranged from 5.27 to 5.33±0.09 with a mean of 5.30±0.08 in Ukwani, 5.70 to 5.90±0.22 with a mean of 5.83±0.08 in Ndokwa. Organic

Table 2: Critical limits Soil fertility rating in Nigeria.

	Range			Soil pH level	
Soil properties	Low	Medium	High	Strongly acidic	5.0 - 5.5
Organic matter (%)	< 2.0	2.0-3.0	> 3.0	Moderately acidic	5.6 – 6.0
Total nitrogen (%)	< 0.15	0.15-0.20	> 0.20	Slightly acidic	6.1 – 6.9
Phosphorus (mg/kg)	< 10	10-2	>20		
Potassium (cmol/kg)	< 0.15	0.15-0.3	>0.3		
Calcium (oml../kg)	< 1.5	2-5	>5		
Magnesium (cmol/kg)	< 0.3	0.3-1.0	>1		
Sodium (cmol/kg)	<0.1	0.1-0.3	>0.3		

Source: Chude *et al.* (2011)

matter was lowest in Ebedei and highest in Abi. It ranged from 1.42 to 1.64±0.12% with a mean of 1.49±0.11% in Ukwani, 1.56 to 2.02±0.13% with a mean of 1.74±0.11% in Ndokwa. Total N was highest Abi in Ndokwa. Available P ranged between 9.57 - 11.50±0.47 mg/kg with a mean of 10.14±2.27 mg/kg Ukwani and ranged between 10.83 - 14.90±1.25 mg/kg with mean of 12.52±0.81 mg/kg in Ndokwa. The values Ca ranged from 0.18 – 0.58±0.12 in Ukwani and ranged from 1.14 - 1.41±0.13 in Ndokwa.

Table 3: Soil fertility status of the farming communities in Ukwani and Ndokwa West.

Community	pH	OM	TN	P	Ca	Mg	K	Na
	H_2O	—%—		Mg/kg			—cmol/kg—	
Ukwani LGA								
Umuekun	5.33a	1.43a	0.15a	11.50a	0.36a	0.49a	0.30a	0.39a
Ebedei	5.30a	1.42a	0.14a	9.37b	0.18a	0.53a	0.29a	0.32a
Umuaja	5.27a	1.64a	0.18a	9.57b	0.58a	0.44a	0.27a	0.35a
LSD	0.29	0.41	0.06	1.62	0.41	0.16	0.1	0.13
SE	0.09	0.12	0.02	0.47	0.12	0.05	0.03	0.04
Ndokwa West LGA								
Abi	5.90a	2.02a	0.20a	14.90a	1.41a	1.29a	1.92a	0.23a
Umuseti	5.90a	1.56b	0.14b	10.83a	0.96a	1.33a	1.37b	0.33a
Isumpe	5.70a	1.66ab	0.14a	11.83a	1.14a	0.38b	0.31c	0.31a
LSD	0.77	0.41	0.05	4.32	0.45	0.29	0.33	0.11
SE	0.22	0.13	0.01	1.25	0.13	0.08	0.1	0.03

Means labeled with the same letters are not significantly different at $\alpha_{0.05}$

Note: LSD = least significant difference, SE = standard error

Table 4: Soil fertility status of the farming communities in Ika South and Aniocha South LGA.

Community	pH	OM	TN	P	Ca	Mg	K	Na
	H_2O	—%—		Mg/kg			—cmol/kg—	
Ika South LGA								
Ekuku Agbor	6.70a	1.90b	0.19b	15.63a	2.70a	2.43a	1.04a	0.36a
Abavo	6.60a	2.77ab	0.31a	16.83a	5.23a	1.90a	0.39a	0.22b
Oza Nogogo	6.53a	2.97a	0.33a	18.47a	5.30a	1.63a	0.37a	0.36ab
LSD	0.35	0.91	0.06	5.81	2.64	1.12	0.84	0.14
SE	0.1	0.26	0.02	1.68	0.76	0.32	0.24	0.04
Aniocha South LGA								
Ejeme	6.70a	2.10b	0.23a	15.23a	5.67a	3.20a	0.70a	0.44a
Azamu	6.13b	2.33b	0.44a	13.87a	3.07b	1.80a	0.54a	0.37a
Obi Nti	5.97b	3.00a	0.58a	14.43a	3.67ab	2.10a	0.31a	0.38a
LSD	0.19	0.6	0.36	5.63	2.4	1.65	0.56	0.13
SE	0.05	0.17	0.1	1.63	0.69	0.48	0.16	0.04

Means labeled with the same letters are not significantly different at $\alpha_{0.05}$

Note: LSD = least significant difference, SE = standard error.

Table 5: Soil fertility status at a glance in the four LGAs.

LGA	PH	OM	TN	P	Ca	Mg	K	Na
	H_2O	—%—		—Mg/kg—			—cmol/kg—	
Ika South	6.61a	2.54a	0.27b	16.98a	4.41a	1.99a	0.60b	0.31bc
Aniocha	6.27b	2.48a	0.42a	14.51b	4.13a	2.37a	0.52bc	0.39a
Ndokwa	5.83c	1.74b	0.18c	12.52a	1.17b	1.00b	1.20a	0.29c
Ukwani	5.30d	1.49b	0.15c	10.14c	0.37b	0.49c	0.29c	0.35ab
LSD	0.22	0.3	0.09	2.27	0.88	0.49	0.26	0.06
SE	0.08	0.11	0.03	0.81	0.31	0.17	0.09	0.02

Means labeled with the same letters are not significantly different at $\alpha_{0.05.}$

Note: LSD = least significant difference, SE = standard error.

Magnesium, K and Na content of soils were generally high except in Ukwani LGA.

Soil fertility status of the farming communities in Ika South and Aniocha South LGA

Soil pH values were not significantly different at Ika South but significant differences in Aniocha South (Table 4). The values ranged from 6.53 to 6.70±0.1 with a mean of 6.61±0.08 in Ika South and 5.97 to 6.70±0.05 with a mean of 6.27 in Aniocha South. Organic matter was significantly different in both LGAs. It ranged from 1.90 to 2.97±0.26% with a mean of 2.54±0.11% in Ika South and 2.10 to 3.00±0.17% with a mean of 2.48±0.11% in Aniocha South. Total N was not significantly different at Ika but was significantly different in Aniocha South. Available P was not significantly different in both LGAs. Calcium was generally high in both LGAs while potassium and sodium were generally low.

Soil fertility status at a glance in the four LGAs

Soil pH values in Ika and Aniocha were higher than Ndokwa and Ukwani (Table 5). Organic matter was moderate in Ika and Aniocha but low Ika and Aniocha. Total N was high Ika and Aniocha whereas it was low Ndokwa and Ukwani. Available P was moderate in all the LGAs. Calcium was high in Ika and Aniocha while it was low Ndokwa and Ukwani.

Soil nutrient variability in the LGAs

Soil pH was less variable in the LGAs while OM was less variable in Ukwani and moderately variable in Ndokwa, Ika South and Aniocha South (Table 6). Total N was moderately variable in Ukwani and Udokwa LGA and highly variable in Ika South and Aniocha South. Available P was less variable in Ukwani and Ika South LGA while moderately variable in Ndokwa and Aniocha South. Calcium was highly variable in Ukwani, Ika South and Aniocha South whiles it was moderately variable in Ndokwa. Magnesium and K were highly variable in Ndokwa, Ika South and Aniocha South and moderately variable in Ukwani while Ca was moderately variable in all the LGAs.

Soil nutrients index in the LGA

Soil fertility index are presented in (Table 7). Though, the study areas were generally acidic, Ukwani was more acidic (Strong acidity) while Ndokwa was moderate acidity. Ika South and Aniocha South were slightly acidity. Out of the 7 soil fertility indicators measured, 5 were high and 2 were medium in Ika South. In Aniocha South, 4 were high and 3 were moderate. Contrarily, only Mg was high while other parameters were low and medium in Ndokwa. In Ukwani, 4 parameters were low, 1 was moderate while 2 were high.

Soil pH in the four LGAs is rated as strongly to slightly acidic. The pH range (5.25 - 5.90) in Ukwani and Ndokwa may probably affects nutrient availability leading to the lower level of nutrient recorded. Strong acidic soil conditions hindered organic matter decomposition and nitrogen fixation in soils (Osuji and Nwoye, 2007). The low pH in some communities may affect soil microbial behavior and slow the breakdown of organic material that releases plant

Table 6: Soil nutrient variability in the LGA.

LGA	Soil pH	Rating	Organic matter	Rating	Total nitrogen	Rating	Available phosphorus	Rating	Calcium	Rating	Magnesium	Rating	Potassium	Rating	Sodium	Rating
Ika South	2.6	L	24.8	M	26.0	H	16.5	L	39.0	H	30.1	H	82.1	H	29.3	M
Aniocha	5.5	L	19.4	M	51.6	H	17.3	M	38.0	H	40.5	H	57.1	H	16.8	M
Ndokwa	6.0	L	15.8	M	21.5	M	20.9	M	23.6	M	48.1	H	60.2	H	23.1	M
Ukwani	2.5	L	13.9	L	22.0	M	12.2	L	66.6	H	17.0	M	15.4	M	18.2	M

Note: L – less variable, M – moderately variable, H – Highly variable

Table 7: Nutrients index values of the LGAs.

LGA	pH		Organic m		Nitrogen		Phosphorus		Potassium		Calcium		Magnesium		Sodium	
	Values	Rating	Nutrient index	Rating	Nutrient index	Rating	Nutrient index	Rating	Nutrient index	Rating	Nutrient index	Rating	Nutrient index	Rating	Nutrient index	Rating
Ika South	6.6	Sl A	2.11	M	2.78	H	2.22	M	2.89	H	2.44	H	3.00	H	2.56	H
Aniocha	6.3	Sl A	2.00	M	3.00	H	2.00	M	2.89	H	2.11	M	3.00	H	2.89	H
Ndokwa	5.8	M A	1.33	L	1.89	M	1.78	M	2.33	M	1.00	L	2.67	H	2.33	M
Ukwani	5.3	St A	1.11	L	1.56	L	1.56	L	2.44	H	1.00	L	2.00	M	3.00	H

Note: L – low, M – medium, H- High, LGA – local government area.
Sl A – slightly acidic, M A – moderately acidic, St A – strongly acidic.

nutrients (Oyem and Oyem 2013) causing the lower nitrogen contents in oil producing communities. The nutrient contents in non oil producing LGAs were higher than oil producing areas. This may be linked to the oil exploration activities that reduced the activities of soil microorganisms.

Organic matter in oil producing communities was lower than the non oil producing communities. Chemicals released into the soil during oil exploration might impair metabolic processes which add organic matter (Osuji and Nwoye, 2007), leading to carbon-nitrogen ratio imbalance in the soil (Nkwopara *et al*., 2012). This could cause nitrogen depletion in oil producing communities. The lower organic matter in oil producing communities compared to non oil producing with similar temperature can be attributed to oil exploration activities.

Available phosphorus measured in non oil producing communities were higher this might be attributed to acidic nature in the oil producing community soils that can cause phosphorus fixation (Nkwopara *et al*., 2012). It has been recorded that phosphorus solubility is maximized at pH of about 6.5 (Wang *et al*., 2013) so, the lower pH values found in oil producing communities could also reduce available phosphorus. The microbes which utilize total petroleum hydrocarbon as carbon source can also utilize P when degrading hydrocarbons in the soil (Wang *et al*., 2010).

The level of calcium and magnesium in non oil producing communities invariably implied that oil exploration negatively impacted the elements. It was observed that basic cations can lost in soil with higher acidity (Abii and Nwosu, 2009). The effects of oil exploration activities can be seen from the significant differences between the nutrient in oil producing and non oil producing communities' soil. Oil exploration had no effect on K and Na though, Na is not an essential element so it is not an index for optimum crop production (Abii and Nwosu, 2009).

CONCLUSION

The nutrient contents in Ika south and Aniocha South (non oil producing LGAs) were significantly higher than those in Ukwani and Ndokwa (oil producing LGAs). The correlation studies depict that organic matter and total nitrogen negatively correlated with soil pH. The oil producing communities need nutrients amendment most especially nitrogen, phosphorus and potassium to prevent the soil from further degradation.

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