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Soil Fertility and Productivity Evaluation of Some Benchmark Oil Producing Communities of the Sombreiro Warri Deltaic Plains

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ABSTRACT

Agricultural potentials of soils from four benchmark oil producing communities (Obrikom, Mgbede, Aggah and Okwuzi) in Ogba-Egbema were evaluated. Thirty randomly selected surface soil samples (0-15 and 15-30 cm) were assessed for their physical and chemical properties, THC and BTEX contents. Obrikom soils were strongly acid to acid (pH 4.8 to 5.8 and 4.7 to 6.0 for surface and subsurface horizons respectively); Mgbede soils were acid to neutral (pH 4.5 to 7.4 and 4.7 to 7.3; Aggah soils were strongly acid to acid (4.8 to 5.1 and 4.9 to 6.0) and Okwuzi soils were acid to slightly acid (pH 4.5 to 5.8 and 4.5 to 5.4 respectively for surface and subsurface horizons. Available P was generally low (range of 3.33 to 9.95 mg/kg) with exception of few locations (OB3T, MG1B, MG2T and MG2B) above 10 mg/kg. The results support high P absorption capacity for the soils. TOC ranges in the catchments were: Obrikom (0.76 - 3.02% top; 0.25 - 1.01% bottom); Mgbede (0.71 - 1.15%; 0.37 - 1.09%); Aggah (0.49 - 1.09%; 0.72 -0.86%); and Okwuzi (0.53 - 2.26%; 0.41 - 0.94%). Exchangeable Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} values in the surface layers are generally higher reflecting the soils juvenile status and limited loss of nutrient through leaching. Heavy metals concentrations are generally low with no evidence of pollution. THC and BTEX values are far below critical levels indicating no contamination by petroleum hydrocarbon. Despite the years of oil and gas production in the area, the soils are both fertile and productive. The Soil Evaluation Factor (SEF) and Soil Fertility Index (SFI) ranges of 5 – 35 and 10 – 65 respectively obtained in the area are indications that the soils are productive and fertile.

Keywords: Soil Evaluation Factor, Soil Fertility Index, Soil Productivity, Benchmark Oil Producing Communities

INTRODUCTION

Soil management for improved agricultural productivity is an integral part of land management which may focus on differences in soil types and soil characteristics to define specific interventions aimed at enhancing soil quality. This involves operations, practices, and treatments to protect soil and enhance performance (such as soil fertility or soil mechanics). In agriculture, some amount of soil management is needed both in non-organic and organic types to prevent agricultural land from becoming poorly productive over decades. Soil characterization is an essential tool for classifying soil and determining chemical and physical properties especially those not visible in the field examination (Buol *et al.*, 2003). Hence, it is important in identifying the most appropriate use of soil, estimating production, extrapolating knowledge gained at one location to other often relatively unknown locations, and providing the basis for future research need (Nortcliff, 2006).

The purpose of land evaluation is to predict the usefulness of land either for agriculture or other uses. These evaluations take the form of land suitability or land capability assessment. Land potential is defined as the inherent potential of the land to sustainably generate ecosystem services. Management determines whether the inherent potential is sustainably realized. Land potential includes three elements: (i) inherent potential for generation of ecosystem services, (ii) potential degradation resistance, and (iii) potential resilience, which is the capacity to recover following degradation (UNEP, 2016). Herrick *et al*. (2013) defined land potential to include both potential productivity and potential resilience.

In Ogba-Egbema agricultural potentials in the rural farmer's perspective is mainly determined by rainfall levels (rain-fed agriculture). Climate change, resulting from global and local changes, is partly for the developments in the region's agriculture (Roger *et al*., 2008). It creates disruption and uncertainty of weather pattern and its future impact is preoccupying. Agricultural production requires to be considerably increased to satisfy the requirements of a growing worldwide population while at the same moment improving the storage and adaptation of terrestrial carbon (IAASTD 2009, UNEP 2014). Current efforts focus on intensifying production on presently used lands as well as expanding onto lands not presently used for agriculture. The long- term sustainability of both strategies, and their impacts on ecosystem health and biodiversity, require understanding the potential efficiency of the land, and its resilience which is the capacity to withstand or recover from degradation (UNEP, 2016). Potential productivity and resilience, and response to climate change, can vary widely within a field or watershed, depending on soils, topography, and climate (Webb *et al*., 2012).

Productivity evaluation of soils is expedient in order to know and understand the nature and properties of soils which is critical for making decision with regard to agricultural productivity as well as other uses of land. The evaluation of the potential of soils to produce food, fodder, fibre and fuel can be done through the precise measurement of the nature and properties of the soil as well as proper management of nutrients and moisture requirements (Esayas and Debele, 2006; Teshome *et al.*, 2006). There is paucity of information on soil characterization and agricultural potentials of Ogba-Egbema area of Rivers State. This study was initiated and carried out in some soils of Ogba-Egbema area to make available the necessary soil data for agricultural productivity evaluation.

MATERIALS AND METHODS

Study Area

Ogba-Egbema is located in ONELGA, on the eastern bank of the River Niger and in the heart of the Niger Delta region. The area lies between latitude $4^o39'$ and $5^o33'$ and longitude $6^o30'$ and $7^o00'$E. The area is a typically rural and semi-urban agrarian setting with reported declining land productivity associated with over forty years of neglect due to oil and gas production. Four representative communities: Obrikom, Mgbede, Aggah and Okwuzi, which are home to large numbers of oil wells and facilities, were selected for the study.

Field study and laboratory analysis

A total of thirty surface soils samples taken from fifteen locations and at two soil depths of 0 – 15 and 15 – 30cm were randomly collected from Obrikom, Mgbede, Aggah and Okwuzi. The soil samples were processed and analysed following the procedures of Soil Survey Laboratory Staff (1992).

Total Hydrocarbon Contents (THC)

THC, Poly Aromatic Hydrocarbon (PAH) and Benzene, Toluene, Ethylbenzene and Xylenes (BTEX) were analyzed by shaking 5 gram air dried soil sample with 50 ml isopropyl alcohol. Analar grade known weight of the extract was taken and spiked with an appropriate internal standard (usually 1 chlorooctadene). A gas chromatograph, varian, coupled with a flame ionization detector was used. A 200cm-glass column packed with 3 % OV 101 chromosorb WHP ON 80-100 mesh was used to peak area analysis using the Perkin Elmer Computer.

Computation of Evaluation Indices

Values of Soil Fertility Index (SFI) (Moran *et al*., 2000) and Soil Evaluation Factor (SEF) (Lu *et al.,* 2002) were calculated to quantify soil fertility. The following equations were used to calculate the values (Lu *et al.,* 2002):

SFI = pH +organic matter (%, dry soil basis) +available P (mg kg−1, dry soil) + exch. K (cmolckg−1, dry soil) + exch. Ca (cmolckg−1, dry soil) + exch. Mg (cmolckg−1, dry soil) −exch. Al (cmolckg−1, dry soil)

SEF = [exch. K (cmolckg−1, dry soil) + exch. Ca (cmolckg−1, dry soil) + exch. Mg (cmolckg−1, dry soil) – log(1 + exch. Al (cmolckg−1, dry soil))]×organic matter (%, dry soil) +5

RESULTS AND DISCUSSION

Physical Properties and Productivity Evaluation

The data for the physical properties of the soil is presented in Table 1. Texture is one of the most important properties of a soil, and it greatly affects crop production, land use, and management. Soil texture is directly related to nutrient retention and drainage capabilities. The texture of a soil in the field is not readily subject to change, so it is considered a permanent soil attribute (Brady and Weil 2007). Since "these components of soil are largely unalterable, there is not much you can do to change them" (Gershuny, 1993). The texture for Obrikom varied from sandy loam to sandy clay loam and loamy sand to sand at the surface and sandy clay loam to sand and sandy loam to loamy sand at the subsurface. The texture of Mgbede soils are predominantly sandy loam. For Aggah soils, the texture is majorly sand and Okwuzi soils are characterized by sand texture at the surface and sandy loam texture at the sub surface soils.

Regardless of the texture, every soil type has an inherent capability and its own advantages. The chemical relationships influencing soil fertility are complex and are affected by the parent material from which soil develops, the type of clay present, and the proportions of the different-sized particles (sand, silt, and clay) which also have important effects on soil structure (FAO 2016). For the sandy soils (Okwuzi, Aggah and Mgbede), the categories of crops that would be profitable include vegetables and crops like, cassava, yam, potatoes, maize and shrubs among others. The clayey soils (some Obrikom soils) would be suitable for perennials, vegetables such as fluted pumpkin, pepper, water leaf, etc, shrubs as well as ornamental plants. Also, many moisture-loving trees as well as vegetable and fruit crops do well in silty soils that have adequate drainage (Barton, 2013).

Silt/clay ratio ranged from 0.17 to 3.36, 0.47 to 1. 63 and 0.24 to 2.45 for Obrikom soils (OB1T – OB5B), Mgbede soils (MG1T – MG3B), Aggah and Okwuzi soils (AGIT – OK4B) respectively. According to Sharu *et al.* (2003) "old" parent materials usually have a silt/clay ratio below 0.15 while silt/clay ratios above 0.15 are indicative of "young" parent materials. Results of this study showed that all the soils have silt/clay ratio above 0.15 indicating that the soils are relatively young with high degree of weathering potential. Silt/clay ratios are relatively higher in the surface soils than the subsurface soil. The decrease in silt/clay ratio with depth is an indication that subsoils horizons are more weathered than surface horizons (Yakubu, 2006).

Generally, bulk density ranged between 1.07 g/cm^3 to 1.81 g/cm^3 in the soils of Ogba Egbema. It ranged between 1.16 to 1.64, 1.18 to 1.54, 1.14 to 1.56 and 1.07 to 1.81 for Obrikom soils (OB1T – OB5B), Mgbede soils (MG1T – MG3B), Aggah soils (AG1T – AG3B) and Okwuzi soils (OKIT – OK4B). Plant performs best in bulk densities below 1.4 g/cm^3 and 1.6 g/cm^3 for clayey and sandy soils respectively (Donahue *et al;* 1990). Bulk density values higher than these indicate possible limitations to root growth and penetration (Doran and Jones 2011). The total porosity values of the soils ranged from 18 to 51%. Generally, the soils of the study area are characterized by low total porosity. These soils are easily eroded under heavy rainfall. In a previous study Kamalu (2015) had attributed flooding and erosion risk of some soils of the Ogba- Egbema area to low total porosity. According to Kamalu (2017), soil bulk density, soil porosity and particle density enable the compaction and aeration of the soil. The combining impact of the predominantly sand to loamy sand texture with bulk density and porosity further enhances the performances of plants in the area and are indicative of moderate to high inherent soil quality.

Chemical Properties and Productivity of the Soils

Data on the chemical characterization of the soils of the study area are presented in Table 2.

Soil pH

The study area had a wide range in soil pH with the following values: 4.8 to 5.8 and 4.7 to 6.0 (Obrikom); 4.5 to 7.4 and 4.7 to 7.3 (Mgbede); 4.8 and 4.9 to 5.1 and 6.0 (Aggah); and 4.5 to 5.8 and 4.5 to 5.4 (Okwuzi) for the surface and subsurface soils respectively. With the exception of Mgbede area the soils are generally lightly acid to acid to strongly acid (Gbadegesin and Akinbola, 1995). The soil pH values recorded are predominantly strongly acid through acid. This result might be attributed to high rate of rain fall leading to leaching loss of basic cations and the possibility that the parent materials of the soils are of acid in origin. This observation is in agreement with the views of Chiekezie *et al.* (2010). In Mgbede area the soils are near neutral with some stations (MG2T, MG2B and MG3T) having pHs of 7.4, 7.3 and 6.8 respectively, which are not common in the study area. It could be recalled that MG2 and MG3 sample locations are close to local palm oil extraction facility. The disposal of the ash and other wastes from the extraction facility may have affected the pH values.

Table 1: Physical Properties of the Soils

Sample Id	Bulk Density g/cm^3	Particle Density g/cm^3	Porosity	Percent (%) Sand	Silt	Clay	Silt : Clay	Textural Class
OB1T	1.16	1.7	32	46.2	16.2	37.6	0.43	Sandy Clay
OB1B	1.21	1.8	33	60.4	7.4	32.2	0.23	Sandy Clay Loam
OB2T	1.19	1.6	26	68.4	11.4	20.2	0.56	Sandy Clay Loam
OB2B	1.18	1.7	31	62.4	9.4	28.2	0.33	Sandy Clay Loam
OB3T	1.50	2.2	32	86.4	9.4	4.2	2.23	Loamy Sand
OB3B	1.54	2.4	36	90.4	1.4	8.2	0.17	Sand
OB4T	1.35	2.2	47	90.4	7.4	2.2	3.36	Sand
OB4B	1.38	2.4	42	82.4	3.4	14.2	0.24	Sandy Loam
OB5T	1.64	2.4	A	96.4	1.4	2.2	0.64	Sand
OB5B	1.62	2.2	26	87.8	4.0	8.2	0.49	Loamy Sand
Mean	**1.38**	**2.1**	**31**	**77.1**	**6.2**	**15.7**	**0.87**	
MG1T	1.27	1.8	29	78.4	9.4	12.2	0.77	Sandy Loam
MG1B	1.18	2.0	41	70.4	9.4	20.2	0.47	Sandy Loam
MG2T	1.19	2.4	50	92.4	3.4	4.2	0.81	Sand
MG2B	1.22	2.4	49	88.4	5.4	6.2	0.87	Loamy Sand
MG3T	1.54	2.2	30	78.4	11.2	10.4	1.08	Sandy Loam
MG3B	1.41	2.5	44	78.4	13.4	8.2	1.63	Sandy Loam
Mean	**1.30**	**2.2**	**41**	**81.1**	**8.7**	**10.2**	**0.49**	
AG1T	1.40	2.1	33	92.4	5.4	2.2	2.45	Sand
AG1B	1.39	2.4	42	96.4	5.4	2.2	2.45	Sand
AG2T	1.52	2.5	39	82.4	1.4	2.2	0.64	Sand
AG2B	1.14	2.2	4	96.4	3.4	14.2	0.24	Sandy Loam
AG3T	1.27	2.4	47	96.4	1.4	2.2	0.64	Sand
AG3B	1.56	2.4	35	92.4	1.4	2.2	0.64	Sand
Mean	**1.38**	**2.3**	**33**	**92.7**	**3.1**	**4.2**	**1.18**	
OK1T	1.27	2.2	42	82.4	5.4	2.2	2.45	Sand
OK1B	1.37	2.2	38	90.4	3.4	14.2	0.24	Sand Loamy
OK2T	1.07	2.2	51	87.8	5.4	4.2	1.29	Sand
OK2B	1.30	2.1	38	87.8	4.0	8.2	0.49	Loamy Sand
OK3T	1.81	2.2	18	92.4	3.4	4.2	0.81	Sand
OK3B	1.42	2.5	43	96.4	1.4	2.2	0.64	Sand
OK4T	1.42	2.2	35	96.4	1.4	2.2	0.64	Sand
OK4B	1.48	2.5	41	82.4	3.4	14.2	0.24	Sandy Loam
Mean	**1.39**	**2.3**	**38.3**	**89.5**	**3.5**	**6.5**	**0.85**	

Total Organic Carbon, Total Nitrogen and Available Phosphorus

Total organic C in the Obrikom soil samples varied from 0.76 to 3.02% in the surface soil and 0.25 to 1.01% in the subsurface layer (Table 2) whereas in the Mgbede soil samples, organic C varied from 0.71 to 1.15% and 0.37 to 1.09% in the surface and subsurface soil layers, respectively. Soils from Aggah recorded total organic C values varying from 0.49 to 1.09% and 0.72 to 0.86% whereas those from Okwuzi were 0.53 to 2.26% and 0.41 to 0.94% in the surface and subsurface soil layers, respectively. Gbadegesin and Akinbola (1995) reported that soils with organic C less than 0.3% is very low; 0.0-1.0%, low; 1.0-2.0%, medium; 2.0-5.0%, high; and greater than 5.0%, very high. As presented in Table 2, organic C values of OB2T, OB4T, OB5T and OK2T fall into high category, OB1T, OB2B, MG1B, MG2T, MG3T, AG2T and AG3T fall into medium category OB5B into very low category and the remaining eighteen into low category. Low organic C in the Niger Delta area has been ascribed to climatic, local relief and frequent flushing by sea water intrusions (Gbadegesin and Akinbola, 1995). The low organic C values recorded in this study are associated with climatic factors and less return of organic materials to the soil due to high frequency of cultivation (Yihenew, 2002).

Total N in the Obrikom soil samples varied from 0.04 to 0.15% and 0.01 to 0.05% in surface and subsurface soil samples while the samples from Mgbede recorded values varying from 0.04 to 0.06% and 0.02 to 0.06% in the respective soil layers. For the Aggah soil samples, total N varied from 0.03 to 0.06% and 0.04% in the surface and subsurface layers while in the Okwuzi samples, total N varied from 0.03 to 0.11% and 0.02 to 0.05% in the respective layers. Total N values are generally low and agreed with what was recorded by Egbuchua and Ojobor (2011) for hydric soils in the Niger Delta area.

Available P in the Obrikom soil samples varied from 3.33mg/kg to 6.66mg/kg and 23.31mg/kg in the surface and subsurface soil layers while Mgbede soil available P varied from 3.33mg/kg to 49.95mg/kg and 13.32mg/kg in the respective soil layers. In the Aggah soil samples, available P varied from 3.33mg/kg to 6.66mg/kg in both layers and that of Okwuzi was 3.33mg/kg in all the layers (Table 2). Available P values were generally low except for OB3T, MG1B, MG2T and MG2B. Egbuchua and Ojeifo (2007) and similarly recorded low available P values for some hydric soils in the Niger Delta area which is associated with high content of siliceous parent materials, high P absorption capacity and the acidic nature of the soils.

Carbon-Nitrogen Ratio

Carbon-Nitrogen Ratio (C:N) is usually a single number (Flavel and Murphy, 2006). It is defined as the ratio of the weight of organic carbon to the weight of total nitrogen in a soil or organic matter. It is the relationship between organic matter and nitrogen content of soils. C:N of the sampling stations ranges from 16 to 27 as shown in Table 2. The mean of the C:N follow the trend Aggah (19) < Okwuzi (20) < Mgbede (21) and Obrikom (21). The implications of the narrow C:N ratios in some of the soils as shown in Table 2 reflect high levels of microbial activity and rapid decomposition of organic matter with concomitant release of nutrient elements into soil solution for plant uptake. This conforms to the observation of Akpan-Idiok (2012).

Exchangeable Cations

Generally alkaline earth metals in soils from the study area decrease with increase in depth which is indicative of the fact that the soils have not been subjected to extreme weathering (ILACO-NEDECO, 1966; Anderson, 1967). In the soils of Obrikom, exchangeable K^+ varied from 0.31 to 2.36 Cmol/kg soil and 0.12 to 1.30 Cmol/kg soil in the surface and subsurface respectively, while in the Mgbede soils, exchangeable K^+ varied from 0.18 to 0.32 Cmol/kg soil and 0.11 to 0.13 Cmol/kg soil in the respective layers. Similarly, in Aggah area, exchangeable K^+ varied from 0.12 to 0.33 Cmol/kg soil and 0.13 to 0.93 Cmol/kg soil in the surface and subsurface layers while in the Okwuzi samples, exchangeable K^+ varied from 0.19 to 2.19 Cmol/kg soil and 0.18 to 1.13 Cmol/kg soil (Table 2) in the respective layers. Generally, exchangeable K^+ values are higher in the surface layer than in the subsurface layer and exchangeable K+ is moderate which shows that the soils are young and leaching loss of K^+ from the surface layer is limited. Similarly, exchangeable Na values are generally moderate to high. Whereas, exchangeable Na^+ in the Obrikom soils varied from 0.16 and 2.15 Cmol/kg soil and 0.15 and 1.15mg/kg in the surface and subsurface layers, for the Mgbede soils, exchangeable Na^+ varied between 1.09 and

2.12 Cmol/kg soil and 0.98 and 1.30 Cmol/g soil in the respective layers. In the Aggah soil samples, exchangeable Na^+ varied between 0.68 and 1.12 Cmol/kg soil and 0,17 and 1.11 Cmol/kg soil, in the Okwuzi soils, exchangeable Na^+ varied between 0.14 and 1.75 Cmol/kg soil and 0.14 and 1.04 Cmol/kg soil in the surface and subsurface layers, respectively. Like K^+, exchangeable Na^+ values in the surface layer are generally higher than the values in the subsurface reflecting the recentness in the origin of the soils parent materials.

Exchangeable Ca^{2+} in the Obrikom soils varied from 1.27 to 2.11 Cmol/kg soil and 0.18 to 2.12 Cmol/kg soil in the surface and subsurface layers while in the Mgbede soils, Ca^{2+} varied from 1.62 to 1.98 Cmol/kg soil and 0.16 to 1.35 Cmol/kg soil in the respective layers. In Aggah area exchangeable Ca^{2+} varied between 1.56 and 2.10 Cmol/kg soil and 0.21 and 0.95 Cmol/kg soil in the surface and subsurface layers, in the Okwuzi samples, exchangeable Ca2+ varied between 1.57 and 1.92 Cmol/kg soil and 0.80 and 2.00 Cmol/kg soil in the respective layers. Similarly, exchangeable Ca^{2+} values are generally higher in the surface than in the subsurface layer.

Similar to the results obtained for exchangeable K^+, Na^+ and Ca^{2+}, exchangeable Mg^{2+} values are generally higher in the surface than in the subsurface layers of most of the sampling locations. For instance, in the soils from Obrikom, exchangeable Mg^{2+} varied from 1.93 to 3.59 Cmol/kg soil in the surface layer and 0.78 to 4.40 Cmol/kg soil in the subsurface layer while in the Mgbede soil samples, exchangeable Mg^{2+} varied from 2.91 to 3.31 Cmol/kg soil and 0.72 to 2.10 Cmol/kg soil in the respective soil layers. For the soil samples from Aggah, exchangeable Mg^{2+} varied from 2.71 to 3.58 Cmol/kg soil and 0.94 to 1.11 Cmol/kg soil in the surface and subsurface layers while for the soils from Okwuzi, exchangeable Mg^{2+} varied from 2.72 to 3.13 Cmol/kg soil and 1.01 to 3.21 Cmol/kg soil in the respective soil layers.

Exchangeable Acidity (EA), Cation Exchange Capacity (CEC) and Base Saturation

EA in the soils from Obrikom increased with increase in depth while in the samples from Mgbede, Aggah and Okwuzi, EA decrease with increase in depth which could be reflective of the fact that the soils have not gone through much leaching. EA in the Obrikom soil samples varied from 0.16 to 1.12 Cmol/kg soil in the surface and 0.68 to 1.84 Cmol/kg soil in the subsurface while in Mbede, EA varied from 0.84 to 1.04 Cmol/kg soil and 0.36 to 0.80 Cmol/kg soil in the respective soil layers. In the Agah soils, EA varied from 0.68 to 1 92 Cmol/kg soil and 0.44 to 0.68 Cmol/kg soil while in the soils from Okwuzi, EA varied from 0.88 to 1.56 Cmol/kg soil and 0.04 to 1.21 Cmol/kg soil (Table 2), in the respective layers.

Effective cation exchange capacity (E.CEC) similarly decreased with depth in almost all the locations. E.CEC of the samples collected from Obrikom varied from 6.40 to 9.37 Cmol/kg soil and 2.76 to 8.63 Cmol/kg soil in the surface and subsurface while in Mgbede E.CEC varied from 7.07 to 8.53 Cmol/kg soil and 2.73 to 4,94 Cmol/kg in the respective layers. For the samples collected from Aggah, E.CEC in the surface and subsurface layers varied from 5.84 to 8.79 Cmol/kg soil and 2.93 to 3.77 Cmol/kg soil while in the soil samples from Okwuzi, E.CEC varied from 6.68 to 8.91 Cmol/kg soil and 2.16 to 7.64 Cmol/kg soil respectively for surface and subsurface respectively. E.CEC values are moderate to high which is attributed to recentness of the parent materials that form the soils (Jungerius and Levelt, 1964; Anderson, 1967; Short and Stauble, 1967) and the presence of easily weatherable minerals rich in nutrient cations (Porrenga, 1966; Loganathan *et al.,* 1995). Sanchez (1976) reported that tropical soils with E.CEC values of 4 Cmol/kg soil and above are capable of withstanding heavy leaching loss of nutrients. In this study, apart from OB1B, OB3B, Mg2B, AG1B, AG2B, OK1B and OK2B, which recorded ECEC values lower than 4 Cmol/kg soil, more than seventy percent of the soils had ECEC values higher than the critical value of 4 Cmol/kg soil Sanchez (1976). Apart from OB1B and OB3B, even the samples with ECEC values less than 4 Cmol/kg had base saturation values higher than 75%. Generally, the soils are highly base saturated which might be attributed to the recentness of the parent materials that formed the soils and the richness of the parent materials in weatherable minerals (Porrenga, 1966; Loganathan *et al.*, 1995).

Total Hydrocarbon Content (THC) and Heavy Metal Status of the Soils

The range of Total hydrocarbon Content (THC) in study area was 0.1 – 8.6 mg/kg which is far below the 50 mg/kg and 86 mg/kg biogenic hydrocarbon production levels reported by CONCAWE (1972) and Howells (1983) respectively (Table 3). Department of Petroleum Resources (DPR, 2002) considered 10 mg/kg as the critical concentration level of THC and BTEX in inland soils in the country but the values recorded in this study are far below the 10 mg/kg critical level. The highest THC level recorded in OB4T (8.6 mg/kg) is still lower than 10 mg/kg critical level set by DPR (2002) for inland soils of Nigeria. The recorded THC levels are indicative of the fact that the sampled spots have not been contaminated by crude oil.

Table 2: Chemical Characteristics of the Soils of the Study Area

SAMPLE ID	pH	EC (µS/cm)	TOC (%)	TOM (%)	Total N (%)	C:N	Avail P (mg/kg)	Exch. Cations (Cmol/kg)				Exch. Acidity (Cmol/ kg)	ECEC (Cmol/kg)	B.S. (%)
								K^+	Na^+	Ca^{2+}	Mg^{2+}			
OB1T	4.8	53.1	1.95	3.36	0.10	20	6.66	1.91	1.13	1.27	1.93	0.16	6.40	98
OB1B	4.7	10.7	0.49	0.84	0.02	25	6.66	0.15	0.65	0.18	0.78	1.20	2.96	59
OB2T	4.9	211.0	3.02	5.21	0.15	20	3.33	2.36	2.15	1.40	2.34	1.12	9.37	88
OB2B	4.8	67.5	1.01	1.74	0.05	20	6.66	1.30	1.15	0.98	1.20	1.24	5.87	79
OB3T	4.8	31.5	0.76	1.31	0.04	19	3.33	1.17	1.00	2.11	2.59	0.84	8.71	90
OB3B	5.2	0.0	0.43	0.74	0.02	22	23.31	0.19	0.16	0.26	0.99	1.16	2.76	58
OB4T	5.8	0.0	2.28	3.93	0.11	21	3.33	1.31	0.16	1.93	3.17	0.40	6.97	94
OB4B	6.0	38.8	0.41	0.71	0.02	21	3.33	0.12	1.07	1.01	1.15	0.68	4.03	83
OB5T	5.8	0.0	3.02	5.21	0.15	20	6.66	0.31	0.16	2.00	3.25	0.92	6.64	86
OB5B	5.2	0.0	0.25	0.43	0.01	25	3.33	0.12	0.15	2.12	4.40	1.84	8.63	79
MEAN	**5.2**	**41.26**	**1.36**	**2.35**	**0.07**	**21**	**6.66**	**0.89**	**0.78**	**1.33**	**2.18**	**0.96**	**6.23**	**81**
MG1T	4.5	110.3	0.71	1.22	0.04	18	3.33	0.26	2.12	1.62	2.91	1.04	7.95	87
MG1B	4.7	33.5	1.15	1.98	0.06	19	9.99	0.13	1.00	1.35	2.10	0.36	4.94	93
MG2T	7.4	145.6	1.09	1.52	0.04	27	49.95	0.32	2.00	1.98	3.31	0.92	8.53	89
MG2B	7.3	70.8	0.88	1.52	0.04	22	13.32	0.11	1.30	0.16	0.72	0.44	2.73	84
MG3T	6.8	44.5	1.07	1.85	0.05	21	3.33	0.18	1.09	1.85	3.11	0.84	7.07	88
MG3B	4.8	29.5	0.37	0.64	0.02	19	3.33	0.13	0.98	1.00	1.31	0.80	4.22	81
Mean	**5.9**	**43.4**	**0.88**	**1.46**	**0.04**	**21**	**13.88**	**0.19**	**1.42**	**7.96**	**2.24**	**0.73**	**5.91**	**87**
AG1T	5.0	18.7	0.49	0.84	0.03	16	3.33	0.21	0.68	1.56	2.71	0.68	5.84	88
AG1B	5.2	0.0	0.86	1.48	0.04	22	3.33	0.93	0.17	0.21	0.94	0.68	2.93	77
AG2T	5.1	26.2	1.09	1.88	0.06	18	6.66	0.33	1.02	2.10	3.58	1.76	8.79	80
AG2B	4.9	46.7	0.72	1.24	0.04	18	3.33	0.15	1.12	0.95	1.11	0.44	3.77	88
AG3T	4.8	42.4	1.03	1.78	0.05	21	6.66	0.12	1.11	1.68	2.95	1.92	7.78	75
AG3B	6.0	34.4	0.76	1.31	0.04	19	3.33	0.13	1.04	0.92	1.10	0.56	3.75	85
Mean	**5.2**	**28.1**	**0.83**	**1.42**	**0.04**	**19**	**4.44**	**0.31**	**0.86**	**1.24**	**2.07**	**1.01**	**5.48**	**82**
OK1T	4.5	37.3	0.72	1.24	0.04	18	3.33	0.21	1.05	1.57	2.73	1.12	6.68	83
OK1B	4.5	28.5	0.82	1.41	0.04	21	3.33	0.20	0.99	0.84	1.05	0.36	3.44	90
OK2T	4.8	0.0	2.26	3.90	0.11	21	3.33	2.19	0.14	1.90	3.12	1.56	8.91	82
OK2B	4.8	0.0	0.94	1.62	0.05	19	3.33	0.17	0.14	0.80	1.01	0.04	2.16	98
OK3T	5.8	26.8	0.53	0.91	0.03	18	3.33	1.71	0.99	1.70	3.01	0.00	8.29	89
OK3B	5.3	0.0	0.72	1.24	0.04	18	3.33	1.13	0.15	1.22	1.72	0.64	4.86	87
OK4T	5.5	0.68	0.68	1.17	0.03	23	3.33	0.19	1.75	1.92	3.13	1.52	8.51	82
OK4B	5.4	0.41	0.41	0.71	0.02	21	3.33	0.18	1.04	2.00	3.21	1.21	7.64	84
Mean	**5.1**	**11.71**	**0.89**	**1.53**	**0.05**	**20**	**3.33**	**0.75**	**0.78**	**1.43**	**2.37**	**0.81**	**6.31**	**87**

Benzene, Toluene, Ethylbenzene and Xylenes (BTEX)

BTEX values recorded were far below 1 mg/kg (Table 3.0) while Department of Petroleum Resources (DPR) considered 10 mg/kg as the critical concentration level of BTEX in inland soils of Nigeria. The BTEX values recorded in this study indicated that the sampled soils have not been contaminated by petroleum hydrocarbon.

Heavy Metals

The concentrations of heavy metals in the soils from the study area are presented in Table 3 while on Table 4 is presented background levels of heavy metals in some other countries. Comparing the concentration of heavy metals in these soils (Table 3) and the background levels of the heavy metals in other countries (Table3) there is no evidence of heavy metal pollution in these soils.

Soil Fertility Evaluation

Results for Soil Fertility Index (SFI) and Soil Evaluation Factor (SEF) are presented in Figures 1 - 4. The Figures compare Soil Fertility Index (SFI) and Soil Evaluation Factor (SEF) of Obrikom (OB), Mgbede (MG), Aggah (AG) and Okwuzi (OK) and used same to assess the quality of the soils in the area. The results showed that SEF was generally lower than SFI with ranges of SEF (5 - 35) and SFI (10 - 65).

In the Obrikom soils, SFI was higher in OB3T, OB4T and in all the bottom samples while SEF was higher in OB1T, OB2T and OB5T. The highest SFI (30) value for Obrikom soil was recorded in OB3B while the highest SEF (36) was recorded in OB2T (Fig. 1). In the Mgbede soils, SFI values were higher in all the soil samples and the highest value (65) obtained in this study was recorded in MG2T (Fig. 2). Similarly, SFI values were higher in all the soil samples from Aggah with the highest SFI and SEF values recorded in AG2T (Fig. 3). In Okwuzi soil higher SFI values were recorded in all the soil samples except OK2T where a higher SEF value was recorded (Fig. 4). Comparing the SFI and SEF values using the moving average lines in Figures 2 to 5, SFI values were generally higher than SEF values in all the study sites which agreed with the findings of Dickson *et al*. (2019) for the Meander Belts soils of Bayelsa State, Nigeria and Aiza *et al.* (2013) in Malaysia. Dickson *et al.* (2019), reported higher SFI and SEF values in soils higher in nutrient concentration while Aiza *et al*. (2013) assessed soil fertility status of rehabilitated degraded tropical rainforest and reported highest SEF value in a soil high in organic matter and low in exchangeable Al. Moreover, they reported SEF values lower than 5 in rehabilitated and secondary forests and such soils were considered as soils with extremely poor fertility following what was earlier established by Lu *et al.* (2002). For the soils under consideration, SEF values were above 5 for all and a SEF value of 35 was recorded for OB2T which shows that the soils are fertile, further corroborating the recentness of the soils. Obviously, organic matter played dominant role in making the SFI and SEF, as clay content in most of the soils is low except in some of the soils from Obrikom.

CONCLUSION

This study assessed the soil fertility and productivity status of some benchmark oil producing communities of the Sombreiro Warri Deltaic Plains. The study revealed that these modal communities have remained part of the food baskets of the Niger Delta despite over four decades of oil and gas production. Though the soils are generally acid with pH range of 4.5 – 7.4, low in nutrient and moderate in total organic carbon status, the soils are rated high in productivity. Carbon-Nitrogen Ratio (C:N) ranged from 16 to 27 reflecting high levels of microbial activity and rapid decomposition of organic matter with concomitant release of nutrient elements into soil solution for plant uptake. Exchangeable Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} values in the surface layer are generally higher than the values in the subsurface layer reflecting the juvenile status of the soils and limited loss of nutrient through leaching. Heavy metals concentrations were generally low with no evidence of pollution in the soils. THC and BTEX values recorded in this study are far below the critical level, implying that the samples have not been contaminated by petroleum hydrocarbon. With SEF and SFI ranges of 5 – 35 and 10 – 65 the soils were evaluated as productive and fertile. However, continuous biomass accumulation is critical to fertility maintenance of the soils and addition of farm inputs in the form of organic and inorganic fertilizers is of utmost importance in sustaining the productivity of these soils.

Table 3: Heavy Metal (mg/kg) and Hydrocarbon (mg/kg) Status of the Soils

Sample	Zn	Cu	Mn	Pb	Cr	Cd	V	THC	BTEX
OB1T	197.30	<0.01	38.28	<0.01	2.50	<0.001	<0.001	0.2	0.011
OB1B	153.70	<0.01	30.81	<0.01	0.17	<0.001	<0.001	0.3	0.009
OB2T	173.10	<0.01	26.72	<0.01	1.15	<0.001	<0.001	0.1	0.009
OB2B	28.50	<0.01	31.45	<0.01	0.19	<0.001	<0.001	0.3	0.008
OB3T	124.00	<0.01	27.34	5.03	0.21	<0.001	<0.001	0.3	0.012
OB3B	73.00	<0.01	33.11	10.03	0.10	<0.001	<0.001	0.2	0.010
OB4T	30.51	<0.01	20.99	<0.01	1.00	<0.001	<0.001	8.6	0.011
OB4B	112.30	<0.01	25.08	4.30	<0.01	<0.001	<0.001	0.1	0.010
OB5T	22.89	<0.01	33.85	<0.01	0.17	<0.001	<0.001	0.4	0.012
OB5B	61.52	<0.01	23.98	14.75	0.09	<0.001	<0.001	0.1	0.011
MG1T	121.30	<0.01	32.01	10.01	0.19	<0.001	<0.001	0.4	0.010
MG1B	147.80	<0.01	21.05	<0.01	<0.01	<0.001	<0.001	0.2	0.008
MG2T	139.40	<0.01	27.11	7.30	1.30	<0.001	<0.001	0.1	0.009
MG2B	103.70	<0.01	27.10	3.80	<0.01	<0.001	<0.001	0.1	0.006
MG3T	78.73	<0.01	33.08	<0.01	0.18	<0.001	<0.001	0.1	0.006
MG3B	145.90	<0.01	15.32	8.31	0.11	<0.001	<0.001	0.6	0.004
AG1T	34.08	<0.01	32.01	4.30	1.31	<0.001	<0.001	0.1	0.016
AG1B	13.75	<0.01	12.32	<0.01	1.55	<0.001	<0.001	0.2	0.010
AG2T	41.31	<0.01	<0.01	<0.01	0.14	<0.001	<0.001	0.5	0.019
AG2B	20.93	<0.01	28.15	3.10	0.05	<0.001	<0.001	0.1	0.015
AG3T	28.13	<0.01	21.00	<0.01	0.05	<0.001	<0.001	0.5	0.012
AG3B	49.08	<0.01	20.82	2.90	0.10	<0.001	<0.001	0.3	0.010
OK1T	34.51	<0.01	28.10	<0.01	0.14	<0.001	<0.001	0.1	0.008
OK1B	34.14	<0.01	20.21	<0.01	0.15	<0.001	<0.001	0.4	0.006
OK2T	137.90	<0.01	32.09	<0.01	1.41	<0.001	<0.001	0.2	0.001
OK2B	81.37	<0.01	32.90	<0.01	0.09	<0.001	<0.001	0.2	0.001
OK3T	9.40	<0.01	21.98	10.01	0.18	<0.001	<0.001	0.3	0.005
OK3B	31.14	<0.01	31.21	<0.01	1.37	<0.001	<0.001	0.4	0.005
OK4T	37.14	<0.01	32.01	<0.01	0.18	<0.001	<0.001	0.3	0.008
OK4B	31.00	<0.01	27.01	<0.01	<0.01	<0.001	<0.001	0.6	0.007

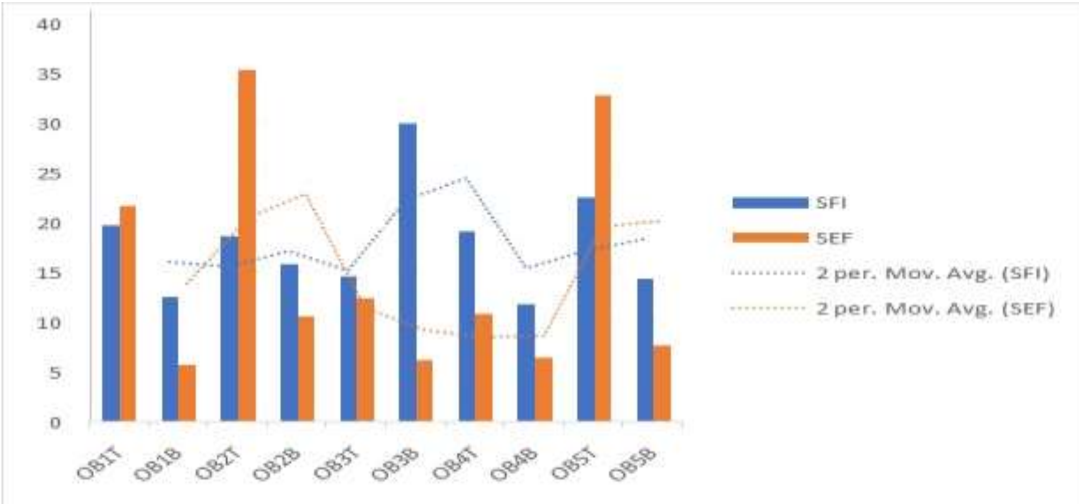

Figure 1: Comparison of SFI and SEF in Obrikom Soil

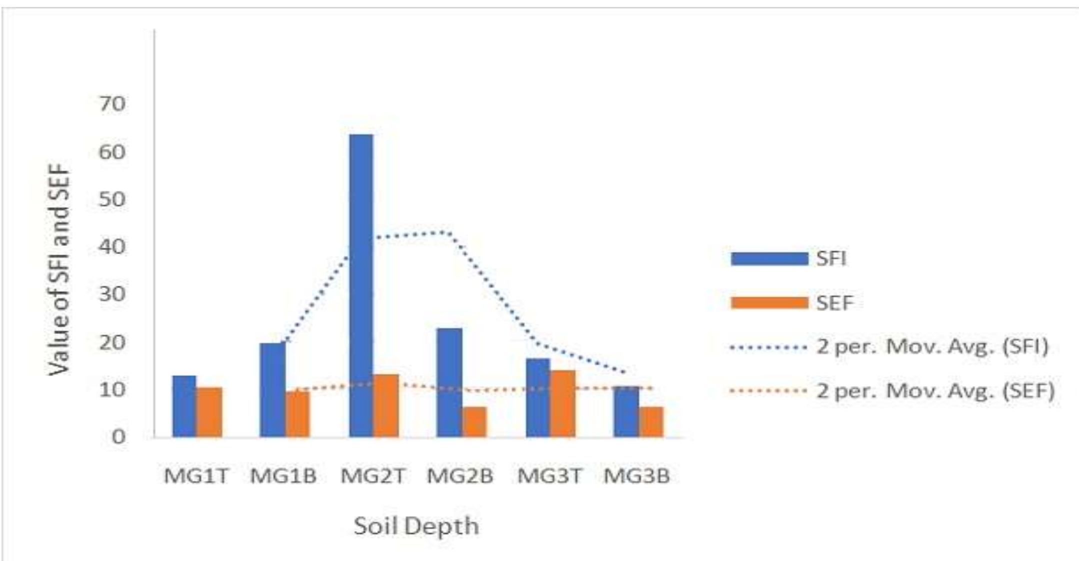

Figure 2: Comparison of SFI and SEF in Mgbede Soil

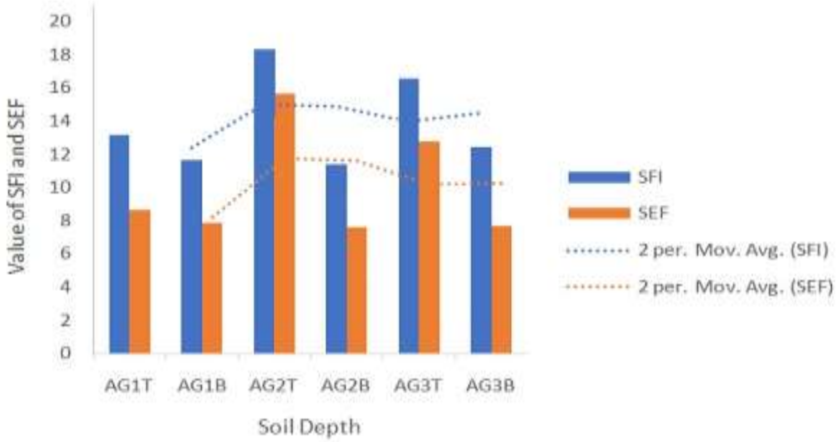

Figure 3: Comparison of SFI and SEF in Aggah Soil

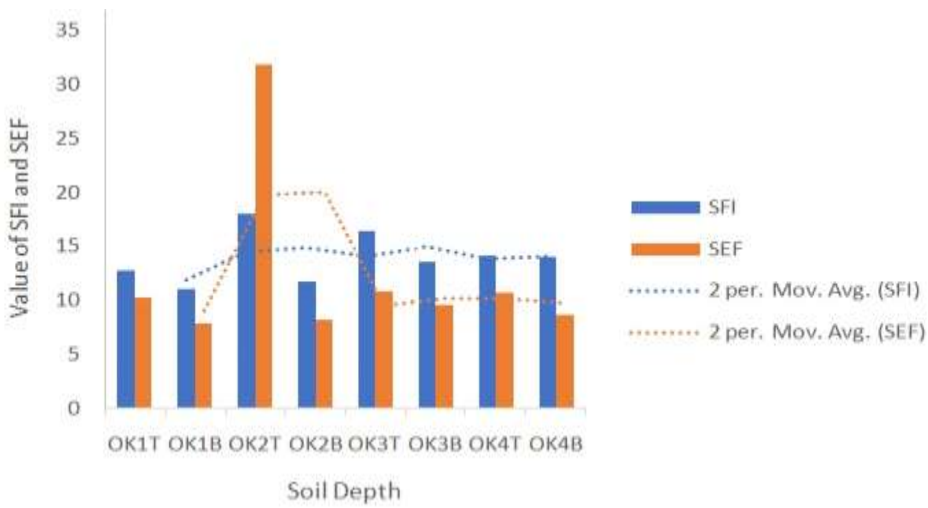

Figure 4: Comparison of SFI and SEF in Okwuzi Soil

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