Influence of Cropping Systems on the Characteristics and Fertility of Beach Soils in The Niger Delta Area of Akwa Ibom State, Nigeria

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Abstract: The influence of cropping systems on the characteristics and fertility of soils derived from beach sands was investigated. The study site was the Cross-River Basin farm, Onna Local Government, in the Niger Delta area of Akwa Ibom State, Nigeria. Two cropping systems- sole cropping (SC) and mixed cropping (MC) and fallow plot [FP] as control, were examined. Pineapple (Ananas commosus) plot and water melon (Citrullus lanatus) plot, represented SC. Plantain/cassava (Musa spp/Manihot esculenta) plot and water leaf/scent leaf (Talinum triangulare L./Ocimum grattissimum) plot represented MC. Representative soil samples were collected at 0-15 and 15-30 cm depths from each plot for laboratory analysis. The result showed that irrespective of cropping system or soil depth, total nitrogen [N] and exchangeable potassium (K) were low – (values below critical levels: < 0.15% and < 0.20 cmol/kg, respectively). Available phosphorus (P) was medium 8 – 20 mg/kg) at both depths in the pineapple plot, and high (> 20mg/kg) at both depths in all others cropping systems. Organic matter (OM) was low (< 2%) in the plantain/cassava MC, and medium (2 – 3%) in other cropping systems, at 0 – 15 cm depth, but at 15 – 30 cm, OM was medium in water melon SC and plantain/cassava MC and low in other cropping systems. Exchangeable bases (Ca, Mg, K) and P were highly variable (coefficient of variation (CV), > 35%) within each cropping system. Analysis of variance (ANOVA) test showed that, irrespective of soil depth there were significant differences (P ⩾ 0.05) among the cropping systems in 11 (79%) of the 14 soil characteristics tested. In view of the deficiencies and variations in soil fertility, regular soil testing for proper fertilizer recommendations is essential to ensure balanced soil nutrient application. Also, well planned crop combinations and rotation programmes will ensure optimum and sustainable land productivity, improved ecological balance and environmental quality.

To cite this article
[Udoh, B. T., & Ekwere, E. O. (2017). Influence of Cropping Systems on the Characteristics and Fertility of Beach Soils in The Niger Delta Area of Akwa Ibom State, Nigeria. The Journal of Middle East and North Africa Sciences, 3(1), 8-14]. (P-ISSN 2412- 9763) - (e-ISSN 2412-8937). www.jomenas.org. **2**

Keywords: Cropping systems, beach soils, nutrient deficiencies, soil testing, Niger Delta.

1. Introduction:

Soil is the natural capital asset upon which agricultural system is based. Therefore, land and soil degradation affects food shortage, food insecurity or underdevelopment and livelihood for poor farmers and the entire citizens of any continent (Yahaya et al., 2014; Ogunkunle, 2015). Agricultural activities largely influence soil properties since these operations affect the soil environment in terms of physical, chemical and biological properties, fertility, organic matter content and nutrient cycle.

Amidst food production, the main concern of agriculture is to ensure sustainability of crop yield, minimum environmental degradation and profitability of the poor farmers within the minimum use of input. Therefore, one of the challenges facing agriculture is the need to develop viable minimum degradation cropping systems for sustainable crop production (Bello, 2008). Already, there is a widespread decline in the yields of most crops because poverty and the need to produce more food, the change in land use and farming practices have resulted in soil organic matter depletion, nutrient mining and soil degradation (Van Keulen and Breman, 1990; De Jager et al., 1998).

These observations, over time, have led to the development of farming systems that are productive and profitable, conserve natural resources base (the soil), protect the environment and enhance health and safety in the long run.

Cropping system is defined as the pattern and spatial arrangement of crops on a piece of land (Bello, 2008). Many important crops in Nigeria and other parts of Africa are grown under different cropping systems. Inter cropping, the practice of growing two or more crops simultaneously in the same field is common throughout the tropics. It is practiced in 80% of the cultivated area in West Africa.

A sustainable cropping system ensures biophysical sustainability by restoring and protecting life support system through reducing contamination of air, water and soil by reducing or eliminating the use of biocides and fertilizer. Cropping patterns enhance biotic diversity. This occurs by introduction of new spices into the agro-ecosystem and must employ mixed cropping pattern for diversification of the ecosystems.

There is no single cropping system which can be used for sustainability of the tropical environment, but the best approach is the diversification of both traditional and modern cropping systems such as, sole cropping, relay cropping, multiple cropping, inter cropping, etc. The multistorey homestead gardens where more than three annual crops and regrettable species are mixes – planted with the crops are common in the humid forest regions (Juo and Manu, 1996).

The Cross-River Basin Development Authority (CRBDA) farms in Akwa Ibom State practice a range of these cropping systems, particularly under the use of supplementary irrigation, which encourages continuous crop production on the farms all – round the year. The soil serves as a medium for plant growth by supplying plants with growth factors, controlling the development and distribution of roots, and movement of nutrients, water and air to root surfaces for absorption.

Different crops exhibit various root distribution and growth habit, thus under varying cropping systems the network of root distribution differs (Millar & Turk, 2002). Therefore, the crop combinations employed in cropping system practice directly influence the soil nutrient management and consequently crops yields and farmers' income. Furthermore, land use and soil management practices influence the soil nutrients and related soil processes, such as erosion, oxidation, mineralization and leaching, etc. (Celik, 2005; Xiao-Li et al., 2010).

The scarcity of information on cropping systems and land management as they affect soil properties and fertility in the CRBDA farm necessitated the setting up of this research study. Therefore, the aim of this study was to examine some cropping systems and determine their influence on the characteristics and fertility of soils derived from the beach sands parent material in the CRBDA farm, Onna, Akwa Ibom State Nigeria. This is with a view to generating relevant information to facilitate the development of improved and adaptable technology to ensure optimum crop yield and sustainable land productivity and environmental quality.

2. Materials and Methods:

2.1. Study Area:

The study was conducted in the cross-river basin development authority (CRBDA) farm, Onna Local Government Area (LGA), Akwa Ibom State Nigeria. The area is located between latitudes 4035 and 4043'N and longitudes 7050' and 7055' E. It is bounded by the following L.G.A: on the west, by Mkpat Enin; east by Eket; south, by Ibeno; north, by Etinan; and south- west by Eastern Obolo. It is situated near large offshore oil and gas drilling operations. The farm covers a total land area of about 360 hectares.

The climate characteristics of the area are typical of a humid tropical environment, having mean annual rainfall of 2900-3100 mm; temperature range of 27-320C and relative humidity between 75 and 85% (Ekanem, 2010; Itina et al., 2013). Soils are derived from the beach ridge sands (BRS) parent material and highly influenced by the Qua Iboe River in the east, and the Atlantic Ocean in the south. Thus, the area has characteristic features of a coastal environment such as mangrove and swamp lands.

2.2. Field Work:

Two cropping systems – mixed cropping (MC) and sole cropping (SC) were used for the study. The MC system was represented by plantain/cassava (Musa spp/Manihot esculenta) intercrop and waterleaf/scent leaf (Talinum triangulare L/ Ocimum grattissimum) intercrop plots. Similarly, the SC system was represented by pineapple (Ananas commosus) plot and water melon (Citrullus lanatus) plot. Fallow plot (FP) was used as control. From each of the plots, soil samples were randomly collected from two depths: 0-15 cm and 15- 30 cm. Each depth was represented by three bulked samples per plot. Core samples were also collected. All the samples were subjected to relevant laboratory analysis and determinations.

2.3. Laboratory Analysis:

Some physical and chemical analyses performed on the soil samples included the following: particle size distribution, saturated hydraulic conductivity and bulk density. Particle size was determined by hydrometer method (Gee and Or, 2002) while hydraulic conductivity and bulk density were determined as described by Klute (1982) and Grossman and Rein sch (2002), respectively. Soil pH was read by pH meter at a soil: water ratio of 1: 2.5; available P (phosphorus) was by Bray P-1 extractant

(Udo et al., 2009). Exchangeable acidity was extracted with IN KCl and titrated against 0.05M NaOH. Organic carbon was determined by Walkley and Black wet digestion method (Page, 1982). Total nitrogen (N) was estimated from organic carbon. Exchangeable bases (Mg, Ca, Na and K) were extracted with neutral ammonium acetate (at pH 7), K+ and Na+ contents were read with the aid of flame photometer, while Ca2+ and Mg2+ were determined by EDTA complexiometric titration method (Jacson, 1965). Effective cation exchange capacity (ECEC) was by summation of exchangeable acidity and exchangeable bases (Soil Survey Staff, 2010), while base saturation was calculated as the percentage of ECEC occupied by Ca, Mg, Na and K.

2.4. Statistical Analysis:

Statistical analyses carried out included descriptive statistics and analysis of variance (ANOVA) to assess the impact of cropping systems on soil properties (SAS Institute, 1996), as well as t-test analysis to determine the influence of depth on soil properties.

3. Results and Discussion:

3.1. Soil Fertility Status (Rating) in the Study Area:

The rating of soil fertility status under the different cropping systems used for the study, is shown in Table 1. The soil fertility status was assessed based on the criteria by the Fertilizer Procurement and Distribution Division (Enwezor et al., 1989)

The result (Table 1), shows that, irrespective of the cropping system or soil depth, all the soils in the farm were rated low (below critical level) in two of the major plant nutrients, namely, N and K. values for N ranged between 0.03 and 0.07%, while those of K ranged between 0.03 and 0.15 cmol/kg. On the other hand, P was rated high (21.33-62.71 mg/kg) under four of the cropping system and fallow plot (control), and medium (10.33-15.53 mg/kg) under pineapple (SC). Previous works have had similar results. Udo et al. (2007) and Ibia and Udo (2009), have observed that soils derived from the beach sands are generally low in N and K and medium to high in P nutrients.

Organic matter (OM) content (at 0-15 cm depth) was rated medium (2.02-2.46%) under all the cropping systems except plantain/ cassava (MC) which was low (1.64%) At 15-30 cm depth, water melon (SC) and plantain/ cassava (MC) were rated medium (2.59-2.96%) in OM content. Other cropping systems and the fallow (control) plot, were rated low (1.41-1.84%). The relatively low values may be attributed to intensive cultivation (all- year-round farming) which the soil is subjected to, which accelerates OM mineralization and rapid losses from the soil.

Table 1: **Rating of Soil Fertility Status Under Different Cropping Systems in the Study Area.*

Cropping System	N (%)	Rating*	P (mg/kg)	Rating*	K (cmol/kg)	Rating*	OM (%)	Rating*
				0 – 15 cm Depth				
Sole cropping (SC)								
Pineapple	0.05	Low	15.53	Medium	0.06	Low	2.02	Medium
Water melon	0.06	Low	33.14	High	0.11	Low	2.46	Medium
Mixed cropping (MC)								
Plantain/ Cassava	0.04	Low	39.77	High	0.08	Low	1.64	Low
Waterleaf/scent leaf	0.05	Low	61.32	High	0.15	Low	2.09	Medium
Control								
Fallow plot (FP)	0.05	Low	30.88	High	0.06	Low	2.36	Medium
				15-30cm Depth				
Sole cropping (SC)								
Pineapple	0.03	Low	10.33	Medium	0.07	Low	1.41	Low
Water melon	0.06	Low	21.43	High	0.09	Low	2.59	Medium
Mixed cropping (MC)								
Plantain/cassava	0.07	Low	21.33	High	0.05	Low	2.96	Medium
Waterleaf/scent	0.04	Low	62.71	High	0.12	Low	1.84	Low
Control								
Fallow plot (FP)	0.04	Low	32.44	High	0.03	Low	1.63	Low

* = Fertility rating based on the criteria by Enwezor et al., (1989).
N = Total nitrogen; P = Available phosphorus.
K = Exchangeable potassium; OM = Total organic matter.
Low = The value below critical level.
Medium =The range above the critical level where the variable response to fertilization is expected.
High = The range where the response is unlikely and fertilization may not be necessary.

3.2. Some Chemical Properties of Soil and their Variation Under Different Cropping Systems:

In assessing some chemical properties and their variation in soils of the different cropping systems, mean values of the two sole crops (pineapple and water melon) and those of the two mixed crops (plantain /cassava and waterleaf/ scent leaf) were used as mono cropping and mixed cropping, respectively, while fallow (FP) was control. Table 2 shows the values of the soil characteristics and their respective coefficient of variation (CV) under the different cropping systems.

The result in Table 2 shows that the soil reaction (pH) at 0- 15 cm depth for the FP (control), was very strongly acid (4. 86) whereas for mono cropping and mixed cropping plots, it was strongly acid (5. 13 and 5.50, respectively) (FitzPatrick, 1980). The trend was similar at 15-30 cm depth although the values were relatively lower. Soils of the beach ridge sands have been described as "acid sands" and therefore acidic in reaction (Udo and Sobulo, 1981; Udoh et al., 2013). However, the relatively lower pH in the control plot compared to the cultivated (mixed- and mono- cropping) plots, seems to indicate good soil management by the farmers which tend to suppress soil acidity.

The values of electrical conductivity (EC) at 0-15 cm, were 0.047, 0.033 and 0.45 dS/m, for control, mono cropping and mixed cropping, respectively. In all the cropping systems, the values decreased at 15-30 cm depth as follows: 0.026, 0.031 and 0.039 dS/m, respectively. By the Soil Survey Staff (2012) rating, all the soils are non-saline (dS/m: 0-2), therefore, salinity does not pose any problem in the farm. The coefficient of variation (CV) test, carried out to assess the variability of the properties under the different cropping systems showed that the fp (control) plot, had the least number of highly variable soil properties, both at 0-15 and 15-30 cm, depths. The result (Table 2) showed that in the FP (control) at 0-15 cm depth, Ca and Mg were highly variable (CV > 35% (Wilding and Dress, 1983). Under mono cropping, four soil properties: Ca, Mg K and P were highly variable whereas under mixed cropping three properties: Ca, Mg, and K were highly variable. Similarly, at 15-30 cm depth: zero, five and four soil properties under control, mono cropping and mixed cropping, respectively, were highly variable.

The above result has shown that exchangeable cations (Ca, Mg and K) and available P were the highly variable (CV > 35%), of the 11 soil properties tested. The other seven properties at both depths had CV ratings between less and moderately variable (CV < 15 and 15-35 %). Furthermore, soil properties under intensive cultivation (mono-or mixed cropping) were more variable than under fallow condition. This could be the result of different tillage and management practice including the application of soil amendments and fertilizers by the farmers which have a strong influence on the more easily variable properties.

Influence of land use, cultural and management practices on the variation of soil properties had been reported by Udoh et al., (2007). Similarly, Ogunkunle and Eghaghara (1992) and Ogunkunle and Erinle (1994), observed significant changes in certain soil properties resulting from different land uses. Also, Beckett and Webster (1971) had observed soil variation as a result of contrasting crops, soils amelioration and the addition of fertilizers while Fasina (2003), also noted high level of variation in some properties imposed by management practices and activities such as bush burning, grazing and different cultivation practices.

Table 2: *Some Chemical Properties of Soils and their Variation Under Different Cropping Systems.* X = Mean, SD= Standard deviation; CV= Coefficient of variation (*significant CV>35%)

Soil properties	Fallow Land			Mono Cropping			Mixed Cropping		
	$\bar{X}$	SD	CV	$\bar{X}$	SD	CV	$\bar{X}$	SD	CV
0-15cm									
pH (H_20)	4.860	0.047	0.965	5.130	0.221	4.30	5.500	0.245	4.45
Nitrogen (%)	0.059	0.013	22.03	0.056	0.007	1.33	0.046	0.008	0.42
OM (%)	2.357	0.513	21.76	2.246	0.292	13.00	1.870	0.320	17.11
Ca^{2+} (cmol/kg)	7.520	3.847	51.15*	4.240	2.374	56.00*	6.160	3.585	58.19*
Mg^{2+} (cmol/kg)	2.507	1.282	51.13*	1.413	0.791	56.00*	2.053	1.195	58.20*
Na^+(cmol/kg)	0.088	0.004	4.54	0.086	0.014	17.20	0.098	0.012	12.24
K^+ (cmol/kg)	0.061	0.002	3.27	0.092	0.035	38.10*	0.114	0.039	34.20*
EA (cmol/kg)	0.587	0.150	25.55	0.826	0.143	17.30	0.853	0.119	13.95
EC (ds/m)	0.047	0.002	4.25	0.033	0.006	19.60	0.045	0.012	26.66
BS (%)	85.73	2.861	3.33	85.30	4.706	5.50	92.91	2.310	2.48
Av. P (mg/kg)	30.88	0.316	1.02	24.23	8.984	37.00*	50.54	11.39	22.59
15-30cm									
pH (H_20)	4.967	0.047	0.95	5.067	0.197	3.88	5.433	0.292	5.37
Nitrogen (%)	0.040	0.004	10.00	0.050	0.021	42.00*	0.059	0.017	28.81
OM (%)	1.632	0.192	11.76	2.006	0.843	42.02*	2.396	0.676	28.21
Ca^{2+} (cmol/kg)	9.920	2.941	29.64	3.600	2.459	68.30*	6.240	2.799	44.85*
Mg^{2+} (cmol/kg)	3.306	0.980	29.64	1.200	0.819	68.20*	2.080	0.932	44.80*
Na^+(cmol/kg)	0.078	0.001	1.28	0.094	0.004	4.25	0.096	0.013	13.54
K^+ (cmol/kg)	0.039	0.004	10.25	0.084	0.021	25.00	0.088	0.032	36.26*
EA (cmol/kg)	0.853	0.150	17.58	0.773	0.109	14.10	0.987	0.283	28.67*
EC (ds/m)	0.026	0.001	3.85	0.031	0.005	16.12	0.039	0.008	20.51
BS (%)	82.78	6.481	7.83	82.13	9.295	11.31	92.65	2.217	2.39
Av. P (mg/kg)	32.44	1.258	3.87	15.88	11.98	75.44*	42.02	22.05	54.17*

3.3. Soils Differences Among Cropping Systems:

The result of analysis of variance (ANOVA) to test the differences among soils under the different cropping systems, with respect to some soil physical and chemical properties is shown in Table 3. The result showed that there were significant differences ($p \geqslant 0.05$) among the five cropping systems (pineapple (SC); water melon (SC); plantain/cassava (MC); waterleaf/scent leaf (MC) and fallow (control) plot (FP), in 11(79%) of the 14 soil properties considered.

In term of coarse sand, waterleaf/scent leaf (MC) was significantly different from all other cropping systems. Also, except water melon: (SC) and waterleaf/scent leaf (MC) which were statistically similar in terms of soil clay content all other cropping systems were significantly different. In the case of soil pH, FP and water melon (SC), were similar, but were significantly different from pineapple (SC), which was similar to plantain/cassava (MC). The result (Table 3), further reveal that except waterleaf/scent leaf (MC), which was significantly different, all other cropping systems were similar with respect to electrical conductivity (EC). On the other hand, FP, pineapple (SC) and waterleaf/scent leaf (MC) were significantly different in terms of available P. whereas OM in FP, pineapple (SC) and waterleaf/scent leaf (MC) was similar, but significantly different from water melon (SC) and plantain/cassava (MC) which were also similar. Similar trends were exhibited by total N and exchangeable bases (Mg, Ca, K and Na).

Several other studies have also shown the influence of land use/ cropping system on soil properties. Yimer et al. (2007), observed a decrease in soil organic carbon and total N in crop lands as compared to forest lands. Celik (2005) and Xiao-Li et al. (2010) observed the influence of land use and soil management practices on soil nutrients and related soil processes such as erosion, oxidation, mineralization and leaching, which can modify the process of transport and re-distribution of nutrients (Selassie, & Ayanna, 2013). Also, Akamigbo, (1999) and Onweremadu, (2009) observed that changes in soil properties due to land use had a significant influence on P, K, Ca, Mg, total N, organic matter and bulk density.

However, the result (Table 3) also revealed that there was no significant difference among the five cropping systems in terms fine sand and silt fractions as well as exchangeable acidity (EA). This is a manifestation of the inherent characteristics of the beach ridge sands parent material. They describe as fluvio-marine deposit of unconsolidated sands deposited by tidal waters along the fringes of the Atlantic Ocean (Tahal Consultants, 1982; Enwezor et al., 1990). Soils formed from this parent material are described as “acid sands” (Udo and Sobulo, 1981) and are coarse textured (sandy), loose, highly leached and strongly acidic (Udo et al., 2013).

Conclusion:

The result of the study has revealed that irrespective of the cropping system or soil depth, soils of the CRBDA farm, Onna, are generally deficient in total N and exchangeable K but have high to medium values of available P. The result further showed that there were significant differences ($P \geqslant 0.05$) among the five cropping systems –pineapple (sole cropping) water melon (sole cropping), plantain/cassava (mixed cropping), waterleaf/scent leaf (mixed cropping) and fallow (control) plot in 11 (79%) of the 14 soil properties considered.

Table 3: *Result of Analysis of Variance (ANOVA) to Test Effect of Cropping System on Soil*

Soil properties	Cropping Systems*					
	FP	**P**	**WM**	**P/C**	**W/S**	**LSD $_{(0.05)}$**
Coarse sand (%)	21.30	27.30	29.40	26.90	36.80	12.80*
Fine sand (%)	70.30	64.70	60.20	62.30	52.40	12.45
Silt (%)	6.00	6.30	6.67	6.33	6.00	0.795
Clay (%)	2.40	1.70	3.06	4.40	3.40	0.660*
pH	4.91	5.28	4.91	5.31	5.61	0.236*
EC	0.03	0.03	0.03	0.03	0.05	0.007*
Av. P (mg/kg)	31.70	12.80	27.30	30.50	62.00	9.48*
OM (%)	1.99	1.72	2.52	2.30	1.96	0.379*
TN (%)	0.04	0.04	0.06	0.05	0.04	0.009*
K (cmol/kg)	0.05	0.07	0.10	0.06	0.13	0.026*
Ca (cmol/kg)	8.72	3.04	4.80	8.32	4.08	2.971*
Mg (cmol/kg)	2.91	1.01	1.60	2.77	1.36	0.990*
Na (cmol/kg)	0.08	0.08	0.09	0.08	0.11	0.007*
EA (cmol/kg)	0.72	0.82	0.77	0.93	0.90	0.214

FP = Fallow plot; P = Pineapple sole cropping;
WM = Watermelon sole cropping;
P/C = Plantain/cassava mixed cropping;
W/S = Waterleaf/scent leaf mixed cropping.

For optimum and sustainable crop production, appropriate soil tests are indispensable in order to establish the required amount of each of the deficient essential nutrients needed. This is to avoid over - or under-application and the resultant deleterious effects of nutrient imbalances.

Furthermore, the farm should adopt well planned crop combinations and rotation programmes. This will result not only in optimum land productivity but in improved ecological balance and environmental quality. In view of the coarse/loose and fragile nature of the soils due to high sand content and organic fertilizer should be the principal means of soil nutrient replenishment under continuous cultivation.

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Received September 10, 2016; revised October 01, 2016; accepted October 15, 2016; published online January 01, 2017.