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Full Length Research Article

Evaluation of the Effect of Oil Palm on some Physical and Chemical Properties of *Rhodic* paleudults

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ABSTRACT: The study was carried out in an Oil Palm Plantation bearing 20 year old palm in an area of about 4.05 ha. The general objective of this study was to understand the variations that result in the soil (*Rhodic paleudult*) due to some physical and chemical properties resulting from the impact of oil palm trees planted on the soil over the years. Descriptive statistical analysis rated the status of total N as high, while available P and exchangeable K were rated low. Exchangeable Ca was rated high in the surface layer and subsoil while Mg was rated high in the surface but low at the subsoil. Variability in the contents of available P, exchangeable K, Ca and Mg was high, but moderate for total N. The experiment shows that oil palm does have remarkable influence on soil chemical properties. The high level variation in the organic carbon content, total nitrogen, available phosphorus, calcium, magnesium and potassium observed could be attributed to oil palm impact on the soil as no fertilization have been carried out on this field for over fifteen years.
Keywords : Evaluation, oil palm, soil physical properties, soil chemical properties.

INTRODUCTION

Growing tree crops implies that nutrients are removed from the soil through harvest either for food, fibre or wood and crop residues. Nutrient removal may result in a decline in soil fertility if replenishment with inorganic fertilizers or manure is inadequate. A decline in soil fertility implies a decline in the quality of the soil (Hartemink, 2005). One of the first studies investigating long-term changes under oil palm was conducted by Tinker (1963) in West Africa. During the first five years of the plantation, there was a marked increase in soil fertility, but thereafter K and Mg levels and the pH decreased, whereas soil organic C levels remained constant (Kowal and Tinker, 1959; Tinker, 1963). Soil changes under oil palm have been well documented in Malaysia. PORIM (1994) summarized them as follows: levels of nutrients are found to increase in the early years under oil palm after forest because of the fertilizer applications and due to the N fixation by the leguminous cover crop. Longer-term trends are less well known, but it is likely that soil nutrients decline due to palm uptake and retention exceeding fertilizer applications.

In many cases it is found that soil fertility under plantation crops is lower than that under forest. However, the rate of decline under plantation cropping is often much lower than under annual cropping because of the higher rates of nutrient inputs and possibly because of lower losses when compared with annual crops (Hartemink, 2003).

Apart from changes in soil properties it has been established also that soils are characterized by a high degree of spatial variability due to the combined effect of physical, chemical or biological processes that operate with different intensities and at different scales (Gooverts, 1998). Spatial variability of soil can result from a natural variability of soil properties as well as from human activity. Most physical and chemical soil properties show spatial variations by the change in the parent material and topographic position. Also, species, age and frequency of the vegetation grown on forested areas can have great influence on the characteristics of soil properties (Basaran *et al.*, 2006).

Previous studies on soil variability studies (Ogunkunle, 1986) also revealed very high variations between soil properties of two closely spaced spots 10m apart on a uniform terrain. Variations in soil properties have also been found to influence soil management and crop production (Fasina, 2005). Spatial variability in soils occur mostly naturally from pedogenic factors. Variability can also occur as a result of the type of land use and management (Shittu *et al.*, 2006). However, soil properties can vary largely along depths due to active soil-forming processes of illuviation and eluviation down the profile.

In the study of the soil some basic knowledge have been elucidated that soil organic matter is a powerful soil attribute for assessing soil quality in different regions of the world under varied land use and management (Ajami *et al.*, 2006). Vagen *et al.*, (2006) support the dependency of soil physical, chemical and biological attributes to soil organic matter. Increased soil organic matter improves aggregation, nutrient-retention capacity, colloidal characteristics, and biodiversity in soil. The amount of organic material in a soil is often expressed as the amount of organic carbon. Organic carbon in soils mainly serves as an energy source for soil and microorganisms that decompose organic material (Bridges, 1978).

However, soil properties are continuous variables and their values at various points differ according to changes in direction and distance from nearby samples (Burgess and Webster, 1980). Boruvka *et al*. (2002), remarks that the task is to reveal at least some of the factors influencing soil variation and use this knowledge to design agricultural management practices that would be both environmentally friendly and highly productive. In order to locate homogenous areas Castrignano *et al*., (1998) describes that spatial characterization of soil properties becomes necessary so as to be carefully managed for agricultural sustainable development. We hypothesize that oil palm can cause changes and variation in soil properties over years in the field. This changes can assist in management planning. Based on this the knowledge of the variability in soil properties will serve as a key for designing site-specific management practices. Therefore, the objective of this study was to evaluate the variations of some physical and chemical properties in the soil as a result of the impact of oil palm and to be able to recommend proper management practices.

MATERIALS AND METHODS

Description of Study Area

The experiment was conducted in an oil palm plantation located at Lat. 6° 30'N and Long. 5° 30'E, Benin City, Nigeria. This area is situated in the rain forest zone of Southern Nigeria. The rainfall has a characteristic bimodal distribution with peaks occurring in June/July to September and a period of lower precipitation mostly in August known as August break. This fluctuates within July to September. The area is lowland and rises up to about 100m above sea level. The region has a humid, tropical climate with total annual rainfall between 1595-1958mm and a mean annual temperature of 31.8 - 32°C. The area has two distinct cropping seasons due to bimodal character of rainfall distribution. The area is characterized by tall trees and oil palm trees.

Soil Sampling

A 20 year old soil oil from palm plantation that has received neither organic nor inorganic fertilization for about fifteen years was sampled. A systematic design was employed for soil sampling using the soil auger at two depths of 0-30cm as surface layer and 30-60cm as subsoil based on a cluster of 6 palms. This sampling depth was chosen because the roots of oil palm are concentrated in the 0 – 60cm depth of the soil. A total of 150 soil samples were collected consisting of 75 samples each for surface layer and subsoil based on the cluster of oil palm. The samples were air-dried at room temperature, crushed and sieved through a 2mm sieve. A subsample of the composite soil sample was weighed for laboratory analysis.

Laboratory Analysis

Soil pH was determined using the glass electrode pH meter using soil:water ratio of 1:1 and in 1N KCl solution at a ratio of 1:2. Particle size analysis was carried out by Bouyoucus (1951) hydrometer procedure after the destruction of organic matter with concentrated hydrogen peroxide. Organic carbon was determined by wet oxidation procedure of Walkley and Black (1934). Total Nitrogen was extracted by the micro-Kjeldahl procedure as described in Black (1965). Available phosphorus was extracted using Bray P-1 extractant and the available P was determined by the vanadomolybdate method of Murphy and Riley (1972). Exchangeable bases (Ca, Mg, K and N) were extracted with 1N neutral NH_4OAc. Na and K in the extract were determined by flame photometer while the Ca and Mg were determined by atomic absorption spectrophotometer. Exchange acidity was extracted with 1N KCl solution and titrated with 0.1N NaOH solution (Jackson, 1962). The analytical results for each soil parameter were averaged and this was compared with the critical level of each element as established in literature.

RESULTS AND DISCUSSION

The soil of the study area has been mapped as Ultisol with Rhodic Paleudult as modal profile, as classified by Ogunkunle (1986). Table 1 shows some soil properties of surface layer (0-30cm soil depth) and subsoil (30 - 60 soil depth) from the oil palm field and the textural class was Loamy Sand. The soils were generally high in sand in the surface layer and subsoil levels. The soils were acidic as revealed by the pH values of 4.66 at the surface layer and 4.71 at subsoil. There was significant difference in organic carbon at $P<0.001$. The high organic carbon content may have been due to the accumulation of organic matter over the years on the surface layer which corroborates with similar works done by Ogunkunle and Eghaghara (1992) and Ogeh and Ogwurike (2006). At the 0 - 30cm depth, N value was 25.2 gkg^{-1} while at 30 – 60cm the value was 9.6 gkg^{-1}. It was sufficient at the surface layer but deficient at subsoil based on the critical level of 20 gkg^{-1} (Hartley, 1977). K values at the surface layer and subsoil was 0.03 $cmol+kg^{-1}$ and 0.02 $cmol+kg^{-1}$ respectively. The soil was deficient of K based on the critical level of 0.30 $cmol+kg^{-1}$ (Hartley, 1977). Mg value was 0.23 $cmol+kg^{-1}$ and 0.15 $cmol+kg^{-1}$ at the surface layer and subsoil respectively. This element was low at the subsoil based on the critical value of 0.2 $cmol+kg^{-1}$ (Hartley, 1977). At surface layer and subsoil level Ca values were above the critical level of 0.1 $cmol+kg^{-1}$ (Hartley, 1977). The surface layer and subsoil were low in available phosphorus based on the critical value of 18 $mgkg^{-1}$ (Hartley, 1977). This findings are in agreement with that of Hartemink, (2005).

The coefficient of variation of the properties for the individual soil parameter at the top and subsoil level indicates that some soil properties are more variable than others. From the particle size data the coefficient of variation (CV) of sand for top soil and sub soil was 3.10 $^{o}/_{o}$ and 3.30 $^{o}/_{o}$ respectively. The CV of 29.00 $^{o}/_{o}$ and 32.18 $^{o}/_{o}$ for silt was recorded for top soil and sub soil respectively. Clay was moderately variable in the top soil with CV 17.30 $^{o}/_{o}$ and least variable in the sub soil with CV 9.00 $^{o}/_{o}$. It shows that clay and silt fraction of the soil were more heterogeneous with variable differences at different points in the oil palm field. All three soil fractions shows significant difference when the top soil was compared with the sub soil ($P<0.001$).

Magnesium is extremely variable with CV 66.44 $^{o}/_{o}$ and 56.51 $^{o}/_{o}$ in the top soil and sub soil respectively. The CV for potassium was 24.18% and 52.02% in the top soil and subsoil respectively. It can be said that the potassium had been fixed by the presence of high exchangeable aluminum and Iron ions and their oxides.

Table 1: Some properties of the top soil and sub soil in the oil palm

	0-30 cm soil depth				**30 – 60 cm soil depth**			
Soil Properties	Mean	Range	SEM	CV($^{o}/_{o}$)	Mean	Range	SEM	CV($^{o}/_{o}$)
pH (H_2O)	4.66	4.40-4.80	0.021	2.12	4.71	4.50-4.90	0.023	2.39
*C (gkg^{-1})	10.35	7.60-18.10	0.470	21.77	3.90	1.20-5.50	0.230	28.27
**N (gkg^{-1})	2.52	1.80-4.30	0.113	21.55	0.96	0.30-1.40	0.060	29.88
***P ($mgkg^{-1}$)	2.50	1.09-4.82	0.198	37.98	1.71	0.27-8.18	0.400	111.10
Ca ($cmolKg^{-1}$)	0.59	0.10-0.94	0.054	44.45	0.64	0.16-2.20	0.088	65.89
Mg ($cmolKg^{-1}$)	0.23	0.05-0.75	0.032	66.44	0.15	0.04-0.28	0.018	56.51
Na ($cmolKg^{-1}$)	0.31	0.23-0.36	0.010	14.59	0.31	0.22-0.38	0.012	18.25
K ($cmolKg^{-1}$)	0.03	0.02-0.05	0.002	24.18	0.02	0.01-0.07	0.002	52.02
CEC ($cmolKg^{-1}$)	2.10	1.36-2.70	0.074	16.85	2.06	1.29-3.33	0.103	23.93
Sand	833	742-862	5.300	3.10	735	692-812	5.100	3.30
Silt	50	34-84	3.050	29.00	30	14-54	2.050	32.18
Clay	117	80-174	4.300	17.30	235	214-294	4.500	9.00
Textural Class =	Loamy	Sand			Loamy	Sand		

SEM= standard error of mean * Organic Carbon ** Total Nitrogen ***Available Phosphorus

Table 2 shows the statistical significance (5$^{o}/_{o}$) of the various soil properties between the top soil and sub soil. The soil pH of the top soil and sub soil was not significantly different in the acidity level. The acidity can be due to high content of Al in the exchangeable form. Liming may be necessary to increase the pH of the soil to a pH level where more soil nutrients can be available for plant use since high pH reduces availability of soil nutrients. The organic carbon, nitrogen, magnesium and potassium content of the top soil and subsoil were significantly different. There was variation between available phosphorus at the top soil and sub soil but there was no significant difference when compared.

Table 3 shows the grouping of soil properties using their CV values. pH was least variable at the top soil and subsoil. The extremely variable properties at the top soil and subsoil were P, Ca and Mg. CEC, organic carbon and N were moderately variable at the top and subsoil.

The experiment shows that oil palm do have remarkable influences on soil chemical properties, as reported by Kang (1977), Ogunkunle (1986) and Kamaruzaman (2004).

Table 2: Variation of the various soil properties between the top and sub soil

Soil Properties	SED	Probability	Significance
pH (H_2O)	0.031	=0.133	Ns
*C (gkg^{-1})	0.523	<0.001	S
**N (gkg^{-1})	0.128	<0.001	S
***P ($mgkg^{-1}$)	0.444	=0.085	Ns
Ca ($cmolKg^{-1}$)	0.104	=0.589	Ns
Mg ($cmolKg^{-1}$)	0.036	=0.042	S
Na ($cmolKg^{-1}$)	0.015	=0.910	Ns
K ($cmolKg^{-1}$)	0.003	=0.005	S
CEC ($cmolKg^{-1}$)	0.126	=0.755	Ns
Sand	7.404	<0.001	S
Silt	3.678	<0.001	S
Clay	6.204	<0.001	S

* Organic Carbon ** Total Nitrogen ***Available Phosphorus Ns = not significant, s = significant, SED= standard error of difference

Table 3: Ranking soil properties by coefficient of variability (CV) of top soil and subsoil

Ranking	**top soil**		**subsoil**	
	Range of CV	Properties	Range of CV	Properties
Least variable	<15 $^{0}/_{0}$	pH (H_2O), Na, Sand	<15 $^{0}/_{0}$	pH (H_2O), Sand, Clay
Moderately variable	15-35 $^{0}/_{0}$	org. C, total N, K, CEC, Silt, Clay	15-35 $^{0}/_{0}$	org. C, total N, Na, CEC, Silt
Extremely variable	>35$^{0}/_{0}$	av. P, Ca, Mg	>35$^{0}/_{0}$	P, Ca, Mg, K

CONCLUSION

The observed variation of the soil physical properties is most likely to be due to its soil forming processes and variation of the soil chemical properties is due to soil management practices. The high level variation in the Organic Carbon content, Total Nitrogen, Available Phosphorus, Calcium, Magnesium and Potassium observed could be attributed to soil management practices employed in this field as it has not received any form of fertilizer for about fifteen years. Total soil Nitrogen in the study area can be classified into low to high level, whereas, available Phosphorus and exchangeable Potassium varied from low to moderate levels. Total Nitrogen had a strong relationship with soil Organic Carbon. Meanwhile, exchangeable Potassium in surface layer and subsoil varied significantly. With regards to soil fertility status the soils are low. Sustaining and improving the production capacity of agricultural plantations is therefore important, and maintenance of the soil resources is a key issue for sustainable production.

REFERENCES

Ajami, M., Khormali, F., Ajami, M. Ayoubi, S.H. and Omrani, R.A. (2006). Soil Quality changes due to deforestation in Golestan province, Northern Iran. 8th International Soil Meeting (ISM) on "Soil Sustaining Life on Earth, Managing Soil and Technology". *Proceedings.* Pp: 501-504

Basaran, M., Ozcan A.U., Erpul G. and Anga M.R. (2006). Spatial Variability of Organic Matter and Some Properties of Mineral Topsoil in Cankiri Indagi Blackpine Plantation Region. *Journal of Appied Sciences* **6(2):** 445-452.

Black, C.A. (1965). *Methods of soil analysis as a monograph* No. 9 American society of Agronomy Madison, Wisconsin. USA.

Boruvka L., Donatova, H. and Nemecek, K. (2002). Spatial distribution and correlation of soil properties in a field: A case study. *Rostlinna Výroba*, **48:** 425–432.

Bouyoucus, C.J. (1951). A recalibration of the hydrometer method of making mechanical analysis of soil. *Agronomy Journal* **43:** 434-438.

Bridges, E.M. (1978). *World soils.* 2nd ed. University Press, Cambridge. ISBN 0-521-29339-1

Burgess, T.M. and Webster, R. (1980). Optimal interpolation and arithmic mapping of soil properties: the semivariogram and punctual Kriging. *Soil Science*, **31:** 315-331.

Castrignano, A., Mazzoncini, M. and Giugliarini, L. (1998). Spatial characterization of soil properties. *Advances in Geoecology,* **31:** 105–111.

Fasina, A.S. (2005). Influence of landuse on the variability of topsoil properties of Alfisol in Southern Nigeria. *Journal of Agricultural Research and Development.*, **4:** 12 – 16.

Gooverts, P. (1998). Geostatistical tools for characterizing the spatial variability of microbiological and physico-chemical soil properties. *Biology and Fertility of Soil,* **27:** 315-334.

Hartemink, A.E. (2003). *Soil Fertility Decline in the Tropics – With Case Studies on Plantations*, ISRIC-CABI Publishing, Wallingford..

Hartemink, A.E. (2005). Plantation agriculture in the tropics: Environmental issues *Outlook on Agriculture* **34(1):** 11–21

Hartley, C.W.S. (1977). *The oil palm*, 2nd Ed London, Longman group Ltd.

Jackson, M.L. (1962). *Soil chemical Analysis*, Prentice Hall, New York.

Kamaruzaman, J. (2004). Evaluation of Spatial Variability of Soil in an Oil Palm Plantation. *ISCO* 2004 - 13th International Soil Conservation Organisation Conference – Brisbane.

Kang, B.T. (1977). Effect of some biological factors on soil variability in the Tropic. II Effect of oil palm trees (*Elaeis guineensis*). *Plant Soil***, 47:** 451-462.

Kowal, J.M.L. and Tinker, P.B.H. (1959). Soil changes under a plantation established from high secondary forest', *Journal of the West African Institute for Oil Palm Research*, **2:** 376–389.

Murphy, J. and Riley, J.P. (1962). A modified single solution method for the determination of phosphorus in neutral waters. *Analytica Chimica Acta* **27:** 31 - 36

Ogeh, J.S. and Ogwurike, P.C. (2006). Influence of Agricultural Land Use Types on some Soil Properties in Midwestern Nigeria. *Journal of Agronomy* **5(3):** 387-390.

Ogunkunle, A.O. and Eghaghara, O.O. (1992). Influence of land use on soil properties in a Forest region of Southern Nigeria. *Soil Use and Manage*, **8:** 121-125.

Ogunkunle, A.O. (1986). Spatial variability of some chemical properties between two mapping units in southern Nigeria. *Soil Survey and Land Evaluation*, **6:** 26-32.

PORIM (1994), *Environmental Impacts of Oil Palm Plantations in Malaysia*, Palm Oil Research Institute of Malaysia, Malaysia.

Shittu, O.S., Adebooye, O.C., Fasina, A.S. and Omolayo, F.O. (2006). Response of Leaf Yield and Chemical composition of *Amaranthus cruentus* L. and *Celosia argentia* to landuse types and fertilizer regime. *International Journal of Agricultural Research*, **1:** 286-292.

Tinker, P.B.H. (1963) 'Changes occurring in the sedimentary soils of southern Nigeria after oil palm plantation establishment', *Journal of the West African Institute for Oil Palm Research*, **4:** 66–81.

Vagen, T. G, Andrianorofanomezana, M.A.A. and Andrianorofanomezana, S. (2006). Deforestation and cultivation effects on characteristics of Oxisols in the highlands of Madagascar. *Geoderma*. **131:** 190-200.

Walkley, A. and Black, C. A. (1934). An examination of the Degte jaref method of determining soil organic matter and a proposed modification of chromic acid titration method. *Soil Science* **37:** 29 – 38.