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QUANTIFYING THE PRODUCTIVITY OF SPENT OIL CONTAMINATED SOIL AMENDED WITH ORGANIC WASTES USING PRODUCTIVITY INDEX IN ABAKALIKI, SOUTH EASTERN NIGERIA

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ABSTRACT: *A study on quantifying the productivity of spent oil contaminated soil amended with organic wastes using productivity index (PI) was carried out at the Teaching and Research Farm of the Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki. The study involved a modification of Pierce et al. productivity index model with simultaneous exclusion of sufficiencies for aeration and electrical conductivity. The applicability and validity of the modified Pierce et al. productivity index model were determined using maize as a test crop. Result showed highly significant (r=0.96 at P<0.01) relationship between PI and grain yield of maize. The general mean PI and grain yield of maize were 0.32 and 0.94 tha^{-1}for the treatments. The mean productivity indices with grain yield of maize were 0.20 and 0.50tha^{-1}, 0.40 and 1.2otha^{-1}, 0.26 and 0.80 tha^{-1} and 0.42 and 1.3tha^{-1} for control, burnt rice husk dust, unburnt rice husk dust and saw dust amended soils, respectively. The burnt rice husk dust which had highest prediction of 0.58 also predicted highest grain yield of maize of 2.2tha^{-1}. The grain yield of maize followed productivity index predictions. Organic wastes could be recommended for attenuating problem of spent oil contamination of soil in Abakaliki.*

KEYWORDS: Amended, Contamination, Soil, Quantifying, Organic wastes, Productivity, Spent oil.

INTRODUCTION

Accurate estimate of future soil productivity is essential to make agricultural policy decisions and to plan the use of land from field scale to the national level (National Soil Erosion and Productivity Research Planning Committee, 1981). Similarly, relationship between soil properties and soil's capacity for producing plants or soil productivity is today the focus of a number of research projects (Follet and Stewart, 1985;Nwite and Obi, 2008). The projects according to Gantzer andMcCarty (1987) have grown out of a need to increase the knowledge of quantitative relationships between plant growth and soil properties.

Various approaches have been developed which attempt to numerically relate soil properties to its productivity (Anikwe, 2000). These include the Universal Soil Loss Equation (USLE) and Erosion Productivity Impact Calculation (EPCI) (National Soil Erosion and Productivity Research Planning Committee, 1981). However, a simple numericalindex model is now preferred to others because of its simplicity and applicability in many soils (Anikwe, 2000). The model widely used today in quantification of soil productivity is the productivity index (PI) model modified by Pierce *et al.* (1983). This productivity index is based on the use of physical and chemical properties to predict effect of soil erosion on productivity (Pierce *et al.*,

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1983). Productivityindex is an algorithm based on the assumption that crop yield is a function of root growth which includes rooting depth as controlled by soil environment (Lindstorm*et al.,* 1992).

Soil productivity is the capacity of a soil to produce a particular crop or sequence of crops under a specified management practices (Brady and Weil, 2002). The productivity of soil is reduced though soil degradation in form of erosion, contamination, deforestation and dissertation (Williams, 1990; Nwite, 2013). The reduction may manifest as soil constraints such as loss of plant nutrients, loss of storage capacity for plant-available water, degradation of soil structure and decreased uniformity of soil conditions within a field (Williams, 1990). Soil productivity constraints in tropical Africa have been grouped into four broad categories by Woomer and Muchena (1993) as nutrient availability and retention, nutrient toxicities, water availability and physical degradation.

Spent oil has become increasingly common source of soil contamination in many urban areas especially around mechanic villages and where automobile works are carried out. Whenever such occurs, farmers are always apprehensive of soils' loss of productive capacity. This fear had been authenticated in the Niger Delta areas where oil spillage had been a problem. Organic wastes are known to play key roles in productivity restoration. It is for these reasons that this kind of simulation study was carried out. The objective of this experiment was to quantify the productivity of a spent oil contaminated soil amended with organic wastes using productivity index in Abakaliki, southeastern Nigeria.

MATERIALS AND METHODS

Site Description and Location

The experiment was carried out at the Teaching and Research Farm of the Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki. The area is located by Latitude $06^{0}o4^{/N}$ and longitude 08^{o} $65^{/E}$. The rainfall pattern is bimodal and spread between April-July and September-November with a break in August popularly referred to as "August break". The minimum and maximum annual rainfall ranges from 1700mm-2000mm with mean annual rainfall of 1800mm. The area has minimum temperature of $27^{o}C$ which occurs around December and maximum temperature of $31^{o}C$ common in dry season. The relative humidity ranges from 60-80% with maximum occurring in the rainy season (ODNRI, 1989). The soil is derived from unconsolidated coastal sedimentary deposits fromcretaceous and tertiary periods. According to Federal Department of Agricultural Land Resources (1985), Abakaliki agricultural zone lies within"Asu River" and is associated with olive brown sandy shales, fine grained sand stones and mud stones. The soil is shallow with unconsolidated parent material within 1m of the soil surface and classified as ultisolbelonging to the order *typichaplustult*. The area had been under cultivation for the past two years. Crops that were grown in the soil include maize (*Zeamays L.*) Cassava (*Manihotspp*) and Yam (*Dioscoreaspp*). The area was grown with native vegetation, shrubs and herbs before the experiment.

Field Methods

The area of the land used for the experiment was approximately 0.03ha. The land was cleared of existing vegetation and debris removed. Twenty litres of spent oil sourced from mechanic village, Abakaliki urban was spread with spraying machine on the soil. The soil was allowed to stay for two weeks without any activity to ensure spent oil infiltration. Afterward, the land

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was demarcated into plots and blocks using Randomized Complete Block Design. The plots measured 2m x2m with 0.5m space while the blocks were set apart by 1m alley. The treatments were 20tha^{-1}equivalent to 8kg/plot each of Burnt Rice Husk Dust (BRHD),Unburnt Rice Husk Dust (URHD), Sawdust (SD) and control. These treatments were replicated five times to give a total of twenty experimental plots in the study.

Maize (Oba super II) hybrid variety was used as a test crop. The maize seed was collected fromEbonyi State Agricultural Development Programme Office, OnuebonyiIzzi, Abakaliki. The maize seeds were planted at a seed rate of two per hole at a planting distance of 25x75cm. Two weeks after seedling Emergence (WASE), they were thinned down to one per hole. Those which did not germinate including weak ones were replaced through replanting. This gave a plant population of 53, 333 per hectare. Fertilizer NPK 15:15:15 was applied at 400kgha^{-1} to all the beds after thinning.Soil samples were collected with auger at 0-20cm depth for routine pre-planting analysis. The samples were composited before laboratory determinations. Furthermore, auger and Core samples were collected at 0-15, 15-30, 30-45, and 45-60cm depths in each plot for physicochemical properties determinations.

The cobs were harvested when the husks had dried. The cobs were dehusked, shelled and grain yield determined at14% moisture content.

Laboratory Methods

The Core samples were used to determine soil physical properties. Bulk density determination was done using the method of Blake and Hartge (1986). Available water capacity was determined with pressure plate apparatus as described by Obi (2000). Total porosity was calculated from bulk density data according to Obi (2000) procedure. Water retention was determined as follows:

$$WR = \frac{Ws-wd}{Wd}$$

where

WR = Water Retention

Ws = Weight of Wet soil (g)

Wd = Weight of dry soil (g)

Macroporosityand microporosity determinations were done using hanging column of water technique as described by Obi (2000). Auger soil sample was dried,sieved with 2mm sieve, bulked and used to determine pH in water/soil solution ratio of 1:2.5. The values were read off in a pH meter. Rootingdepth was measured with metric rule.Total hydrocarbon was determined byOdu*et al.*(1989) method.

Productivity Index Model and Its Modification

The modified productivity index model of Pierce *et al.* (1983) was used. This model was based on simple measurable soil properties. The expression is:

$$PI = \sum_{i=i}^{r} (A_i x B_i x C_i X D_i X E_i x Wf_i) \qquad \ldots 1$$

where

PI = Productivity index

A_i = sufficiency for available water capacity for ith soil layer

B_i = Sufficiency for bulk density forith soil layer

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C_i = Sufficiency for pH for ith soil layer
D_i = Sufficiency for aeration for ith soil layer
E_i = sufficiency for electrical conductivity for ith soil layer
r = number of horizons in the rooting zone
Wfi = Root weighting factor

The above model was modified with the exclusion of sufficienciesfor aeration and electrical conductivity while other parameters were retained. The modified model expression is:

$$PIM = \sum_{i=i}^{r}(A_i x B_i x C_i X Wf_i) \quad \ldots 2$$

where
PIM = Modified productivity index
PI = Productivity index
A_i = sufficiency for available water capacity for ith soil layer
B_i = Sufficiency for bulk density for ith soil layer
C_i = Sufficiency for pH for ith soil layer
r = number of horizons in the rooting zone
Wfi = Root weighting factor

Data Analysis
Productivity index was determined by calculating soil sufficiency values. Correlation analysis was used to determine the relationship between soil properties and grain yield of maize according to Steel and Torrie (1980).

RESULTS AND DISCUSSIONS

Properties of Organic Wastes and Spent oil
Table 1 showsproperties of organic wastes used in soil amendment as well as spent oil. The nutrient composition of organic wastes was generally low. The exchangeablecations were low in the organic wastes according to Howeler(1996). The percentage organic carbon and total nitrogen ranged from 6.92 to 16.39 and 0.28 to 0.48 in the organic wastes and rated high (FMARD, 2002). Available phosphorus ranged from 3.00 to 14.00 $mgkg^{-1}$inthe organic wastes and rated low using critical values established for soils by Landon (1991). The C:N ratios were 23, 32 and 34 for burnt rice husk dust, sawdust and unbrunt rice husk dust, respectively.

The values of Cu, Zn and P^b in spent oil were within the normal levels in soil as recommended by Alloway (1990). However, Cd reached critical value (Alloway, 1990). The percentage of organic carbon and total nitrogen were 17.3 and 6.8 respectivelyin spent oil and rated high (FMARD, 2002). Available phosphorus was rather very low with value of 0.02$mgkg^{-1}$ (Landon, 1991). The C:N ratio and total hydrocarbon values were 11.38 and 33.11%.

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Table 1. Properties of Organic Wastes and Spent Lubricant Oil

Organic wastes	Properties	Unit	Values
Burnt rice husk dust	Na	cmolkg^{-1}	0.04
	K	cmolkg^{-1}	0.06
	Ca	cmolkg^{-1}	1.17
	Mg	cmolkg^{-1}	0.27
	Oc	%	6.92
	N	%	0.30
	P	mgkg^{-1}	14.00
	C:N		23
Sawdust	Na	cmolkg^{-1}	0.07
	K	cmolkg^{-1}	0.13
	Ca	cmolkg^{-1}	0.30
	Mg	cmolkg^{-1}	0.10
	Oc	%	8.99
	N	%	0.28
	P	mgkg^{-1}	3.00
	C:N		32
Unburnt rice husk dust	Na	cmolkg^{-1}	0.07
	K	cmolkg^{-1}	0.24
	Ca	cmolkg^{-1}	0.50
	Mg	cmolkg^{-1}	0.12
	Oc	%	16.39
	N	%	0.48
	P	mgkg^{-1}	7.00
	C:N		34
Spent lubricant oil	Cd	mgkg^{-1}	15.6
	Cu	mgkg^{-11}	9.1
	Zn	mgkg^{-11}	31.2
	P^b	mgkg^{-1}	4.0
	Oc	%	17.3
	N	%	6.8
	P	mgkg^{-1}	0.02
	C:N		11.38
	THC	%	33.4

OC-Organic carbon, C:N-Carbon-nitrogen ratio, THC-Total Hydrocarbon

Some Properties of Soil Studied

Some properties of soil contaminated with spent oil amended with organic wastes are shown in Table 2. The result indicates that bulk density of control was slightly higher than the mean as well as those amended with organic wastes, respectively. Similarly, available water capacity, total porosity, water retention, macroporosity and microporosity were lower in control when compared with those amended with organic wastes and mean values. Sawdust amended plot had higher available water capacity, macroporosity and micropososity, respectively compared to mean values and those amended with burnt rice husk dust and unburnt rice husk dust. Total

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porosity and water retention were higher in burnt rice husk dust amended plots compared to mean and those amended with unburnt rice husk dust and sawdust. However, soil pH generally varied among the treatments with plot amended with unburnt rice husk dust having slightly higher values of pH relative to mean and those amended with burnt rice husk dust and unburnt rice husk dust.

Lower bulk densities in amended soil show that organic wastes have the potential to reduce bulk densities. Anikwe*et al.* (2003) reported the potential of organic wastes to ameliorate the problem of higher bulk densities in soil. Low bulk densities in amended soil had multiplier positive impacts on soil which includes opening up soil pores. The increase in soil pores in turn could lead to higher available water capacity, total porosity, macroporosity and microporosity. These observations are in line with the report of Nwite (2013) that organic wastes amendment increased those soil physical properties due to their positive impacts on soil. Soil pores are known to store water so that total pore volume has reciprocal relationship with water storage. Improved soil pH obtained in soils amended with organic wastes indicates the potentiality of the wastes to ameliorate soil acidity by increasing soil pH.Increased soil pH is a positive indicator of soil condition to ensure high release of nutrients to growing crops and hence generally highersoil productivity.

Table 2. Some Properties of spent oil contaminated soil amended with organic wastes

Treatment	**Bulk Density (gcm^{-3})**	**Awc(cm/cm)**	**TP(%)**	**WR(%)**	**Mac(PR)**	**M.Cd**	**pH(kcl)**
Control	1.72	0.48	36.13	21.33	6.32	29.31	4.7
Burnt rice husk dust	1.59	0.50	42.90	24.55	7.77	35.13	4.8
Unburntrice husk dust	1.59	0.54	37.84	23.34	7.48	32.27	4.9
Saw dust	1.63	0.60	40.33	22.69	8.16	42.57	4.8
Mean	1.62	0.53	39.30	22.98	7.48	34.82	4.6

Soil productivity index and Ascribed sufficiency values

Table 3 shows the average soil properties, ascribed sufficiency values and predicted productivity indices of the soils. The soil properties were used to calculate ascribed sufficiency values and computation of productivity index. Highest productivity index of 0.58 was obtained under soil amended with burnt rice husk dust when compared to control and those of sawdust and unburnt rice husk dust amended plots. This represents increase in productivity index of 0.48, 0.44 and 0.09 relative to control, unburnt rice husk dust and sawdust amendment respectively.High productivity index implies capacity of soil to support and sustain soil productivity. This could also be projected to future use and ensure sustainability of soil to crop production. According toNwiteand Obi (2008), high soil productivity index is a good indicator of soil capacity to support crop productionfor long period of time. Alternatively, organic wastes amendment could restore and sustain soil productive capacity. Poor productivity index recorded under control could be attributed to depletion of soil nutrients without replacement and negative effects of soil contamination. This is in line with the observation of Mbah (2004) and Adeleye*et al.* (2010) that cultivation of soil without amendment led to low and unsustainable productivity.

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Table 3. Mean Soil ssproperties, sufficiency values and calculate productivity index

Control

Soil Properties	Soil depth (cm) 0-15	15-30	30-45	45-60	Sufficiency values 0-15	15-30	30-45	45-60
Bulk density(gcm^{-3})	1.57	1.72	1.26	1.760.79	0.29	0.29	0.19	
AWC (cm/cm)	0.36	0.46	0.49	0.49	1.00	1.00	1.00	1.00
Depth of rooting(cm)	60	60	60	60	1.00	1.00	1.00	1.00
pH(kcl)	5.5	5.4	5.1	4.8	0.09	0.00	0.00	0.00
PI					0.20			

Burnt Rice Husk Dust

Soil Properties	Soil Depth (cm) 0-15	15-30	30-45	45-60	Sufficiency Values 0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.09	1.21	1.44	1.64	1.00	0.59	1.00	1.00
AWC(cm/cm)	0.31	0.42	0.46	0.46	1.00	1.00	1.00	1.00
Depth of rooting (cm)	60	60	60	60	1.00	1.00	1.00	1.00
pH (kcl)	5.6	5.0	4.6	4.2	0.19	0.39	0.00	0.00
PI					0.40			

UnburntRice Husk Dust

Soil Properties	Soil Depth (cm) 0-15	15-30	30-45	45-60	Sufficiency Values 0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.09	1.21	1.44	1.64	1.00	0.59	1.00	1.00
AWC(cm/cm)	0.31	0.42	0.46	0.46	1.00	1.00	1.00	1.00
Depth of rooting (cm)	60	60	60	60	1.00	1.00	1.00	1.00
pH (kcl)	5.6	5.45.4		4.4	0.19	1.001.00		0.00
PI					0.26			

Saw Dust

Soil Properties	Soil Depth (cm) 0-15	15-30	30-45	45-60	Sufficiency Values 0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.18	1.45	1.59	1.61	1.00	1.0000.700.69		
AWC(cm/cm)	0.56	0.62	0.68	0.931.00	1.00	1.00	1.00	
Depth of rooting (cm)	60	60	60	60	1.00	1.00	1.00	1.00
pH (kcl)	5.3	5.25.2		4.0	0.49	0.39	0.39	0.00
PI					0.42			

Individual Productivity index and grain yield of maize

Table 4 shows productivity index and grain yield of maize. Sufficiency values were used to calculate productivity indices. Productivity index generally varied with the amendments. The plots amended with burnt rice husk dust had highest productivity index compared to other organic wastes amended plots and control. The grain yield of maize followed the trend of productivity indices predictions. Burnt rice husk dust which had the highest productivity index (PI) prediction of 0.58 also predicted highest grain yield of maize of 2.2tha^{-1}. Furthermore, the average of all PI was 0.32 with average grain yield of 0.94t ha^{-1}.

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The trend of grain yield of maize being intandem with productivity indices predictions indicates that productivity index could be used to quantify or predict yield of crops. On the other hand, soil productivity has direct reciprocal relationship with crop yields. Anikwe (2000) reported that grain yield of crops followed the trend of productivity indices. This was corroborated by Nwiteand Obi (2002) in their study of quantifying the productivity of Abakaliki and Nsukka soils using productivity index. It is important to quantify soil productivity in order to plan for effective, proper and sustainable use of land. Low PI could be attributed to contamination of soil withspent oil.According to Aulakh*et al.* (2007), poor crop yield implies low utilization of nutrients. Brady and Weil (2002)corroborated low grain yield of maize in soil contaminated with spent lubricantoil and attributed it to degradation of soil production capacity.

Table 4. Individual Productivity Indices and Grain Yieldsof Maize

Treatment	Productivity Index	Grain Yield of Maize(tha^{-1})
Control	0.10	0.2
Control	0.10	0.2
Control	0.15	0.4
Control	0.23	0.6
Control	0.42	1.1
Burnt rice husk dust	0.29	0.7
Burnt rice husk dust	0.32	0.7
Burnt rice husk dust	0.34	0.8
Burnt rice husk dust	0.49	1.5
Burnt rice husk dust	0.58	2.2
Unburnt rice husk dust	0.14	0.3
Unburnt rice husk dust	0.15	0.4
Unburnt rice husk dust	0.17	0.5
Unburnt rice husk dust	0.41	1.0
Unburnt rice husk dust	0.45	1.8
Sawdust	0.29	0.7
Sawdust	0.39	0.9
Sawdust	0.43	1.3
Sawdust	0.49	1.5
Sawdust	0.54	2.1
Mean	**0.32**	**0.94**

Relationship between Productivity Index and Grain Yield of Maize

The result on Table 5 shows the relationship between productivity index and grain yield of maize. Correlation analysis showed highly significant ($r=0.96$ at $P<0.01$) relationship between productivity index and grain yield of maize.This finding indicates that productivity index could indeed be used to predict grain yield of maize and by extension other crops. This result is supported by the report of Anikwe (2000) where he observed that productivity index was a veritable tool forquantifying soil productivity. Significantly higher relationship between productivity index and grain yield of maize further suggests that the organic wastes attenuated the problem of spent oil contamination of soil. Organic wastes amendment had been reported by Adeleye*et al.* (2010) to have improved the productivity of soil.

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Table 5. Relationship between Productivity Index and Grain Yield of Maize

Dependent parameters	Regression Model	Correlation Coefficient
PI and grain yield of Maize	Y = 3.47x-0.12	0.96

PI – Productivity index **-Significantly at P<0.01

CONCLUSION

The result of this study indicated that productivity of spent oil contaminated soil amended with organic wastes could be quantified. Sufficiency values of available water capacity, bulk density, rooting depth and soil pH could be used to quantity productivity index of soil. Furthermore, productivity index has direct reciprocal relationship to a great extent with yield of crops.Spent oil contaminated soil amended with organic wastes gave a highly significant relationship between productivity index and grain yield of maize. Consequently, with organic wastes amendment, the productivity of spent oil contaminated soil could not only be improved but can be maintained at a sustainable basis.

REFERENCES

Adeleye, E.O., Ayeni, L.S.,Ojeniyi, S.O. (2010). Effect of Poultry Manure on Soil Physicochemical Properties, Lead Nutrient Contents and Yield of Yam (*Dioscorearotudata*) on Alfisol in South Western Nigeria.*Journal of African Science*6(**10**):509-518.

Alloyway, B.J. (1990).*Heavy metals on Soil*. New York: John Wiley and Sons, Inc. 280p.

Anikwe, M.A.N., Obi, M.E. and Agbim, N.N. (2003).Effect of Crop and Soil Management Practices on Soil Compactibilityin Maize and Groundnut plots in a *paleustult*in Southeastern Nigeria.*Plant and Soils* 253:457-465.

Anikwe, M.A.N. (2000). *Use of Numerical Index Methods for Quantifying the Productivity of some soils in Southeastern Nigeria.*Ph.DThesis, University of Nigeria Nsukka, 89pp.

Aulakh, M.S., Garg, A.K. and Kabba, B.S. (2007).Phosphorus accumulation, leaching and residual effects on crop yields from long-term applications in the subtropics.*Soil Use and Management*23:417-427.

Blake, G.R. and Harge, K.H. (1986).*Bulk density. In:*Klute, A. (ed).Methods of Soil Analysis.Physical and Mineralogical Methods.*American Society of Agronomy* I: 365-375.

Brady, N.C. and Weil, R.R. (2002).*The Nature and Properties of Soil.*New Jersey, Pearson Education, Inc. 837p.

FMARD (2002).Federal Ministry of Agriculture and Rural Development (FMARD) Fertilizer Use and Management Practice for Crops in Nigeria. Produce by the Federal Fertilizer Department by Aduayi, E.A., Chude, V.O., Adebusuyi, B.A. and Olayiwola, S.O. (eds). Abuja, 2002, 188p.

Follet, R.F. and Stewart, B.A. (1985).Soil Erosion and Crop Production.Wisconsin,Madison,USA.

Gantzer,C. and McCarty, T.R. (1987).Predicting Corn Yields on Clay using Soil Productivity Index. *American Society of Automobile Engineers* 30:1347-1352.

Howeler, R. (1996).*Mineral Nutrition in Cassava. In:*Cranwell, E.T., Asher, C.J. and O' Sullivan, J.N. (eds).Mineral Nutrient Disorders of Root Crops in the Pacific.Proceedings of the Workshop on Mineral Disorders in Root Crops. Nukualofa, Kingdom of Tonga, 17-20 April 1995.

ISSN 2053-5805(Print), ISSN 2053-5813(Online)

Landon, J.R. (eds). (1991).*Booker, Tropical Soil Manual*.A Handbook for Soil Survey and Agricultural Land Evaluation in Tropics and Sub-tropics., John Willey and Sons Inc.New York, USA, Third Avenue.

Lindstorm, M.J., Schumacher, T.E., Jones, A.J. and Gantzer, C. (1992).Productivity Index and Model Comparison for Selected Soils in North Central United States.*Journal of Soil and Water Conservation*47**(6)**:491-494.

Mba, C.C. (2004).*Selected Methods for Soils,Plant and Environment Analysis:* Department of Soil Science.Handbook.Department of Soil Science, University of Nigeria, Nsukka 47p.

National Soil Erosion and Productivity Research Planning Committee (1981). Soil erosion effects on soil productivity. A research perspective.*Journal of Soil and Water Conservation*36:82-90.

Nwite, J.N. and Obi.M.E. (2008).Quantifying the productivity of selected Soils in Nsukka and Abakaliki, Southeastern Nigeria using productivity Index.*Agro-Science* 7(**3**):170-178.

Nwite, J.N. (2013).*Evaluation of the Productivity of Automobile Oil Contaminated Soil amended with Organic Wastes in Abakaliki, Southeastern Nigeria.*Ph.D Thesis, University of Nigeria, Nsukka1-130pp.

Obi, M.E. (2000).*Soil Physics*.A Compendium ofLectures Nsukka.Altanto publishers, Nigeria 28p.

ODNRI (1989).Overseas Development of Natural Resources Institute.Nigeria Profile of Agricultural Potential,ODA United Kingdom 3p.

Odu, C.T.I., Nwoboshi, L.C., Fagade, S.O. and Awani, P.E. (1989). *Post -impact study of SPDC's Nun River and delivery line of oil spillage*. Final Report SPDC Nigeria 95p.

Pierce, F.J., Larson, W.E., Dowdy, R.H. and Graham, W.A.P. (1983). Productivity of Soils.Assessing long term changes due to erosion.*Journal ofSoil and Water Conservation* 38:39-44.

Steel, G.D. and Torrie, J.H. (1980).*Procedures of Statistics*.A Biometrical Approach 2nded. New York: McGraw Hill, Book Company 63p.

Williams, J.R., Sharpley, A.N. and Taylor, D. (1990).The Erosion Productivity Impact Calculator.*In:*Boardman, J., Foster, I.D.L. and Dearing, J.A. (eds). Soil Erosion on Agricultural Land. John Wiley and Sons, New York.

Wommer, P.L. and Muhena, F.N. (1993).Overcoming Soil Constraints in Crop Production in Tropical Africa.*In*: Sustaining Soil Productivity in Intensive African Agriculture.Proceedings of AgriculturalAssociationin Tropical Africa15-19 November, Accra Ghana.

ISSN 2053-5805(Print), ISSN 2053-5813(Online)