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Evaluation of productivity indices of spent lubricant oil contaminated soil bioremediated with organic wastes in abakaliki, southeastern, Nigeria

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ABSTRACT

This experiment was carried out at the Teaching and Research Farm of the Faculty of Agriculture and Natural Resources Management, Ebonyi State University Abakaliki in order to evaluate productivity indices of spent lubricant oil-contaminated soil bio-remediated with organic wastes for three (2006 – 2008) cropping seasons. The field was laid out in randomized complete block design (RCBD). The spent lubricant oil was applied blanket on soil at 5 % equivalent to 50,000 mg kg-1 to all the plots to serve as source of contamination. The organic wastes were burnt rice husk dust, unburnt (fresh) rice husk dust, sawdust and control applied at 20 t ha-1 equivalent to 8 kg ha-1 and replicated five times. Modified Pierce et al. productivity index was used to compute the productivity indices. The modified productivity index entailed use of sufficiencies for bulk density, available water capacity, root weighting factor (RWF), pH and exclusion of sufficiencies for aeration and electrical conductivity. The productivity indices (PI) were highest (P1=0.31, 0.27, 0.27 and 0.27) for oil contaminated soil treated with saw dust (OS), oil contaminated soil treated with unburnt rice husk dust (OU), oil contaminated soil amended with (OS) and oil contaminated soil treated with unburnt rice husk dust (OU) amended plots in 2006, 2007 and 2008 cropping seasons, respectively. These PI were 29, 35 and 80% higher than the control for the three seasons for the respective treatments of OS, OU and OS and OU. The mean productivity indices were (x=0.19, 0.27, 0.24 and 0.27) for control, OU, OB and OS amendments, respectively. Grain yields of maize of 1.72 and 1.70 t ha-1 were obtained for PI of 0.31 and 0.30 for oil contaminated soil treated with saw dust (OS) and oil contaminated soil amended with unburnt rice husk dust (OU) amended plots, respectively. Oil contaminated soil treated with unburnt rice husk dust (OU) (x=27) and oil contaminated soil amended with saw dust (OS) (x=0.27) wastes predicted highly for spent oil contaminated soil amended with organic wastes and could be recommended for bio-remediation of such soil in Abakaliki.

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Introduction

Soil is a primary recipient of a myriad of waste products and chemicals used in modern industrial society (Brady and Weil, 2002). Modern industrialized societies have developed plastics and plasticizers, lubricants, and refrigerants, fuels and solvents, pesticides and preservatives (Adesodun, 2004). According to Lauhanen *et al.* (2004), organic chemicals might enter the soil as contaminants in wastes applied on soils or as fertilizer, in large or small lubricants and fuel leaks and as sprays applied to control pests (Adesodun, 2004). Some of these waste compounds are toxic in very small concentrations. Once waste materials enter the soil, they become part of a biological cycle that affect all forms of life. Contamination of a soil with toxic substances can degrade its productive capacity to provide habitant for crops (Brady and Weil, 2002).

In Nigeria, the common sources of soil contamination are household wastes, agricultural wastes, gas flaring and spent lubricant oil. However, soil and water contamination by crude oil is a sensitive issue in the Niger Delta areas (Anon, 1985). Nevertheless, the impact of spent lubricant oil contamination in the environment has been shown to be more wide spread than crude oil (Atuanya, 1987). For instance, Nigeria was reported to account for more than 87 million litres of spent waste annually (Anon, 1985) and adequate attention has not been given to its disposal (Anoliefo and Vwioko, 1994). Contamination of soil and groundwater with spent lubricant oil commonly called in Nigeria as “condemned” engine oil obtained after servicing of automobiles is a common phenomenon in the mechanic village known as “site” in Abakaliki. The spent lubricant oil is disposed off indiscriminately by “motor mechanics” and it spreads to gutters, water drains and farms. Farmers abandon such farms for contamination and odour problem.

Reclamation of land contaminated with waste organic materials coupled with enhanced awareness of their potential adverse effects on the human and environment has received increasing international attention in recent years (Susan and Kelvin, 1993). Physical and chemical methods most widely used for land treatment of oil-based waste have been criticized as inadequate and ineffective (Abu and Ogiji, 1996). Besides, the methods could result in further contamination of the environment. Since oil degradation is limited by scarcity of nutrients such as nitrogen and phosphorus as well as, oxygen and temperature (leahy and Colwell, 1990; Ladousse and Tramier, 1991), bio-remediation has been recommended as cost

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effective, safe and environmentally friendly for treatment of hydrocarbon contaminated soils.

Bioremediation is introduction of organic matter to oil contaminated soil (Odokuma and Dickson, 2003). Reclamation of crude oil contaminated soil has increased but little or no research has been carried out to reclaim the spent lubricant oil contaminated soils at Abakaliki area of Nigeria. The objective of this study was to evaluate the productivity index of spent lubricant oil-contaminated soil amended with organic wastes.

Materials and Methods

The study was carried out at Teaching and Research Farm of the Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki. The area is located by latitude 06^o4^1N and longitude 08^o65^1E in the derived savannah zone of the southeast agro-ecological area of Nigeria. The rainfall pattern is bimodal (April – July and September – November), with a short dry spell in August normally referred to as "August break". The total annual rainfall in the area ranges from 1500 to 2000 mm with a mean of 1,800 mm. At the onset of rainfall, it is torrential and violent and sometimes lasting for one to two hours. The area is characterized by high temperatures with minimum mean daily temperature of 27^oC and maximum mean daily temperature of 31^oC throughout the year. Humidity is 80% and 60% for rainy and dry seasons (ODNRI, 1989). Geologically, the area is underlain by sedimentary rocks derived from successive marine deposits from the cretaceous and tertiary periods. Abakaliki agricultural zone lies within Asu river group and consists of olive brown sandy shales, fine grained sand stones and mudstones. The soil is shallow with unconsolidated parent materials (shale residuum) within 1 m of the soil surface. It belongs to the order ultisol and is classified as Typic Haplustult (FDALR, 1985).

The vegetation of the place is primarily derived savannah, with bush regrowth and scanty economic trees. There was growth of native vegetation such as *Trida spp, Odoratum spp, Aspilia africana* and *Imperata cylindrico* before and cultivation.

Field Methods

An area of land (0.021ha) was used for the study. The field was demarcated into plots and replicates using Randomized Complete Block Design (RCBD). The plots measured 2 m x 2 m with plot alley of 0.5 m spacing. The four replicates were separated by 1 m spaces each. 5% of spent lubricant oil collected from mechanic village, Abakaliki was sprayed uniformly on the entire field with spraying machine after clearing before demarcation. This was allowed for one week in other for the spent lubricant oil to infiltrate into the soil. Then, the field was demarcated into plots. The treatments were control, 20 tha^{-1} of burnt rice husk dust, unburnt rice husk dust and saw dust. The organic wastes were sourced from agro rice mill industry for rice husk dust both burnt and unburnt rice husk dust, and timber shade market for saw dust. These wastes were spread on the plots and incorporated into the soil using native hoe during seedbed preparation. The treatments were replicated five times to give a total of twenty plots in the experiment. In the second year, the procedure was repeated while residual effect was tested in third year.

Maize seed (Suwan -1-SR-hybrid variety) sourced from Ebonyi State Agricultural Programme (EBADEP) was planted (2 seeds per hole) at 5 cm depth and spacing distance of 25 x 75 cm two weeks after organic wastes application. Two weeks after emergence (WAE), the plants were thinned down to one per hole while lost stands were replaced. Weak plants were rouged out and replaced by planting another seed leaving a plant population of approximately 53,000 stands per hectare. There was application of NPK 20:10:10 fertilizer at 400 kg ha^{-1} to all the plots two weeks after plant emergence (WAPE). The fertilizer was banded and placed 5 cm away from the maize plants. Weeds were removed at three-weekly intervals up till harvest.

Soil Sampling

Initial soil samples were collected from 0 – 20 cm depth using soil auger and cores at different points in the study site before application of spent lubricant oil, organic wastes and cultivation. Core and auger samples were collected at 0 – 15, 15 – 30, 30 – 45 and 45 – 60 cm depths in each plot and used for soil productivity index evaluation.

Agronomic Data

The cobs were harvested at plant maturity. This was when the husks were dried. The cobs were dehusked and further dried before shelling and grain yield determined at 14% moisture content.

Evaluation of soil productivity index

The modified Pierce *et al.* (1983) productivity index model was used. The Pierce *et al.* (1983) productivity index is expressed thus:

$$P1 = \sum_{i=1} (A_i \times B_i \times C_i \times D_i \times E_i \times Wf_i) \quad \ldots\ldots\ldots \quad 1$$

where PI = productivity index

A_i = Sufficiency for available water capacity for the ith soil layer

B_i = sufficiency for aeration for the ith soil layer

C_i = sufficiency for pH for the ith soil layer

D_i = sufficiency for bulk density for the ith soil layer

E_i = sufficiency for electrical conductivity for the ith soil layer

Wfi = Root weighting factor

r = number of horizons in the rooting zone

Modification of Pierce *et al*. (1983) productivity index model

Modified Pierce *et al.* (1983) productivity index model entailed exclusion of sufficiencies for aeration since it could be predicted from bulk density and electrical conductivity which is common in the dry north of the country. The electrical conductivity is not common in Southeastern Nigeria where the experimental was carried out. The modified productivity index is thus expressed as follows:

$$P1_m = \sum_{i=1} (A_i \times C_i \times D_i \times Wf_i) \quad \ldots\ldots\ldots \quad 2$$

where

$P1_m$ = Modified productivity index.

A_i = Sufficiency for available water capacity for the ith soil layer

C_i = sufficiency for pH for the ith soil layer

D_i = sufficiency for bulk density for the ith soil layer

Wfi = Root weighting factor

r = number of horizons in the rooting zone

Hence, the modified productivity index was calculated based on sufficiencies for available water capacity, pH, bulk density, root weighting factor and number of horizons in the rooting one.

Laboratory Methods

Core samples were used to determine physical properties of soil. Bulk density determination was done as described by Blake and Hartge (1986). Available water capacity was determined using pressure plate apparatus (Obi, 2000). Soil rooting zone (RWF) was by measurement using meter rule. Auger samples were air dried and passed through a 2 mm sieve. They were used to determine soil pH in soil/water solution ratio of 1:2.5. The pH value was read off using Beckman Zeromatic pH meter (Peech, 1965).

Table 1. Some properties of the soil at the initiation of the study

Soil properties	Unit	Values
Sand	gkg^{-1}	660
Silt	gkg^{-1}	210
Clay	gkg^{-1}	130
Textural class		Sandy loam
pH in KCL		5.1
OC	%	1.84
OM	%	3.17
N	%	0.16
Na	$Cmolkg^{-1}$	0.17
K	$Cmolkg^{-1}$	0.18
Ca	$Cmolkg^{-1}$	5.20
Mg	$Cmolkg^{-1}$	3.80
Available P	$Mgkg^{-1}$	4.70
Base saturation	%	6.8
CEC	$Cmolkg^{-1}$	10.3
EA	$Cmolkg^{-1}$	0.7
ECEC	$Cmolkg^{-1}$	7.97

OC-organic carbon, OM-organic matter, N-nitrogen CEC-cation exchange capacity, EA-exchangeable acidity, ECEC-effective cation exchange capacity.

Table 2. Some properties of organic wastes and spent lubricant oil

Treatment	Parameter	Unit	Value
Burnt rice husk dust	Na	$Cmolkg^{-1}$	0.4
	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
Saw dust	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	$Cmolkg^{-1}$	-.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	$Cmolkg^{-1}$	15.6
	Cu	$Cmolkg^{-1}$	9.1
	Zn	$Cmolkg^{-1}$	31.2
	Pb	$Cmolkg^{-1}$	4.0
	OC	%	17.3
	N	%	6.8
	P	$Mgkg^{-1}$	0.02
	C:N	%	11.38
	THC	%	33.4

OC-organic carobon, N-nitrogen, C:N-Carbon nitrogen, P-available phosphorus, THC-total hydrocarbon.

Table 3. Some properties, ascribed sufficiency values and calculated productivity indices 2006

O Soil property	Measured property soil depth (cm)				Ascribed sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.68	1.69	1.78	1.80	0.12	0.11	0.02	0.01
AWC (Cm/cm)	0.16	0.17	0.19	0.20	0.60	0.65	0.78	0.79
pH in Kcl	3.4	3.2	3.1	3.0	0.21	0.12	0.07	0.03
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.24			

OU Soil property	Measured property soil depth (cm)				Ascribed sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.66	1.68	1.76	1.78	0.13	0.12	0.04	0.02
AWC (Cm/cm)	0.17	0.18	0.19	0.10	0.65	0.70	0.78	0.78
pH in KCL	3.5	3.4	3.3	3.2	0.25	0.21	0.16	0.12
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.28			

OB Soil property	Measured property soil depth (cm)				Ascribed sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.60	1.64	1.78	1.79	0.20	0.16	0.04	0.01
AWC (Cm/cm)	0.17	0.18	0.19	0.20	0.65	0.70	0.78	0.79
pH in KCL	3.5	3.5	3.4	3.4	0.25	0.25	0.21	0.21
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.28			

OS Soil property	Measured property soil depth (cm)				Ascribed sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.63	1.66	1.68	1.70	0.17	0.14	0.12	0.10
AWC (Cm/cm)	0.17	0.18	0.19	0.20	0.65	0.70	0.78	0.79
pH in Kcl	3.9	3.9	3.8	3.6	0.43	0.43	0.38	0.30
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.31			

O – Oil, OU, oil contaminated amended with lubricant rice husk dust, OB – oil contaminated amended with burnt rice husk dust, OS-oil contaminated amend with saw dust, P1-productivity index.

Table 4. Soil properties ascribed sufficiency values and calculated productivity indices – 2007

O Soil property	Measured property soil depth (cm)				Ascribed sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.80	1.80	1.81	1.84	0.10	0.09	0.02	0.01
AWC (Cm/cm)	0.16	0.17	0.18	0.18	0.60	0.65	0.70	0.70
pH in KCL	3.5	3.3	3.1	3.0	0.25	0.16	0.07	0.03
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.20			

OU Soil property	Measured property soil depth (cm)				Ascribed sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.67	1.79	1.80	1.80	0.30	0.03	0.04	0.04
AWC (Cm/cm)	0.18	0.19	0.19	0.21	0.65	0.78	0.78	0.78
pH in KCL	3.5	3.5	3.4	3.3	0.65	0.65	0.65	0.65
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.27			

OB Soil property	Measured property soil depth (cm)				Ascribed sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.66	1.68	1.80	1.83	0.14	0.12	0.04	0.01
AWC (Cm/cm)	0.18	0.18	0.19	0.19	0.65	0.65	0.78	0.78
pH in KCL	3.5	3.5	3.5	3.4	0.25	0.25	0.25	0.21
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.23			

OS Soil property	Measured property soil depth (cm)				Ascribed sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.66	1.68	1.78	1.80	0.14	0.12	0.04	0.04
AWC (Cm/cm)	0.16	0.18	0.19	0.19	0.60	0.70	0.78	0.78
pH in KCL	3.9	3.9	3.8	3.6	0.43	0.43	0.38	0.30
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.27			

O – Oil, OU, oil contaminated amended with lubricant rice husk dust, OB – oil contaminated amended with burnt rice husk dust, OS-oil contaminated amend with saw dust, P1-productivity index.

Table 5. Soil properties, ascribed sufficiency values and calculated productivity indices – 2008

O Soil property	**Measured property soil depth (cm)**				**Ascribed sufficiency**			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.85	1.89	1.91	1.92	0.05	0.02	0.01	0.01
AWC (Cm/cm)	0.15	0.16	0.17	0.18	0.55	0.60	0.65	0.70
pH in Kcl	3.6	3.5	3.5	3.4	0.30	0.25	0.25	0.21
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.15			

OU Soil property	**Measured property soil depth (cm)**				**Ascribed sufficiency**			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.80	1.82	1.84	1.85	0.04	0.08	0.06	0.01
AWC (Cm/cm)	0.16	0.17	0.18	0.19	0.60	0.65	0.07	0.78
pH in Kcl	4.1	4.1	4.0	4.0	0.52	0.52	0.47	0.47
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.27			

OB Soil property	**Measured property soil depth (cm)**				**Ascribed sufficiency**			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.82	1.83	1.85	1.87	0.08	0.07	0.03	0.03
AWC (Cm/cm)	0.16	0.16	0.17	0.18	0.60	0.60	0.65	0.70
pH in Kcl	4.2	4.1	4.0	4.0	0.56	0.52	0.47	0.47
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.23			

OS Soil property	**Measured property soil depth (cm)**				**Ascribed sufficiency**			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (Mgm^{-3})	1.81	1.82	1.84	1.86	0.09	0.08	0.06	0.04
AWC (Cm/cm)	0.17	0.17	0.18	0.18	0.65	0.65	0.70	0.70
pH in Kcl	4.1	4.1	4.0	3.8	0.52	0.52	0.47	0.38
RWF (DRZ) cm	60	60	60	60	1.00	1.00	1.00	1.00
P1					0.25			

O – Oil, OU, oil contaminated amended with lubricant rice husk dust, OB – oil contaminated amended with burnt rice husk dust, OS-oil contaminated amend with saw dust, P1-productivity index.

Table 6. Productivity index and grain yield of maize

Treatment	**P1**	**Grain yield of maize (t ha^{-1})**
O	0.24	1.63
O	0.20	1.50
O	0.15	1.30
OB	0.28	1.70
OB	0.23	1.62
OB	0.23	1.62
OU	0.28	1.70
OU	0.27	1.68
OU	0.27	1.68
OS	0.31	1.72
OS	0.27	1.68
OS	0.25	1.66

O – Oil, OU oil contaminated amended with lubricant rice husk dust, OB – oil contaminated amended with burnt rice husk dust, OS-oil contaminated amend with saw dust, P1-productivity index.

Total nitrogen was determined using the micro Kjeldhal distillation method of Bremner (1996). Available phosphorus determination was by Bray-2 method as described in Page *et al.* (1982). The method described by Nelson and Sommers (1982) was used to determine organic carbon. The exchangeable bases of calcium (Ca) and Magnesium (Mg) were determined by titration method (Mba, 2004). Sodium (Na) and potassium (k) were extracted with IN ammonium acetate solution (NH_4OAC) and determined using flaming photometer. Carbon – Nitrogen (C: N) was calculated as the product of value of organic carbon divided by value of nitrogen. The heavy metals of copper (Cu), Zinc (Zn) lead (Pb) and cadmium (Cd) were extracted using the method of Ano (1994). Total hydrogen carbon content (THC) determination was done gravimetrically using cold extraction method of Odu *et al*. (1989).

Results and discussion

Some soil initial properties

Table 1 shows soil properties at the initiation of study before soil contamination, cultivation, planting and application of treatments. The samples were taken at 0 – 20 cm depth. The value of organic carbon and organic matter were moderate (Landon, 1999). Available phosphorus was low (Enwezor *et al* 1982). Exchangeable calcium (Ca) and Magnesium (Mg) dominated the exchange complex (Table 1). The exchangeable sodium (Na) and potassium (K) were low (Asadu and Nwake, 1999). Cation exchange capacity was rated low according to Asadu and Nweke (1999) while percent base saturation (6.8%) was very low. Exchangeable acidity (EA) and effective cation exchange capacity (0.7 – 7.97 cmolkg^{-1}) were low (Asadu and Nweke 1999)

Bulk density (1.48 Mg m^{-3}) was low and non-limiting (Arshad *et al.*, 2006). Available water capacity was high (0.20 cm^{-1}) and non-limiting according to Grossman and Berdanier (1982). Total porosity was 44 % and rated as medium (Obi, 2000) and not limiting to soil productivity. The pH (4.8 in KCL was very strongly acidic (Schoeneberger *et al.*, 2002).

Nutrient composition of treatments

Nutrient composition of treatments (Table 2) is generally low compared to the soil (Table 1). The exchangeable cations were low (Landon, 1991). However, percentage organic carbon and total N ranged from 6.92 to 16.3 % and 0.28 to 0.48 % in the organic wastes and rated high according to Landon (1991). Available phosphorus ranged from 3.00 to 14.00 m kg^{-1} in the organic wastes and rated low (Enwezor *et al.*, 1981). The C: N ratios were 23, 32 and 34, respectively for burnt rice husk dust, saw dust and unburnt rice husk dust, respectively.

The values of Cu, Zn and Pb in spent lubricant oil were within normal levels as recommended by Alloway (1990). The percentage of organic carbon (OC), total N were 17.3 and 6.8, respectively for the spent lubricant oil and according to Enwezor *et al.* (1981) are high. Available phosphorus was very low with value of 0.02 mg kg-^{1} (Landon, 1991) in the oil. The C N ratio and total hydrocarbon values were 11.38 and 33.4% (Table 2).

Productivity Index

Soil properties, ascribed sufficiency values and calculated productivity index (PI) under different treatments for three seasons are shown in Tables 3 -5. The soil properties and their individual sufficiency values were used in the computation of productivity index under each treatment and study year. Productivity index is an algorithm which expresses relationship between soil depth and crop yield. On the other hand, ascribed sufficiency value is a response curve which relates a measured value for a soil factor to a dimensionless sufficiency of root growth between 0.0 and 1.0. Soil weighting factor is the relative importance of a soil layer for the plant.

The productivity index was 0.31, 0.28, 0.28 and 0.24 for oil contaminated soil treated with saw dust (OS), oil contaminated soil treated with burnt rice husk dust (OB), oil contaminated soil treated with unburnt rice husk dust (OU) and control (oil application without organic wastes amendment) (O) in the first season, respectively. Productivity index in OS was 23, 10 and 10 % higher when compared to control, OU and OB in first season. Even though, the productivity index decreased generally in the second year, they were of the order OS = 0.27 > OU=0.27>OB=0.23> C=0.20. P1 was higher in OU and OS amended plots by 26 and 15 % when compared to control and OB treated soil in the second year. The productivity index was generally lower in the residual season (third year). The trend is OU =0.27>OS=0.25>OB=0.23 >C=0.15. Furthermore, the productivity index of OU increased by 7, 15 and 44 % relative to OS, OB and control in third season. Generally, the productivity index for three years of study could be in the order of OS>OU>OB>C. Therefore, in assessing the productivity index of treatments, P1 of OS and OU could be rated as medium, P1 of OB as low and P1 of control very low. Similar finding of productivity index performance in oil contaminated soil amended with organic wastes was reported in the study area by Nwite, (2013).

Productivity index and grain yield of maize

Table 5 indicates that grain yield of maize of 1.72 t ha^{-1} was highest for productivity index of 0.31 and this was obtained in OS amended plots. Productivity index of 0.30 for OU amended plots gave 1.70 t ha-^{1} yield of maize. The productivity index increased or decreased with grain yields of maize. High productivity indices gave correspondingly high grain yield of maize while low grain yield of maize was obtained in where productivity indices were low. These findings are consistent with the report of Nwite and Obi (2008), Nwite *et al.* (2009), Nwite (2002) and Anikwe (2000) that grain yields of maize followed the trend of increases or decreases in productivity index. According to Pierce *et al.* (1983), Anikwe (2000), Nwite (2002) and Nwite and Obi (2008), productivity index is a veritable tool for predicting soil productivity.

Conclusion

The findings in the study show that productivity index of spent lubricant oil contaminated soil amended with organic wastes could be evaluated. The productivity index of oil contaminated soil amended with saw dust (OS) predicted highest yield of maize followed by unburnt rice husk dust (OU) treated plot. The burnt rice husk dust amended soil predicated low productivity and control very low. The grain yields of maize confirmed the productivity index predictions obtained from the different treatments. Generally, saw dust or unburnt rice husk dust could be recommended for bio-remediation of spent lubricant oil contaminated soil for enhanced productivity.

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