Prediction Of Productivity Of Spent Lubricant Oil Uncontaminated And Contaminated Soil Amended With Organic Wastes Using Modified Productivity Index In Abakaliki, Nigeria

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Abstract: A research was carried at the Teaching and Research farm of the Faculty of Agriculture and Natural resources Management, Ebonyi State University, Abakaliki to predict the productivity of spent lubricant oil contaminated and uncontaminated soil amended with organic wastes. Maize (Oba super II hybrid) variety was used as a test crop. The productivity index was modified by excluding sufficiencies for aeration and electrical conductivity. Soil parameters namely available water capacity, bulk density, rooting depths, soil horizons and soil P^H were used to compute productivity index. The results indicated that modified productivity indices for uncontaminated soil amended with organic wastes were highest when compared with contaminated soil. Similarly, Maize grain yields increased with increase in productivity index and decreased with decrease in productivity index. Relationship between productivity index and maize grain yield showed highly significant correlation (r= 0.96 at p >0.01) in uncontaminated soil but was reduced to r= 0.79 at p <0. 01 in contaminated soil. This represented 18% increase in correlation coefficient of uncontaminated soil over contaminated soil. Spent lubricant oil contamination of soil could not probably be a limiting factor to soil productivity. [Nature and Science. 2009;7(7):100-112]. (ISSN: 1545-0740).

Keywords: Modified, Prediction, Productivity, Spent Lubricant oil, Soil.

INTRODUCTION

Soil is a universal recipient of myriad of organic wastes and chemicals (Brady and Weil, 2002) produced in modern industrial society. Modern industrial society has manufactured among other things plastic and plasticizers, paints, refrigerants, fuels and lubricants. These products when they enter into the soil become contaminants and capable of reducing its productivity. Soil contaminants are any chemical, physical, biological or radiological materials introduced into the soil. Oil products and hydrocarbons are the most common sources of soil contamination. Contamination of soils could also result in most cases from careless use of chemicals such as fertilizer or simply out of ignorance (Lauhanen ***et al.,*** 2004). Soil contamination occurs when contaminants reach any level that is harmful (Adesodun, 2004).

Lubricant oil contaminated soil has serious fertility problems (Vuoto ***et al.,*** 2005). Soil properties such as bulk density, soil porosity, infiltration rate, hydraulic conductivity, Soil p^H, moisture content, soil type and amount of major nutrients are affected as well as microbial and mineral concentrations of soil. These attributes of soil could be used to evaluate soil productivity. Soil productivity according to Soil Science Society of America (1975) is the capacity of a soil in its normal environment to produce a particular plant or sequence of plants under a specified management system. This is expressed when soil is able to produce a good crop yield with a minimal input at a given set of practices.

Spent lubricant oil contamination had been widely reported by (Atuanya, 1987) and most common in Nigerian cities. Abakaliki is affected by oil drained from machines by mechanics" which is often discarded indiscriminately on the soil. Incidentally, researchers do not seem to take particular interest in this direction which has resulted to paucity of information. The objective of this study was to predict the productivity of a spent lubricant contaminated and uncontaminated soil amended with organic wastes using modified productivity index of Pierce ***et al.*** (1983).

Materials and Methods

Location and Site Description

The experiment was conducted at the Teaching and Research farm of the Faculty of Agriculture and Natural Resources Management of Ebonyi State University, Abakaliki. The area is located by latitude 06^0 4' N and longitude 08^0 65' E of the derived savannah zone of Nigeria.

The rainfall pattern is bimodal. The mean annual minimum rainfall is 1800 mm while the mean annual maximum rainfall is 2000 mm spread between April to early November. There is short spell in August popularly referred to as "August break". At onset of rainfall, it is violent and often torrential lasting for 1-2 hours. The minimum temperature is 27 ^oC while maximum is 31 ^oC. The relative humidity is highest during rainy season (80%) and declines to 60% in dry season especially at harmattan period. The bedrock geology is shale residuum due to successive marine deposit. The soil belongs to the order ultisol classified as Typic Haplustult (FDALR, 1985).

Field Methods

A total land area of 0.032 hectare was cleared and used for the experiment. The land was demarcated into blocks and plots using a 2 x 4 x 4 split plot in randomized complete block design. Plots measured 2 x 2 m and were separated by 0.5 m while blocks were set apart by 1m giving a total of 32 plots. Spent lubricant oil was sourced from mechanic village, Abakaliki. It was spread uniformly using spraying machine on plots receiving it and allowed one week before applying organic wastes treatment. Organic wastes of burnt rice husk dust, un-burnt rice husk dust and saw dust were applied at 20 t ha^{-1} equivalent to 8 kg $plot^{-1}$ on both contaminated and uncontaminated soils.

Maize Oba super II hybrid variety which was used as a test crop was planted two seeds per hole after two weeks of organic wastes treatment. The plants were spaced 25 x 75 cm. They were thinned to one per hole after two weeks of germination leaving 53,000 stands per hectare. Harvest was taken at maturity of crops and yield data adjusted to 14% moisture content.

Soil samples were collected with auger and core. The samples were collected at 0-15, 15-30, 30-45 and 45-60 depths. Core samples were used to determine physical properties of the soil after passing it through 2 mm sieve.

Laboratory Methods

Bulk density was determined by the method described by Blake and Hartge (1986). Available water capacity determination was by Stolte (1997) method using 1000 kpa (wilting point) and 1500 KPa (permanent wilting point). Soil p^H was by 1:2.5 soil / water ratio and values read in p^H meter.

Productivity Index Model and its Modification.

Pierce ***et al.*** (1983) productivity index is stated as follows:

$$PI = \sum_{i=1}^{r} (A_i \times B_i \times C_i \times D_i \times E_i \times wf_i) \qquad \text{.....1}$$

Where

PI = Productivity index

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

Bi = sufficiency for aeration for the ith soil layer

C_i = sufficiency for p^H 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

Wf_i = Root weighting factor

r = Number of horizons in the rooting zone

Pierce ***et al***. (1983) productivity index was modified to exclude sufficiencies for aeration and electrical conductivity.

Modified productivity index (PIM).

$$PIM = \sum_{i=1}^{r} (A_{ii} \times C_i \times D_i \times Wfi) \qquad \text{.....2}$$

Where

PIM = Modified productivity index

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

C_i = sufficiency for p^H for the ith soil

Di= sufficiency for bulk density for the ith soil layer.

Wfi= root weighting factor.

r= Number of horizons in the rooting zone.

Data Analysis

Data generated after soil analysis were used to compute productivity index and also used to determine relationship between soil properties and grain yield using correlation analysis (Steel and Torrie, 1980).

Results and Discussion

Productivity Index Parameters and Ascribed Sufficiency Values for Contaminated Soil.

Tables 1-4 show soil properties, ascribed sufficiency values and predicted productivity indices for contaminated soils. The soil properties and their individual sufficiency values were used in the computation of productivity index. The result indicated highest productivity indices of 0.57, 0.77, 0.34 and 0.31, respectively for UBRHD, BRHD, BRHD and UBRHD in Tables 1-4.

The control plots contaminated with spent lubricant oil but unamended with organic wastes recorded least productivity indices. These represent 83, 81, 82 and 81%, respectively relative to control productivity indices. This further indicates that organic wastes could be used in ameliorating spent lubricant oil contamination of soil. This result suggest that unburnt and burnt rice husk dust that predicted higher productivity index could be preferred in treatment of spent lubricant oil contaminated soil (Tables 1-4).

Soil Productivity Index Parameter and Ascribed Sufficiency Values for Uncontaminated Soil.

The results on Table 5-8 show soil productivity index parameters and ascribed sufficiency values for uncontaminated soil. Results followed the same trend as in contaminated soil by PI being highest in organic wastes amended soil while they were reduced in control plots un-amended. Productivity indices were 0.87, 0.54, 0.49 and 0.41, respectively for BRHD, SD, BRHD and UBRHD treatments. These results accounted for 44, 82, 14 and 44%, respectively when compared with control plots un-amended with organic wastes.

High productivity index suggest soil with improved soil properties that could boost crop yield. The organic wastes enhanced soil properties such as available water capacity, bulk density, rooting zone and P^H of the soil. Several researchers (Opara-Nadi 1990; Nnabude and Mbagwu, 2000; Agbim, 1985) had earlier reported positive effects of organic wastes in increasing soil productivity.

Soil Productivity Index and Grain Yield of Maize of Contaminated and Uncontaminated Soil Amended with Organic Wastes

Table 9 Shows soil productivity index values and maize grain yields for contaminated and uncontaminated soil amended with organic wastes. The table indicated that mean productivity index value for uncontaminated soil is 0.28 with a corresponding mean maize grain yield value of 1.0 t ha^{-1}. Productivity index recorded highest (0.77) value in burnt rice husk dust amended organic waste in uncontaminated soil, which also had highest maize grain yield of 2.3 tha^{-1}. However, control plots un-amended with organic wastes recorded least value of productivity index and a corresponding least value of maize grain yield (Table1). The table further showed a general and consistent decline in maize grain yield. This suggests that productivity index increase and / or decrease with maize grain yield. This finding is consistent with the report of Nwite (2002) and Anikwe (1999) that maize grain yield increased with productivity index and declined with fall in productivity index.

Similarly, results of contaminated soil show that the mean value for productivity index is 0.34 with a corresponding maize grain yield of 1.06t ha^{-1}. Burnt rice husk dust amended organic waste recorded the highest productivity of 0.58 and a corresponding maize grain yield of 2.2. tha^{-1}. Furthermore, control plot un-amended with organic waste recorded least productivity index of 0.10 and also maize grain yield of 0.3 tha^{-1}. Productivity index had been described by Pierce ***et al.*** (1983), Anikwe (1999) and Nwite (2002) as a veritable tool for predicting soil productivity.

Relationship between Productivity Index and Grain Yield of Maize

Table 10 shows the relationship between productivity indices and maize grain yields of contaminated and uncontaminated soils amended with organic wastes. The results show positive correlation on the two soils. There was a highly significant relationship ($r=0.96$; $P>0.01$) between productivity index and maize grain yield in uncontaminated soil. However, relationship between productivity index and maize grain yield showed significant correlation coefficient of $r = 0.79$ at $P<0.01$ in contaminated soil. The uncontaminated soil increased by 18% in correlation coefficient relative to contaminated soil. The results suggest that although spent lubricant oil could reduce soil productivity, it was not totally limiting. This could be possible since spent lubricant oil contamination has little or no effect on physical properties of soil such as available water capacity, bulk density and rooting depth that are used as parameters for assessing the productivity in this study. Furthermore, Ogbohodo ***et al.*** (2001) had noted that oil contamination had little or no effect on physical properties of soil.

Conclusion

The results of this study indicate that spent lubricant oil contaminated and uncontaminated soil amended with organic wastes could be predicted using modified productivity index. The predicted productivity indices of uncontaminated soils were generally higher relative to contaminated soils. Similarly, productivity indices corresponded with maize grain yields. This showed that spent lubricant oil contamination of soil is probably not limiting to soil productivity. Furthermore, organic wastes could be used to ameliorate spent lubricant oil contamination of soil.

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Table1. Soil Productivity and Ascribed Sufficiency values for uncontaminated soil

CONTROL

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15- 30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{3})	1.57	1.72	1.72	1.76	0.79	0.29	0.24	0.19
AWC (cm/cm)	0.36	0.46	0.49	0.49	1.00	1.00	1.00	1.00
p^H in KCL	4.8	5.5	5.4	5.1	0.09	0.00	0.00	0.00
Depth of rooting								

Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.10

BRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15,	15- 30,	30-45,	45-60	0-15,	15-30,	30-45,	45-60
Bulk density (gcm^{-3})	1.09	1.21	1.44	1.64	1.00	1.00	1.00	0.59
AWC (cm/am)	0.31	0.42	0.46	0.46	1.00	1.00	1.00	1.00
p^H in KCL	5.6	5.0	4.6	4.2	0.00	0.00	0.19	0.39
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.87

UBRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15,	15- 30,	30-45,	45-60	0-15,	15-30,	30-45,	45-60
Bulk density (gcm^{-3})	1.14	1.57	1.67	1.74	1.00	0.79	0.49	0.20
AWC (cm/cm)	0.32	0.38	0.55	0.69	1.00	1.00	1.00	1.00
p^H in KCL	5.6	5.4	5.4	4.4	0.00	0.00	0.00	0.29
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.14

SD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15,	15- 30,	30-45,	45-60	0-15,	15-30,	30-45,	45-60
Bulk density (gcm^{-3})	1.18	1.45	1.59	1.61	1.00	1.00	0.70	0.69
AWC (cm/cm)	0.56	0.62	0.68	0.93	1.00	1.00	1.00	1.00
p^H in KCL	5.3	5.2	5.2	4.0	0.00	0.00	0.00	0.49
Depth of rooting Zone	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.49

Table 2. Soil Productivity and Ascribed Sufficiency values for uncontaminated soil.

CONTROL

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15,	15- 30,	30-45,	45-60	0-15,	15-30,	30-45,	45-60
Bulk density (gcm^{-3})	1.72	1.78	1.86	1.88	0.29	0.09	0.00	0.00
AWC (cm/cm)	0.26	0.40	0.37	0.67	1.00	1.00	1.00	1.00
p^H in KCl	5.1	5.3	4.3	5.5	0.00	0.00	0.00	0.00
Depth of rooting Zone	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.10

BRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15,	15- 30,	30-45,	45-60	0-15,	15-30,	30-45,	45-60
Bulk density (gcm^{-30})	1.14	1.49	1.49	1.65	1.00	1.00	1.00	1.00
AWC (cm/cm)	0.36	0.47	0.44	0.53	1.00	1.00	1.00	1.00
p^H in KCl	5.3	5.4	5.4	4.4	0.00	0.00	0.00	0.00
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.29

UBRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15,	15- 30,	30-45,	45-60,	0-15,	15-30,	30-45,	45-60
Bulk density (gcm^{-3})	1.49	1.55	1.57	1.79	1.00	0.79	0.88	0.09
AWC (cm/cm)	0.39	0.43	0.70	0.45	1.00	1.00	1.00	1.00
p^H in KCl	5.4	5.4	5.4	4.6	0.00	0.00	0.00	0.00
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI					0.17			

SD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15,	15- 30,	30-45,	45-60	0-15,	15-30,	30-45,	45-60
Bulk density (gcm^{-3})	1.54	1.61	1.67	1.69	0.89	0.69	0.49	0.39
AWC (cm/cm)	0.47	0.60	0.67	0.75	1.00	1.00	1.00	1.00
p^H in KCl	4.0	4.2	4.9	5.0	0.48	0.39	0.09	0.00
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.45

Table 3. Productivity index and Ascribed sufficiency values for uncontaminated soil

CONTROL

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15,	15- 30,	30-45,	15-60	0-15,	15-30,	30-45,	45-60
Bulk density (gcm^{-3})	1.57	1.59	1.68	1.75	0.79	0.70	0.40	0.19
AWC (cm/cm)	0.47	0.52	0.56	0.58	1.00	1.00	1.00	1.00
p^H in KCl	5.9	4.4	4.3	4.3	0.29	0.00	0.30	0.30
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI					0.42			

BRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15,	15- 30,	30-45,	15-60	0-15,	15-30,	30-45,	45-60
Bulk density (gcm^{-3})	1.50	1.52	1.70	1.83	1.00	1.00	0.39	0.00
AWC (cm/cm)	0.25	0.36	0.54	0.65	1.00	1.00	1.00	1.00
p^H in KCl	5.3	4.5	4.5	4.4	0.00	0.20	0.20	0.29
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.49

UBRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15,	15- 30,	30-45,	45-60	0-15,	15-30,	30-45,	45-60
Bulk density (gcm^{-3})	1.51	1.58	1.61	1.77	0.99	0.78	0.69	0.10
AWC (cm/cm)	0.40	0.54	0.67	0.74	1.00	1.00	1.00	1.00
p^H in KCl	5.3	4.5	4.5	4.4	0.00	0.20	0.20	0.29
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI					0.45			

SD

Soil Properties	Soil Depth (cm)	Ascribed Sufficiency

	Soil Depth (cm) 0-15, 15- 30, 30-45, 45-60				Ascribed Sufficiency 0-15, 15-30, 30-45, 45-60			
Bulk density (gcm^{-3})	1.52	1.67	1.68	1.89	0.98	0.49	0.40	0.00
AWC (cm/cm)	0.39	0.59	0.68	0.93	1.00	1.00	1.00	1.00
p^H in KCL	5.4	4.9	4.4	4.1	0.00	0.09	0.29	0.40
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI						0.43		

Table 4. Productivity index and Ascribed sufficiency values for uncontaminated soil.

CONTROL

Soil Properties	Soil Depth (cm) 0-15, 15- 30, 30-45, 45-60				Ascribed Sufficiency 0-15, 15-30, 30-45, 45-60			
Bulk density (gcm^{-3})	1.51	1.5	1.69	1.70	0.99	0.79	0.39	0.39
AWC (cm/cm)	0.42	0.49	0.56	0.60	1.00	1.00	1.00	1.00
p^H in KCl	5.5	5.2	4.4	4.3	0.00	0.00	0.29	0.30
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI							0.23	

BRHD

Soil Properties	Soil Depth (cm) 0-15, 15- 30, 30-45, 45-60				Ascribed Sufficiency 0-15, 15-30, 30-45, 45-60			
Bulk density (gcm^{-3})	1.68	1.71	1.73	1.74	0.40	0.30	0.29	0.20
AWC (cm/cm)	0.37	0.37	0.44	0.63	1.00	1.00	1.00	1.00
p^H in KCl	4.5	4.4	4.4	4.3	0.20	0.29	0.29	0.30
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI						0.32		

UBRHD

Soil Properties	Soil Depth (cm) 0-15, 15- 30, 30-45, 45-60				Ascribed Sufficiency 0-15, 15-30, 30-45, 45-60			
Bulk density (gcm^{-3})	1.57	1.64	1.66	1 .70	0.79	0.59	0.49	0.39
AWC (cm/cm)	0.53	0.60	0.60	0.63	00	1.00	1.00	1.00
p^H in KCl	5.7	5.3	4.6	4.5	0.00	0.30	0.19	0.20
Dept of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.41

SD

Soil Properties	Soil Depth (cm) 0-15, 15- 30, 30-45, 45-60				Ascribed Sufficiency 0-15, 15-30, 30-45, 45-60			
Bulk density (gcm^{-3})	1.48	1.79	1.80	1.81	1.00	0.09	0.00	0.00
AWC (cm/cm)	0.42	0.42	0.56	0.60	1.00	1.00	1.00	1.00
p^H in Kcl	5.5	5.2	4.4	4.3	0.00	0.00	0.29	0.30
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.29

Table 5. Productivity index and Ascribed sufficiency values for contaminated soil

Soil Properties	Soil Depth (cm) 0-15	15- 30	30-45	45-60	Ascribed Sufficiency 0-15	15-30	30-45	45-60
CONTROL								
Bulk density (gcm^{-3})	1.56	1.76	1.77	1.86	0.80	0.19	0.10	0.00
AWC (cm/cm)	0.44	0.52	0.55	0.56	1.00	1.00	1.00	1.00
p^H in KCl	5.5	5.5	5.4	4.3	0.00	0.00	0.00	0.30
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI							0.10	
BRHD								
Bulk desity (gcm^{-3})	1.60	1.61	1.71	1.91	0.69	0.69	0.39	0.00
AWC (cm/cm)	0.31	0.47	0.57	0.64	1.00	1.00	1.00	1.00
p^H in KCl	5.5	5.3	4.5	4.3	0.00	0.00	0.20	0.30
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.27
UBRHD								
Bulk density (gcm^{-3})	1.30	1.56	1.62	1.65	1.00	0.80	0.60	0.50
AWC (cm/cm)	0.49	0.50	0.56	0.58	1.00	1.00	1.00	1.00
p^H in KCl	5.4	5.1	4.4	4.1	0.00	0.00	0.29	0.40
Depth or rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.57
SD								
Bulk density (gcm^{-3})	1.36	1.49	1.70	1.82	1.00	1.00	0.39	0.00
AWC (cm/cm)	0.44	0.49	0.60	0.87	1.00	1.00	1.00	1.00
p^H in KCl	5.5	5.1	4.3	4.3	0.00	0.00	0.30	0.30
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI							0.30	

Table 6. Productivity index and Ascribed Sufficiency values for contaminated soil

Soil Properties	Soil Depth (cm) 0-15	15- 30	30-45	45-60	Ascribed Sufficiency 0-15	15-30	30-45	45-60
CONTROL								
Bulk density (gcm^{-3})	1.36	1.71	1.73	1.95	1.00	0.30	0.29	0.00
AWC (cm/cm)	0.35	0.38	0.44	0.45	1.00	1.00	1.00	1.00
p^H in KCl	5.6	5.1	4.4	4.0	0.00	0.00	0.29	0.49
Depth or rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00

PI								0.15

BRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.45	1.46	1.55	1.63	1.00	1.00	0.88	0.59
AWC (cm/cm)	0.35	0.38	0.40	0.43	1.00	1.00	1.00	1.00
p^H in KCl	5.5	4.5	4.5	4.2	0.00	0.20	0.20	0.39
Depth or rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.77

UBRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.67	1.70	1.78	1.85	0.49	0.30	0.09	0.00
AWC (cm/cm)	0.44	0.50	0.58	0.65	1.00	1.00	1.00	1.00
p^H in KCl	5.6	5.4	4.3	4.3	0.00	0.00	0.30	0.30
Depth or rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.15

SD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.48	1.58	1.78	1.84	1.00	0.78	0.09	0.00
AWC (cm/cm)	0.35	0.47	0.50	0.65	1.00	1.00	1.00	1.00
p^H in KCl	5.5	4.5	0.45	4.2	0.00	0.20	0.20	0.39
Depth or rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.39

Table 7. Productivity index and Ascribed sufficiency values for contaminated soil

CONTROL

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.64	1.74	1.79	1.91	0.59	0.20	0.20	0.00
AWC (cm/cm)	0.36	0.38	0.41	0.50	1.00	1.00	1.00	1.00
p^H in KCl	5.4	5.2	4.5	4.3	0.00	0.00	0.30	0.20
Depth or rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.60

BRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.64	1.74	1.79	1.91	0.59	0.20	0.20	0.00
AWC (cm/cm)	0.36	0.38	0.41	0.50	1.00	1.00	1.00	1.00
p^H in KCl	5.4	5.2	4.5	4.3	0.00	0.00	0.30	0.20
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00

PI								0.34

UBRH

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.42	1.68	1.77	1.78	1.00	0.40	0.10	0.09
AWC (cm/cm)	0.35	0.38	0.51	0.76	1.00	1.00	1.00	1.00
p^H in KCl	5.6	5.2	4.6	4.3	0.00	0.09	0.09	0.30
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.32

SD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.34	1.48	1.81	1.82	1.00	1.00	0.09	0.00
AWC (cm/cm)	0.42	0.43	0.45	0.57	1.00	1.00	1.00	1.00
p^H in KCl	4.7	4.5	4.4	3.9	0.10	0.20	0.29	0.52
Depth or rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.30

Table 8. Productivity index and Ascribed sufficiency values for contaminated soil

CONTROL

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.45	1.76	1.77	1.79	1.00	0.19	0.10	0.09
AWC (cm/cm)	0.32	0.46	0.47	0.50	1.00	1.00	1.00	1.00
p^H in KCl	5.6	5.1	4.3	4.3	0.00	0.00	0.30	0.30
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.06

BRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.59	1.59	1.63	1.66	0.70	0.70	0.59	0.49
AWC (cm/cm)	0.41	0.50	0.59	0.59	1.00	1.00	1.00	1.00
p^H in KCl	5.4	5.3	4.9	4.3	0.00	0.00	0.09	0.70
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00
PI								0.26

UBRHD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency			
	0-15	15-30	30-45	45-60	0-15	15-30	30-45	45-60
Bulk density (gcm^{-3})	1.67	1.67	1.68	1.90	0.49	0.49	0.40	0.00
AWC (cm/cm)	0.40	0.50	0.55	0.58	1.00	1.00	1.00	1.00
p^H in KCl	5.6	5.1	4.4	4.4	0.00	0.00	0.29	0.29
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00

PI									0.31

SD

Soil Properties	Soil Depth (cm)				Ascribed Sufficiency				
	0-15,	15- 30,	30-45,	45-60	0-15,	15-30,	30-45,	45-60	
Bulk density (gcm^{-3})	1.76	1.77	1.79	1.82	0.19	0.10	0.09	0.00	
AWC (cm/cm)	0.34	0.43	0.44	0.47	1.00	1.00	1.00	1.00	
p^H in KCL	5.3	4.4	4.1	4.1	0.00	0.29	0.40	0.40	
Depth of rooting Zone (cm)	60	60	60	60	1.00	1.00	1.00	1.00	
PI									0.11

Table 9. Soil productivity index and maize grain yield of uncontaminated and contaminated soil

Uncontaminated soil			Contaminated		
Treatments	PI	Maize grain yield (t ha^{-1})	Treatments	PI	maize grain yield (t ha^{-1})
C	0.10	0.4	C	0.10	0.30
C	0.15	0.6	C	0.10	0.30
C	0.06	0.2	C	0.42	1.3
C	0.06	0.2	C	0.23	0.6
B	0.27	1.8	B	0.58	2.2
B	0.77	2.6	B	0.29	0.8
B	0.24	1.3	B	0.49	1.5
B	0.26	1.7	B	0.32	0.9
U	0.57	2.4	U	0.14	0.4
U	0.15	0.6	U	0.17	0.7
U	0.32	1.2	U	0.45	1.4
U	0.31	1.0	U	0.14	1.1
S	0.30	0.9	S	0.49	1.5
S	0.39	1.8	S	0.54	2.0
S	0.30	0.9	S	0.43	1.2
S	0.11	0.5	S	0.29	0.8
Total	4.46	16.1	Total	5.45	17.0
Mean	0.28	1.01	Mean	0.34	1.06

C – Control
B – Burnt
U – Unburnt
S – Sawdust

Table 10. Relationship between productivity index and maize grain yield

Dependent parameters	regression model	correlation (r) Coefficient	Soil type
PI VS maize grain yield (tha^{-1})	Y = 3.47 x – 0.12	0.96 **	uncontaminated
PI VS maize grain yield (tha^{-1})	Y = 2.99 x + 0.17	0.79 *	contaminated

AWC - Available water capacity
BRHD - Burnt rice husk dust
Control - control plot un-amended with organic wastes
PI - Productivity index
SD - Saw dust
UBRHD - Un-burnt rice husk dust
VS - Versus
* - Significant
** - Highly significant

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