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# Productivity Assessment of an Ultisol Contaminated with Crankcase Oil in Abakaliki Southeastern, Nigeria

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## ABSTRACT
Productivity assessment of an Ultisol contaminated with crankcase oil was carried out in an ultisol for threecropping seasons. Core and auger soil samples were collected at twelve points each year in the experimental plot to determine physicochemical properties for productivity assessment. Maize variety (Oba super II) hybrid was used as a test crop. Data obtained from soil and crop was subjected to correlation and regression analysis to determine relationship between soil properties and grain yield of maize. Results showed highly significant ($P<0.05$) relationship between bulk density (r=0.91), available water capacity (r=0.94), organic carbon (r=0.85), available phosphorus (r=0.82), pH (r=0.97) and grain yield of maize, respectively. Significant ($P<0.05$) relationships were obtained between total porosity (r=0.50), magnesium (r=0.59) and grain yield of maize. Regression analysis indicated highly significant ($P<0.05$) relationships between bulk density ($r^2$=0.83), available water capacity ($r^2$= 0.89), organic carbon ($r^2$= 0.72), pH ($r^2$=0.94) and grain yield of maize. Other soil properties studied showed positive relationships with grain yield of maize indicating that they influenced soil productivity. Productivity assessment is therefore an effective tool to assess soil's continuing ability to provide food for mankind. It is concluded that proper and sound evaluation of soil through periodic productivity assessment should be carried out for its effective management for sustainable productivity.

**KEYWORDS:** Assessment, Contaminated, Crankcase oil, Productivity, Ultisol,

## INTRODUCTION

With the advent of technology and industrialization, modern societies developed lubricants, fuels and solvents, pesticides, herbicides and preservatives [21]. The soil isa sink for these chemicals which become contaminants when they are applied to the soil [29] to serve some specific purposes such as to control pest or weeds [26]. Some of the waste compounds are toxic in very small concentrations so that once the materials enter the soil, they become part of a biological cycle that affects all forms of life. Contamination of a soil with toxic substances can degrade its productive capacity to provide habitat for crops [15].

In Nigeria and at Abakaliki in particular, the common sources of soil contamination are house hold wastes, agricultural wastes and crankcase oil [26]. The impact of contamination of crankcase oil in the environment is widespread [2] and yet adequate attention has not been given to it [32]. For instance, presence of spent lubricant oil in soil increases bulk density, decreases water holding capacity and aeration propensity [3]. The authors also noted reduced nitrogen, phosphorus, calcium, magnesium, potassium and increased levels of heavy metals in soil contaminated with spent oil.

In most cities and towns in Nigeria, farmers or residents grow vegetables, maize [34] or any other edible crops around or within crankcase oil contaminated environment without much concern about its productivity. There has been a report of general unsatisfactory seed germination, growth and yield in soil contaminated with spent lubricant oil. Agbogidi and Enujeke [3] reported low yield and decreased growth of plant grown in spent lubricant oil contaminated soil. These negative observations were further corroborated by other researchers such as Okonokhua*et al.* [33] including Agbogidi and Nweke [4] and Wang *et al.* [41].

There are numerous mechanic workshops in Abakaliki urban environment and rural areas. Our traditional approach of food production without proper and sound evaluation of soil as most common in developing countries [1] can no longer be relied upon for sustainable production. It is on this basis that there is need to carry out a research on crankcase oil contaminated soil.

This would not only raise awareness on the degradation of soil lay a combined practice of crankcase oil contamination and tillage but could assist critical stakeholders, farmers, agronomists, and other land users as well as policy makers to develop best soil management practices that would enhance durable productivity. The objectives of this work were (1) study crankcase oil contaminatedtilled soil (2) assess its productivity using maize as a test crop for three consecutive years in Abakalikiagroecological environment of Nigeria.

## MATERIALS AND METHODS

*Experimental Site:*

The research work was carried out for three years 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 $06^0 04^/$N and longitude $08^0 65^/$E of southeast in the derived Savannah agricultural zone of Nigeria. The pattern of rainfall observed in the area is bimodal and is spread from April-July and September-November with a break in August usually referred to as “August break”. The minimum rainfall is 1700 mm while maximum is 2000 mm with a mean of 1800 mm. The temperatures are $27^0$C and $31^0$C for minimum and maximum, respectively. The relative humidity is 60% during the dry period and 80% in the rainy season [35]. The soil of the area is derived from successive marine deposits from cretaceous and tertiary periods. According to Federal Department of Agricultural Land Resources (FDALR) [19], Abakaliki agro-zone lies within “Asu River” and is associated with Olive brown sandy shale, fine grained sandstones and mudstones. The soil is shallow with unconsolidated parent material (Shale residuum) within 1 m of the soil surface. The soil belongs to the order ultisol and is classified as *Typichaplustult* [20].

The vegetation of the areas is primarily derived Savanna with bush regrowth and scanty economic trees. The site had history of previous cultivation of maize (*Zea mays L.)* and cassava (*Manihot spp.)*. There is growth of native vegetation such as *Tridaxspp*, *panicum* maximum and other herbs and shrubs.

*Fields Methods:*

A land area of 0.04ha was cleared of existing vegetation and used for the experiment. The debris left after clearing was removed without burning from the site. 50%of crankcase oil equivalent to 50,000mgkg$^{-1}$was applied to the plot each year for three cropping seasons. Traditional hoe was used to till the soil flattwo weeks after oil application. There were no beds. Maize (Oba super II) hybrid variety was used as a test crop. The maize seeds were obtained from Ebonyi State Agricultural Development Programme (EBADEP) office at OnuebonyiIzzi, Abakaliki. The maize seeds were planted at two seeds per hole and at 25 cm x 75 cm planting distance. Two weeks after germination (WAG), the maize seedlings were thinned down to one per hole, weak ones and those which did not germinate were replaced by replanting. This gave a total of approximately 53,000 plants per hectare. Fertilizer, NPK 15:15:15 was applied at rate of 400kgha$^{-1}$ to the plot two weeks after planting at 5cm depth and 10-15cm away from plants for the three cropping seasons. Weeds were removed by using hand hoe at two weekly intervals till harvest. Grain yield was collected at harvest by harvesting the cobs when the husks had dried, dehusked, threshed, dried and grain yield determined by weighing to constant weight.

*Soil Sampling:*

Soil samples were collected with cores and soil auger. Soil samples were sampled at 0-20 cm depth each year at twelve points. The core soil samples were used to determine physical properties of soil while auger samples were for determination of particle size distribution (PSD) and chemical properties.

*Laboratory Methods:*

Bulk density was determined using the core method of Blake and Hartage [14]. The method described by Obi [31] was used in determination of available water capacity. Total porosity was calculated as described by Obi [31]. Soil pH determination was done using soil/water solution ratio of 1:2.5. Soil pH values were read off using Beckman Zaromatic pH meter [37]. Organic carbon determination was done as described in Page *et al.* [36]. Available phosphorus was extracted using Bray-2 method as described in Page *et al.* [36]. Exchangeable calcium and magnesium were extracted according to Mba [25] while potassium and sodium were extracted using flame photometer.Cation exchange capacity was determined in1N $NH_4OAC$. Effective cation exchangeable capacity was determined using summation method as follows:

$$ECEC = TEB + TEA \quad (1)$$

Where:
ECEC = Effective cation Exchange capacity (Cmolkg$^{-1}$ soil)
TEB= Total Exchangeable bases (Cmolkg$^{-1}$ soil)
TEA = Total exchangeable acidity (Cmolkg$^{-1}$ soil)

*Data Analysis:*

Correlation and regression analysis were used to determine relationships between soil properties and grain yield of maize using Statistical Analysis System (1985).

## RESULTS AND DISCUSSION

*Initial Properties of Soil:*

Table 1 shows some initial properties of soil at the beginning of the study. Particle size distribution (PSD) analysis indicates that the fractions generally varied but textural class was sandy loam. The pH in KCl was 5.1 and this implies that the soil was slightly acidic [20]. The percentage organic carbon and available phosphorus were respectively 1.84% and 4.70 mgkg$^{-1}$ and rated low accordingly to Landon [24] benchmark for Nigerian soils. The soil exchange complex was strongly dominated by calcium and magnesium. This is a characteristic of a highly weathered tropical soil as obtainable in southeasternpart of the country. Exchangeable sodium (Na) and potassium (K) were low [11]. The soil was medium (68%) in base saturation [8]. Cationexchange capacity (CEC) and effective cation exchangeable capacity(ECEC) were low according to the ratings of Federal Ministry of Agriculture and Rural Development benchmark for Nigerian soils [20].

**Table 1:** Initial Properties of the soil at the beginning of study

| Soil properties | Unit | Value |
|---|---|---|
| Sand | gkg$^{-1}$ | 660 |
| Silt | gkg$^{-1}$ | 210 |
| Clay | gkg$^{-1}$ | 130 |
| Textural class | | sandy loam |
| pH in kcl | | 5.1 |
| Organic carbon | % | 1.84 |
| Nitrogen | % | 0.16 |
| Available phosphorus | mgkg$^{-1}$ | 4.70 |
| Calcium | cmolkg$^{-1}$ | 5.20 |
| Magnesium | cmolkg$^{-1}$ | 3.80 |
| Sodium | cmolkg$^{-1}$ | 0.17 |
| Potassium | cmolkg$^{-1}$ | 0.18 |
| Base saturation | % | 68.0 |
| Cation exchange capacity | cmolkg$^{-1}$ | 10.3 |
| Effective cation exchangecapacity | cmolkg$^{-1}$ | 7.97 |

*Nutrient Composition of Crankcase Oil:*

Nutrient Composition of Crankcase Oil is presented in Table 2. The respective values of copper (Cu), cadmium (Cd), lead (Pb) and zinc (Zn) in crankcase oil were within the recommended high levels in soils [23]. The percentage organic carbon and total N were 17.3 and 6.8% respectively and rated high according to the standard set by Federal Ministry of Agriculture and Water Resources [20] for Nigerian Soils. Available phosphorus was very low with valueof 0.02 mgkg$^{-1}$ [24]. The C:N ratio and total hydrocarbon (THC) were 11.38 and 33.4% (Table 2).

**Table 2:** Nutrient Composition of Crankcase Oil

| Nutrients | Unit | Value |
|---|---|---|
| Cadmium | mgkg$^{-1}$ | 15.6 |
| Copper | mgkg$^{-1}$ | 9.1 |
| Zinc | mgkg$^{-1}$ | 31.2 |
| Lead | mgkg$^{-1}$ | 4.0 |
| Organic carbon | % | 17.3 |
| Nitrogen | % | 6.8 |
| Available phosphorus | mgkg$^{-1}$ | 0.02 |
| C:N | | 11.38 |
| Total hydrocarbon | | 33.4 |

*Some Properties of Soil after Contamination:*

Table 3 shows some properties of soil after contamination. Although, the values for particle size distribution varied slightly from pre-contamination ones and across the years, the textural class remained sandy loam. Sand fraction was persistently higher than silt and clay for the three cropping seasons. Furthermore, silt fraction in pre-contamination was higher than that of contamination value and clay fraction except in 2013 season. Bulk density generally increased after first season. Bulk density was 2 and 3% higher in 2012 and 2013 than the one for 2011. Total porosity had inverse relationship with bulk density and followed its trend within the years. Available water capacity decreased by 7 and 8% respectively in 2012 and 2013 seasons when compared to first cropping season. Soil pH was higher in 2011 and decreased afterwards by 5and 8% relative to the value for 2012 and 2013 seasons. Though, it appeared there was phenomenal increase in available phosphorus in 2012 compared to 2011, the value decreased in 2013 season. This accounts for 2 and 6% increments in available phosphorus in 2012 respectively compared to 2011 and 2013 seasons. Organic carbon had same value for 2011 and 2012 study seasons and was subsequently reduced by 37% when compared to 2011 and 2012 values. Total nitrogen was higher in first season and generally decreased by 18% each in subsequentyears. The exchangeablecationsvaried across the seasons but were generally higher in first year while they decreased in 2012 and 2013 seasons. Calcium and magnesium were predominantly higher in the soil across the seasons compared to potassium and sodium, respectively. Thecations were lower in the soil exceptpotassium when compared to pre-contamination study.

High sand contents of the soil compared to other fractions could be attributed to property inherited from the parent materials than contamination and tillage.Sand content of the soils in southeastern region of Nigeria is a characteristic of sand formed on unconsolidated coastal plain and sandstone from Asu River [19]. The distribution of particle sizes gave rise to sandy loam texture. Obi [31] noted that texture was immutable and as a result could not be changed by cultural or temporary management practices. Texture has good relationship with nutrient storage and release, water retention, porosity [31] and specific surface area, soil compatibility and compressibility [38] which affect inherit productivity of soil. The increase in bulk density after first season could be attributed to continuous cultivation and contamination which caused realignment and subsequently compaction of soil particles. This finding is supported by the report of Mbah *et al.* that bulk density increased in hydrocarbon oil contaminated soil after cultivation. The effect of crankcase oil contamination of the soil could be severe and limiting to soil productivity due to continuous cultivation andcompaction. The bulk densities across the seasons were above critical and limiting values for root proliferation and soil productivity [8,31]. Low total porosity as well as available water capacity could be adduced to be the negative implication of high bulk density of soil. Low total porosity hinders root proliferation and limits its capacity to access nutrients and water for physiological process as well as carbohydrate synthesis. Total porosity and available water capacity ranged from critical to limiting values for soil productivity [7]. The decrease in total porosity and available water capacity after first season implies that contamination and continuous tillage could impose impedimentsof poor aeration and moisture stress on soil and cause low productivity (Table 3).These findings validate the earlier reports by Anikwe *et al.* [6,9] that high bulk density reduced cumulative feeding area of roots of plants and caused poor yield of crops through poor aeration, low availablemoisture and nutrients.

Low soil pH obtained in the soil was attributed to utilization of nutrients by crops on one hand and impact of soil contamination and continuoustillage.Vuotoe *et al.* [40] noted that spent lubricant oil contaminated soil had serious fertility problem as it affected soil pH and nutrient availability. Mbah [27] corroborated that continuous tillage reduced soil pH to critical levels for soil productivity. The soil pH values in those three seasons were below critical levels for soil productivity [9] and very strongly acidic. The low available phosphorus, percentage organic carbon and total nitrogen could be as a result of impact of crankcase oil contamination and already low pH of soil. These chemical properties are low according to the ratings of Federal Ministry of Agriculture and Rural Development benchmark for Nigerian soils [20]. Asadu and Akamigbo [12] pointed out that organic matter contents of the soils of the tropics was low because of high temperatures which caused rapid mineralization and negatively influenced organic carbon and total nitrogen of soil.Crankcase oil contamination with high temperature of the tropics and continuous tillage could be very depletive on soil nutrients and this would render it low in productivity. Furthermore, the soil of study was already degraded in terms of its fertility trend.On the other hand, crankcase oil contamination negatively impacted on soil and maskedimprovement that could have been recorded.

Exchangeable cations of calcium (Ca) and magnesium (Mg) were predominantly higher in the soil than potassium (K) and sodium (Na) and thus are as a result of initial high values in the soil. The high values of Ca and Mg could also be attributed to inherent property of sandy loam soils and parent material. However, low exchangeable K and Na implies immobilization due to formation of complexes [5]. Exchangeable Ca and Mg are of low to medium ratings [11] while K and Na are low [22].

**Table 3:** Some properties of soil after contamination

| Some soil properties | 2011 | 2012 | 2013 |
|---|---|---|---|
| Sand ($gkg^{-1}$) | 710 | 580 | 650 |
| Silt ($gkg^{-1}$) | 220 | 300 | 200 |
| Clay ($gkg^{-1}$) | 80 | 120 | 150 |
| Textural class | Sandy loam | sandy loam | sandy loam |
| Bulk density ($gcm^{-3}$) | 1.70 | 1.73 | 1.76 |
| Total porosity (%) | 35.94 | 34.90 | 33.77 |
| Available water capacity ($cm^{-1}$) | 0.14 | 0.13 | 0.12 |
| pH KCL | 3.7 | 3.5 | 3.4 |
| Available phosphorus ($mgkg^{-1}$) | 23.04 | 23.39 | 22.05 |
| Organic carbon (%) | 1.18 | 1.18 | 0.74 |
| Nitrogen (%) | 0.17 | 0.14 | 0.14 |
| Calcium ($cmolkg^{-1}$) | 2.25 | 2.05 | 2.04 |
| Magnesium ($cmolkg^{-1}$) | 1.34 | 1.26 | 1.25 |
| Potassium ($cmolkg^{-1}$) | 0.63 | 0.58 | 0.54 |
| Sodium ($cmolkg^{-1}$) | 0.17 | 0.16 | 0.15 |

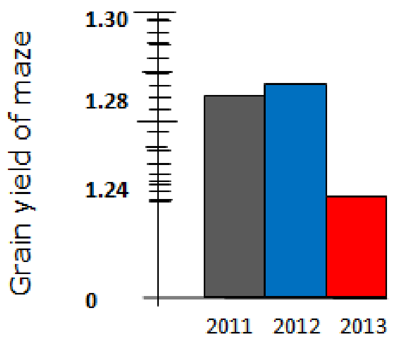
*Grain Yield of Maize:*

Table 4 and figure 1 show grain yield of maize for three seasons as influenced by continuous tillage and crankcase oil contamination. The grain yield of maize was higher in 2011 and generally decreased in subsequent seasons. The reductions in grain yield of maize in 2012 and 2013 seasons were 2 and 5% respectively in respect of 2011 yield (Table 4).

Low grain yield of maize is therefore, expected due to low trend of nutrients across the seasons (Table 3) consequent upon continuous tillage and contamination. The implication is that the maize crops had low nutrient utilization in the soil as observed by Aulakh *et al.* [13]. High bulk, low total porosity and poor availability of moisture would be major physical constraints to grain yield of maize. Anikwe *et al.* [13] earlier noted that high bulk density and low total porosity reduced root penetration and feeding area to crop which contributed to low grain yield of maize. On the other hand, Brady and Weil [15] corroborated by Agbogidi *et al.* emphasized that contamination of soil with hydrocarbon oil reduced productive capacity of soil and yield of crops.Grain yield of maize for the three seasons fell below high to medium values that had been obtained in southeastern states of Nigeria [28]. This implies that continuous tillage with contamination of soil with crankcase oil could impose severe productivity problem on soil and frustrate the touted fight against food insecurity in the country.

**Table 4:** Grain yield of maize

| Seasons | Grain yield of maize ($t\ ha^{-1}$) |
|---|---|
| 2011 | 1.30 |
| 2012 | 1.28 |
| 2013 | 1.24 |




*Relationship between studied soil properties and grain yield of maize:*

The relationships between studied soil properties and grain yield of maize are shown in Table 5. The results indicated that there were positive relationships between all studied soil properties and grain yield of maize.

The Bulk density, Available water capacity, organic carbon and soil pH had respectively highly ($P<0.01$) correlation coefficient and coefficient of determination with grain yield of maize. The relationships were r=0.95 and $r^2$ =0.89, r=0.94 and $r^2$= 0.89, r =0.88 and $r^2$ = 0.72 and r =0.97 and $r^2$= 0.94 for bulk density, available water capacity, organic carbon and soil pH with grain yield of maize.Similarly, there were r=0.50, r= 0.82 and $r^2$=0.67 andr =0.59 relationships with grain yield of maize for total porosity, available phosphorus and total nitrogen, calcium and magnesium. Total nitrogen, calcium, potassium and sodium had no significant relationships with grain yield of maize.

The highly significant relationships obtained between bulk density, available water capacity, organic carbon, soilpH and grain yield of maize show that these soil properties influence soil productivity. According to

Nwite [30], bulk density, available water capacity, total porosity and nutrient storage influenced productivity of soil. Obi [31] corroborated that soil physical conditions improved the productivity ofsoil.Furthermore, the significant relationships between total porosity, available phosphorus and exchangeable magnesium and grain yield of maize emphasize that these nutrients increase soil productivity as well as crop yield. Organic carbon, available phosphorus and magnesium are major constituents of plant materials [11]. Significant relationship between soil pH and grain yield of maize depicts the fact that it is contributory to soil productivity and enhance crop yield by creating conducive environment for availability of nutrients and their uptake by crops.

**Table 5:** Relationship between studied Soil properties and grain yield of maze

| Parameter | Regression model | r | $r^2$ |
|---|---|---|---|
| Bulk density Vs grain yield of maize | Y=6.42x-2.94 | 0.91** | 0.83** |
| Total porosity Vs grain yield of maize | Y=0.53x+0.02 | 0.50* | $0.25^{ns}$ |
| Available water capacity Vs grain yield of maze | Y=7.74x+0.30 | 0.94** | 0.89** |
| Soil pH Vs grain yield of maize | Y=0.27x+0.32 | 0.97** | 0.94** |
| Organic Carbon Vs grain yield of maize | Y=0.90x-0.22 | 0.85** | 0.72* |
| Available phosphorus Vs grain yield of maize | Y=1.00x+0.01 | 0.82** | 0.67* |
| Nitrogen Vs grain yield of maize | Y=1.06x+1.32 | $0.35^{ns}$ | $0.12^{ns}$ |
| Calcium Vs grain yield of maize | Y=1.16x+0.03 | $0.25^{ns}$ | $0.08^{ns}$ |
| Magnesium Vs grain yield of maize | Y=0.95x+0.18 | 0.59* | $0.35^{ns}$ |
| Potassium Vs grain yield of maize | Y=1.29x+0.04 | $0.09^{ns}$ | 0.01 |
| Sodium vs grain yield of maize | Y=0.08x+1.35 | $0.39^{ns}$ | $0.15^{ns}$ |

VS- Versus, r= correlation coefficient, $r^2$ = coefficient of determination, **-highly significant at P<0.01, *- significant at P< 0.05, ns – not significant.

*Conclusion:*

The results of this study have shown that productivity of an ultisol subjected to continuous tillage and crankcase oil contamination could be assessed using physicochemical properties. Continuous tillage andcrankcase oil contamination increased bulk density, reduced total porosity and available water capacity of the soil to critical and limiting values for productivity. Organic carbon, available phosphorus, nitrogen, pH and exchangeable cations were below the recommended levels for enhanced soil productivity. Continuous tillage with improper soil management practice such as advertent or inadvertent contamination with hydrocarbon oil could impose the danger of low productivity and scuttle the dream for food security. However, with good and proper management by avoidance of continuous tillage and contamination with hydrocarbon oil, productivity of the soil could be sustained at reasonable basis.

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