Ethiopian Journal of Environmental Studies and Management Vol. 6 No.3 2013

PRELIMINARY ASSESSMENT OF THE IMPACT OF CHARCOAL PRODUCTION ON PHYSICO-CHEMICAL PROPERTIES OF SOIL IN RIVERS STATE, NIGERIA

*CHIMA, U.D., ADEDEJI, G.A., and ULOHO, K.O.

http://dx.doi.org/10.4314/ejesm.v6i3.9

Received 6th February 2013; accepted 13th April 2013

Abstract

The charcoal business is rapidly spreading in Nigeria without adequate knowledge of the soil impact. This study examined the impact of charcoal production on selected soil physico-chemical properties and the spatial extent of such impacts. Soil samples were collected at the core of charcoal production sites and at 5m and 10m intervals from the core in North, South, East and West directions, before and after charcoal production. Soil samples were analyzed for particle size distribution, pH, Ca, K, Na, Mg, total N, available P, organic C, Mn, Fe, Cu, Zn, and Bo, using standard analytical laboratory procedures. Student t-test was used to test for significant differences in soil properties before and after charcoal production at different locations. Change index (%) was computed for different locations to ascertain the extent of change in soil properties following charcoal production. There were no significant differences ($p > 0.5$) in percentage sand, silt and clay before and after charcoal production at the core and both 5m and 10m distances in the four directions. Mn, Fe, Cu, Zn, B, pH, exchangeable cations and percentage base saturation increased after charcoal production and varied significantly ($p < 0.5$) before and after production especially at the core. Organic C, total N and available P increased by 0.82%, 0.15% and 13.10mg/kg respectively at the core after charcoal production. Indices of change for soil properties were highest at the core and decreased with increasing distance from the core. The study showed that charcoal production increases the level of most soil chemical properties and that such increase diminish with an increasing distance from the centre of the production site. However, longer period of sampling at specific time intervals is recommended to ascertain the longevity or otherwise of such impacts.

Key words: *Charcoal, Soil, Change index, Niger Delta, Nigeria*

Introduction

The use of charcoal is dominant in rural households. Charcoal is used for small-scale processing activities such as fish smoking, garri frying, maize/plantain roasting, blacksmithing, etc. Increasing populations and incessant outrageous increases in the prices of other energy sources, especially kerosene, has given prominence to the charcoal business which is now spreading rapidly in different parts of Nigeria (Chima, 2006).

However, charcoal production and utilization have their ecological consequences. Despite the economic benefits of charcoal production much concern has been expressed towards the consequences that follow its production. Allen and Barnes (1985) reported that about 7.5 million hectares of closed forest and 3.8 million hectares of African forests are cleared yearly for a variety of purposes ranging from timber production, construction purposes, agriculture as well as charcoal production.

As charcoal production continues, much debate has been generated as to whether the economic benefits of charcoal production worth the environmental consequences that trail its production. Aiyeloja and Chima (2011) having observed that the populations of tree species preferred for charcoal making were on the decline in all the sampled sites with change indices of over 50 per cent in some of the sites, opined that meeting the increasing demand for charcoal and sustaining the profitability of the enterprise will not be realized without ecological consequences. Giller (2001) noted that charcoal production not only affects microbial population and activities in the soil, but also plant- microbe interaction through their effects on nutrient availability and modification of habitat. Charcoal production has also been seen to damage more of the natural

Department of Forestry and Wildlife Management, University of Port Harcourt- Choba, P.M.B. 5323, Port Harcourt, Rivers State, Nigeria.
** Corresponding author* : punditzum@yahoo.ca

ecosystem and contribute more to the loss of the biodiversity (Kokou and Nuto, 2009).

In Nigeria, little attempt has been made to evaluate the soil impact of charcoal production. Oguntunde *et al*. (2004) examined the effects of charcoal production on maize yield, chemical properties and texture of soil, while Ogundele *et al*. (2011) assessed the impacts of charcoal production on soil properties in the derived savanna of Oyo State, Nigeria. This study however, was undertaken to ascertain the preliminary impact of charcoal production on selected soil properties in a rural community within the Niger Delta Region of Nigeria where the charcoal business is emerging. In addition, it examined the spatial extent of such impact with a view to recommending an appropriate distance from which other land uses can be combined effectively with charcoal production. As a preliminary study, it is equally aimed at providing baseline data for further evaluation and monitoring.

Materials and Methods

Description of Study Area

The study was carried out in Odufor Community in Etche Local Government Area. Etche is one of the twenty-three Local Government Areas in Rivers State. It is located at 4.990833^{0}N and 7.054444^{0}E. Rivers state lies on the coastal plain of the eastern Niger Delta. It is found in the humid tropical zone with annual rainfall that ranges from 2000-2470mm, with an annual temperature ranging from 23^{0}C minimum to 32^{0}C maximum and a high relative humidity amounting to 70-90% (NDES, 2001). The inland part of Rivers State consists of tropical rainforest; towards the coast the typical river delta environment features many mangrove swamps. Freshwater swamp forests also abound. Figure 1 is the Map of Etche Local Government Area showing the study location.

Selection of study sites

Three production sites were selected for the study based on the information provided by charcoal producers. There was a distance of not less than 100m between sites. The sites were taken from typical secondary forests. Plant species present at the sites include *Elaeis guineensis, Musanga cecropioides, Irvingia gabonensis, Ceiba pentandra, Terminalia superba, Pentachlethra macrophylla, Milicia excelsa, Annona muricata, Dactyladenia barteri, Alchornea cordifolia, Ficus exasparata, Aspilia africana,* and *Panicum maxima.*

Soil Sampling

Soil samples were collected at the core (centre of the production site) and in four different directions - North, South, East and West, from the core at 5m-intervals up to 10 m on each direction, before and after charcoal production. The collected soil samples were enclosed in polybags and taken to the laboratory for analysis.

Soil Analyses

The soil analysis was done using standard laboratory procedures. Particle size analysis was done using the hydrometer method (Bouyoucous, 1951); the exchangeable bases were determined by the summation method (lITA, 1979); available phosphorus was determined by Bray No. I method (Bray and Kurtz, 1945); exchangeable acidity was determined by extraction with IN Kcl and titrating with NaOH; organic carbon was determined by Walkley Black wet oxidation method (Allison, 1965) and organic matter derived there from by multiplying with 1.72 (Agbenin, 1995); total nitrogen was determined by Kjedahl method (Bremner, 1965); Soil pH was measured in 1:1 soil: water ratio; effective cation exchange capacity was determined as the sum of exchangeable bases and exchangeable acidity; while percentage base saturation was computed by dividing the sum of the charge equivalents of the base forming cations (Ca, Mg, K and Na) with the effective cation exchange capacity of the soil and multiplying by 100 (Lemenih, 2004).

Data Analyses

T-test was used to test for significant differences in means of soil properties before and after charcoal production at the core and different distances/directions. Change Index (%) was used to measure the extent of change in soil properties following charcoal production. The change index was computed according to Islam and Weil (2000); Chima *et al*. (2009), Aiyeloja and Chima (2011), and Awotoye *et al*. (2011). The index of change was derived by finding the difference between means of a determined soil property before and after charcoal production, and expressing the difference as a percentage of the mean value of the soil property before charcoal production. The change index was used as degradation or improvement index.

The formula used for computing the change index is given below.

Change Index (%) = $(\bar{X} - \bar{X}_i / \bar{X}) \times 100$

Where: $\bar{X}$ = mean of a soil property before charcoal production.

$\bar{X}_i$ = mean of the same soil property after charcoal production.

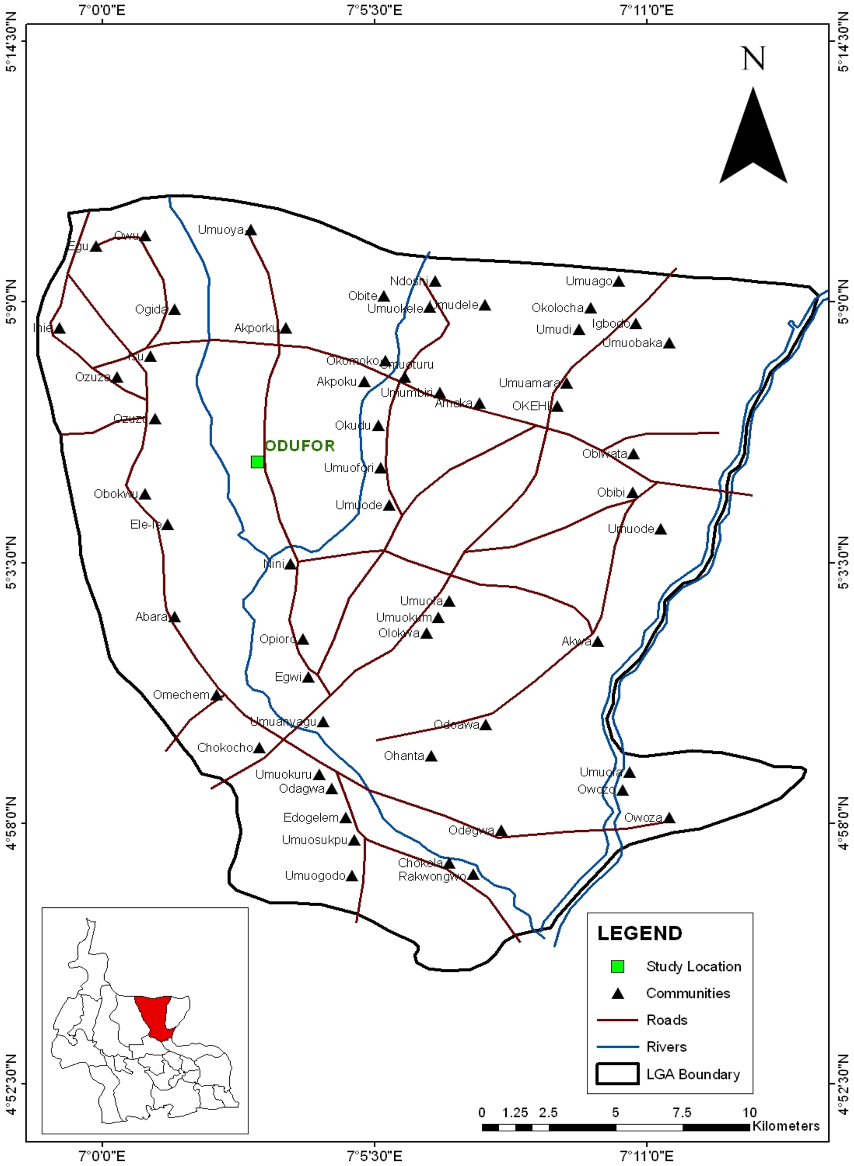

Figure 1 Map of Etche Local Government Area showing the study location (Inset: Map of Rivers State showing Etche Local Government Area)

Results

Table 1 shows the particle size distribution of soil before and after charcoal production in different locations/directions. There was no significant differences in sand, silt and clay contents before and after charcoal production at the core and both 5m and 10m distances in the north, south, east and west directions.

Table 1 Particle size distribution before and after charcoal production

Location	%		
	Sand	Silt	Clay
C_B	84.00^{a}	6.00^{a}	10.00^{a}
C_A	86.00^{a}	5.00^{a}	9.00^{a}
$N1_B$	86.00^{b}	4.00^{b}	10.00^{b}
$N1_A$	85.00^{b}	4.00^{b}	11.00^{b}
$N2_B$	86.00^{c}	6.00^{c}	8.00^{c}
$N2_A$	86.00^{c}	5.00^{c}	9.00^{c}
$S1_B$	87.00^{d}	4.00^{d}	9.00^{d}
$S1_A$	88.00^{d}	4.00^{d}	8.00^{d}
$S2_B$	86.00^{e}	4.00^{e}	10.00^{e}
$S2_A$	86.00^{e}	5.00^{e}	9.00^{e}
$E1_B$	84.00^{f}	5.00^{f}	11.00^{f}
$E1_A$	85.00^{f}	4.00^{f}	11.00^{f}
$E2_B$	86.00^{g}	4.00^{g}	10.00^{g}
$E2_A$	86.00^{g}	3.00^{g}	11.00^{g}
$W1_B$	85.00^{h}	5.00^{h}	10.00^{h}
$W1_A$	85.00^{h}	4.00^{h}	11.00^{h}
$W2_B$	86.00^{i}	4.00^{i}	10.00^{i}
$W2_A$	86.00^{i}	5.00^{i}	9.00^{i}

Values are means for three locations

Means with the same alphabet on the same column and location are not significantly different ($p > 0.05$)

Data for selected micronutrients are presented in Table 2. There were significant differences in all the evaluated micronutrients at the core before and after charcoal production. Manganese varied significantly except at N2, S2, E1 and W2. There was no significant difference in Fe at S1, S2, E1, E2, and W2. Copper did not vary significantly at N1, N2, S1, E1, E2, W1 and W2. Zinc did not vary significantly at N1, N2, S2, and W1, while there was no significant difference in boron levels at N1, N2, E1, and E2.

Table 3 shows the data for soil pH, the exchangeable cations and percentage base saturation. There were significant differences in pH, exchangeable cations and percentage base saturation at the core before and after charcoal production. However, no significant difference was observed in pH at N1, N2, S2, E1 and E2. Calcium did not vary significantly at N2, S1, S2, E1 and W2. Magnesium did not vary significantly at S2, E1 and W1. Sodium varied significantly except at W2. Potassium did not vary significantly at N1, S1 and W2. Exchangeable H did not vary significantly at N2, S2 and E2, while exchangeable Al and ECEC were significantly different in all directions and distances before and after charcoal production. Percentage base saturation was significantly different except at N2 and S2.

Organic carbon, total nitrogen and available P at all locations before and after charcoal production are shown in Figure 2. There was an increase in the levels of these elements after charcoal production though, the increment was sharper at the core and decreased with an increasing distance from the core in all directions.

Table 2 Micronutrients before and after charcoal production

Location	mg/kg				
	Mn	Fe	Cu	Zn	B
C_B	4.70[a]	40.10[a]	0.35[a]	1.10[a]	33.27[a]
C_A	12.40[b]	88.20[b]	0.96[b]	2.29[b]	84.21[b]
$N1_B$	10.70[a]	42.40[a]	0.98[a]	4.05[a]	83.54[a]
$N1_A$	10.00[b]	40.80[b]	0.95[a]	4.06[a]	84.00[a]
$N2_B$	9.60[a]	78.10[a]	0.50[b]	2.98[b]	68.26[b]
$N2_A$	9.55[a]	79.00[b]	0.50[b]	2.87[b]	68.50[b]
$S1_B$	4.80[a]	22.40[a]	0.97[c]	1.61[a]	41.28[a]
$S1_A$	4.52[b]	23.00[a]	0.98[c]	1.59[b]	40.98[b]
$S2_B$	7.40[a]	24.00[b]	0.85[a]	1.46[c]	38.94[a]
$S2_A$	7.10[a]	22.50[b]	0.74[b]	1.46[c]	38.98[b]
$E1_B$	5.70[b]	16.90[c]	0.66[d]	2.69[a]	98.66[c]
$E1_A$	5.82[b]	15.00[c]	0.68[d]	2.88[b]	99.00[c]
$E2_B$	5.50[a]	62.90[d]	0.82[e]	2.82[a]	81.37[d]
$E2_A$	5.80[b]	63.30[d]	0.83[e]	2.77[b]	82.00[d]
$W1_B$	3.20[a]	19.40[a]	1.05[f]	3.93[d]	79.26[a]
$W1_A$	4.50[b]	18.90[b]	1.03[f]	3.97[d]	78.80[b]
$W2_B$	5.90[a]	33.10[e]	0.85[g]	3.35[a]	34.28[a]
$W2_A$	5.82[a]	34.00[e]	0.86[g]	3.29[b]	34.22[b]

Values are means for three locations

Means with the same alphabet on the same column and location are not significantly different ($p > 0.05$)

Table 3 Soil pH and exchangeable cations before and after charcoal production

		cmol (+) kg -1							
Location	pH (H2O)	Ca	Mg	Na	K	H	Al	ECEC	BS (%)
C_B	4.70[a]	0.21[a]	0.33[a]	1.01[a]	0.21[a]	4.10[a]	2.70[a]	13.26[a]	49.00[a]
C_A	6.50[b]	5.99[b]	0.37[b]	1.15[b]	0.86[b]	0.80[b]	0.25[b]	15.92[b]	93.00[b]
$N1_B$	4.20[a]	0.20[a]	1.05[a]	1.27[a]	0.37[a]	3.70[a]	1.20[a]	11.99[a]	59.00[a]
$N1_A$	5.00[a]	0.25[b]	1.10[b]	1.05[b]	0.40[a]	2.95[b]	0.80[b]	11.55[b]	71.00[b]
$N2_B$	4.80[b]	0.07[a]	0.94[a]	1.19[a]	0.52[a]	4.00[a]	2.50[a]	14.02[a]	54.00[a]
$N2_A$	4.70[b]	0.06[a]	0.55[b]	0.90[b]	0.33[b]	3.90[a]	2.20[b]	12.64[b]	52.00[a]
$S1_B$	4.50[a]	0.06[b]	0.16[a]	1.02[a]	0.25[c]	4.90[a]	2.00[a]	12.89[a]	46.00[a]
$S1_A$	5.20[b]	0.08[b]	0.22[b]	0.91[b]	0.40[c]	1.10[b]	0.40[b]	8.31[b]	82.00[b]
$S2_B$	4.30[c]	0.04[c]	0.16[a]	1.18[a]	0.66[a]	3.50[c]	2.50[a]	12.34[a]	51.00[c]
$S2_A$	4.50[c]	0.04[c]	0.15[a]	0.97[b]	0.88[b]	3.20[c]	2.10[b]	11.84[b]	55.00[c]
$E1_B$	4.30[d]	0.02[d]	0.47[b]	1.02[a]	0.55[a]	3.60[a]	2.00[a]	11.96[a]	53.00[a]
$E1_A$	5.00[d]	0.04[d]	0.49[b]	0.92[b]	0.90[b]	1.90[b]	1.25[b]	10.50[b]	70.00[b]
$E2_B$	4.50[e]	0.02[a]	0.46[a]	0.99[a]	0.63[a]	3.00[d]	2.10[a]	11.70[a]	56.00[a]
$E2_A$	5.00[e]	0.21[b]	0.22[b]	0.71[b]	0.76[b]	2.00[d]	1.20[b]	10.10[b]	68.00[b]
$W1_B$	4.50[a]	0.08[e]	0.40[c]	1.40[a]	0.62[a]	2.90[a]	1.50[a]	11.40[a]	61.00[a]
$W1_A$	5.20[b]	0.09[e]	0.56[c]	0.91[b]	0.66[b]	1.40[b]	0.60[b]	9.42[b]	79.00[b]
$W2_B$	4.40[a]	0.05[f]	0.42[a]	0.98[a]	0.40[d]	3.20[a]	2.00[a]	11.45[a]	55.00[a]
$W2_A$	5.30[b]	0.05[f]	0.45[b]	0.98[a]	0.42[d]	1.40[b]	0.60[b]	9.20[b]	78.00[b]

Values are means from three locations

Means with the same alphabet on the same column and location are not significantly different ($p > 0.05$)

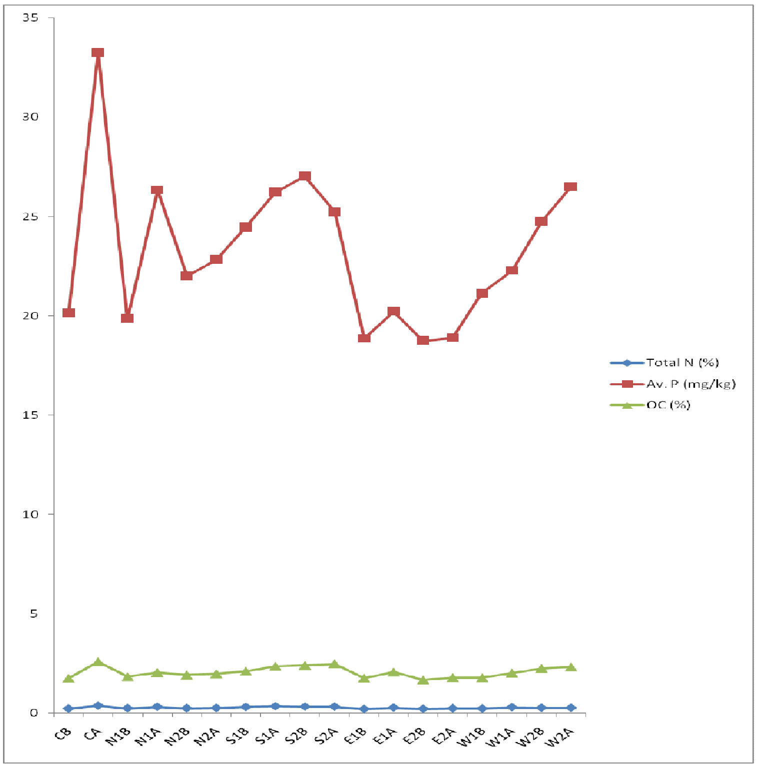

Figure 2 Organic carbon, total nitrogen and available phosphorus before and after charcoal production

The indices of change (%) for selected soil properties are presented in Table 4. The extent of change was highest at the core and decreased with an increasing distance from the core.

Table 4 Indices of change for selected soil properties after charcoal production

Soil property	Change Index (%)								
	Core	N_1	N_2	S_1	S_2	E_1	E_2	W_1	W_2
Organic C	-46.60	-11.41	-3.13	-11.37	-3.33	-16.95	-6.55	-13.48	-3.11
Total N	-65.22	-28.00	-3.85	-12.90	0.00	-33.33	-9.10	-30.43	0.00
Available P	-65.01	-32.58	-3.86	-7.15	6.62	-7.26	-0.69	-5.25	-7.23
Ca	-2752.40	-25.00	14.29	-33.33	0.00	100.00	-950.00	-12.50	0.00
Mg	-12.12	-4.76	41.50	-37.50	6.25	-4.26	52.17	-40.00	-7.14
Na	-13.86	17.32	24.37	10.78	17.79	9.80	28.28	35.00	0.00
K	-309.50	-8.12	36.54	-60.00	-33.33	-63.64	-20.63	-6.45	-5.00
BS%	-89.80	-20.34	-3.70	-78.26	-7.84	-32.08	-21.43	-29.08	-41.32
Mn	-163.84	6.54	0.52	5.83	4.05	-2.11	-5.45	-40.63	1.36
Fe	-119.10	3.77	-1.15	-2.68	6.25	11.24	-0.64	2.58	-2.72
Cu	-174.29	3.06	0.00	-1.03	12.94	-3.03	1.22	-1.90	1.79
Zn	1.08	-0.25	3.69	1.24	0.00	-7.06	1.77	-1.22	1.79
B	-153.11	-0.55	-0.35	0.73	-0.10	-0.34	-0.77	0.58	0.18

Negative (-) value indicates a corresponding percentage increase in the mean value of a soil property at a particular location after charcoal production

Discussion

There was no significant differences in sand, silt and clay contents before and after charcoal production at the core and both 5m and 10m distances in the four directions. Soil texture has been known to be affected by the type and nature of the parent material, and not necessarily land cover type. Although soil physical properties like water retention and aggregate stability were not considered in this study, Sertsu and Sanchez (1978) reported that the presence of charcoal affects soil physical properties such as soil water retention and aggregate stability leading to enhanced crop water availability.

Since, the previous studies in Nigeria (e.g. Ogundele *et al*., 2011; Oguntunde *et al*., 2004) did not consider soil micronutrients, it was considered important to include them in the current study. The study reveals a significant increase in the concentration of the micronutrients after charcoal production. Recent studies have shown that soil charcoal amendments are indeed capable of increasing soil fertility. Charcoal significantly increased plant growth and nutrition in a pot experiment by Lehmann *et al*. (2003) and field experiment by Steiner *et al*. (2007). The authors proposed that charcoal can improve soil chemical, physical and biological properties but could not completely discern the mechanisms of fertility enhancement.

The significant increase in soil pH after charcoal production especially at the core is attributable to the deposition of charcoal particle and ash which are rich in basic cations. This probably explains why there were significant differences in the level of basic cations, effective cation exchange capacity and percentage base saturation before and after charcoal production especially at the core. Ogundele *et al*. (2011) reported that soil pH increased from 5.96 to 6.75 after charcoal production. Blanca *et al.* (2009) has also observed an increase in soil pH from 4.5 at an undisturbed soil to 7.0 at kiln sites. These are comparable to the significant increase in soil pH from 4.7 to 6.5 at the core in this study.

There was an increase in the levels of organic carbon, total nitrogen and available phosphorus after charcoal production though, the increment was sharper at the core and decreased with an increasing distance from the core in all directions. Lehmann *et al.* (2003) attributed higher organic carbon at charcoal production sites to carbon accumulation. The increase in total nitrogen after charcoal production could be attributed to the addition of organic fraction of nitrogen due to charcoal production. Solomon *et al*. (2007) attributed an increase in total nitrogen to the presence of wood ash. Ogundele *et al.* (2011) have also reported an increase in available phosphorus contents during charcoal production and attributed it to the presence of wood ash which is rich in phosphorus. Domaar (1979) equally reported a significant increase in available phosphorus due to burning of crop residue.

Although, there is paucity of literature in respect of the degree of change in soil properties following charcoal production, the results of this study showed that there was momentary improvement in all the evaluated chemical properties after charcoal production especially at the core. This improvement dwindled with an increasing distance from the core of charcoal production site. However, there is need for longer studies that will allow sampling of soil over a long period of time to ascertain the longevity or otherwise of the observed improvement in soil properties following charcoal production.

Conclusion

The impact of charcoal production on soil properties was more on the chemical properties than soil texture. Soil pH, exchangeable bases- Ca, K, Na, and Mg, available phosphorous, total nitrogen, micro-nutrients - zinc, copper, iron, and manganese, significantly increased after charcoal production; while sand, silt and clay did not vary significantly before and after charcoal production. However, the impact was more at the core and sharply decreased at a distance of 5m from the core in all directions, with minimal impacts at 10m from the core. Considering the decreasing trend in the impact of charcoal production on soil properties with distance, and the minimal impact at 10m distance, a distance of 20m may be ideal to combine charcoal production with other land use practices.

References

Agbenin, J.O. (1995), Laboratory manual for Soil and Plant Analysis: Selected methods and
data analysis. Faculty of Agriculture/Institute of Agricultural Research, A.B.U. Zaria, 140pp.

Allison, L.E. (1965), Organic matter. pp. 1367 - 1378. In: C. A. Black (ed.). *Methods of Soil Analysis Part* 2. *Chemical and Microbial Properties,* Agronomy 9. American Society of Agronomy, Madison, Wisconsin.

Aiyeloja, A.A. and Chima, U.D. (2011), Economic and ecological consequences of charcoal production in Oyo State, Nigeria. *Asia-Pacific Journal of Rural Development,* 21(1), 85 – 92.

Allen, J. and Barnes, D. (1985), The Causes of deforestation in developing countries.

Annals of the Association of American Geographers, 75(2), 163-184.

Awotoye, O.O., Ogunkunle, C.O. and Adeniyi, S.A. (2011), Assessment of soil quality under various land use practices in a humid agro-ecological zone of Nigeria. *African Journal of Plant Science,* 5(10), 565 – 569.

Blanca, E.G., Rivera-Mosqueda, M.C., Dendooven, L., Va´ zquez-Marrufo, G., and Olalde-Portugal, V. (2009), Charcoal production at kiln sites affects C and N dynamics and associated soil microorganisms in Quercus spp. temperate forests of central Mexico, *Applied Soil Ecology,* 41, 50 – 58.

Bouyoucous, D.H. (1951), A recalibration of the hydrometer for making mechanical analysis of soils. *Agron. Journ.,* 43,434-438.

Bray, R.H. and Kurtz, L.T. (1945), Determination of total organic and available forms of phosphorus in soils. *Soil Science,* 59, 39 - 45.

Bremner, J.M. (1965), Total nitrogen. pp. 1149 – 1178. In: C. A. Black (ed.). *Methods of Soil Analysis Part* 2. *Chemical and Microbial Properties,* Agronomy 9. American Society of Agronomy. Madison, Wisconsin.

Chima, U. D. (2006), The devastating flames of Abacha Coal-Pots and the people's forests. *World Rainforest Movement Bulletin* No. 106, (2006), Available online at http://www.wrm.org.uy/bulletin/106/AF.html in English, French, Spanish and Portuguese

Chima, U.D., Ola-Adams, B.A., Adedire, M.O. and Oyelowo, O.J. (2009), Impacts of land use changes on soil quality of a biosphere reserve in Southwestern Nigeria. *J. of Research in Forestry, Wildlife and Envr.,* 1(1), 120 – 131.

Domaar (1979), Physical and chemical characters of forest soil in western new-found land, Canada, *European J. Forest Res*., 123(4), 321-130.

Giller. K.E. (2001), *Nitrogen Fixation in Tropical Cropping Systems*, 2nd Edition CAB International Wallingford. 42pp.

International Institute for Tropical Agriculture (IITA) (lbadan, Nigeria) (1979), Selected Methods for Soil and Plant Analysis. Manual Series, No.1. 70pp.

Islam, K.R. and Weil, R.R. (2000), Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. *Agriculture, Ecosystem and Environment,* 79, 9-16

Kokou, K. and Nuto, K. (2009), Assessment of charcoal production and impact of environmental policies in limited forest resources countries: The case of Togo, West Africa, *Discovery and Innovation* Vol. 21.

Lemenih, M. (2004), Effects of Land Use Changes on Soil Quality and Native Flora Degradation and Restoration in the Highlands of Ethiopia: Implications for Sustainable Land Management. Doctoral Thesis, Swedish University of Agricultural Sciences. Uppsala, June, 2004.

Lehmann, J.S. Pereira, C., Steiner, T. Nehls, W. Zech and Glaser, B. (2003), Nutrient availability and leaching in an archaeological anthrosols and a ferralsol of the Central Amazon Basin; Fertilizer, Manure and Charcoal amendments. *Plant and Soil*, 249, 343-357.

NDES, (2001), Biological Environmental Research Report, Rivers State University of Science and Technology (RSUST), Port Harcourt, Vol. 46: 251.

Ogundele A. T., Eludoyin O. S. and Oladapo O. S. (2011), Assessment of impacts of charcoal production on soil properties in the derived savanna, Oyo State, Nigeria, *Journal of Soil Science and Environmental Management*, 2(5), 142-146.

Oguntunde, P.G., Fosu, M., Ajayi, A.E., Giesen, N. (2004), Effects of charcoal production on maize yield, chemical properties and texture of soil, *Biol. Fert. Soil*. 39,295-299.

Sertsu, S.M. and Sanchez, P.A. (1978), Effects of healing on some charges in soil properties in relation to an Ethiopian land management practice. *Soil Sci. Soc Am.,* 42, 40-544.

Solomon, D., Lehmann, J., Thies, J., Schafer T., Liang B., Kinyangi J., Neves, E., Peterson J., Luizo F., and Skjemstad, J. (2007), Molecular signature and source of biochemical recalcitrance of organic carbon in amazonian dark earths. *Acta* 71:2285-2298.

Steiner, C., Teixera, W.G, Lehmann, J., Hehls, T., Macedo, J.L.V., Blum, W.E.W. and Zech.W. (2007), Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered central Amazonian upland soil. *Plant and Soil,* 291, 275-290