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SELECTED FERTILITY INDICES OF TOPSOIL IMPACTED BY EARLY STAGE EROSION IN FOUR LOCAL GOVERNMENT AREAS OF ABIA STATE NIGERIA

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ABSTRACT

The study evaluated the effect of rill erosion on soil fertility in Isuikwuato, Ohafia, Ukwa East and Ikwuano LGAs in Abia state, Nigeria. In each location, five composite topsoil samples of 0 – 20 cm depth were collected from sites which exhibited surface erosion and compared with non eroded soils of the same location. Soil fertility indices were significantly reduced in eroded soils, with mean values of organic carbon at 3.3% in non eroded areas, and only 1.9% in eroded soils. Nitrogen was also significantly lower in eroded soils (0.06% mean) than in non eroded soils (0.07%). Sodium Adsorption Ratio was significantly higher in eroded soils than non- eroded sites across all four locations (8.36 and 6.17 respectively), although salt concentrations were below salinity levels. There was no significant differences in pH, P, K, Ca, exchangeable acidity and effective cation exchange capacity (ECEC) due to rill erosion, even though the values were lower in eroded soils.

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INTRODUCTION

The fertility of a soil is defined as the capacity of that specific soil to sustain plant and animal productivity within natural or managed ecosystems by supplying essential nutrients in adequate and available forms (Karlen et. al., 2008). Soil fertility status is usually estimated in terms of nutrient reserves (Sharma et al., 2011), and this is dependent on microbial communities as microorganisms play a critical role in soil nutrient status and overall crop health and productivity (Ibekwe et al., 2002). Soil quality is the inherent property of a soil to function and it is an overall product of its physical (structural), chemical (fertility) and microbiological status (Olusegun *et. al.,* 2011).

Low organic matter is one of the major constraints to adequate soil fertility in addition to low plant-available nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K) (Agbede, 2009). Topsoil contains most of the soil's nutrients and organic matter, and erosion causes these components to move leaving behind soil with poorer structure and lower fertility (Onweremadu et al., 2007). Organic matter affects crop growth and yield directly by supplying nutrients and indirectly by modifying soil physical properties that can improve the root environment and stimulate plant growth (Hati et al., 2007). Soil erosion causes significant reductions in soil fertility by carrying away the organic matter present in the lighter fractions of the soil surface (Gregoricha *et. al.,* 1998, Mbah and Idike, 2011). In eroded soils, nutrients are depleted, causing a reduction in fertility and general soil

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productivity which ultimately result in lower crop yields (Henao and Baanante, 2001; Lal, 1995). In South East Nigeria, the major causes of erosion are high rainfall, deforestation, fragile nature of the soil and farming activities like bush burning (Igwe and Ejiofor, 2005).

Soils of Abia State Nigeria are developed from coastal plain sand and shale parent materials, and are classified as either Alfisols or Ultisols (Oguike and Mbagwu, 2009). Alfisols are highly leached productive soils but susceptible to erosion if the organic matter cover is removed as occurs from the common practice of bush burning. Burning of natural vegetation also causes the pH of the topmost soil layer to rise and facilitates its disaggregation (Onweremadu et al., 2007). Ultisols on the other hand are strongly acidic soils which are extensively weathered and have low to moderate nutrient reserve. The chemical components of the soil are very important because they have a direct influence soil nutrient availability and consequently, on plant nutrition (Agbede, 2009).

Maintaining production to optimum standards can first and foremost be linked to good, productive, sustainable soils (Nwachukwu and Onwuka, 2011). Soil fertility indices include acidity, organic matter content, macro and micronutrient content, base saturation and cation exchange capacity (Sharma et al., 2011). Soil erosion critically affects these indices, food production efforts, the health of a people and their economy (Uwaegbute, 2011). The objective of this study was to assess the effect of rill erosion on the fertility status of topsoils in four locations in Abia State, Nigeria.

MATERIALS AND METHOD

Four local Government Areas were used in the study, namely Isuikwato, Ohafia, Ikwuano and Ukwa East, randomly selected to represent north, central and south of Abia State.

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Chart 1 Map of Abia State showing the study Locations

The different locations in the State were selected to ensure that the evaluation comprised of heterogeneous soil types or differences due to location. The experiment was designed as 4 X 2 factorial in Completely Randomised Design using 4 local Government areas (locations) and two soil status (eroded soils and non eroded), with five replications. At each LGA (location), five sampling points were selected showing rill or surface erosion, while five non-eroded sampling points were also selected nearby. To obtain the five points in each LGA, a random selection was generally made as point 1, and other sampling points were made at four points within a radius of one kilometre spread out on the four cardinal directions away from the primary sampling point 1. Each point formed a replicate at the given location.

Distances between sampling points and direction were determined by utilizing The Global Positioning System. At each sampling point, five sub samples were collected and bulked to

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make a composite sample. Thus for instance, Ohafia LGA had five composite samples of eroded and five composite samples of non eroded points. The depth of 0 – 20cm was selected because the interest was on rill erosion, and because changes in fertility indices such as organic carbon, pH and essential nutrients in that depth of soil may be corrected more easily in the short term. Samples collected from each location were then conveyed to the Michael Okpara University of Agriculture greenhouse where they were air dried for 48 hours after which they were sieved and stored until analyzed.

DESCRIPTION OF SAMPLING LOCATIONS

Isuikwuato

Global Position: From 5^{o}43’18”N and 7^{o}33’2” E to 5^{o} 45’8”N and 7^{o}29’7”E

Land Use type: Cashew Plantations, arable crop farms of cassava maize, okra, telfaria, cocoyam and yam, with stone mining activities going on in many areas around the farm fields. Traditional homesteads and grazing cattle were observed. The soil was sparsely covered with vegetation showing a lot of exposed soil even on fallow fields. There were hardy perennials on fallow fields and tall grasses along the edge of cultivated fields. Land marks were Amaba- Okigwe – Mbalano road; Isuikwuato LGA headquarters, Cashew plantations, Onicha – Amiyi uhu Road Amuta – Otamkpa road.

Ohafia

Global Position: 5^{o}39’8”N and 7^{o}49’3”E to 3^{o}39’10” N and 7^{o} 49’15”E

Land Use Type: Traditional farm lands of mixed crops of cassava, okra, maize and cocoyam, native oil palm trees interspersed with housing development projects of the Abia State government. Few perennial shrubs were present, while main vegetative cover was hardy grasses on fallow fields. Land Marks were Igbere – Ohafia – Arochukwu road, Ohafia LGA offices, Isiama- Ohafia Housing estates and Nigerian Army Camp, Ohafia.

Ukwa East

Global Position: from 4^{o} 53’22”N and 7^{O}20’57” to 4^{o}59’45”N and 7^{o}20’36”E

Land Use type: Rubber plantations, Nigerian oil pipeline routes, and traditional homesteads and villages. Vegetative Cover was of mixed crop farmlands, many fallow fields of perennial shrub and forest trees, oil palm and rubber plantations. Landmarks were Rubber research Institute of Nigeria, Ukwa East LGA HQ, Asa – Akwete – Obohia road, Umuibe - Akwete – Ndoki road.

Ikwuano

Global Position: 5^{o}28’29” N and 7^{o}32’33”E to 5^{o}29’26”N and 7^{o} 32’ 20”

Land use type: Research Fields of the National Root Crops Research Institute Umudike, Eastern and Western Research fields of the Michael Okpara University of Agriculture, Umudike, Umuariaga community cocoa plantation and shifting cultivation

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farms at Itu Olokoro. Vegetative cover comprised of arable crops, traditional fallow lands, oil palm trees, cassava, cocoa plantation at Umuariaga and forested fields at Ihu Mmuo Itu Olokoro. Landmarks were National Root Crops Research Institute Umudike, Michael Okpara University of Agriculture Umudike, and Umuahia - Ikot Ekpene Road.

The fertility indices determined were pH in a soil: water ratio of 1:2.5; organic matter content (Walkley and Black, 1934) and organic carbon calculated as 58% of that, total nitrogen was determined by the Kjeldahl method (Bremner & Mulvaney, 1982); available phosphorus (Bray and Kurtz, 1945) while potassium and sodium were leached with ammonium acetate and the extract read on a flame photometer. Calcium, Magnesium and Manganese were determined with EDTA titrations (Jackson, 1964). Percentage base Saturation (%B.S) was obtained by calculation after obtaining the individual values of calcium, magnesium, potassium, sodium and aluminium and added with the exchange acidity to give an estimate of the CEC known as Effective Cation Exchange Capacity (ECEC). Sodium Absorption Ratio (SAR) was calculated by the method of Seilsepour et. al. (2009). Analysis of Variance was carried out using Gen Stat 7.2 DE and where significant, means were separated using LSD at 5%.

RESULTS AND DISCUSSION

There was significant effect of surface erosion on the soil content of organic carbon (Table 1), as mean organic carbon in eroded soils (3.3%) was significantly lower than that in non eroded soils across all four LGAs. Such depletion of organic matter leads to lower soil fertility, microbial activity and soil-water-plant relations, crop growth and yield (Freixo et al., 2002). Decrease in soil organic carbon can also reduce cation exchange capacity and soil aggregate stability (Oguike and Mbagwu, 2009).

There was no significant effect of surface erosion on pH, exchangeable acidity and effective cation exchange capacity (Table 1), even though there were general reductions in their values in eroded areas. It may be inferred that this could be due to the early stage of erosion under study. It has been shown however that as erosion becomes more pronounced, it leads to significant impact on the pH of the soils. pH is significant in the assessment of erosion impact on soils because a single one unit change in pH equals a ten-fold change in acidity (Agbede, 2009), and small changes in acidity can drastically affect soil quality.

NITROGEN, PHOSPHORUS AND POTASSIUM

Nitrogen levels were significantly reduced by surface erosion at Isiukwuato and Ikwuano LGAs (Figure 1). Ukwa and Ohafia were not significantly different, even though N levels were higher in rill eroded soil (Figure 1).

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This increase may have been caused by 'hill creep' of nutrients to the lower end of slopes in such locations. Reduced soil nitrogen has adverse implications for crop production because N is a major nutrient essential for vegetative growth of plants (Havlin et al., 2005).

Phosphorus concentrations were not significantly different from that in non eroded soil (Figure 2), although this may change if erosion progresses beyond rill stage.

Potassium was significantly reduced by surface erosion at Ohafia and Ikwuano LGAs, whereas Isiukwuato was not significantly different (Figure 3).

On the other hand, Ukwa showed significantly higher K in eroded soil (Figure 3). This may be due to the fact that the soils of Ukwa East are generally high in clay content (data not shown). Potassium is known to be closely associated with clay, and clay dispersion is aggravated in the presence of erosion (Singha et al., 2011).

Exchangeable bases were significantly reduced by surface erosion (Table 2). Exchangeable cations form a significant component of the fertility of a soil, and this is usually supplied in sufficient quantity to the plant in soils with adequate organic matter content (Paul, 1984).

SODIUM ABSORPTION RATIO

Sodium Absorption Ratio (SAR) was significantly higher in eroded soils than in non eroded soils across the four locations tested (Figure 4). The difference was greatest at Ohafia, where SAR in eroded soils was double that in the non eroded soil (Figure 4).

The Exchangeable sodium Percentage in the study area was however still below the values at which salt accumulation becomes a problem, so the eroded soils may not be classified as sodic or saline. An SAR value below 13 is desirable because when the value is above 13, sodium can cause soil structure deterioration and water infiltration problems (Seilsepour et al., 2009). However, with the SAR value in Ohafia eroded soil at 10.8 (Figure 4), there is indication that unchecked erosion could lead to sodicity in such soils.

CONCLUSION

Erosion affects soil fertility adversely, and these effects can be both direct and indirect. This study showed that organic carbon, nitrogen and exchangeable cations were significantly reduced by surface erosion. Other indices of fertility like phosphorus, exchangeable acidity and effective cation exchange capacity were also lower due to early stages of erosion, although not significantly different from non eroded soils. Sodium adsorption ratio was significantly higher in eroded soils, and this may reach sodic levels in future, which would result in further soil disaggregation. It is apparent that with time, if erosion is not checked in Abia State, loss of nutrients and organic matter will reach levels that will not sustain food productivity. As pre-emptive and mitigation measures, agricultural practices like integrated use of organic and inorganic nutrient sources, inclusion of legumes as intercrops or in

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rotation with other staple crops and conservation tillage should be adopted to continually replenish soil fertility in the highly leached ultisols of Abia State.

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Table 1 Effects of erosion on pH, organic carbon, exchangeable acidity and effective cation exchange capacity in four LGA's of Abia State

Location	pH (water)	Organic C (%)	Exch. Acidity (cmolc/kg)	ECEC (cmolc/kg)
Isuikwuato				
Eroded	5.3	1.6	3.78	19.34
Non eroded	5.2	3.0	3.70	19.66
Ohafia				
Eroded	4.7	1.7	3.60	18.59
Non eroded	5.1	2.9	3.30	18.85
Ukwa East				
Eroded	5.0	1.9	3.72	19.37
Non eroded	5.0	3.1	3.82	18.76
Ikwuano				
Eroded	4.7	2.3	4.18	19.25
Non eroded	5.0	4.2	4.58	20.03
LSD (0.05)	ns	0.42	ns	ns

(Values are means of five replications)

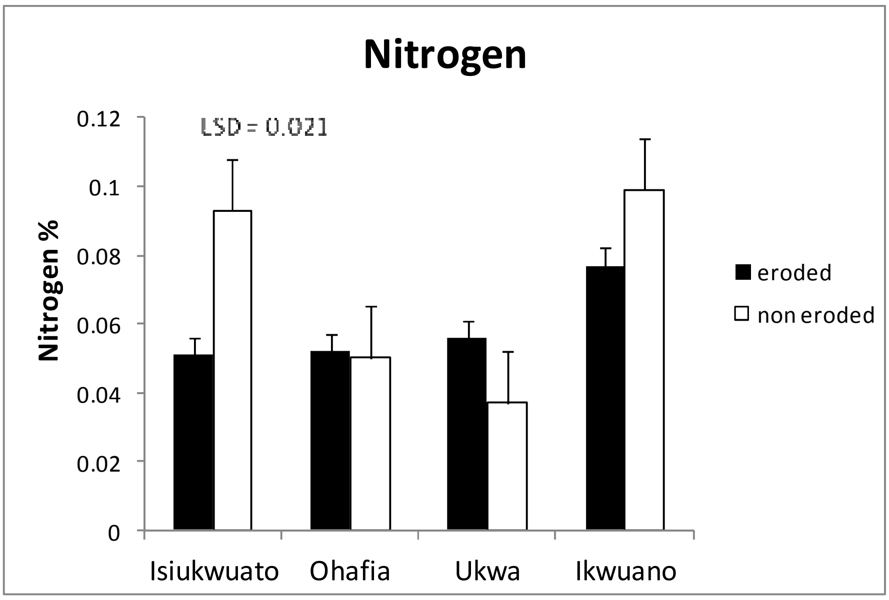

Figure 1 Effect of Erosion on Nitrogen level of Soils in Four LGA's of Abia state

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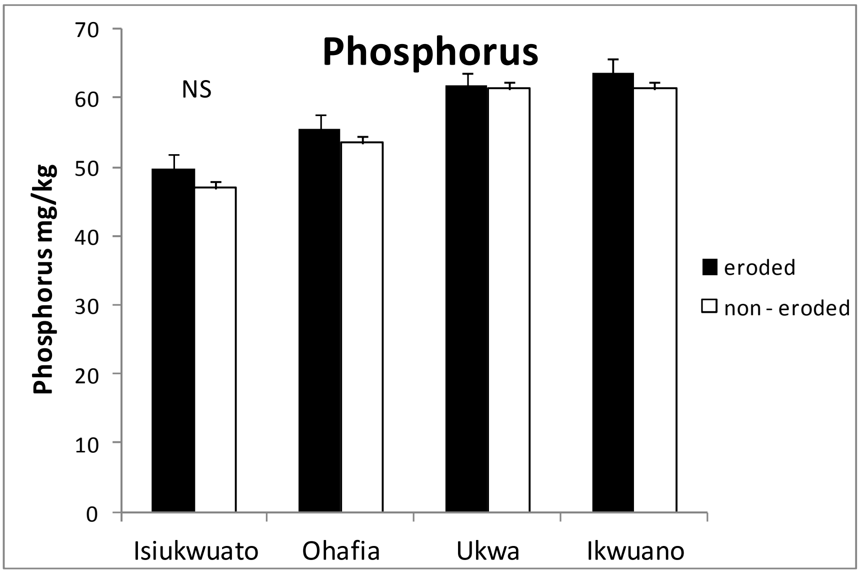

Figure 2 Effect of Erosion on Phosphorus levels of four LGA's of Abia State

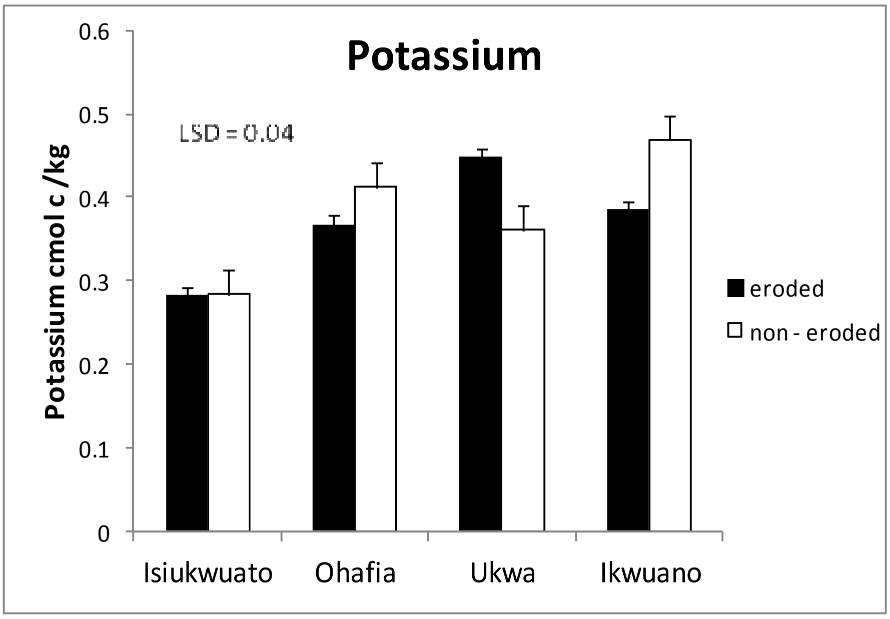

Figure 3 Effect of erosion on Potassium levels on soils of four LGA's of Abia State

Table 2 Effect of erosion on Exchangeable bases in soils of four LGAs.

Location	Ca	Mg	Na	K	TEB
Isuikwuato (eroded)	0.66	0.42	14.2	0.3	15.58

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Isuikwuato (N_eroded)	0.46	0.3	14.9	0.3	15.96
Ohafia (eroded)	0.6	0.32	13.7	0.4	15.02
Ohafia(N_eroded)	1.14	0.36	13.6	0.4	15.50
Ukwa(eroded)	0.56	0.6	14.0	0.4	15.56
Ukwa(N_eroded)	0.68	0.2	13.7	0.4	14.98
Ikwuano(eroded)	0.68	0.5	13.5	0.4	15.08
Ikwuano(N_eroded)	0.6	0.38	14	0.5	15.48
LSD (0.05)	0.3	0.1	0.5	0.13	

Values are means of five replications

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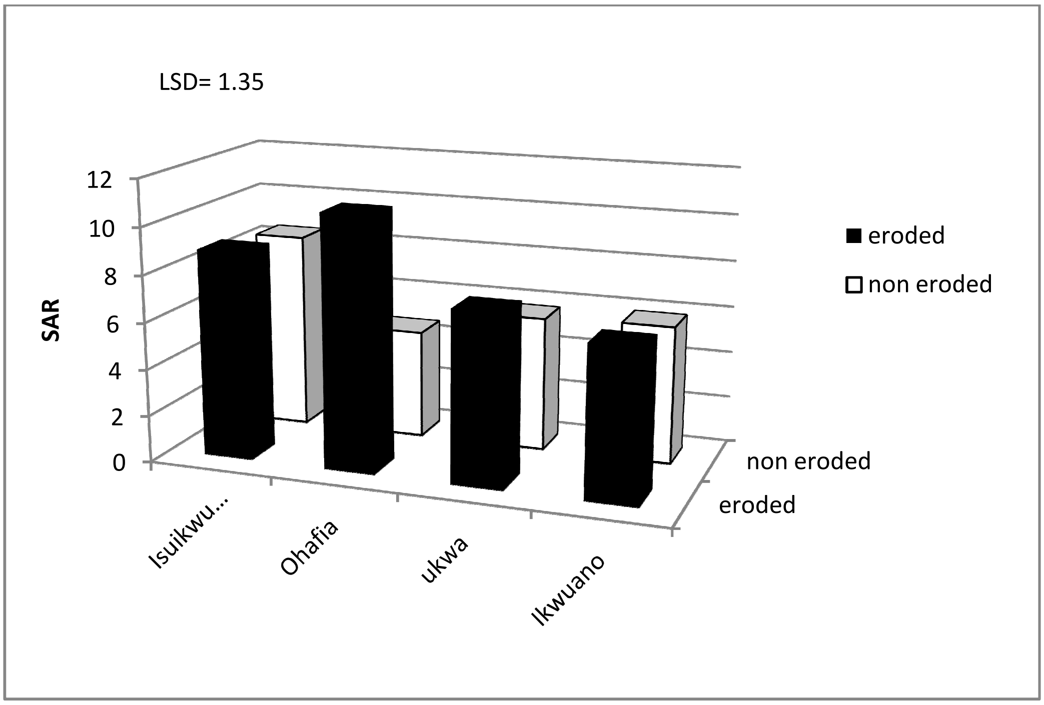

Figure 4 Effect of Erosion on the Sodium Absorption Ratio (SAR) in soils of Four LGA's in Abia