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RESEARCH ARTICLE

Assessment of Productivity of Sandy Loam in Abakaliki, Southeastern Nigeria

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ABSTRACT

Assessment of productivity of sandy loam was carried out at Teaching and Research Farm of Faculty of Agriculture and Natural Resources management, Ebonyi State University, Abakaliki for three cropping seasons. Core and auger samples were collected at seven designated points each year in the experimental plot. These soil samples were used to determine physicochemical properties for assessment of soil productivity. Maize variety (Oba super 11) hybrid was used as a test crop. Data obtained from both soil and grain yield of maize were subjected to correlation and regression analysis to determine relationship between soil properties and grain yield of maize. The result showed highly significant ($P<0.01$) relationships between bulk density ($r=0.95$), total porosity ($r=0.90$), available water capacity ($r=0.75$) and grain yield of maize. Significant ($P<0.05$) relationships were obtained between organic carbon ($r=0.57$), available phosphorus($r=0.63$), exchangeable magnesium ($r=0.59$) and pH ($r=0.76$) and grain yield of maize. Regression analysis indicated highly significant (r^2 = 0.89 and 0.82) relationships between bulk density and total porosity but significant (r^2 = 0.57 and 0.58) relationships between available water capacity and soil pH with grain yield of maize, respectively. Other soil parameters showed positive relationships with grain yield of maize indicating that they influenced soil productivity. Texture remained sandy loam for the three cropping seasons. Soil physico chemical properties could be used to assess soil productivity in order to determine its continuing ability to support and provide food and fibre to mankind.

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INTRODUCTION

Soil productivity which is the capacity of a soil for producing a particular plant or sequence of plants under a specified set of management practices (Brady and Weil, 2002) is affected by soil texture, tilth and nutrient storage. A productive soil must be in it's normal environment and should have the potential to sustain crop yields. Today, maintaining soil productivity is becoming very difficult probably because of more pressure exacerbated by lack of good agricultural practices. Soil tith and organic matter are difficult to restore (McCinty *et al.,* 1979) especially in fragile soils without adequate water retention.

Soil physical and chemical properties such as bulk density, available water capacity, total porosity, texture, pH and nutrient storage are important indicators of soil productivity (Nwite, 2013; Anikwe, 2000). Relationships between soil properties and a soil's capacity for producing plants or soil productivity are the focus of research projects (American Society of Agricultural Engineers (ASAE) 1985). Such research project is necessitated by the need to increase the knowledge of quantitative relationships between crop yields and soil properties. The productive capacity of soil or its expectable yields are useful in determining suitability of any soil for agricultural use (Nwite, 2002; De La Rose *et al.,* 1981). Estimates have been made for the productivity of individual kinds of soil (Anikwe, 2000).

The productivity of a soil is reduced through such soil degradative processes such as erosion and desertification. The reduction may manifest as soil constraints such as loss of plant nutrients, loss of storage for plant available water, degradation of soil structure and decreased uniformity of soil conditions within a field (Williams *et al.,* 1990). Degradation in tropical agro environment of any kind detrimentally affects the productivity of the soil (Nwite, 2013). Consequently, there is a steady decline in food production in sub-sahara Africa which leads to direct human suffering (Tarawali and Ogundibe, 1995). Rapid depletion of soil fertility and non sustainable land use particularly in the developing countries are the cause of wide spread poverty (International Soil Conservation Organization (ISCO), 1996).

Although limited research has been devoted to soil productivity problem, considerable effort had not gone into most of the processes involved such as elaborate quantitative relationships between soil properties and crop yield. This would help farmers to evolve a sound sustainable basis for maintaining soil productivity for its continued production of food and fibre. The objective of this study was to assess productivity of sandy loam in Abakaliki, southeastern Nigeria.

MATERIALS AND METHODS

Experimental site

The research work was conducted 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 $06^{0}4^{/}$ 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 1700mm while maximum is 2000 mm with a mean of 1800mm. The temperatures are 27^{o}c and 31^{o}c for minimum and maximum, respectively. The relative humidity is 60% during the dry period and 80% in the rainy season (ODNRI, 1989). 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) (1985), 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 consolidated parent material (shale residuum) within 1 m of the soil surface. The soil belongs to the order ultisol and is classified as *Typic haplustult* (FDALR, 1985).

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 *Tridax spp, Panicum maximum* and other herbs and shrubs.

Field methods

A land area of 0.04ha was cleared of existing vegetation and used for the experiment. The debris after clearing was removed without burning from the site. Traditional hoe was used to till the soil flat. There were no beds. Maize (Oba super II) hybrid variety was used as a test crop. The maize seeds were obtained from Ministry of Agriculture, Ebonyi State, Abakaliki. The maize seeds were planted at two seeds per hole and at 25 x 75cm planting distance. Two weeks after germination (WAG), the maize stands 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, NPK15:15:15 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 seven designated 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 Hartge (1986). The method described by Obi (2000) was used in determination of available water capacity. Total porosity was calculated as described by Obi (2000). Soil pH determination was done using soil/water solution ratio 1:2.5. Soil pH values were read off using Beckman Zeromatic pH meter (Peech, 1985). Organic carbon determination was done as described in Page *et al*. (1982). Available phosphorus was extracted using Bray -2 method as described in Page *et al.* (1982). Exchangeable cations were determined in IN NH_4OAC. Exchangeable calcium and magnesium were extracted according to Mba (2004) while potassium and sodium was extracted using flame photometer.

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

Properties of the soil at initiation of the study

Table 1 shows some properties of soil at the initiation of the study. The particle size distribution (PSD) analysis indicates that the textural class was sandy loam. The pH in KCL was 5.1 indicating that the soil was strongly acidic according to the rating of USDA-SCS (1974). The percentage organic carbon was 1.84 and rated low by Enwezor *et al.* (1981). Available phosphorus was 4.70 mgkg^{-1} and rated low (Landon, 1991). The soil exchange complex was dominated by calcium and magnesium. Exchangeable sodium (Na) and potassium (K) were low (Asadu and Nweke, 1999). The soil was low (68%) in base saturation (Landon, 1991). Cation exchange capacity (CEC) and effective cation exchangeable capacity were low (Asadu and Nweke, 1999).

Some soil studied properties after planting

Table 2 shows studied soil properties after planting. Although, the values for particle size distribution varied across the years, the textural class remained sandy loam. Sand fraction was higher than silt and clay for the three cropping seasons. Bulk density was generally higher after the first cropping season. Total porosity had inverse relationship with bulk density and followed its trend. Available water capacity decreased after first season of

Table 1: Some properties of the soil at initiation 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
Effect cation exchange capacity	$cmolkg^{-1}$	7.97

Table 2: Some properties of soil studied after planting

Soil Properties	2006	2007	2008
Sand (gkg^{-1})	660	570	650
Silt (gkg^{-1})	250	300	210
Clay (gkg^{-1})	100	130	140
Textural class	Sandy loam	Sandy loam	Sandy loam
Bulk density (gcm^{-3})	1.61	1.69	1.69
Total Porosity (%)	39.42	37.16	37.16
Available water capacity (cm/cm)	0.17	0.16	0.16
pH KCl	4.7	4.7	4.5
Available phosphorus ($mgkg^{-1}$)	0.17	0.16	0.16
Available phosphorus ($mgkg^{-1}$)	27.16	26.67	26.65
Organic Carbon (%)	1.23	1.20	1.08
Nitrogen (%)	0.79	0.76	0.74
Calcium ($cmolkg^{-1}$)	3.78	3.32	3.32
Magnesium ($cmolkg^{-1}$)	2.27	2.23	2.23
Potassium ($cmolkg^{-1}$)	0.83	0.72	0.72
Sodium ($cmolkg^{-1}$)	0.19	0.18	0.17

Table 3: Grain yield of maize

Cropping season	Grain yield of maize (tha^{-1})
2006	2.10
2007	2.00
2008	2.00

cropping. Soil pH was higher in 2006 and 2007 cropping seasons. There were slight variations in pH across the years of study. The exchangeable cations were higher in first season of cropping and subsequently decreased in 2007 and 2008 seasons. Available phosphorus was higher in 2006 cropping season and decreased in 2007 and 2008 study seasons, respectively. Percentage organic carbon and total nitrogen followed the same trend as obtained in other chemical parameters of the soil. Organic carbon and nitrogen were higher in first cropping season and decreased afterwards.

High sand content of the soil than other fractions could be attributed to property inherited from the parent material. Sand content of the soils in southeastern region of the country is a characteristic of sand formed on unconsolidated coastal plain and sandstone from Asu River (FDALR, 1987). Obi (2000) noted that texture was a permanent property of soil which could not be changed by cultural practice. Texture has good relationship with nutrient storage, water retention, porosity (Foth and Turk, 1972) and specific surface area, soil compatibility and compressibility (Smith *et al*., 1998) which affect inherit productivity of the soil. The increase in bulk density after first season could be attributed to continuous cultivation which caused realignment and subsequent compaction of soil particles. Mbah *et al.* (2009) reported increase in bulk density after first year of cropping due to continuous cropping. The bulk densities were within non-limiting values for root proliferation (Grossman and Berdaner, 1982). Improved total porosity could be attributed to positive impact of bulk density on soil. Good soil total porosity encourages proper root penetration, water infiltration and storage and nutrient supply culminating in soil productivity. The decrease in total porosity after first season could be due to impact of continuous cropping. The decrease in available water capacity after first season was as a result of increase in bulk density and subsequent decrease in total porosity (Table 2). Low available water capacity could jeopardize soil productivity, although, the values were not limiting (Grossman and Berdanier, 1982).

Low soil pH obtained was attributed to utilization of nutrients by crops as well as inherit property of sandy loam soil. Exchangeable cations of Ca and Mg were predominately higher in the soil than K and Na and thus are as result of their initial high levels in the soil. Low exchangeable K and Na could be as result of immobilization due to formation of complexes after decomposition. Exchangeable Ca and Mg are of high to medium rating (Howeler 1996). The more available P in first season is due to its flow into the soil and as it was used up by plants, it decreased. High available P increases soil productivity through its positive influence on soil pH. Percent organic carbon and total N are not above low values recommended by Enwezor *et al.* (1981). According to Asadu (1990) Organic matter contents of the soils of the tropics are low because of high temperatures which cause rapid mineralization and which negatively influence organic carbon and total nitrogen of soil.

Grain yield of maize

Table 3 shows grain yield of maize for three cropping seasons. Grain yield of maize was higher in first season and subsequently decreased in other cropping seasons. The grain yield of maize was 5% each higher in first study season compared to 2007 and 2008 cropping seasons.

Low grain yield of maize could be as a result of low trend of nutrients obtained in those study seasons (Table 2). This implies low nutrient utilization in the soil (Aulakh *et al.*, 2007). According to Nwite (2013), high bulk density and low total porosity particularly would reduce root penetration and feeding area to crop all contributing to low grain yield of maize. However, the grain yield of maize in first and other cropping seasons is comparable and could be rated as within medium values as obtained in southeastern states of Nigeria (NPAFS, 2010). Similarly, the failure to sustain the grain yield of maize in 2006 cropping season in subsequent seasons could be attributed to continuous cropping. Mbah *et al.* (2009) noted that continuous cropping without application of amendments reduced grain yield of maize.

Relationship between studied soil properties and grain yield of maize

The relationship between studied soil properties and grain yield of maize is shown in Table 4. The result indicated that there were positive relationships between

Table 4: Relationship studied soil properties and grain yield of maize

Parameter	Regression model	r	r^2
Bulk density Vs grain yield of maize	y=5.64X – 2.16	0.95**	0.89**
Total porosity Vs grain yield of maize	y = 0.07X – 0.85	0.90**	0.82**
Available water capacity vs grain yield of maize	y = 5.18X +1.24	0.75**	0.57*
Organic carbon Vs grain yield of maize	y =1.77X + 0.18	0.57*	0.32^{ns}
Nitrogen Vs grain yield of maize	y = 2.09X + 0.05	0.13^{ns}	0.02^{ns}
Available Phosphorus Vs grain yield of maize	y= 1.78X + 0.01	0.63*	0.39^{ns}
Calcium Vs grain yield of maize	y = 1.84X + 0.06	0.33^{ns}	0.11^{ns}
Magnesium Vs grain yield of maize	y = 1.55X + 0.25	0.59*	0.35^{ns}
Potassium Vs grain yield of maize	y = 2.01X + 0.09	0.31^{ns}	0.09^{ns}
Sodium Vs grain yield of maize	y = 2.40x – 1.10	0.25^{ns}	0.06^{ns}
Soil pH Vs grain yield of maize	y = 034X + 0.51	0.76**	0.58*

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

soil properties and grain yields of maize. There were highly significant (P<0.01) correlation coefficient between bulk density, available water capacity, total porosity and grain yield of maize, respectively. The coefficient of determination (r^2) for bulk density and total porosity and grain yield was highly (P<0.01) significant. However, significant (P<0.05) coefficient of determination was obtained between available water capacity and grain yield of maize. The results further showed highly significant (P<0.01) correlation coefficient between soil pH and grain yield of maize. Conversely, significant (P<0.05) correlation coefficient was obtained between percent organic carbon, available phosphorus, exchangeable magnesium and grain yield of maize, respectively. Except for soil pH, there was no significant coefficient of determination between percent total nitrogen, exchangeable calcium, potassium sodium and grain yield of maize. Nevertheless, correlation coefficient and coefficient of determination showed positive relationships with grain yield maize.

The highly significant relationships of bulk density, total porosity and available water capacity with grain yield of maize indicate that these soil properties influence soil productivity. This was corroborated by Nwite (2013) that bulk density, total porosity and available water capacity influenced water availability, aeration status and nutrient storage of soil. Similarly, Obi (2000) reported that soil physical conditions improved soil productivity. Furthermore, the significant relationships between percent organic carbon, available phosphorus, exchangeable magnesium and grain yield of maize emphasize that these nutrients increase soil productivity and crop yield. According to Asadu and Nweke (1999), percent organic carbon, available P and Mg are major constituents of plant materials. Significant relationship between soil pH and grain yield of maize show that it is contributory to soil productivity and hence enhance crop yield.

Conclusion

The result of this study indicates that productivity of sandy loam could be assessed using soil physicochemical properties. High bulk density, low total porosity and available water capacity could limit productivity of sandy loam. Low inherit organic carbon, nitrogen, pH, available phosphorus and exchangeable cations are limiting to the productivity of the soil. Perhaps, the greatest threat to productivity of sandy loam is continuous cultivation which has depletive effect on soil nutrients. However, with good management through avoidance of continuous cropping, productivity of the soil can be sustained at reasonable level.

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