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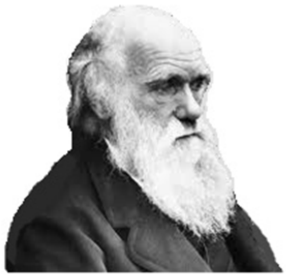

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Hydraulic Properties of Soils of Akani Esuk Orok in Calabar, Cross River State, Nigeria

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ABSTRACT

The study highlights the hydraulic properties of Akani Esuk Orok in Calabar, Cross River State, Nigeria. Twenty soil samples were collected from Akani Esuk in Calabar on a grid measuring 6 m X 6 m at a distance of 2 m apart to determine the hydraulic conductivity and to assess its influence on bulk density, particle density, total porosity and texture. The mean value of hydraulic conductivity was 14. 91cmhr^{-1}, bulk density1.3 g cm^{-3}, particle density 2.5 g cm^{-3}, total porosity 47.6 %, sand content 80.1 %, silt content 8.4 % and clay content 11.5 %. The texture of the experimental plot was loamy sand. The mean values of pH were 5.4; effective cation exchange capacity (ECEC) was 63.9 cmol kg^{-1}.These values, which are rated medium for the soils are probably responsible for the luxuriant growth of several crops cultivated in the area. The mean base saturation of the soils was 58.3 %. The potassium level of the study area was low, a mean value of 0.11 2 mg kg^{-1}. Though the soils were strongly acidic in reaction and the fertility status was considered low, medium and high taking consideration values of organic carbon, total nitrogen, ECEC and base saturation. Hence, the fertility should be maintained by planting *Calopogonium municoides, Centrosema pubescens* and adoption of appropriate cultural practices.

Keywords: Hydraulic conductivity, Bulk density, Particle density, Total porosity, Texture

1. INTRODUCTION

The hydraulic properties that influence movement of water, nutrients and aeration of roots of plants are hydraulic conductivity, porosity, infiltration rate, bulk density, particle density, soil texture and structure. Hydraulic conductivity symbolically represented as *K*, is a property

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of vascular plants, soils and rocks that describe the ease with which a fluid (usually water) can move through pore spaces or fractures which depends on the intrinsic permeability of the material, the degree of saturation, and the density and viscosity of the fluid as put by Wosten *et al.* [6]. The rate of water movement through the soil generally decreases with decreasing pore species. Hydraulic conductivity is important in that it makes water and nutrients available to crops through conducting pores that maintain moisture content well above the wilting point as put by Jain *et al.* [2]. Hydraulic conductivity is an important property of the soil that ensures constant movement of water and nutrients that sustain crop production [3].

Hydraulic conductivity is important in that it makes water and nutrients available to crops through conducting pores that maintain moisture content well above the wilting point as put by Jain *et al.* [2]. This very important property of the soil ensures constant movement of water and nutrients that sustain crop production [3]. The portion of the soil in which air and water occupy is the pore space and the volume percentage of the total bulk soil not occupied by solid particle is the porosity. In order to quantify the state of compaction and the amount of pore spaces in a soil, the volume and mass of solids which are extensive quantities are related by the intensive term, bulk density. An important physical property related strongly to bulk density is the particle density. Particle density is defined as the mass of soil particle divided by the volume occupied by the solids (excluding voids and water). Changes in soil management may cause a change in the particle density. Quartz, a predominantly soil mineral has a value of about 2.65 g cm^{-3}, being representative of many soils. This value enters into calculation of useful properties such as porosity and particle size distribution.

The soil texture and structure, type of vegetation and organic matter content have direct influence on hydraulic conductivity. Sandy soils for example have higher saturated hydraulic conductivity than clayey soils due to their large pore size distribution and low organic matter content. Another factor which affects the movement of water in a saturated condition is the permeability. Permeability is defined as the ease with which the soil pore permits movement of water [1]. Thus, permeability is related directly to hydraulic conductivity by the water moving force. Also related to the hydraulic conductivity is the infiltration, which is a key process because it determine how much water from rainfall and irrigation enters the soil and how much becomes runoff [9]. It is also a key process in erosion in that there can be no erosion without runoff to transport and scour sediments.

2. MATERIALS AND METHODS

Location of the study

The study was carried out in Akani Esuk Orok Community in Calabar, Cross River State. Akani Esuk is located on latitudes 4.5ºN and 5.2ºN and Longitudes 8.0ºE of the Greenwich meridian. These Co-ordinates were geo-referenced using Global Positioning System (GPS).

Climate

The climate of the area is a typical tropical humid climate. It is determined mainly by the direction of the north east and south west winds known by distinct wet and dry seasons. The wet season is often intensive. The season starts from February/March and lasts till about October/November with a short dry duration of one week or more in the month of July/August (August break). The annual rainfall of Calabar ranges between 2500 mm and 400 mm per annum. The dry season starts in November through February with mean annual temperature ranging between 25 ºC and 29 ºC.

Topography and Vegetation

The area under study has a moderately gentle slope originally; the vegetation is a tropical rain forest type but human interference through construction and farming activities have helped to modify the vegetation.

Geology of soils

The geology of the study area is dominated by coastal plain loamy sand. According to [1] the soils belong to the broad class of Utisols in the USDA (1975) soil classification. The soils are yellowish red, gravelly and brown sandy soils derived from acid crystalline rocks.

Experimental Layout

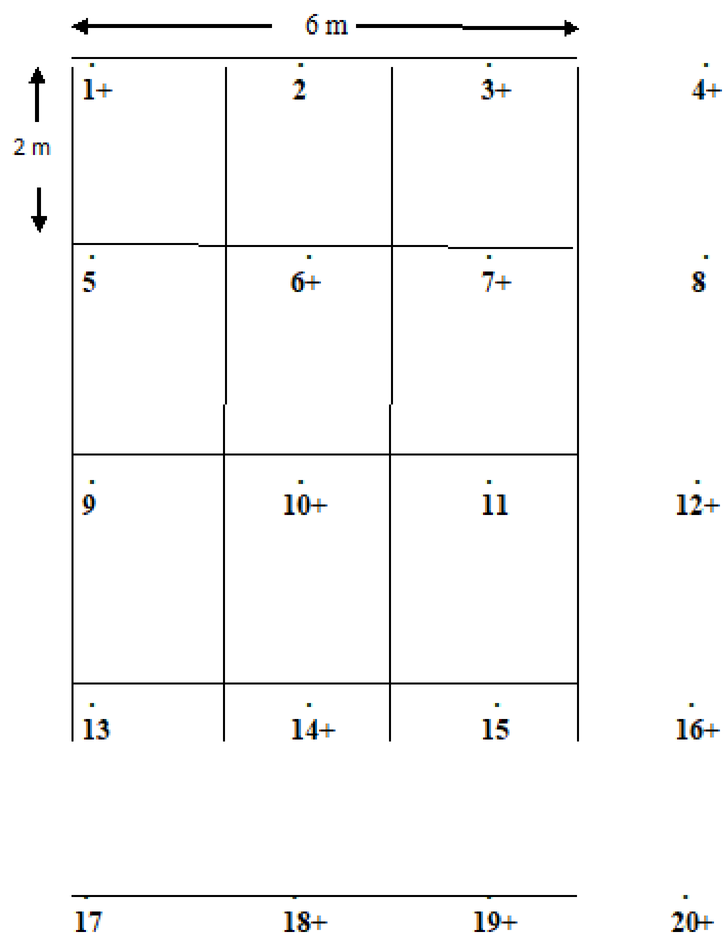

Fig. 1. A grid showing experimental test points
\+ Hydraulic conductivity runs
· Sampling points for bulk and particle density determinations

The area was marked out on a grid of 6 m × 6 m at a distance of 2 m apart with 20 observation points. Sampling was performed at observation points (Fig. 1.) for particle size analysis, bulk density, particle density, total porosity and hydraulic conductivity. Samples for hydraulic conductivity measurement were collected at points marked with dots.

Laboratory Analysis

Soil samples from the site were air-dried, gently crushed with pestle and mortar and sieved through a 2.00 mm sieve to obtain the fine earth fraction for the analysis. Particle size analysis was determined by the hydrometer method using sodium hexametaphosphate VII (Calgon) as a dispersant. Bulk density was determined by the undisturbed core cylinder method. Particle density was determined with the use of a pycnometer. Soil pH was determined in 1:2 soil: water ratios using a glass electrode pH meter [7].

The organic carbon was determined by wet oxidation method of walkey – Black as described by Srikanth *et al.* [4]. The available phosphorus was determined by No 1 method of Bray and Kurtz as described by Srikanth *et al.* [4]. The total Nitrogen was determined by sieving the sample in a 0.5mm mesh using the macro-Kjeldahi method as described by Srikanth *et al.* [4]. Exchangeable Acidity $A1^{3+}$ and H^+ were determined by leaching the soil with KCL solution and the extract titrated with standard NaOH solution as described by Srikanth *et al.* [4] Exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na^+ were leached from the soil sample using NH_4OAC (pH 7) buffer. The Na and K were measured with a flame photometer while Ca and Mg were determined by EDTA titrated. Base saturation was obtained by expressing the sum of exchangeable cation as a percentage of the effective cation exchange capacity.

Data analyses

Data collected were subjected to simple descriptive statistics of mean with the help of SPSS soft ware data analysis and correlation analysis between hydraulic conductivity and soil physical properties.

3. RESULTS AND DISCUSSION

Physical properties

Particle size distribution, Bulk density, Particle density and total porosity and Hydraulic conductivity

Table 1 shows the values of the above named parameters. The sand, silt and clay contents were 76.9 %, 8.4 % and 14.8 % respectively and the texture was loamy sand. The soils of the area being coastal plain sand are characterized by low water retention as could be observed from the high percentage of sand.

The mean value of bulk density of soils of the study area was 1.3 g cm^{-3} (1300 kg m^{-3}).

The medium value of bulk density is ideal for the good performance of the crops as no mechanical impediment would occur. Thus the roots of the crops would not encounter restriction and also movement of water in the area was not impeded.

The mean value of particle density of the area was 2.5 g cm^{-3} (2500 kg m^{-3}). The present mean value of particle density (2.5 g cm^{-3}) falls slightly outside the particle density range of

2.60 – 2.75 g cm^{-3}. Particle density is not subject to change. It is an intrinsic property of the soil being governed by the type of parent material.

Total porosity had a mean value of 4.76 %. The value was higher than that given by [1] who obtained a range of 2.0 – 4.0 % from the coastal plain soils of Calabar. The soils of the study area were well aerated and would offer a good condition for the microorganisms.

The mean result of hydraulic conductivity was 15.28 cm hr^{-1}. According to [5], this value was moderate. The soils of the study area were moderate in conducting water. Apart from water conduction through the soil, hydraulic conductivity has some relevance to the drainage of the area.

Table 1. Physical properties of the study area

Sampling points	PSA			TC	H. C	P.D	BD	TP
	Sand	Silt	Clay					
	←	%	→		cm hr^{-1}	← g cm^{-1}	→	(%)
1	81.6	7.0	11.4	LS	5.72	2.4	1.2	5.0
2	78.6	9.0	12.4	LS	24.09	2.3	1.3	4.4
3	71.6	6.0	22.4	LS	9.01	2.4	1.3	4.6
4	81.6	9.0	9.4	LS	15.34	2.5	1.3	4.8
5	79.6	9.0	11.4	LS	7.54	2.4	1.4	4.2
6	80.6	9.0	10.4	LS	11.53	2.6	1.3	5.0
7	79.6	10	10.4	LS	11.5	2.2	1.1	5.0
8	71.6	8.0	20.4	LS	8.06	2.7	1.4	4.8
9	71.6	8.0	20.4	LS	21.66	2.8	1.4	5.0
10	71.6	8.0	20.4	LS	16.55	2.4	1.2	5.0
11	81.6	9.0	9.4	LS	13.8	2.9	1.3	4.8
12	79.6	9.0	11.4	LS	19.33	2.6	1.4	4.8
13	71.6	8.0	20.4	LS	18.46	2.4	1.2	5.0
14	80.6	8.0	11.4	LS	13.26	2.6	1.3	5.0
15	71.6	9.0	19.4	LS	28.66	2.5	1.3	4.8
16	81.6	8.0	10.4	LS	11.07	2.4	1.4	4.2

17	71.6	9.0	19.4	LS	16.08	2.5	1.3	4.8
18	79.6	8.0	12.4	LS	17.33	2.5	1.28	4.8
19	80.6	8.0	11.4	LS	21	2.2	1.3	4.4
20	71.6	8.0	20.4	LS	15.6	2.7	1.4	4.8
MEAN	**76.9**	**8.35**	**14.8**		**15.28**	**2.5**	**1.3**	**4.76**

PSA = Particle size analysis: TC = Textural class; HC = Hydraulic conductivity;
PD = Particle density; BD = Bulk density; TP = Total porosity

Chemical properties

The Chemical properties are presented in Table 2. The pH was 5.4; this is strongly acidic [8]. This might be attributed to the high rainfall in the area. This is in line with the work of [10] who stated that the acidic conditions of the soils might be due to the high rainfall exceeding 3500 mm which could leach out basic cations from the soil solum in the area. The level of organic matter is rated high, a mean value of 6.82 % [11]. Such level can support production of crops if maintained and improvement of other that is low in nutrients. Total nitrogen was low, a mean value of 1.04 %. The available phosphorus was also low, a mean values of 24.7 mg/kg. The ECEC was 63.87 cmol/kg while the base saturation was 58.3 %.

Table 2. Chemical properties of the study area

Sampling Point	pH	Org. C.	Total N.	Av. P	Exc. Bases				Exc. Acidity		ECEC	BS
					Ca	Mg	K	Na	Al	H		
		%	(%)	mg/kg	←			cmol/kg			→	%
1	5.6	11.9	1.2	29.6	3.8	2.2	0.12	0.08	0.24	0.80	36.84	68.2
2	5.8	2.0	1.3	26.1	3.6	1.8	0.13	0.08	0.16	0.96	32.83	57.7
3	5.3	1.2	1.1	28.2	4.0	2	0.10	0.09	0.28	0.74	63.13	62.4
4	5.5	9.8	0.9	17.8	4.0	1.8	0.11	0.09	0.30	0.66	24.76	59.7
5	5.6	1.0	1.0	32.8	3.2	2.2	0.10	0.08	0.32	0.58	38.8	59.6
6	4.9	11.0	1.0	37.2	4.2	2.2	0.12	0.07	0.32	0.68	44.11	66.7
7	4.8	11.7	1.0	21.9	3.6	1.8	0.1	0.07	0.36	0.72	27.83	57.5
8	5.7	10.8	1.1	24.5	3.4	1.8	0.11	0.06	0.34	0.70	30.91	72.5
9	5.7	11.1	1.1	15.7	3.6	2.0	0.13	0.09	0.36	0.76	22.64	61.2

10	5.6	13.0	1.1	24.1	3.8	2.0	0.12	0.07	0.32	0.68	31.11	61.4
11	5.5	1.1	1.0	18.7	3.8	2.0	0.1	0.07	0.28	0.96	25.91	61.7
12	5.6	0.9	0.9	18.4	4.0	1.8	0.1	0.09	0.28	0.36	25.53	62.5
13	5.4	8.9	0.9	21.1	3.8	1.8	0.12	0.08	0.20	0.90	28.00	6.00
14	5.6	1.0	1.0	23.3	4.0	2.2	0.13	0.08	0.24	0.70	30.65	65.9
15	5.6	1.1	1.0	15.6	3.4	2.0	0.1	0.06	0.36	0.38	21.90	57.7
16	5.4	16.1	1.1	19.0	3.6	1.8	0.11	0.07	0.40	0.56	25.54	57.8
17	5.3	11.4	1.1	32.0	3.4	1.8	0.11	0.07	0.36	0.60	38.34	54.9
18	5.6	1.2	1.0	30.7	3.4	2.0	0.10	0.08	0.28	0.72	37.35	57.1
19	5.6	9.9	0.9	27.7	3.8	2.0	0.11	0.09	0.40	0.52	34.62	61.6
20	5.4	1.3	1.0	29.6	3.4	1.6	0.12	0.06	0.36	0.66	656.6	52.8
MEAN	**5.475**	**6.82**	**1.035**	**24.7**	**3.69**	**1.94**	**0.112**	**0.077**	**0.308**	**0.682**	**63.87**	**58.25**

4. CONCLUSION

The result affirmed that soil properties such as bulk density, soil texture, among others influenced the hydraulic conductivity of the soil. The soil was strongly acidic and requires liming. Soil fertility should be maintained by planting *Calopogonium municoides, Centrosema pubescens* and adoption of appropriate cultural practices.

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