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Determining the Field Capacity, Wilting point and Available Water Capacity of some Southeast Nigerian Soils using Soil Saturation from Capillary Rise.

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Abstract
Water is a unique material resource which plays a vital role in nature and in agriculture. The objective of this study was to find out the applicability of saturation percentage (SP) to estimate field capacity (FC) and permanent wilting point (PWP) of soils across different texture in southeast Nigeria. Top 0-20 cm soil sample were randomly collected from 28 points in different parts of southeast Nigeria and analyzed for particle size distribution, organic carbon (OC %) and moisture constants. Simple correlations and regression models were used to relate the moisture constants at various suctions to saturation percentage (SP).Results of the study showed that sand, silt and clay contents of the soils ranged between 2-73%, 2-48% and 8-76%, respectively. Similarly, OC % ranged between 0.08-3.03 % while the ranges of 24.3-75.7, 8.3-50.5% and 2.3-32.6% were observed for SP, FC and PWP, respectively. Results showed strong linear relationship between SP and the moisture constants (FC, PWP) and that the readily available water capacity (RAWC) and total available water capacity (TAWC) cannot be estimated from SP across the texture of the studied soils.

Keywords: Moisture constants, Agriculture, Saturation percentage, texture, Water.

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Introduction

Many agronomic and hydrologic practices require the knowledge of the amount of water contained in a particular soil volume. According to Ritchie (1981) soil is a reservoir of water and the ability of soil to store and release water slowly to plant roots is one of the important factors influencing the productivity of land. Studies on water relations of plants have demonstrated the beneficial effects of an adequate supply of soil moisture on plant growth. Grewal *et al.* (1990) observed that knowledge of the soil water content at field capacity (FC) and permanent wilting point (PWP) is important for irrigation scheduling, assessing plant water requirement and assessing soil suitability for different land uses. Studies by Salter and Williams (1980) provided a framework for estimating FC while that of Waters (1969) gave a source of information regarding PWP. Similarly, Banin and Amiel (1970) showed information concerning relationship among clay content, surface area and water content at several index points while Peterson *et al* (1996) related soil surface area and other properties to water holding capacity. However, laboratory determination of this moisture constants (fc, pwp) using tension tables and pressure plate apparatus is time consuming and tedious and in many developing countries the pressure plate apparatus in unavailable. Van Genuchen (1980) and Clapp and Hornberger (1978) observed that other approaches for estimating water retention through modeling soil moisture characteristics requires prior paired measurements of soil water content and potential. Similarly, research results [Mbagwu and Bazzoffi, (1985), Aina and Periswamy (1985), Madankuman (1985), Mbagwu and Mbah, (1998), Mbagwu *et al*. (1983) showed that most of the work on soil water content concentrated on predicting water retention capacity from physical properties. Using Newzealand soils to explore an alternative and simpler approach for estimating FC and PWP, Grewal *et al. (*1990) observed a strong linear relationship between mass percentage water content, PWP and SP. The aim of this study was to investigate the applicability of the readily measured saturation percentage (SP) as a possible index for estimating FC, PWP and AWC of some tropical soils from southeast Nigeria.

Materials and Methods

Soil sampling and data collection: This study was conducted with 28 air dried 2mm-sieved surface soil samples (0-20 cm) collected from three states in southeast Nigeria. The states are;

Enugu (lat.$06^0 25^1$ N and longitude 07^0 15^1 E). Nine soil samples were randomly collected from the Teaching and Research farm of Faculty of Agriculture, Enugu state University of Science and Technology, Agbani campus.

Ebonyi (lat.06^0 25^1N and long 08^0 3^1E). Nine soil samples were randomly collected from the Teaching and Research farm of Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki.

Imo (lat.04^0 4^1 and 08^0 5^1 N and long. 06^0 40^1 and 08^0 15^1 E). Ten soil samples were randomly collected from the Teaching and Research farm of School of Agriculture and Agricultural Technology, Federal University of Technology, Owerri. The soils belong to the order ultisol (FDALR,1985).

Laboratory analysis: Particle size was determined by the pipette method (Gee and Orr, 1994) while organic carbon (OC%) was analyzed by Walkey and Black procedure (Nelson and Somners, 1982). Organic matter (OM%) was calculated by multiplying OC with conventional Vanbameller factor. Saturation percentage (SP) was determined using the following procedure:

Fifty six (56) perforated crucibles were weighed (C) and labeled in duplicate. Portions of the soil samples were transferred into the crucibles in duplicate until they were ¾ full. The soil was packed by tapping the crucibles on the table about ten times. This was done until the crucibles were almost full.

The crucibles were then placed in a basin and distilled water added to a depth of about 3 cm. They were then allowed to stand for 24 hours. At the end of this period the soil samples inside the crucibles absorbed water by capillary rise through the porous base of the crucibles. After wiping the outside dry, the crucibles were weighed and the weight of the crucibles plus the saturated soil recorded (K).The crucibles and their contents were transferred to the oven and air-dried at a temperature of 105^0C for 24 hours. After drying the crucibles and its dried soil were weighed and the weight recorded (J).The Saturation percentage of soil was calculated as follows.

$$SP = \frac{K-J}{J-C}$$

Where J = weight of crucible + dry sample, C =weight of crucible only. K = weight of crucible + wet sample, Moisture retained at FC, PWP and AWC were determined at 0.1 bar, 1.0 bar and 15.0 bar, respectively using pressure plate (extractor) apparatus (Obi, 1974). The total available water capacity (TAWC) and readily available water capacity (RAWC) were determined as difference between the moisture retained at 0.1 and 15.0 suction bars and 0.1 and 1.0 suction bars, respectively.

Data analysis: Simple correlations and regression models were used to relate the moisture constants at various suctions to saturation percentage (SP).

Results:

Results of the soil mechanical analysis (Table 1) distributed the soil to eight

Table 1: Particle Size Distribution, Texture and Organic Matter Contents of the Soils

S/N	% Clay	% Silt	% F.S	% C.S	% O.C	% O.M	TEXTURE
1	18	18	46	18	0.72	1.24	SL
2	66	10	13	11	2.67	4.60	C
3	42	4	17	37	0.39	0.69	SC
4	42	14	22	22	0.92	1.59	C
5	26	40	32	2	2.59	4.47	L
6	8	2	28	62	0.84	1.45	S
7	12	14	73	1	0.44	0.76	SL
8	16	22	28	34	1.52	2.62	SL
9	8	10	41	41	0.68	1.17	SL
10	56	26	15	5	0.64	1.10	C
11	60	10	3	27	0.08	0.14	C
12	60	6	4	30	0.20	0.32	C
13	76	14	2	6	1.76	3.03	C
14	76	14	7	3	0.56	0.97	C
15	38	38	10	14	1.56	2.69	CL
16	50	40	2	8	0.68	1.17	SiC
17	22	48	23	7	1.28	2.21	L
18	26	30	37	7	0.92	1.57	L
19	12	28	44	16	3.03	5.22	SL
20	34	16	15	35	1.84	3.17	SCL
21	38	22	33	7	2.95	5.09	CL
22	30	10	40	11	2.03	3.50	SCL
23	34	12	37	17	2.59	4.47	SCL
24	20	10	52	18	2.91	5.02	SCL
25	26	8	41	25	1.92	3.31	SCL
26	20	14	41	23	2.71	4.67	SCL
27	32	16	18	34	2.31	3.98	SCL
28	20	14	65	1	1.48	2.55	SCL
Total	968	510	798	522	42.23	72.77	
Mean	34.57	18.21	28.5	18.64	1.51	2.60	

C = Clay, Sand, SL = Sandy Loam, SCL = Sandy Clay Loam, L = Loam, SiC = Silty Clay, CL = Clay Loam

textural classes viz Clay (C), silty clay (SiC), clay loam (CL) sandy clay loam (SCL), sandy loam(SL),loam(L) , sandy clay(SC) and sand (S).The clay content varied between 8-76% with an average of 34.575.Similarly,the silt and the sand contents ranged between 2-48% and 2-73%, respectively. Results of the study also showed low mean OC content of 1.51% according to the ratings of Landon (1991).

Table 2 showed the moisture relations at 0.1 bar (FC), 15.0 bar (PWP), RAWC, TAWC and SP. Observed results showed ranges of 24.3-75.7%(SP).

Table 2: Moisture Relations of the Soils (on Gravimetric Basis %)

S/N	Saturation Percentage	0.1 bar	1.0 bar	15.0 bar	TAWC	RAWC
1	29.9	23.2	8.4	5.1	18.1	14.8
2	75.7	48.1	47.5	32.6	15.5	0.6
3	39.3	22.3	13.8	11.1	11.2	8.5
4	49.8	29.2	19.6	16.8	12.4	9.6
5	70.1	50.4	30.7	20.2	30.2	19.7
6	29.9	8.3	5.8	4.4	3.9	2.5
7	36.3	32.1	9.2	6.3	25.8	22.9
8	31.0	27.9	14.3	9.5	18.4	13.6
9	24.3	11.1	4.9	3.8	7.3	6.2
10	49.0	32.4	22.0	16.7	15.7	10.4
11	42.6	26.6	18.3	16.1	10.5	8.3
12	49.2	26.5	18.2	2.6	23.9	8.3
13	54.6	42.0	28.5	2.3	39.7	13.5
14	67.8	47.8	34.6	29.3	18.5	13.2
15	40.9	30.1	17.8	11.5	18.6	12.3
16	47.3	33.1	22.3	16.3	16.8	10.8
17	41.3	37.0	16.4	7.1	29.9	20.6
18	40.3	36.8	17.0	8.9	27.9	19.8
19	49.2	29.9	17.5	12.5	17.4	12.5
20	68.3	35.1	24.5	19.0	16.1	10.6
21	50.2	41.8	24.5	17.5	34.3	17.3
22	47.7	25.8	14.5	10.8	15.0	11.3
23	57.4	25.6	16.9	12.4	13.2	8.7
24	28.8	22.9	13.5	7.0	15.9	9.4
25	45.6	19.9	12.4	9.7	10.2	7.5
26	35.9	20.4	11.7	9.9	12.5	8.7
27	36.0	18.2	10.1	6.6	21.6	8.1
28	39.7	22.0	12.0	7.2	14.8	10.0

8.3-50.4% (FC), 2.4-32.6(PWP), 3.9-39.7(TAWC and 0.6-22.9%(RAWC).Table 3 showed the regression equation for predicting the moisture constants from SP. The correlation (r^2 = 0.0000007 and 0.0736) for RAWC and TAWC, respectively indicate that RAWC and

Table 3: Regression Equations for Predicting the Moisture Constants from Saturation Percentage

Regression	R^2	Significant level
FC = 0.6149SP + 1.4493	0.6055	**
PWP = 0.4323SP – 7.8315	0.5965	**
TAWC = 0.1676SP + 10.753	0.0719	NS
RAWC = - 0.0017SP + 11.497	0.00002	NS

TAWC=total available water capacity RAWC=readily available water capacity
** = Significant at P < 0.01NS = Non-significant at P < 0.01

TAWC have no relationship with SP. The inability of SP to correlate with TAWC and RAWC according to Grewal *et al*., (1990) could be attributed to the fact that SP is a compound index of the ability of a soil to absorb water on remoulding, the SP point occurring when the soils absorption capacity is fulfilled and free begins to be expressed from the soil. The authors noted that SP will integrate the effects of factors such as texture, OM content, clay mineralogy and cation balance, and other constituents. The authors also observed that while these factors also contribute to AWC, they will probably compound in different ways to determine SP compared to their influence on AWC (TAWC and RAWC). Figures 1, 2, 3 and 4 illustrates the regression analysis between SP and FC, PWP, TAWC and RAWC, respectively.

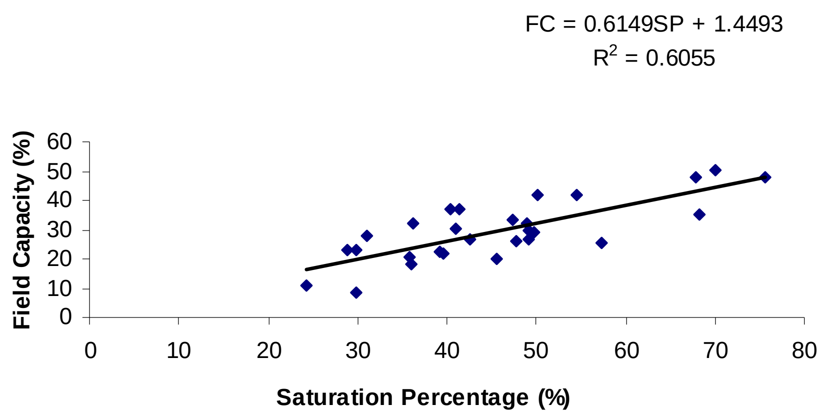

Figure 1: Regression Analysis between Field Capacity (FC) and Saturation Percentage SP)

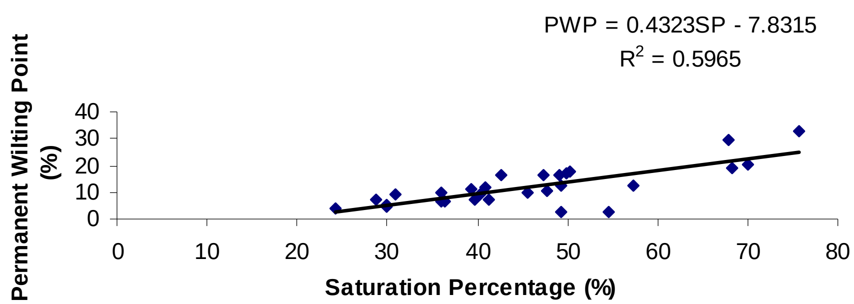

Figure 2: Regression Analysis between Permanent Wilting Point (PWP) and Saturation Percentage (SP)

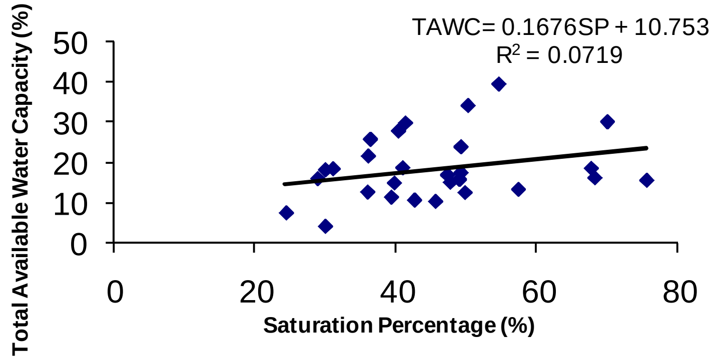

Figure 3: Regression Analysis between Total Available Water Capacity (TAWC) and Saturation Percentage (SP)

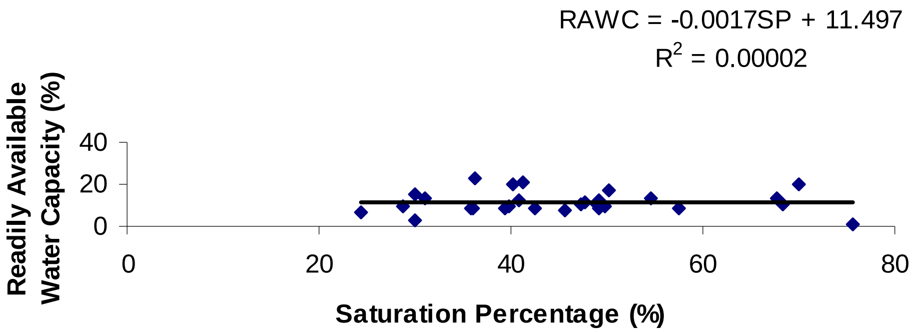

Figure 4: Regression Analysis between Readily Available Water Capacity (RAWC) and Saturation Percentage (SP)

Results in Figs. 1 and 2 showed a strong relationship between Sp and the moisture constants FC and PWP in line with the observation of Mbagwu and Mbah, (1998). This can be explained to the fact that SP is a measure on mass basis of the water absorption capacity of soil (under prescribed conditions) and so can be expected to correlate better with FC and PWP also expressed on mass basis.The result of this study is line with the observations of Dahiya *et al.*, (1988) and Kakanis (1983) when they determined FC and PWP of soils from their saturation percentage. Similarly, Grewal *et al. (*1990) reported strong linear relationship between the moisture constants and SP when the authors estimated FC and PWP of some Newzealand soils from their SP. However results in Figs. 3 and 4 indicated that TAWC and RAWC cannot be estimated from SP of the studied soils.

Conclusion

Knowledge of the soil water content at field capacity (FC) and permanent wilting point (PWP) is important for irrigation scheduling, assessing plant water requirement and assessing soil suitability for different land uses. Results of the study showed that the moisture constants (FC and PWP) could be estimated using SP while TAWC and RAWC cannot be estimated from SP in the studied soil.

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