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Variability in Some Soil Physical and Chemical Properties of Shambat Farm, Khartoum- Sudan

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Authors' contributions

All the authors are contributed for preparing the paper as well. Authors AASA and MAAM did the experimental tests and prepared the first draft of the manuscript. Author XWG approved the final version of the manuscript prior to submission. The main contribution of the authors BHO and AM managed the literature searches and author MMAE assist authors AASA and MAAM during the laboratory tests and contributed in manuscript revision. Finally, all authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted on the farm of the Faculty of Agricultural Studies, Sudan University of Science and Technology, this soil belongs to the Central Clay Plain of the Sudan which has been formed by alluvial deposit of the Nile, primarily of basaltic origin, and it consider largely as Vertisols. The objective of this study is to evaluate the variability in some physical and Chemical properties of

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soil under investigation in order to identify their spatial distribution to assist in designing land management and support agricultural production. For these purposes, some physical and Chemical properties at five sites across the farm have been investigated. The results indicated that the soils are variably affected by saline and sodic conditions. Non-saline, slightly saline, moderately saline sub soil and non-sodic to moderately sodic soils are found on the farm. Soil texture is clayey throughout, and hydraulic conductivity is very slow to slow .The whole of soil profile is compacted except at the surface layer, the average of soil bulk density is very high when the soil is dry. The soils under investigation are characterized by high water retention but rather narrow range of available moisture as noticed from the difference between the moisture retained between field capacity and wilting point.

Keywords: Cation exchange capacity; sodium adsorption ratio; exchangeable sodium percentage.

1. INTRODUCTION

Soil physical, Chemical and biological properties affect many processes in the soil that make it suitable for agriculture practices and other purposes. Texture, structure, and porosity influence the movement and retention of water, air and solutes in the soil, which subsequently affect plant growth [1]. Most of the soil chemical properties are associated with the colloid fraction and affect nutrient availability, and, in some cases, soil physical properties and chemical composition largely determine the suitability of the soil for plant production and the management requirements to keep it most productive [2]. Soil Chemical such as Soil organic matter encourages granulation, increases cation exchange capacity (CEC) and it is responsible for absorbing power of the soils, up to 90%. Cations such as Ca2+, Mg2+ and K+ are produced during decomposition [3].

The primary physical processes associated with high sodium concentration are the main factors that responsible for the dispersion of soil particles and aggregate swelling. When sodium – induced soil dispersion causes loss of soil structure, the hydraulic conductivity is also reduced. The deterioration of these physical properties is affected by both soluble salt and exchangeable sodium. Soil compaction changes pore space size, distribution, and soil strength. One way to quantify this change is by measuring the bulk density. As the pore space is decreased within a soil, the bulk density is increased. Soils with a higher percentage of clay and silt, which naturally have more pore space and lower bulk density than sandier soils [4]. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation [5]. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, the runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infantometer [6]. Hydraulic conductivity and cumulative infiltration of water are two interrelated parameters [7]. Expansive soils experience three-dimensional volume changes during wetting and drying cycles, increasing volume when wetting and decreasing volume when drying; hence often have some shrink-swell potential as a result of wetting-drying cycles [8]. The objective of this study is to evaluate the variability in some physical and chemical properties of soil under investigation in order to identify their spatial distribution to assist in designing land management and support agricultural production at five sites occurring within the farm of Faculty of Agriculture Studies (SUST).

2. MATERIALS AND METHODS

2.1 Study Area

This study was conducted at Shambat research farm (LAT: 15°40'N LONG: 32°32'E and ALT: 380 M), College of Agricultural Studies, Sudan University of Science and Technology. The main daily temperature is 29.3℃. Average maximum temperature reaches 47.3℃ in May while the minimum temperature is 5.5℃ in February. The mean relative humidity is 28% and show some variation ranges from 16% in April to 45% in August. The average annual rainfall is about 147.5 mms, with most of the rain falling in June – October.

The results of model were directly compared with the laboratory experimental ones using some statistical measurements.

2.2 Methods of Data Collection

2.2.1 Field methods and soil samples

Five pits were opened at the experiment sites, studied in the field and described following the formats of the [9]; Guide lines of soil profile description. Soil samples were collected from the genetic horizons of profiles and they are classified according to the American System of Soil Taxonomy [10].

2.2.2 Laboratory analyses

For each soil sample collected from the profile pits the following analyses were made at the lab of College of Agricultural Studies (SUST) and the lab of Faculty of Engineering (SUST): Soil reaction, Electrical conductivity, soluble cations and anions, Total nitrogen, Available phosphors, Cation Exchange Capacity: Exchangeable cations, Mechanical analysis, Hydraulic conductivity, Bulk density and Field Capacity all these analysis was done according to the method that described by [11]. Soil Organic Carbon and Organic matter was measured according to method of [12]. Soil Calcium Carbonate was measured using Eijkelkamp calcimeter that described by [13] and the Liquid Limit (LL), Plastic Limit (PL) by the method of [14].

2.3 Statistical Analysis

Means and variations acquired by one-way analysis of variance (ANOVA) to compare the means of different soil chemical, physical and mechanical properties under study area, differences between individual means were tested using the Duncan multiples range test (DMRT) ($p = 0.05$ significance level) according to [15].

3. RESULTS AND DISCUSSION

The Chemical and physical soil analysis of soil profiles are given in Table 1 and Table 2 respectively. The plastic limit and liquid limit results are shown in Table 4 and Fig 2. To obtain the Liquid Limit (LL), Plastic Limit (PL) and plasticity index (PI), the sample is treated with HCL to remove $CaCo_3$, washed off the soluble salts and then dispersed with calgon. The pipette is used to sample the clay fraction, coarse sand, and fine sand separated by wet sieving and silt obtained by different as follow:

$$Silt\% = [100-(\%clay+\%c.s +f.s)] \quad (1)$$

The original liquid limit test of Atterberg's involved mixing a part of clay in a round-bottomed porcelain bowl of 10–12 cm diameter [14], while the plastic limit (PL) is defined as the moisture content (%) at which the soil when rolled into threads of 3.2 mm in diameter, will crumble. It is the lower limit of the plastic stage of soil [14]. Fig 2 shows the values of Atterbergs` limits for different soil samples. The plasticity index is the difference between PL and LL (LL-PL).

3.1 Physical and Mechanical Properties

The results of particles size distribution analysis for all profiles are given in Table 1, the results indicated that the Clay content dominantly varies between 31-49%, silt between 38-63% and sand between 6-25%. The highest clay content was reported at pit No .1 and pit No.4. The infiltration category in shambat farm is slow (2.0 cm/h), our results highly agreement with the findings of [16]. The results of hydraulic conductivity (are shown in Table 2) ranging from slow (0.3 cm/h) to very slow (0.02) according to [17]. The values of soil bulk density on dry soil samples varied between 1.5 to 1.8 g/cm3. The top soil is a slightly compacted at all sites and the sub soil is markedly very compacted in all pits except pit No 2, (Table 2). It has been shown that when the bulk density of medium to fine textured sub soil exceeds about 1.7 gm/cm3, hydraulic conductivity values will be too low that drainage problems can be expected [11]. The total porosity of the studied soils ranged from 32 to 43%, which is far less than the capacity of the soil to retain water at saturation point (Table 2). The value of plastic limits of the soil samples varied from 15 to 26 and liquid limits were ranging from 36 to 55 this range is resulting in a relatively high plasticity index. The Vertisols offer extremes of consistence, they are very hard when dry and very sticky and plastic when wet according to [18].

3.2 Chemical Properties

The results of soil pH ranged from 7.3 to 7.9.These values are mildly alkaline and are found in pits 1-2-3 and 4. In pit 5, reaction to moderately alkaline (pH= 7.9) [11]. The electrical conductivity values of the saturation extracts ranged from 0.4 to 12.0 ds/m. The weighted average of the soluble salts within the depth 200 cm indicate slight level of salinity (0.62ds/m) in (pit 4) and moderate (2.4, 2.8, 2.86 ds/m) salinity in (pits 1-2-5) and high (6.28 ds/m) salinity in (pit 3), Table 3 and Fig. 1.

Table 1. Chemical soil analysis

Pit no.	Lab no.	Depth	CaCo3 %	ECe dS/m	pH	CEC	ESP	SAR	OM %	Olsen P	Total N %
	1	0- 15	4	1.0	7.3	43	2	4	1.6	7.8	0.12
	2	15- 45	4	1.6	7.4	43	15	9	1.4	3.2	0.10
1	3	45- 75	4	2.3	7.5	36	22	9	1.2	4.3	0.09
	4	75- 120	4	2.2	7.5	31	26	12	1.0	3.5	0.11
	5	120- 200	3	4.9	7.4	36	39	15	0.9	7.8	0.06
	6	0- 35	6	0.7	7.7	38	10	3	1.6	8.0	0.13
	7	15- 35	6	0.7	7.6	36	14	7	1.2	2.7	0.20
2	8	35- 80	5	1.6	7.7	37	24	12	1.2	3.4	0.10
	9	80- 130	3	8.0	7.5	39	30	25	1.0	3.5	0.08
	10	130- 200	2	3.0	8.0	39	28	17	0.7	3.6	0.06
	11	0- 15	6	1.1	7.8	42	7	4	1.6	4.2	0.13
	12	15- 35	7	1.2	7.7	42	14	9	1.4	5.2	0.12
3	13	35- 55	9	5.7	7.4	37	27	14	1.2	5.8	0.11
	14	55- 120	4	11.4	7.3	43	22	23	1.0	5.9	0.08
	15	120- 200	3	12	7.4	54	24	20	0.7	3.8	0.13
	16	0- 30	4	0.4	7.7	44	3	3	1.6	4.1	0.14
4	17	30- 60	5	0.4	7.7	46	2	1	1.2	3.3	0.09
	18	60- 100	5	0.7	7.6	50	6	5	1.0	3.6	0.08
	19	100- 170	8	0.8	7.6	52	2	4	0.9	2.4	0.10
	20	0- 5	4	1.7	8.2	55	7	10	1.7	3.6	0.08
	21	5- 25	5	1.3	8.7	58	6	8	1.6	4.8	0.18
5	22	25- 70	6	3.0	8.6	63	10	16	1.4	2.2	0.12
	23	70- 130	4	5.5	8.3	57	24	18	1.0	1.6	0.08
	24	130- 200	4	2.8	9.0	66	20	20	0.7	1.6	0.12

Table 2. Physical soil analysis

Pit no.	Lab no.	Depth	Sand	Silt	Clay	Texture	Bulk density g/cm3	Porosity %	H.C cm3/h
	1	0- 15	16	46	38	ZCL	1.6	29	0.09
	2	15- 45	9	46	45	ZC	1.7	22	0.05
1	3	45- 75	16	38	46	C	1.7	29	0.04
	4	75- 120	15	41	44	ZC	1.8	22	0.03
	5	120- 200	12	49	39	ZCL	1.8	25	0.02
	6	0- 35	22	48	30	CL	1.5	38	0.3
	7	15- 35	22	46	32	CL	1.6	33	0.3
2	8	35- 80	25	47	28	CL	1.6	33	0.05
	9	80- 130	19	48	31	ZCL	1.6	33	0.05
	10	130- 200	5	55	39	ZCL	1.8	25	0.06
	11	0- 15	21	52	27	ZCL	1.6	29	0.08
	12	15- 35	20	39	41	C	1.7	22	0.05
3	13	35- 55	17	39	44	C	1.8	22	0.08
	14	55- 120	8	77	15	ZL	1.6	33	0.08
	15	120- 200	8	71	21	ZL	1.6	33	0.07
	16	0- 30	13	55	32	ZCL	1.6	33	0.2
4	17	30- 60	12	39	49	C	1.8	25	0.09
	18	60- 100	8	51	41	ZC	1.7	29	0.06
	19	100- 170	19	63	18	ZL	1.5	33	0.05
	20	0- 5	6	72	22	ZL	1.6	36	0.2
	21	5- 25	15	57	28	ZCL	1.7	29	0.15
5	22	25- 70	20	39	41	C	1.8	22	0.05
	23	70- 130	17	47	38	ZCL	1.8	25	0.06
	24	130- 200	10	64	26	ZL	1.6	33	0.07

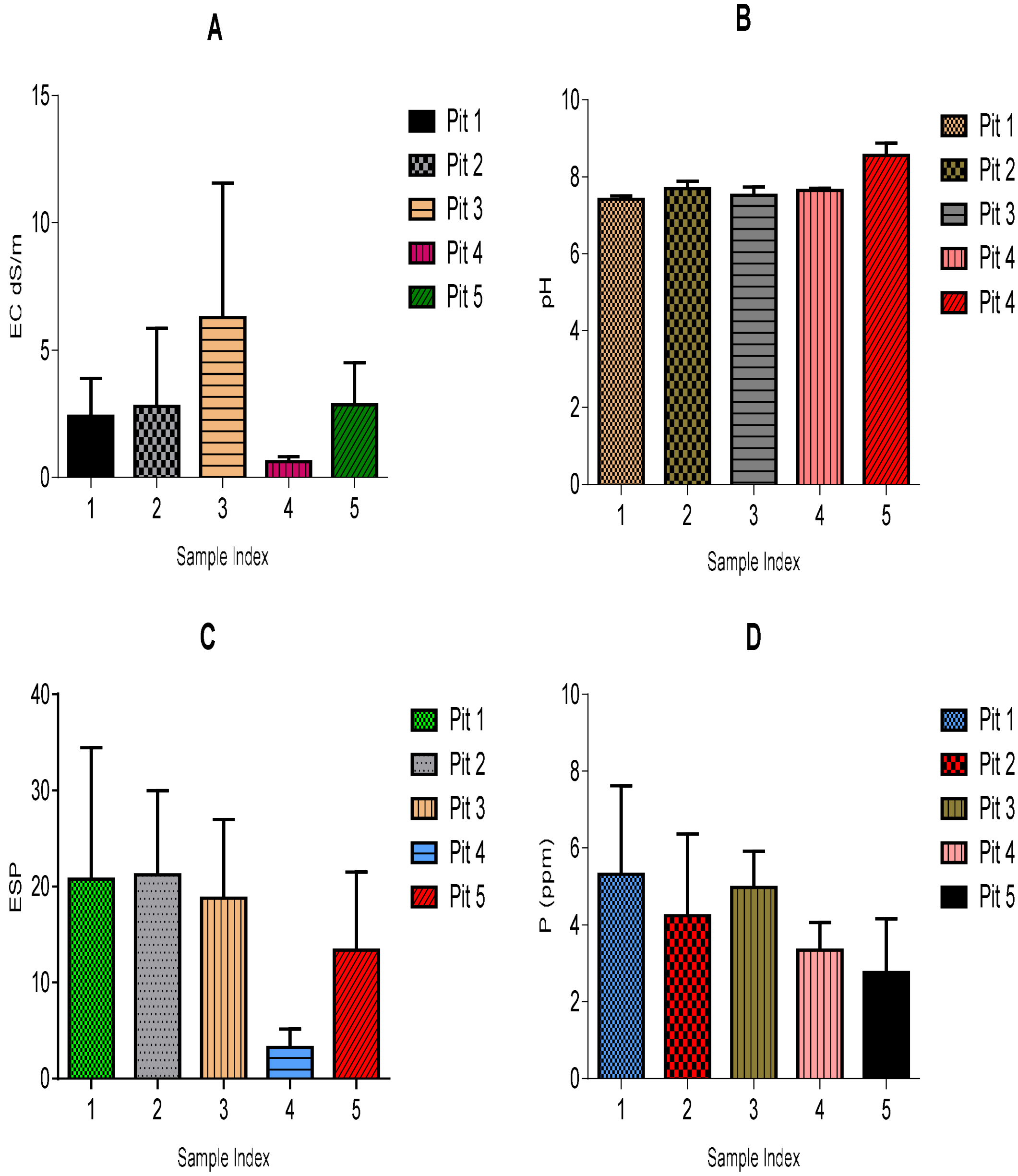

Fig. 1. Values of EC (A), pH (B), ESP (C), and P (D) for different pits

The ESP value of 15 is often regarded as the boundary between sodic and non-sodic soil .In general term, high ESP values have a greater deterious effect on soils with 2:1 lattice clays .Although the onset of adverse physical condition occurs more generally at higher ESP levels in montmorillonitic clays; as indicate by [11]. The critical value of SAR that indicate problem is slightly lower than ESP. The SAR value of only 12 is considered harmful the lower SAR values acquired by pit 4 (3.0) and pit 5 recorded highest values (14.40[a]) Table 3.

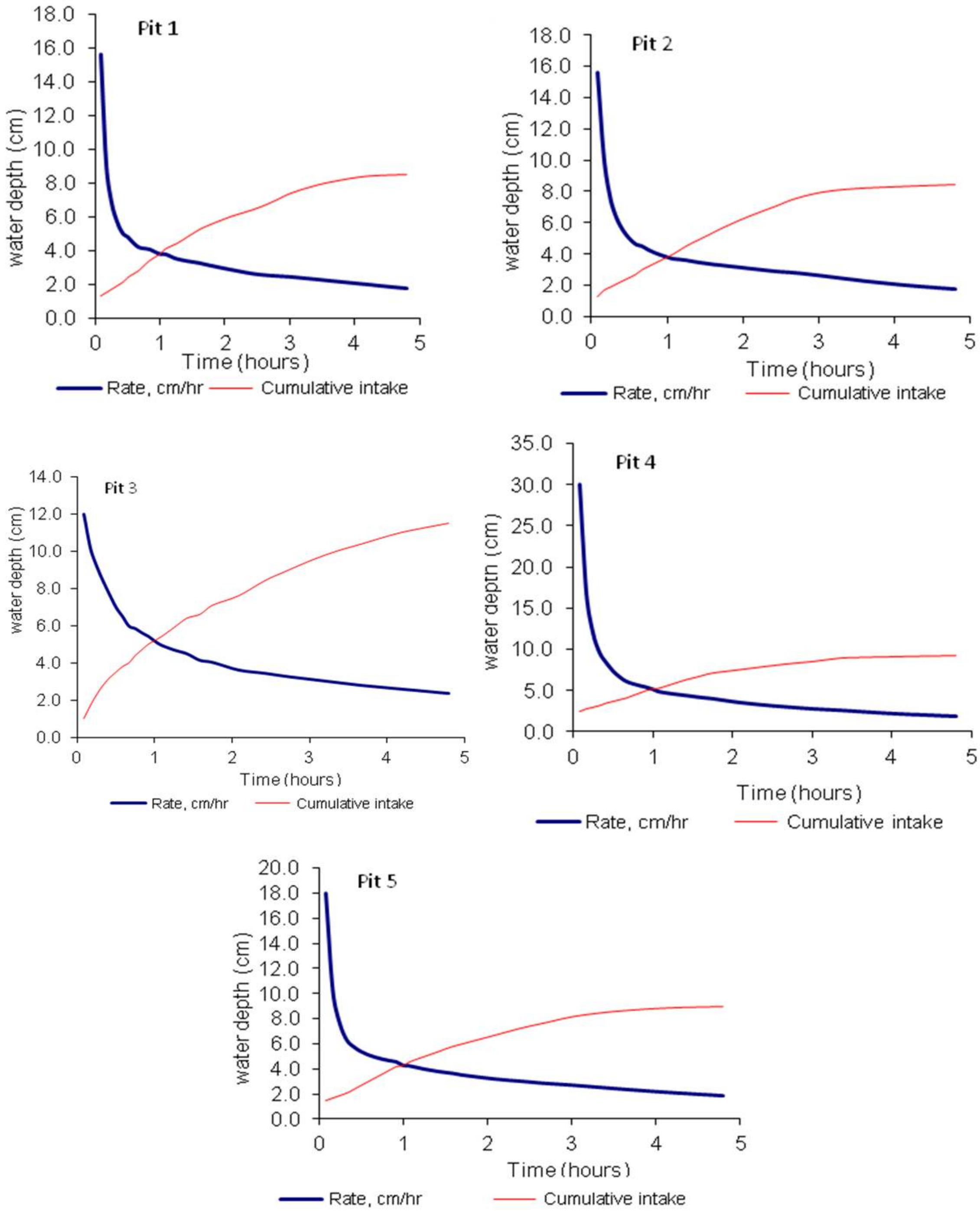

Fig. 1 Double-ring infiltrometer test results for rate and cumulative intake

The Cation Exchange Capacity values ranged from 31 to 66 meq/100 g soil .There is considerable variation from sample to sample. Actually C.E.C values are associated with both clay content, type of minerals and organic matter. In addition silt has a slight effect on C.E.C value, According to [2]. The statistical results indicated that pit 5 recorded highest vales (59.80^{a}) and there is no significant difference between pit 1 (37.80^{b}), pit 2 (37.80^{b}), pit3 (43.60^{b}) and pit 4 (48.8^{b}), Table 3. The Exchangeable Sodium Percent values ranged from 0.9 to 18.

Table 3. Averages and variations of some chemical and physical soil analysis

Soil property	Pit 1	Pit 2	Pit 3	Pit 4	Pit 5	SS	DF	P-value
H.C cm3/h	0.05^{a}	0.15^{a}	0.07^{a}	0.09^{a}	0.11^{a}	0.032	4	0.078465
Porosity %	25.4^{ab}	32.4^{a}	27.80^{a}	30.6^{a}	29.0^{a}	142.6	4	0.157086
CaCo3 %	3.80^{a}	4.40^{a}	5.80^{a}	6^{a}	4.60^{a}	17.84	4	0.218709
ECe dS/m	2.4^{a}	2.8^{b}	6.28^{a}	0.62^{c}	2.86^{b}	84.21	4	0.017084
Ph	7.42^{b}	7.70^{b}	7.52^{b}	7.64^{b}	8.56^{a}	4.2	4	6.27E-07
CEC	37.80^{b}	37.80^{b}	43.60^{b}	48.8^{b}	59.80^{a}	1687.76	4	2.78E-06
ESP	20.80^{a}	21.20^{a}	18.80^{a}	3.0b	13.40^{a}	1160.56	4	0.000865
SAR	9.80^{a}	12.80^{a}	14.0^{a}	3.0^{b}	14.40^{a}	414.64	4	0.000976
OM %	1.22^{a}	1.14^{a}	1.18^{a}	1.12^{a}	1.28^{a}	0.0824	4	0.159865
Olsen P	5.32^{a}	4.24^{a}	4.98^{a}	3.16^{b}	2.76^{b}	24.8064	4	0.080557
Total N %	0.096^{a}	0.114^{a}	0.114^{a}	0.102^{a}	0.116^{a}	0.001576	4	0.816985

Mean values with different superscript letters in the same column differ significantly ($p < 0.05$).
SS: , df: degree of freedom

Table 4. Liquid and plastic limits

Item	S1A	S1B	S2A	S2B	S3A	S3B
LL %	55	53	36	46	45	48
PL %	27	26	20	17	17	16
PI %	28	27	16	30	29	38

The general pattern is one of non sodic soil. However, in certain places the top soil is slightly affected with sodium (ESP = 6). The subsoil is markedly sodic in pits 1-2-3-5 (ESP =24); Table 1. Generally, the pit 4 showed a lower CEC and ESP values than the other sites, Table 2. The values of phosphorus range between 2 to 8.0 ppm and the total nitrogen values ranged from (0.08-0.18 ppm). The results indicated that available phosphorus and total nitrogen are very poor in these soils [19,20]. Similarly, organic matter is very low and the result obtained for organic carbon is in between (0.4-1.0%), as shown in Table 2. The values of calcium carbonate range from 2-9%, (Table 2). Calcium carbonate has an Effect on most of the physical properties of soil including; particle size distribution, bulk density, permeability and available moisture; more important is the effect of calcium carbonate on availability of nutrients specially phosphorus and microelements, [21].

4. CONCLUSION

The study was carried out to evaluate the variability in some physical and chemical properties of soil under investigation (Farm of Faculty of Agricultural Studies, Sudan University of Science and Technology) in order to identify their spatial distribution to assist in designing land management and support agricultural production. The results represented that the soils are variably affected by saline and sodic conditions. Non-saline, slightly saline, moderately saline sub soil and non-sodic to moderately sodic soils are found on the farm. Soil texture is clayey throughout, and hydraulic conductivity is very slow to slow. The whole of soil profile is compacted except at the surface layer, the average of soil bulk density is very high when the soil is dry. The soils under investigation are characterized by high water retention but rather narrow range of available moisture as noticed from the difference between the moisture retained between field capacity and wilting point.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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