CHARACTERIZATION OF THE SOIL OF THE UPPER NILE UNIVERSITY FARM, EL RENK AREA, SOUTH SUDAN

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ABSTRACT:

The objectives of this study were to characterize the soil physical and chemical properties and to classify the soil in order to assess the soil water and crop management systems under rain fed and irrigated agriculture in soils of the farm of Faculty of Agriculture as data base for experimental research studies in the farm of the Faculty of Agriculture, Upper Nile University. . Two soil profiles were excavated in the study area to a depth of 150 cm and fourteen soil samples were collected. The samples were analyzed in the laboratory for their physical and chemical properties. Physical properties results showed that the bulk density of the soil is high (1.7 to 1.9 g/cm^3) with low pore space (30% to 37%). The infiltration rate is very low to low (0.8 to 1.2 c/hr.). The saturated hydraulic conductivity is very slow to slow (0.7 to 1, 9 cm/hr.) with high available water (23% to 38%). The chemical results indicate that the soil is neutral to slightly alkaline in reaction (pH 7.3 to pH 8.3) non-saline (ECe 2.6 to 3.4 dSm^{-1}), non-sodic (SAR 1.4 to 8.3), non-calcareous, poor in organic matter (1.7 to 2.4%) and nitrogen content (0.05 to 0.09%). The CEC-values are very high (79 to 87%) and this is due to the high clay content and its Smectitic nature as well. The soil was classified as Typic Haplustertst, very fine, Smectitic, super active, hyper thermic according to Soil Survey Staff (2010). The main limitation in this soil is its deficiency in nitrogen, organic matter and phosphorus well. Therefore, it is necessary to add manures or N- fertilizers for sustainable crop yield. The clay content may cause problems of water management and workability of this soil which require good management.

Keywords: Characterization, Physical-Chemical Properties, Classification, Vertisols, South Sudan.

1. INTRODUCTION:

The Studied area is located in the Southern part of the central clay plain of the former united Sudan. This southern part, where El Renk area lies is seen as an extensive plain that is associated with the White Nile and tributaries and stretching towards the plateau and hilly region of the equatorial states and is generally referred to as the southern clay plain, Blokhuis (1993). The area is part of the semi- arid climate (Van der Kevie, 1976) which is hot and dry with summer rain and a cold dry winter season. Whiteman, (1971) reported that this study area is composed mainly of superficial clay deposits and alluvium of the White Nile. The clay mineralogy of the study area is strongly dominated by Smectitic clay minerals (2:1) mainly montmorillonite type, which is an expanding clay mineral (Blokhuis1963). The land form of the study area is almost flat and hence flooding usually stands for a long time after rain. Therefore, surface drainage is necessary to be considered. The major kind of land use includes rain fed agriculture such as traditional and mechanized farms of sorghum, sesame, and sunflower and irrigated agriculture such as fruits and vegetables plots and cotton schemes. Irrigation in these cotton schemes is practiced by pumping water directly from the White Nile River.

White Nile River and its flood plain and rain water constitute the main sources of water supply in the study area, in addition to that, the underground water (wells) is considered as a secondary source of water.

Over the years, soil biodiversity and its physical properties that control water movement and retention in the soils are largely affected due to human, animal activities as well as use of machine for soil tillage purposes (Tilahun, 2007). The ability of a soil to generate some products or perform some functions may decline with certain land uses. These manifests as changes in soil properties such as nutrient content (nitrogen, phosphorus, potassium, calcium, magnesium, sodium), pH, organic matter, cation exchange capacity, structure etc (Akinrinde and Obigbesan, 2000; Akamigbo and Asadu, 2001). It has been observed that as the fertility of soil declines, soil structure weakens and the soil becomes susceptible to erosion (Adetunji, 2004). The decline in soil fertility, therefore, has been caused by the increased withdrawal of plant nutrients from the soil without replenishment consequent to increased plant growth.

Soil physical and chemical properties play a central role in transport and reaction of water, solutes and gases in soils, their knowledge is very important in understanding soil behaviour to applied stresses, transport phenomena in soils, hence for soil conservation and planning of appropriate agricultural practices. Therefore, this study was carried out in order to characterize the soil physical and chemical properties and classify the soil in order to assess the soil water and crop management systems under rain fed and irrigated agriculture in soils of the farm of Faculty of Agriculture as data base for experimental research studies in the farm of the Faculty of Agriculture, Upper Nile University, South Sudan.

2. MATERIALS AND METHODS:

2.1 Location of the study area:

The study area lies on the eastern bank of the White Nile at latitude 11° 45 N and longitude 32° 47 E. The size of the area is approximately about four squared kilometers that totals to about 952 feddan (400 hectares) at the proposed farm of the Faculty of Agriculture Upper Nile University. Two soil profiles were selected to present the farm at El Renk County, Upper Nile State, South Sudan.

2.2 Field Methodology:

Two points of profile were randomly selected. Soil profiles were studied in in the field and described following the format of the FAO(1975) guidelines for soil profile description and the soil samples were sampled according to genetic horizons of the profiles (Profile 1 (PO1) and profile 2 (PO2). Soil samples were taken from two profiles for physical and chemical analysis in the laboratory and the soils were classified following The Soil Survey Staff (2010).

2.3 Laboratory Methods:

The soil samples were air dried and crushed using a wooden mortar and pestle and sieved to pass a 2mm sieve. They were subjected to physical and chemical analysis in the laboratory using Standard methods used at laboratory of Land Water Research Centre, Agricultural Research Corporation (ARC), Wad Medani, Sudan.

2.3.1 Physical and Chemical analysis:

Physical characterization consists of soil moisture content, particle size distribution analysis, bulk density, and total porosity (PT), infiltration rate, hydraulic conductivity, soil available water, and soil moisture characteristic cure were determined. The soil samples were air dried and crushed using a wooden mortar and pestle and sieved to pass a 2mm sieve. Soil moisture content (θ) was determined on an oven dry basis (Taylor, 1955). Particle size distribution (soil texture) was determined following the pipette method (Jackson, 1958); bulk density (ρb) was determined following the clod method using the paraffin wax method (Black and Hartage, 1965), while Total porosity (Ƒ) is considered as an index of the relative pore volume in the soil. Total porosity was obtained by calculation according to the following equation:

$$\%\ \text{Porosity} = \left\{1 - \frac{\text{Bulk density } (\rho_b)}{\text{particle density } (\rho_{s})}\right\} \times 100$$

The density was taken as 2·65g/cm³ which is the density of quartz or aluminosilicates·

The Infiltration Rate (IR) was determined using double-ring infiltrometer method (Landon, 1991). Hydraulic Conductivity (HC) of a soil is its ability to transmit water. The hydraulic conductivity of a saturated soil sample was performed using the constant head method (klute, 1965) and then it was calculated following Darcy's law:

$$K_{sat.} = \frac{Q}{At} \times \frac{L}{H}$$

Whereas, $K_{Sat.}$ Is the saturated hydraulic conductivity (cm hr^{-1}), Q is the volume of water (cm^3) passing through the column in time (hours), t is the time in hours, A is cross-sectional area of the brass cylinder (cm^2), ΔH is the hydraulic head change (cm), L is the length of soil column (cm).

Soil available water (AW) was determined using the pressure plate apparatus (Richards, 1941), calculated as follows:

A.W= F.C- P.W.P

Where A.W. is the soil available water, F.C is the field capacity; P.W.P is the permanent wilting point.

Transformation of the A.W from gravimetric (θ_g) to volumetric (θ_v) is to be done through multiplying the moisture by the soil bulk density:

$$\theta_v = \theta_g \cdot \rho_b.$$

Soil moisture characteristic curve is the reversible relationship between the soil moisture content (θ) And the soil water potential (Ψ_m) and is obtained by plotting the soil moisture content (θ)- values against suction the corresponding suction soil water potential (Ψ_m) —values (Childs, 1940). However, it is a relation between matric suction against soil moisture content and the relation is reversibly proportional.·

The Soil pH is the negative logarithm of the hydrogen ion activity. It is a measure of the acidity or the alkalinity of a soil in order to know whether the soil is neutral (PH 7) or acidic (PH < 7) or alkaline (PH > 7). Soil pH was determined in soil extract (1:2·5 soil: water) and in the saturated soil paste by using pH-meter (Mckeague, 1978). Electrical conductivity is the reciprocal of the resistance of soil to electricity and is expressed in dSm^{-1}. Electrical conductivities (ECe) was determined in the extract from the standard soil paste by using an EC-meter and expressed as d/m (Rhoades, 1974). Calcium Carbonate (CaCO3) was determined following the standard titration method of FAO/UNESCO (1973). Total nitrogen was determined following the standard Kjeldahl method. The organic carbon was performed according to Weakley and Black method (1934).Organic matter content is obtained by multiplying the organic carbon (OC) percentage time's recovery factor of 1.72.

Soluble cations (Na^+, Ca^{+2}, Mg^{+2}) were determined from the extract of the saturated soil paste·

Sodium (Na) was measured by flame photometer while calcium (Ca) and magnesium (Mg) were determined by titration with EDTA (Richards, 1954) ·The same extract was also used to determined soluble anions (CO_3^{-2}, HCO^-, CI^-, SO_4^-) by titration method · Sulfate (SO_4^-) was obtained by difference (total (soluble actions - total soluble anions) according to Dewis and Feritas, 1976)·

Cation exchange capacity (CEC) was determined by using the FAO (1988) method, the method which involves saturating the soil with an index cation, washing of excess salts and replacement of the index cation with another cation. Available phosphorus was determine by Olsen et al; (1954).

Sodium Adsorption Ratio (SAR): The SAR was calculated from the soluble cations by the following equation:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

3. RESULTS AND DISCUSSION:

3.1 Soil physical properties:

3.1.1 Soil particle size analysis:

The particle size distributions of the different soil profile are shown in Table 3. 1 and Table 3. 2. The sand, silt, and clay percentages of the soil samples from the two profiles have high clay content throughout the two profiles. The clay content ranges from 60 to 74%, except the top surface (0-3cm) in profile (PO1) that has 55% whereas sand ranges from 25 to 44%· and silt percentage ranges from 1 to 5%. The textures are clay throughout the two profiles with clay content more than 55%. Soil texture is an important soil physical property because it influences many factors that affect plant growth such as soil moisture, aeration, temperature, workability and mineral nutrients release for plants, (Slater and William, 1965). Despite the fact that texture is an inherent soil property, management practices may have contributed indirectly to the changes in particle size distribution particularly in the surface layers as result of removal of soil by sheet and rill erosions, and mixing up of the surface and the subsurface layers during continuous tillage activities (Tilahun, 2007). It can also be stated that the effect of soil tillage on soil particle size by Gülser et al. (2016) reported that heterogeneity and variation of soil physical parameters in a field due to soil plowing should be taken into consideration for a successful agricultural management.

3.1.2. Saturation percentage:

Table 3.1 and Table 3.2 shown the saturation percentage of the soil profile (PO1) ranges from 56 to 73% whereas in profile (PO2) it ranges from 64 to 78% and in both site this indicates the high water holding capacity of the soil. The saturation percentage in profile (PO2) is higher than that of profile (PO1) and this may be attributed to the high clay content of profile (PO2) which consequently results in higher water holding capacity, (Dudal, R. 1965).

3.1.3. Total porosity:

Total porosity of the studied area ranges from 27 to 37% in profile (PO1) whereas in profile (PO2) it ranges from 30 to 35% as shown in Table 3.1 and 3.2. The total porosity in clay soil is highly variable as the soil alternately swells, shrinks, aggregates, disperses, compacts, and cracks. It also depends on soil-water content (θ), (Diamond, 1970).

3.1.4. Hydraulic conductivity (HC):

Table 3.1 and 3.2 showed the saturated hydraulic conductivity data of the two profiles of the studied area showed that in profile (PO1). HC ranges from 0.9 to 1.9 cm/ hr. whereas in profile (PO2) it ranges from 0.7 to 1.6 cm/hr. The H.C of profile (PO1) is higher than the H.C the soil profile (PO2) this may be due to the sand content in profile (PO1). Generally, in this soil the $K_{Sat.}$ is considered as very slow to slow. These characteristics are actually depicted by montmorillonite clay soils, (Marshall, 1958).

3.1.5. Infiltration Rate (IR):

The infiltration rate (IR) data of the studied soil in profile (PO1) decreased with time and became steady after 7hrs to be 1·2 cm /hr. with wetting front depth of 26·5cm/hr. whereas the infiltration rate in profile (PO2) also decreased with time and reached constant rate after 6hr to be 0·8cm/hr. with wetting front depth of 25·5cm· the infiltration rate in profile(1) was higher than in profile (PO2) probably because of a lighter soil texture in profile(PO1) as shown in (Table 3.1 and 3.2). Thus, the overall drainage of the soil profiles of the studied area can be described as low to moderately well drained ,as it is represented graphically for the two soil profiles in figure (3·1). Basically, fine- textured soils such as clayey or silty soils have infiltration rates which decrease with time for a number of reasons. The most important reason for this is that matric suction (Ψ_m) stands high when the soil is dry and then with time suction decreases. If the soil is fairly dry, its wetting will entrap air in the coarser pores and even when the soil is fairly moist some of the air present in the wider pores may become entrapped. These bubbles will block these pores and then slow down the passage of water through them. In addition to that, the soil crumbs containing high clay or organic matter contents, soil then swells or wets and makes the pores narrower, (Dixon, and Linden, 1972).

Table (3-1): Some soil Physical properties of profile (PO1).

Soil depth cm	Particle size distributions %			Saturation. %	Soil moisture %								Bulk. Density	Porosity %	I.R cm/hr.	H.C cm/hr.
	Sand	Silt	Clay		1/3 bar	15 bar	A.W.C	Vol.%	H_2O in soil cm/cm	H_2O horizon	H_2O in (0-30) cm	H_2O in (30-120) cm	Dry			
0-3	44	01	55	56	34.99	17.50	17.49	30.86	0.31	0.93	9.22	34.96	1.77	33	1.17	1.94
3-7	39	01	60	57	36.06	18.04	18.02	30.63	0.31	1.24			1.70	36		1.83
7-27	37	01	62	58	36.09	18.05	18.04	30.31	0.30	6.00			1.68	37		0.89
27-40	38	01	61	60	36.78	18.40	18.38	34.92	0.35	4.55			1.90	28		0.97
40-62	39	01	60	61	39.56	19.79	19.77	38.35	0.38	8.36			1.94	27		1.51
62-112	38	01	61	65	40.63	20.32	20.31	39.40	0.39	19.50			1.94	27		1.41
112-150	31	05	64	73	46.30	23.16	23.14	44.66	0.45	17.10			1.93	27		0.90

Table (3-2): Some Soil Physical Properties of profile 2(PO2).

Soil depth cm	Particle size distributions %			Saturation. %	Soil moisture %								Bulk density	Porosity %	I.R cm/hr	H.C cm/hr
	Sand	Silt	Clay		1/3 bar	15 bar	A.W.C	Vol.%	H_2O in soil cm/cm	H_2O horizon	H_2O in (0-30) cm	H_2O in (30-120)	Dry			
0-3	37	01	62	69	39.90	19.90	20.00	36.20	o.36	1.08	10.34	37.22	1.81	31	0.75	1.49
3-7	37	02	61	64	38.60	19.40	19.20	35.33	0.35	1.70			1.84	30		1.23
7-28	36	01	63	70	39.67	19.89	19.83	34.31	0.34	7.14			35			1.56
28-44	34	05	61	67	40.79	20.40	20.39	37.57	0.38	6.08			1.84	31		1.45
44-73	33	05	62	67	41.88	20.94	20.94	37.48	0.37	10.73			1.79	32		1.62
73-108	25	03	72	77	46.53	32.27	23.26	42.57	0.43	15.05			1.83	31		0.98
108-150	25	01	74	78	55.21	27.61	27.60	51.06	0.51	21.42			1.85	30		0.69

3.1.6. Bulk Density (ρb):

Bulk density (ρb) of the two soil profiles range from 1·7 to 1·9 g/cm. Such high values of bulk density reflect relatively low total porosity values and reduced hydraulic conductivity and low infiltration rate. Bulk density is an important soil parameter especially in computing total pore space and transferring gravimetric moisture (θ_g) to volumetric moisture (θ_g). It is also used in detection of pan layers in soil profiles and in evaluating the root zone for developing tillage systems, (Brady, 1999). Tables 3.1 and 3.2 shown high bulk density data in both profiles reveal that careful management of this soil is needed particularly water management and tillage operation.

3.1.7. Soil Available Water (A.W):

Field Capacity (F.C) roughly corresponds to the matric potential (Ψ_m) of **1 ⁄ 3** bar in the soil and is considered as the high limit of the available water to plant. F.C is extremely affected by soil depth, structure, tillage pans and compacted layers, (Saxon, et. al; 1986). The F.C-values of the studied soil, in profile (PO1) ranges from 34.9 to 46%, whereas in profile (PO2) it ranges from 39 to 55% as shown in Tables 3.1 and 3.2. Permanent Wilting Point (P.W.P) roughly corresponds to the matric potential (Ψ_m) of 15 bars in the soil and considered as the lower limit of the available water that is retained by the soil reservoir, is too low which cannot represent a true lower limit for any of the following plant processes such as transpiration, cell-division or cell- enlargement, (Gardner and Nieman, 1964). The PWP is fairly correlated with surface area of a soil and not available to plants. The PWP-data of the studied soil, in profile (PO1) ranges from 17.5 to 23%, whereas in profile (PO2) it ranges from 19.2 to 27.6% Tables 3.1 and 3.2.

The available water (AW) of the studied soil which was obtained by the difference of the percentage of water retained at field capacity (33 KPa or –0·33 bar) minus that retained at permanent wilting point (1500 KPa or –15 bar). The available water (AW) in profile (PO2) is higher than that in profile (PO1) probably because of the higher clay content in profile (PO2), (Gardner, 1960).

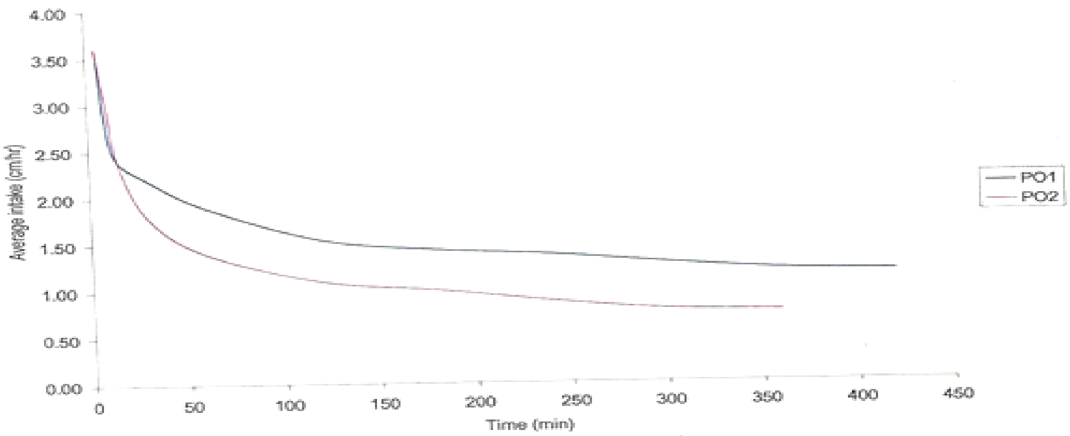

Fig (3.1): Comparison of the infiltration rate of the two Profiles (PO1 and PO2)

3.1.8. Soil moisture characteristic curve:

It is inverse relationship between soil moisture content(θ) and soil suction (Ψ_m). The moisture characteristic curve is obtained when the moisture(θ) of a soil is plotted against its corresponding suction(Ψ_m). The Slope of the moisture – characteristic curve plotted against the suction give apicture of the size distribution of the pores in the soil and in particular it will show if some pore sizes are much more common than others (Drover,1966). This study shows some moisture characteristic curves in two soil profiles in each horizon given in figs.(3. 2, 3.3, 3.4, 3.5). From these curves one can observe that releasing of moisture according to subjected suction(Ψ_m) in these soil profiles occurred smoothly and gradually and this is due to their very fine clay texture(strong retention of water). This is a greed with Hillel (1982) who reported that the greater the clay content in general, the greater the water retention at any particular suction (Ψ_m), and the more gradual the slope of the curve.

3. 2. Soil Chemical Properties:

3.2.1. Soil pH:

The pH-values of the two profiles indicate that soil reaction is neutral to slightly alkaline (pH 7.3 to 8.3). The pH of soil samples of profile 1 ranges from 7.3 to 8.0, whereas the pH of soil samples of profile 2 ranges from 7.4 to 8.3. The pH data indicate that there are no differences between soils of the two profiles, (Tables 3.3 and 3.4). The availability of macro – and micro –nutrients to plants basically depends on the soil-pH, (Sposito, 1989).

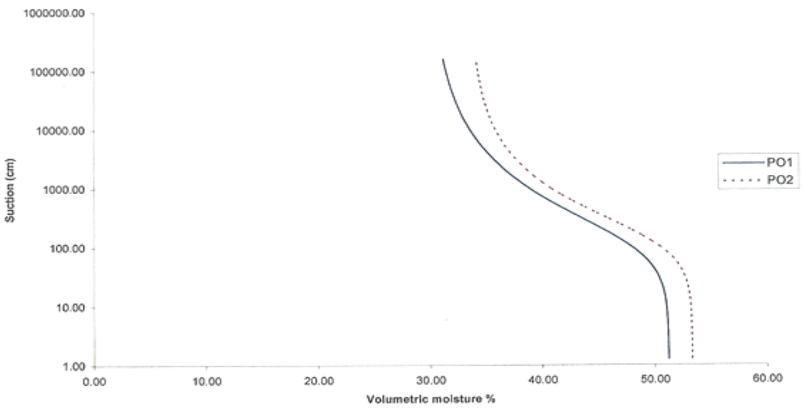

Fig (3.2): Soil moisture characteristic curve for profiles 1 and 2 (depth 0 - 3

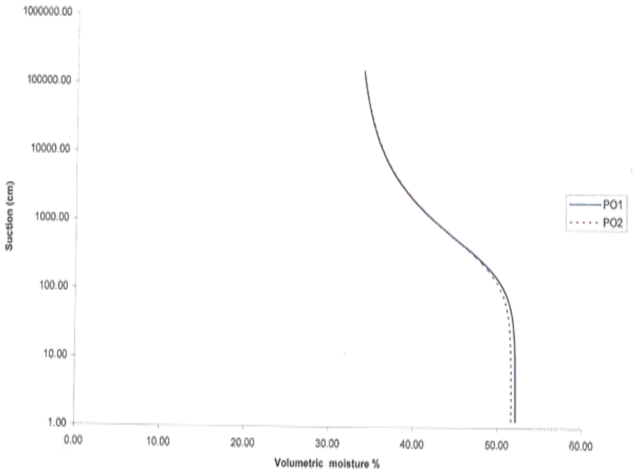

Fig (3.3): Soil moisture characteristic curve for profiles 1 and 2 (depth 3 - 7 cm)

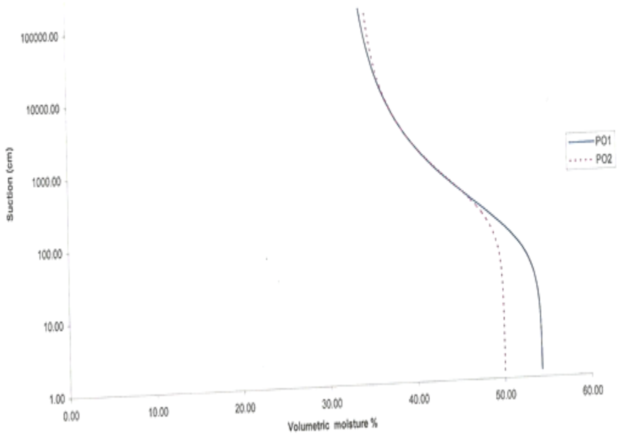

Fig (3.4): Soil moisture characteristic curve for profiles 1 and 2 (depth 7 - 28 cm)

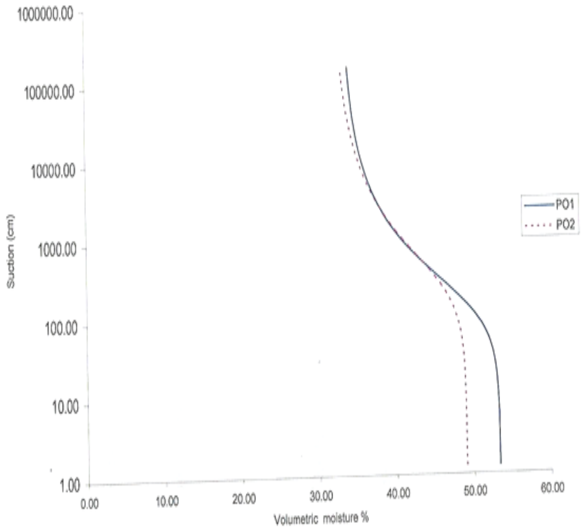

Fig (3.5): Soil moisture characteristic curve for profiles 1 and 2 (depth 28 - 44 cm)

3.2.2. Electrical conductivity (ECe):

The ECe data of the studied soil range from 2.6 to 3.4 ds/m. Thus, the soil is considered as non-saline. The level of soil salinity of the studied soil actually appears to increase with depth due to leaching of salts by rain water from the soil surface horizons to accumulate in the sub-soil horizons in both soil profile samples (table 3.3 and 3.4). According to Fireman, (1957), soils become non-saline as a result of continuous downwards leaching of salts from the root zone.

3.2.3. Calcium Carbonate ($CaCO_3$):

Calcium carbonate results of the two profiles reveal that the soil is non-calcareous (4.0 to 7.0%). And this is because of leaching by rain water that drains the salts downward far away from the root zone (Tables 3.3 and 3.4). Richards, (1960) reported that the content of $CaCO_3$ in the soil increases with the severe aridity of the climate in the area and this may be related to either the lack of annual rainfall or the dryness of the weather condition throughout the months of the year. Thus, the accumulation of $CaCO_3$ on soil surface and subsoil horizons under these previous conditions will be very high due to insufficient leaching process or because of low rainfall.

3.2.4. Soluble Cations and Anions:

The exchangeable cations and exchangeable acidity are presented in Table 3.3 and 3.4. The most cations in soils are calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), Chloride(Cl^{-}), Bicarbonate (HCO^{-}) and Sulphate (SO_4^{--}) anions. The content of monovalent Na^{+1} and divalent Ca $^{+2}$ and Mg^{+2} is generally low. This may be due to the leaching process of salts by rain water or soil parent materials inherited, (Wiklander, 1964).

Table 3.3. and 3.4 indicated that the SAR–values of the two profiles range from 1.4 to 8.3, therefore, these soils are characterized as non-sodic soils. Sodic soils are soils that have SAR-levels > 13, pH > 8.5 and ECe < 4. The concentration of SAR affects the soil physical

properties because it reduces aggregates stability, dry cohesive strength, deflocculating of colloidal surfaces of clay soils. It also decreases the aeration system and infiltration rate due to its dispersive effect on soil features, Robinson, (1968).

3.2.5. Cation exchange capacity (CEC):

The CEC of all the sampled soils (which is a measurement of its ability to bind or hold exchangeable cations) shows ranging from (67% to 87% Cmol + kg¯soil) of the two profiles are seen as very high, and this is mainly due to the high clay content (55% to 74%), and may be due to some increase in organic matter, (Tables 3.3 and 3.4). The CEC is an important criterion of a soil especially in evaluating its fertility status. The studied soil is predominated by Smectitic clay mineral, mainly of montmorillonite type, (Blokhuis, 1963). The most important characteristics of this mineral is its ability to expand and contract in response to the addition and loss of moisture, its ability to absorb cations on its double layer surface and its ability to adsorb or hold water. Montmorillonite has a relatively large amount of isomorphous substitution of silicon (Si^{+4}) by aluminum (Al^{+3}) giving a large number of exchange sites and high exchange capacity, (Bohn et al; 1979).

3.2.6. Organic Matter and Organic Carbon Content:

Table 3.3 and 3.4. Showed the organic matter content of the two profiles its ranges from (1.72 to 2.39% in profile (PO1) and (1.74 to 2.17% in profile (PO2) seem to be adequate because of the prevailing climate where the study area lies is semi-arid region which characterized by warm moist autumn, hot dry summer and cold dry winter. Hence, the chances of organic matter decomposition by micro flora are highly great. Organic matter is an important component of a soil because of its role in stabilizing the aggregates of soil structure especially in clayey soil, improving water holding capacity, acting as pH-buffer, increasing cat ion exchange(Ca^{+2}, Mg^{+2}, K^{+}),and releasing nutrients through microbial decomposition (Greenland et al; 1962). Table 3.3 and 3.4 showed the organic matter content of the two profiles its ranges from 0.01 to 1.39% in profile (PO1) while in profile (PO2) range from 1.0 to 2.26%, the organic carbon in profile (PO1) is slightly higher than in profile (PO2). This may be due to the intensity of natural vegetation cover (in terms of grasses residues or tree leaves) in profile (PO1). Essentially, the value of organic carbon represents the content of soils organic matter. It is an indicator of the fertility status. Plants generally obtain their nitrogen from the soil organic matter, (Mayer, 1994).

3.2.7. C/N Ratio:

C/N ratio results of the two profiles were indicated in Table 3.3 and 3.4 showed that the C/N ratio of the two profiles which is range from 13 to 20 in profile (PO1) and 14 to 23 in profile (PO2) as given in tables 3.3and 3.4, these values are proportional to the increase in the value of organic carbon and nitrogen respectively. The C/N ratio is an indication of the degree of decomposition of organic matter in the soils of grasslands, as it declines with increasing modification or decomposition, e.g. well decomposed soil humus has a C/ N ratio of approximately 12 to 13 in humid temperate soil, whereas in less decomposed plant-residues such as straw, the C/N ratio may reach 40 or more, (Bremner, 1965).

3.2.8. Nitrogen Content:

Table 3.3 and 3.4 showed Nitrogen - values of the studied soil, which range from 0.047 to 0.091, these results reflect the relatively inadequate amounts of organic nitrogen, Tables 3.3 and 3.4. Plants usually take their nitrogen from the soil organic matter or added N-fertilizers. The decomposition of organic materials by micro flora in the soil provides a continuous limited amount of nitrogen, phosphorus and sulfur to plants. This decomposition process increases with the rise in temperature and good supply of oxygen, (Ryden, 1983).

3.2.9. Available phosphorus:

The available phosphorus Table 3.3 and 3.4 showed the available phosphorus of the studied soil ranges from 1.0 to 9.4 mg P kg^{-} soil in profiles (PO1) 7.2 to 9.44 mg P kg^{-} soil and profile (PO2) 1.0 to 6.04 mg P kg^{-}soil. These values characterize these soils as having almost fair quantities of available phosphorus. Response to P-addition is likely if available P-values are between 5 to < 10 mg P kg^{-}soil according to Olsen and Sommer (1982).

The data of available phosphorus of the studied soil in table 3.3 and 3.4 is below that. However, profile (PO2) is having low amounts at depth immediately below 3cm. This site may need or require phosphorus fertilization. The availability of phosphorus to plants is limited in alkaline and calcareous soils, (Lewis and Racz, 1969). The highest availability of phosphorus in soils usually ranges from pH 5.4 to pH 7.0 (Olsen, et al; 1954).

Table (3.3): Some Soil Chemical Properties of Profile 1 (PO1).

Soil depth (cm)	PH 1:2.5	EC_e ds^{-1}	$CaCO_3$	N	OC	O.M	C/N	Soluble Cations			Soluble Anions			CEC Cmol (+) kg^{-1} Soil	SAR	Ava. P mg.kg^{-1} Soil
								Na^+	Ca^{+2}	Mg^{+2}	Cl^-	HCO_3^-	$SO_4^=$			
			%					ml^{-1}								
0-3	7.3	0.4	6.0	0.078	1.25	2.15	16	1.7	1.5	0.5	2.8	1.8	0.0	67	1.70	8.6
3-7	7.6	0.3	5.6	0.094	1.39	2.39	15	1.4	2.0	0.0	1.8	1.3	0.0	75	1.40	8.0
7-27	7.5	0.3	7.0	0.076	1.02	2.72	13	1.5	1.5	0.5	1.8	1.0	0.0	78	1.50	7.8
27-40	8.0	0.5	5.0	0.075	0.01	1.72	13	3.0	1.5	1.0	3.4	1.7	0.0	74	2.68	7.2
40-62	7.9	0.8	6.0	0.064	1.09	1.88	17	6.0	2.0	1.0	7.0	1.5	0.0	73	4.90	7.6
62-112	7.6	2.6	6.0	0.071	1.23	2.12	17	15.6	7.5	3.0	20.2	4.8	1.1	76	6.81	9.4
112-150	7.4	2.4	5.4	0.051	1.25	2.15	20	14.7	5.5	4.0	18.9	4.0	1.0	79	6.74	9.0

Table (3.4): Some Soil Chemical Properties of Profile 2 (PO2).

Soil depth (cm)	PH 1:2.5	EC_e ds^{-1}	$CaCO_3$	N	OC	O.M	C/N	Soluble Cations			Soluble Anions			CEC Cmol (+) kg^{-1} Soil	SAR	Ava. P mg.kg^{-1} Soil
								Na^+	Ca^{+2}	Mg^{+2}	Cl^-	HCO_3^-	$SO_4^=$			
			%					ml^{-1}								
0-3	7.4	0.3	5.6	0.071	1.02	1.76	14	1.5	1.0	0.5	1.9	1.4	0.0	78	1.73	6.0
3-7	7.4	0.4	6.0	0.067	1.23	2.12	18	1.7	1.5	0.5	2.2	2.0	0.0	77	1.70	3.6
7-28	8.3	0.3	5.0	0.062	1.26	2.17	20	1.7	1.0	0.5	1.8	1.2	0.0	79	1.96	2.4
28-44	7.8	0.6	5.6	0.052	1.15	1.98	22	4.7	1.5	0.5	14.6	1.4	0.0	76	4.70	2.8
44-73	7.7	2.5	5.0	0.059	1.21	2.09	21	15.3	5.5	4.0	18.0	4.5	1.2	75	7.02	2.6
73-108	7.5	3.4	4.0	0.053	1.01	1.74	21	25.3	15.0	3.5	28.5	11.3	2.1	85	8.32	1.4
108-150	7.6	2.4	5.6	0.047	1.10	1.91	23	14.9	6.0	2.5	17.8	4.3	1.0	87	7.23	1.0

3.3.1. Soil Profile Description No. 1(PO1)

Classification: Typic Haplustertst, Very Fine, Smectitic, Hyper thermic

Location: El-Renk area

Physiographic Position: Southern Central Clay plain of Sudan

Topography: Flat

Parent Material: Alluvium

0-3 cm: Very dark grayish brown (10YR3/2) dry, very dark gray (10YR3/1) moist; clay; Deep cracks; loose mulch with fine and very fine granular structure; sticky and plastic wet; few to common fine and very fine pores; sand grains, white $CaCO_3$ concretions; non-calcareous; very few shell fragment; many very fine and fine and few medium roots; clear wavy boundary.

3 – 7 cm: Very dark gray (10YR3/1) moist; clay; deep cracks; medium fine to very fine blocky structure; hard dry, friable moist, sticky to very sticky and plastic wet; many fine and fine and very fine pores; many sand grains with white $CaCO_3$ concretions; very few fine quartz crystals; non-calcareous; many very fine and fine few medium roots; clear wavy boundary.

7- 27 cm: Very dark grayish brown (10YR3/2) dry, very dark gray (10YR3/2) moist; clay; moderate medium and very fine prismatic with blocky structure; friable moist, sticky and plastic wet; very few pressure-faces; fine sand pockets with very few fine quartz crystals; few white $CaCO_3$ concretions; non-calcareous; common very fine and fine and very coarse roots; clear wavy boundary.

27-40 cm: Very dark grayish brown (10YR3/2) dry and moist; clay; friable moist, sticky and plastic wet; few pressure faces; few sand pockets; common fine and very few medium pores; few white $CaCO_3$ concretions; non-calcareous; few shell fragments; few to common fine, very fine and medium roots; diffused boundary.

40- 62 cm: Very dark grayish brown (10YR 3/2) moist; clay; weak blocky structure; firm moist, sticky and plastic wet; very fine sand pockets with common sand grains and few fine quartz crystals; few to common $CaCO_3$ concretions; non-calcareous; fine and very fine roots; diffused boundary.

62- 112 cm: Very dark gray (10YR 3/1) moist; clay; weak coarse and medium sub angular blocky; common pressure faces; firm moist, sticky and plastic wet; few very fine pores; few sand pockets and few quartz crystals; non-calcareous; very few very fine and medium roots; clear wavy boundary.

112- 150 cm: Very dark gray (10YR 3/1) moist; clay; massive structure; firm moist, very sticky and plastic wet; few fine pores; few to common white $CaCO_3$ aggregates; few sand pockets; non-calcareous; very few very fine roots.

3.3.2 Soil Profile Descriptions No.2 (PO2):

Classification: Typic Haplustertst, Very Fine Smectitic, Hyper thermic
Location: El-Renk area
Physiographic Position: Southern Central Clay Plain of Sudan
Parent Material: Alluvium
0-3 cm: Very dark grayish brown (10YR3/2) dry and moist; clay; deep cracks; mulch with moderate fine and very fine granular structure; slightly hard dry, friable moist, sticky and plastic wet; few to common, $CaCO_3$ concretions; fine to very fine pores; common white fine concretions with some sand grains; non-calcareous; many very fine and few fine medium roots; clear wavy boundary.
3-7 cm: Very dark grayish brown (10YR3/2) dry and moist; clay; deep cracks; moderate medium, fine and very fine sub angular blocky structure, friable moist, sticky and plastic wet; many fine and very fine pores; sand grains, very few $CaCO_3$ concretions; non-calcareous; many very fine ,fine and medium roots; clear wavy boundary.

7-28 cm: Very dark grayish brown (10YR3/2) moist; clay; moderate coarse, medium and fine prismatic and blocky structure; friable moist, sticky and plastic wet; common very fine, fine and medium pores; common fine sand pockets with very few fine quartz; very few white specks of $CaCO_3$; non-calcareous; very few shell fragments; few very fine and fine roots; clear wavy boundary.

28- 44 cm: Very dark grayish brown (10YR3/2) moist; moderate coarse, medium and fine sub angular blocky structure; friable moist, sticky and plastic wet; few pressure faces; many sand grains and very few sand pockets; common very fine, fine and few medium pores; very few very fine and fine white $CaCO_3$ concretions; non-calcareous; few to common very fine roots; diffused boundary.

44- 73 cm: Very dark grayish brown (10YR3/2) moist; clay; moderate coarse, medium and fine sub angular blocky structure; friable moist, sticky and plastic wet; few pressure faces; many sand grains and very few sand pockets; common very fine, and few medium pores; very few very fine and fine white $CaCO_3$ concretions; very few fine roots and very coarse decayed roots; diffused boundary.

73- 108 cm: Very dark gray (10YR 3/1) moist; clay; very weak coarse and medium sub angular blocky structure; firm moist, very sticky and plastic wet; few pressure faces; few to common gypsum lenses, common sand grains, many whitish specks and few aggregates of $CaCO_3$; non-calcareous; very few and coarse decayed roots; clear smooth boundary.

108- 150 cm: Very dark grayish brown (10YR3/2) moist; clay; massive structure; friable moist, sticky and plastic wet; few sand grains; many soft and hard whitish $CaCO_3$ aggregates with some concretions; non-calcareous.

3.3.3. Soil Classification:

The key to soil taxonomy that was used to classify the studied soils is that of the Soil Survey Staff, (2010). Appendices 1and 2, indicated the climate data of the studied area which is semi- arid with rainy season about 6 to 7 months with annual rainfall average of ten years for the period (1991- 2000) is 595 per annum, Therefore, the moisture regime can be distinguished as Ustic. The annual mean temperature is more than 22 C°, mean temperature for the summer months differ from that of the winter months by more than 6 C°. Therefore, the soil temperature regime can be described as Hyper thermic. The description of soil profiles (PO1) and (PO2) showed that the physical characteristic of the studied soils have deep cracks, pressure faces, wedge-shaped aggregates, clay percentage of 55 to 74% clay throughout the soil profile, (Tables 3.1 and 3.2), no presence of lithic or Para lithic contact or duripan or petro calcic horizon within a depth of 50 cm or a depth of 150 cm. According to the above mentioned characteristics, the soil belongs to the order of Vertisols, the great group is Haplustertst, and the subgroup is Typic Haplustertst with soil moisture regime of ustic and the soil temperature regime of hyper thermic. Therefore, the studied soil is classified as follow: Very Fine, Smectitic, Hyper thermic, Typic haplusterts.

4. CONCLUSION:

The results of the physical properties of the soil showed that the soils texture is clayey with bulk density is high, infiltration rate is very low to low, saturated hydraulic conductivity is very slow to slow and the soil water holding capacity is very high.

The soil is characterized as neutral to slightly alkaline in reaction, non-saline/non-sodic, non-calcareous with high level of CEC reflecting good fertility status of the studied soil.

The soil is classified as Typic Haplustertst, very fine, Smectitic, Super active, hyper thermic according Soil Survey Staff (2010).

The main limitation in this studied soil is the low level of nitrogen, organic matter status and high clay content which require good management.

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Appendix (1): Showing the annual rainfall (mm) at El-Renk Town For the period ten years (1991- 2000).

Month	Year									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
January	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	0.0	0.0	0.0	0.0	0.0	0,0	0,0	7.0	0.0	0.0
April	5.0	0.0	1.5	0.0	27.0	25.0	1.5	6.0	2.0	2.0
May	44.3	21.0	44.3	33.5	27.0	43.4	11.3	17.0	43.5	26.3
June	13.5	59.4	68.2	77.5	106.0	57.4	109.0	22.3	53.8	56.5
July.	172.3	161.0	167.2	258.8	41.2	162.0	180.5	259.0	71.0	214.0
August.	243.1	232.4	107.3	175.9	123.8	201.5	145.5	260.5	234.0	125.0
September	134.1	63.2	72.1	89.3	81.0	70.1	48.3	95.0	94.5	47.0
October	68.2	104.7	47.0	0.0	46.3	45.6	65.5	52.2	105.0	0.0
November	0.0	0.0	12.0	0.0	0.0	10.0	51.0	0.0	0.0	0.0
December.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	680.5	641.7	519.6	635.0	452.3	615.0	612.6	719.0	603.8	470.8

Source: Sudan Meteorological Service, Khartoum

Appendix (2): Showing the annual mean temperature (C°) at El- Renk Town for the period ten years (1991-2000).

Month	Year									
T C°	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
January	24.4	22.6	23.7	26.6	25.4	24.5	25.2	24.6	25.4	25.4
February.	27.4	22.9	24.8	25.6	25.7	27.9	23.6	26.0	27.3	26.9
March	30.0	29.5	29.8	28.0	30.5	30.6	29.4	29.2	29.6	28.6
April	32.9	32.6	32.5	33.4	32.0	32.4	32.2	33.3	32.3	20.9
May	30.8	33.0	32.2	32.3	32.6	31.3	31.4	32.8	31.7	31.8
June	31.1	31.7	30.8	30.3	28.5	28.4	29.4	31.2	30.2	30.4
July	27.7	27.9	27.3	28.6	28.7	28.8	28.4	28.5	28.1	28.1
August	27.5	26.7	28.0	27.2	28.3	27.9	27.5	26.9	27.4	27.0
September	29.1	27.9	28.2	28.4	29.5	28.3	36.2	27.8	28.2	29.2
October.	29.4	29.0	29.9	30.3	30.1	29.8	36.9	29.1	28.3	29.5
November.	28.3	27.5	29.8	27.5	27.7	27.4	33.8	29.0	28.4	28.9
December.	23.7	24.0	26.9	24.0	25.0	26.0	28.9	26.1	26.8	25.3

Source: Sudan Meteorological Service, Khartoum.