

Chapter One

INTRODUCTION

1.1. Background

The concept of an aggregate arises simply because some particles in the soil adhere more strongly than other. Physical aspects of aggregation are fundamental to the character, functions, and behavior of soil.

Soil aggregation is important for the resistance of land surfaces to erosion, and it influences the ability of soils to remain productive. Modification of some soil attributes can be used to evaluate the soil physical condition; determining whether a certain soil management for crop production might improve its natural characteristics or the land capability. (Castro Filho et al., 2002).

Optimum conditions have a large range in pore size distribution. This includes large pores between the aggregates and smaller pores within the aggregates. The pore space between aggregates is essential for water and air entry. This pore space provides zones of weakness through which plant roots can grow. If the soil mass has a low bulk density or large pore spaces, aggregation is less important. For example, sandy soils have low aggregation, but roots and water can move readily. Clay minerals, sesquioxides, and soil organic matter are the soil solids most involved in soil structural development (*Sullivan*, 1990). Among the processes involved in the formation of aggregates are the wetting and drying, freezing and thawing cycles. All these processes are able to orientate fine soil particles and bring them so close together that the physical forces between them hold the particles firmly when allowed to dry (*Allison*, 1968.). The stabilization of soil aggregate takes place due to the cementing action of inorganic and

organic materials, Silicate clays, calcium carbonate and sesquioxides (Koorevar et al. 1983). The aggregate stability is an indicator of organic matter content, biological activity, and nutrient cycling in soil. Generally, the particles in small aggregate are bound by more stable forms of organic matter. Microbial decomposition of fresh organic matter releases products that bind small aggregates into large aggregates. These large aggregates are more sensitive to management's effects on organic matter, serving as a better indicator of changes in soil quality. Greater amounts of stable aggregate suggest better soil quality. When the proportion of large to small aggregate increases soil quality generally increases (Arshad et al 1996).

1.2. Objective:

The objective of this study is to identify the association between some soil properties and aggregate structure.

Chapter Two

LOCATIONS OF STUDY

2.1. Environmental Setup

2.1.1. Location and Climate:

The study was conducted in four sites, Site 1: a farm in western Omdurman, Khartoum state- Sudan. Latitudes 15.68° N and longitudes 32.35° E. The climate of the area is within the semi-desert zone as adopted by (van der kevie 1976). The year is divided into two distinct climatic periods as a dry warm period when the north winds bring hot weather from the northern desert causing wind erosion and as a rainy period when the south western winds predominate. During these rainy periods some depression sites (wadis) are flooded by water whereas in May and June dust storms normally occur. Total rainfall ranges from 0.0 in January, February, April and December to 48.3 mm in August.

Site 2: Kadarro farm is located to the North East of the Khartoum north locality bounding by latitude 15.45° and 13.27° North and longitude 40.96° and 32.35° East. It lies about 19kms to the North of Khartoum North locality, and about 22 km from the National capital Khartoum. The topography of Kadarro farm is a vast plain characterized by its flat, slightly undulated land that slopes from South to North. The climate of study area daily average minimum and maximum temperature is about 28.6° and 46° respectively. Average annual rate of rainfall ranges between some 155-166mm. Rain mainly falls during June and October. The area is also, characterized by dry and cold winter between November and February, and a hot summer between April and June. These weather conditions resemble those of the ecological belt Climate of desert and semi-desert.

Site 3: The farm of Soba is located at the Khartoum south and lies between longitudes 31.5 to 34 °E and latitudes 15 to 16 °N. Semi-desert climates. The weather is rainy in the summer, and cold and dry in the winter. Average rainfall reaches 100–200 mm in the north-eastern areas and 200–300 mm in the northwestern areas. The temperature in summer ranges from 25 to 40 °C from April to June, and from 20 to 35 °C in the months of July to October. In winter, the temperature declines gradually from 25 to 15 °C between March and November.

Site 4: The soil of the study lie within Shambat research farm (LAT: 15° 40' N LONG: 32° 32' E), and situated on the eastern bank of the River Nile, Immediately below the junction of the blue and white Niles. The climate data was taken from Shambat Meteorological Observatory which is the nearest to the location of the site. The area of Shambat in Papadkis classifying falls in the semi-desert climate with summer rains, warm winter. The climate is hot almost throughout the year, except the cooler short winter season (December, January). The main daily temperature is 29.3°C. Average maximum temperature reaches 47.3°C in May. While the minimum temperature is 5.5°C in February. The main relative humidity is 28% and show some variation ranging from 16% in April to 45%in August. The average annual rainfall is about 147.5mms, with most of the rain falling in June-October; maximum in the hot dry summer (April - May) causing dust storms (Haboob) and erosion hazards. The period October –May winds move to south westerly direction due to the approach of inter – tropical convergence zone causing slight and variable rainfall.

2.1.2. The Soils:

The soils studied belong to the orders Vertisols and Entisol in the American system of soil taxonomy.

* Vertisols are soils with a high content of clay minerals that shrink and swell as they change water content. The clay minerals absorb water and increase in volume (swell) when wet and then shrink as they dry, forming large, deep cracks. Surface materials fall into these cracks and are incorporated into the lower horizons when the soil becomes wet again. As this process is repeated, the soil experiences a mixing of surface materials into the subsoil that promotes a more uniform soil profile.

Vertisols are usually very dark in color, with widely variable organic matter content (1 – 6%). They typically form in Ca and Mg rich materials such as limestone, basalt, or in areas of topographic depressions that collect these elements leached from uplands. Vertisols are most commonly formed in warm, subhumid or semi-arid climates, where the natural vegetation is predominantly grass, savanna, open forest, or desert shrub. (USDA-NRCS).

- Entisols are commonly found at the site of recently deposited materials (e.g., alluvium), or in parent materials resistant to weathering (e.g. sand). Entisol soils also occur in areas where a very dry or cold climate limits soil profile development. Productivity potential of Entisols varies widely, from very productive alluvial soils found on floodplains, to low fertility/productivity soils found on steep slopes or in sandy areas (USDA-NRCS).

The soil of west Omdurman is generally reddish brown, sandy loam. They are non calcareous, non saline and non sodic, with slight limitation such as low organic matter. The water movement (Hydraulic Conductivity) through the soil depth decrease may be due to the clay increase under the 30cm surface layer. Most active process and manifested in wind erosion in the form of sand rills and low- shifting sand dunes . water erosion is similarly active forming shallow water courses and small gullies as deflation and deposition,

The soil of Kadarro is brown, sandy clay, calcareous and saline sodic soil, with slight limitation such as low organic matter. The water movement (Hydraulic Conductivity) through the soil depth decrease may be due to the clay increase under the 30cm surface layer.

The soil of Soba area is brown, Sandy Clay Loam, saline sodic and with low organic matter, the water movement through the soil depth decrease may be due to the clay increase under the 30cm surface layer.

The soil of Shambat area is brown, Clay, has low organic matter. The water movement is very slow because this soil has a clay texture.

Chapter Three

LITERATURE REVIEW

3.1. Definition:

Soil aggregates are groups of soil particles that bind to each other more strongly than to adjacent particles. The spaces between the aggregates provide pore space for retention and exchange of air and water. (USDA.1996). the association of soil particles (sand, silt & clay), together with organic matter, into larger sized units called aggregates or peds. A soil aggregate is “a group of primary soil particles that cohere to each other more strongly than to other surrounding particles”. Soil aggregates form through the combined action of aggregation and fragmentation processes. (Nemo, 2004).

Soil is fundamentally made of single solid particles and these particles stick together to form aggregates. Soil Aggregates are fundamental building blocks of the soil structure. Depending on the land use and other environmental factors, soils will have different proportion of various sized aggregates. The amount of stable aggregates in a soil is an important property or characteristic that determines many soil functions. (www.soiltec.eu).

Soil aggregate is the basic unit of soil structure, and its formation and stabilization has direct effect on soil fertility and crop growth. For black soil with high content of organic matter, organic cementing substance is an important factor in forming soil aggregates. (Ying Yong Sheng Tai Xue Bao. 2002).

Soil structure is defined by the way individual particles of sand, silt, and clay are assembled. Single particles when assembled appear as larger particles.

These are called aggregates. Aggregate is secondary structural units made of primary particle that are distinguished from adjacent structures on the basis of failure zone (Kay and Angers 2001).

Soil aggregates are clumps of soil particles that are held together by moist clay, organic matter and gums. The aggregates are relatively stable. Aggregates vary in size from about 2 thousandths of a millimeter across, up to about 2 millimeters across. Soil pores are the spaces between soil particles and between soil aggregates. The aggregates are made up of particles of different sizes and some of these particles fit closely together. Some do not. This means that there are spaces of many different sizes in the soil and these spaces are essential for storing air, water, microbes, nutrients and organic matter and roots penetrations (Kay and Angers 2001).

There are many features that characterize a soil. One such feature is structures. There are many different types of aggregates, such as platy, prismatic, granule, blocky, angular, and more. There are several different factors which influence the formation of these structures. These factors are Organic matter , calcium carbonate and clay content . (Hans Jenny,1941).

3.2. Soil Structure:

Soil structure refers to the grouping of soil particles and their arrangement into aggregates of varying consistency. An aggregate consists of many fine soil particles held in a single mass or cluster. The aggregation of soil particles is an important factor affecting drainage, aeration and ability of the soil to release plant nutrients. (Olaitan et.al 1984).

3.3. Soil Texture:

Soil texture is determined by the size of the soil particles. It refers to the proportion of sand, silt and clay in a soil. In a more general way, texture may be used to describe how a soil feels or behaves under cultivation. Soil texture may be determined by various methods.(S.O. Olaitan et.al 1984). Soil texture (such as loam, sandy loam or clay) refers to the proportion of sand, silt and clay sized particles that make up the mineral fraction of the soil. For example, light soil refers to a soil high in sand relative to clay, while heavy soils are made up largely of clay.

Texture is important because it influences:

- The amount of water the soil can hold
- The rate of water movement through the soil
- How workable and fertile the soil is.

3.4. Factors Effecting Soil Aggregate

- Clay content
- Calcium Carbonate (CaCO_3)
- Sodium saturation ESP
- Soil Organic Matter (OM)
- Oxides

3.4.1. Clay Content

Soil aggregation in relation to other soil properties was studied along a climatologically transect by (Boix-Fayos C et al. 2001). Three sites were selected along this transect ranging from semiarid to sub humid climatologically conditions. The aggregate size distribution, the macro and

micro aggregate stability of the superficial soil horizon and their relations with other soil properties were analyzed. Large aggregates (>10, 10–5, 5–2 mm) were present in highest proportions in the most arid of the studied areas. These large aggregates were associated with high values of water-stable micro aggregates; however, they did not improve soil structure and are related to high bulk densities and low water retention. Aggregates 1–0.105 mm were positively correlated to medium, fine, very fine sand and silt fractions and to organic matter. Aggregates <0.105 mm were positively correlated with organic matter and clay content. Small aggregate sizes (1–0.105 and <0.105 mm) had a positive influence on soil water retention and they seem to be a good indicator of soil degradation.

Stability of micro aggregates showed a positive correlation with clay content, while the stability of the macro aggregates depended on organic matter content particularly when the organic matter content was greater than 5 or 6%. Below that threshold the carbonate content was strongly correlated with aggregate stability. A general conceptual scheme of associations between aggregate size distribution, water-stable micro aggregation and textural characteristics for the area was developed (Boix-Fayos C et al, 2001). Higher clay content of a soil generally makes for more aggregation. Chemicals that precipitate or otherwise turn into cementing agents also enhance aggregation.

Typical cementing substances include calcium carbonate and humus. (Nimmo, 2004).

The decline of soil structure under irrigation is usually related to the breakdown of aggregates and dispersion of clay material as a result of rapid wetting. This is particularly so if soils are sodic; that is, having a high

exchangeable sodium percentage of the cation attached to the clays. (Olaitan and G.Lombin, 1984)

Aggregate size distribution and stability can be used as indicator of soil degradation, but not as a unique parameter (Boix-Fayos C et al , 2001).

Soil aggregate stability is a crucial soil property affecting soil sustainability and crop production. A broad outline of the processes and agents of aggregate formation and aggregate stabilization are presented and discussed in this review. Aggregate stability is difficult to quantify and interpret. The aim of aggregate stability tests is to give a reliable description and ranking of the behavior of soils under the effect of water, wind and management. Numerous methods have been used to determine aggregate stability with varying success. The different methodologies complicate the comparison among aggregate stability data. It is also difficult to obtain a consistent correlation between aggregate stability and other important soil properties. (Taylor & Francis, 1999).

Wet aggregate stability is not the same as dry aggregate stability, which is used for wind erosion prediction. Desirable aggregates are stable against rainfall and water movement. Aggregates that break down in water or fall apart when struck by raindrops release individual soil particles that can seal the soil surface and clog pores. This breakdown creates crusts that close pores and other pathways for water and air entry into a soil and also restrict emergence of seedlings from a soil. The stability of aggregates is affected by soil texture, the predominant type of clay minerals, extractable iron, and extractable cations, the amount and type of organic matter present. Some clay expands like an accordion as they absorb water. Expansion and contraction of clay particles can shift and crack the soil mass and create or

break apart aggregates. Calcium ions associated with clay generally promote aggregation, whereas sodium ions promote dispersion. Soils with over about five percent iron oxides, expressed as elemental iron, tend to have greater aggregate stability. Soils that have a high content of organic matter have greater aggregate stability. Additions of organic matter increase aggregate stability. (USDA, 1996).

Aggregation and stability of soil aggregates are affected by predominant 1.type and amount of clay, 2. Adsorbed cation, such as calcium and sodium, 3. Iron oxide content. Expansion and contraction of clay particles under effect of water (dry- wet) cycle can shift and crack the soil mass and create aggregates or break them apart. Calcium, magnesium, iron, and aluminum stabilize aggregates via the formation of organic matter – clay bridges. In contrast, aggregate stability decreases with increasing amounts of exchangeable sodium (USDA 2008).

Gollany et al (1991) have indicated that the aggregate stability increases with clay content increase.

3.4.2. Calcium Carbonate:

(Mbagwu,1989). have indicated that Calcium Carbonate was more important an stabilizing substances than organic carbon.

Interactions between soil type and Ca^{2+} revealed the importance of polyvalent cations in aggregate stability of soils with low activity minerals. The influence of organic matter varied with quantity; the more there was, the more stable the soil became, particularly in the soil containing little clay. Clay dispersion and slaking of expanding minerals occurred even with large additions of Ca^{2+} and organic matter, emphasizing the overall influence of

mineralogy in determining the response of soils to stability treatments (Wuddivira and Gamps- Road. 2006) .

Organic and mineral soil particles are not isolated from each other, but form structural aggregates (also called “peds”). In 1961, Blackmore and Miller observed how the Ca-montmorillonite may be arranged in groups of four or five particles, depending on various soil characteristics. While a single wet/dry cycle initiated soil structural evaluation in all composite soils, enhancing macroaggregation, the incorporation of barley straw was most effective for the development of water stable aggregates in those soils with 34% and 38% clay. But the large straw additions also tend to enhances soil aggregation (Stephen Winger et al 2007).

3.4.3. Exchangeable Sodium Percent (ESP):

The decline of soil structure under irrigation is usually related to the breakdown of aggregates and dispersion of clay material as a result of rapid wetting. This is particularly so if soils are sodic; that is, having a high exchangeable sodium percentage (ESP) of the cations attached to the clays (Marshall et al, 1979).

The presence of excessive amounts of exchangeable sodium reverses the process of aggregation and causes soil aggregates to disperse into their constituent individual soil particles. This is known as dispersion and occurs in sodic soil. (John Wiley & Sons. 2007).

The primary physical processes associated with high sodium concentrations are soil dispersion and clay platelet and aggregate swelling. The forces that bind clay particles together are disrupted when too many large sodium ions come between them. When this separation occurs, the clay particles expand,

causing swelling and soil dispersion. Soil dispersion causes clay particles to plug soil pores, resulting in reduced soil permeability. When soil is repeatedly wetted and dried and clay dispersion occurs, it then reforms and solidifies into almost cement-like soil with little or no structure. The three main problems caused by sodium-induced dispersion are reduced infiltration, reduced hydraulic conductivity, and surface crusting (Krista et al, 2003).

3.4.4. Organic Matter

Soil Organic Matter is the most important indicator for soil quality improvement because it regulates water movement and water holding capacity, provides nutrients for plants and controls soil structural stability by affecting the quantity of macro- and micro-aggregates (Handayani *et al.*, 2008).

Organic carbon increases the aggregates' inter-particle cohesion. Effects of Soil Organic Carbon on porosity and indirectly aggregate stability have recently been suggested (Lugato *et al.*, 2009).

Organic matter is considered one of the main agents favoring soil aggregation. Part of the aggregate size variation, and therefore, the aggregation indices in tropical soils can be attributed to variations in Soil Organic Matter (Castro Filho, 1988).

The aggregates of a fine-textured soil with much organic matter are likely to be larger than those of a sandy soil. (Nimmo, 2004)

(An et al., 2010; McCarthy et al., 2008; Tang et al., 2011). Have also indicated that soil aggregates are formed and stabilized by Organic Matter.

The encouragements of granular type aggregate in surface soil horizon are due to organic matter (Harris, 1966).

Tisdall and Oades, 1982 classified the organic binding agents in three groups' transient, temporary and persistent material. Transient, binding agents are organic material, which are decomposed rapidly by microorganisms; the most important group is polysaccharides, the effect of which lasts weeks. Temporary, binding agents are roots and persistence, resistant aromatic components associated with polyvalent metal cations, and strongly sorbet polymers The water-stability of micro-aggregates depends on the persistent organic binding agents and appears to be a characteristic of the soil, independent of management., .

Decomposed organic matter was more important than clay content and calcium carbonate on soil aggregate ; the results indicate that soil organic matter levels can be used diagnostically to identify soils which may show problems of structural instability. (Chaney et al, 1986).

Since the beginning of the last century, many studies have reported evidence describing the effects of organic inputs on soil aggregate stability. In 1965, Monnier proposed a conceptual model that considers different patterns of temporal effects on aggregate stability depending on the nature of the organic inputs: easily decomposable products have an intense and transient effect on aggregate stability while more recalcitrant products have a lower but longer term effect. We confronted this conceptual model with a literature review of experimental data from laboratory and field experiments. This literature analysis validated the conceptual model proposed by Elsevier and pointed out gaps in our current knowledge concerning the relationships between aggregate stability and organic inputs. Noticeably, the experimental

dataset confirmed the biological and temporal effects of organic inputs on aggregate stability as proposed in the model. Monnier's model also related the evolution of aggregate stability to different microbial decomposing agents, but this relationship was not made clear in this literature analysis. No direct or universal relationship was found between the aggregative factors induced by organic input decomposition (binding molecules or decomposers of biomass) and temporal aggregate stability dynamics. This suggests the existence of even more complex relationships. The model can be improved by considering (i) the direct abiotic effect of some organic products immediately after the inputs, (ii) the initial biochemical characteristics of the organic products and (iii) the effects of organic products on the various mechanisms of aggregate breakdown. For now, no trend is evident in the effect of the rate of organic inputs or the effect of the soil characteristics (essentially carbon and clay contents) on aggregate stability (Elsevier et al, 2009).

Majority of the accumulation of soil organic matter due to additional carbon inputs was preferentially sequestered in the microaggregates within small macroaggregate. (Angelia et al 2005)

3.4.5. Oxides

The presence of significant amounts of iron oxides in soils is generally considered to exert important effects on their physical properties, but no satisfactory experimental evidence exists to substantiate this view. A series of experiments has therefore been carried out to determine what effect the removal of iron oxides from natural aggregates has on their stability. In addition attempts have been made to improve the aggregation of soils by precipitation of iron and aluminium oxides on the soil particles.

(.Deshpande et al. 1964).

The stability of soil aggregates is considered to be affected by number of soil factors, including iron oxides (Tisdal & Oades.1982).

We investigated the structural stabilities of eight arid zone soils using percent optical transmittance as a measure of flocculation-dispersion behavior. The soils were sodium saturated and their stabilities determined in sodium chloride solutions of varying concentrations. We treated the soils with hypochlorite for organic matter removal, with oxalate for removal of amorphous aluminum and iron oxides, and with dithionite for removal of crystalline aluminum and iron oxides. The removal of amorphous and/or crystalline oxides increased the clay dispersive. This indicated that amorphous and crystalline oxides play important, stabilizing roles in soil structure. The removal of organic matter increased the clay dispersive. The well-known positive effect of organic matter on soil structure probably occurs through binding of soil particles by roots and hyphae at the aggregate level, but at the clay-particle level the negative charge of organic anions enhances clay dispersion.(Goldberg, Sabine et al, 1990).

Chapter Four

MATERIALS AND METHODS

4.1. Materials:

Tools:

The following tools and equipments were used during the course of this study.

- Auger
- Sieves
- Digital Camera
- Pipette instrument
- Desiccators
- Thermometer
- Hot plate,
- Digital burette
- pH. Meter (model 3510, Jenway)
- Calcimeter (model ART. No. 08.53, Eijeklkamp)
- Flame photometer (model M410, Sher wood)
- Ec. Meter(model 470 portable conductivity, Jenway)
- Centrifuge (model Roto fix 32 A Hettich)
- Shaker (model Hs 260 Basic IKA Jenway)
- Balance (model KERN 440.47 N)
- Oven (model Scott science UK)

4.2. Methods:

The following chemical, physical and mechanical properties have been determined.

- . Texture
- . pH
- . Moisture content
- . Saturation percent
- . Electric conductivity
- . Calcium carbonate
- . Organic carbon and organic matter
- . Cation exchange capacity
- . Sodium Adsorption Ratio
- . Exchangeable Sodium percent
- . Soluble cations (Ca + Mg)

The analysis were carried out at lab of Faculty of Agricultural Science in Sudan University of Science and Technology (SUST).

4.2.1 Method of Data Collection:

4.2.1.1. Field Methods and Soil Samples:

Auger samples were collected at (0-20, 20-45cm) depths to provide information on soil properties.

4.2.1.2. Laboratory Methods:

1. Soil Moisture Content

Soil moisture was determined by weighing 10g air dry soil and dried in an oven, at 105°C overnight; remove from oven and cooled in a desiccator for 30 minutes, and re-weighed (Hesse, 1971). Then moisture content was calculated according to the following formula:

$$\text{Moisture Content \%} = \frac{\text{Wet soil} - \text{Dry soil}}{\text{Dry soil}} \times 100$$

2. Saturation Percentage:

The method used to determine the saturation percentage is as follows:

A 100 grams air dry soil was placed in 250ml plastic beaker, and distilled water was added to moisten the soil, mixed with a spatula until the paste flows slightly and slides off the spatula. It is then calculated as follows:

$$\text{Saturation percent} = \frac{(\text{Water used} + \text{Hygroscopic moisture})}{\text{Soil use}} \times 100$$

3. Soil pH:

Soil pH was measured by pH meter combined electrode; Glass- electrode in soil paste extract. (Ryan et al. 1996).

4. Electrical Conductivity:

Electrical conductivity was measured using Ec meter (Ryan *et. al.* 1996).

5. Particle Size Distribution:

The sand fraction was separated by a set of sieves. (coarse sand and fine sand), clay was determined by hydrometer methods (Bouyoucos, 1962; Day, 1967; FAO, 1974). and silt was defined by difference between clay and sand.

6. Calcium Carbonates:

Using Eijkelkamp Calcimeter

Calcium carbonate was determined by dilute HCl and the volume of CO₂ evolved is measured at atmospheric temperature and pressure. Accurate weight of pure CaCO₃ is also titrated with HCl and the volume of CO₂ evolved is measured, and percent of CaCO₃ is calculated according to the following equation:

$$\text{CaCO}_3\% = \frac{\text{Wt.2} (v_1 - v_3) \times 100}{\text{Wt.s} (v_2 - v_3)}$$

Where:

Wt.2= weight of pure CaCO₃

Wt.S= weight of soil sample

V1= volume of CO₂ evolved from soil sample

V2 = volume of CO₂ evolved from CaCO₃

V3= volume of CO₂ due to a blank sample

Final results are expressed on oven dry basis by multiplying the result by the following factor:

$$\frac{100 + m\%}{100}$$

Where: m%= moisture percent

7. Organic Carbon and Organic Matter:

The organic matter was determined on the oxidation of organic carbon with 1N potassium dichromate ($K_2Cr_2O_7$) in acid medium of sulphuric acid and by titration with ferrous ammonium sulphate solution. A factor of 1.72 is used to convert organic carbon into organic matter (walkley and Black method) (Ryan *et. al.* 1996).

8. Cations Exchange Capacity (CEC):

The colloidal complex of soil is first saturated with sodium using sodium acetate, to absorbed sodium. Washed with ethanol to remove excess sodium. Sodium was then replaced by ammonium acetate and measure by flame photometer (Bower, 1952).

9. Exchangeable Sodium:

Was obtained as the different between ammonium acetate and extractable sodium and water soluble Sodium

10. Soluble Cations:

Soluble cations were determined in saturation extract of soil paste and expressed in meq/L. Soluble calcium and magnesium were determined by titration with ethylene diamine tetra acetic acid (EDTA) (Versenate solution), and both soluble sodium (Na) and potassium (K) were determined in 10ml from the saturation extract using digital flame photometer. (Richards, 1954).

11. Sodium Adsorption Ratio (SAR).

The Sodium Adsorption Ratio (SAR) is determined from analysis of water extracted from the soil. Determined by the following equation:

$$\text{S.A.R.} = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

12. Exchangeable Cations (Na⁺, Ca⁺⁺, Mg⁺⁺ and K⁺):

Extracted with ammonium acetate and corrected for soluble fraction as measured in saturation extract. (Bower, 1952) .

13. Exchangeable Sodium Percentage

Was calculated according to the following formula:

$$\text{ESP} = \frac{\text{Exchangeable Sodium}}{\text{CEC}} \times 100$$

14. Index of Structure

$$\text{I.S \%} = \frac{\text{T.C} - \text{W.D.C}}{\text{T.C}} \times 100$$

Where:

I.S = Index of structure

T.C = Total clay

W.D.C = Water dispersible clay

Chapter Five

RESULT AND DISCUSSION

Clay content:

Clay content varies between 17-28; 25-43; 35-52 and 53-70% in west Omdurman, Alkadaro, Soba and Shambat respectively.

Calcium carbonate:

Calcium carbonate (CaCO_3) varies between 0.7-7.4; 21.1-44; 5.6-10.2 and 5-7.7 in west Omdurman, Alkadroo, Soba and Shambat respectively.

Exchangeable Sodium Percentage:

Exchangeable Sodium percentage (ESP) varies between 14-26; 21-60; 4-20 and 3-24 in west Omdurman, Alkadroo, Soba and Shambat respectively.

Index of Structure:

Index of Structure (I.S) varies between 18-50%; 44-67%; 60-69% and 73-80% in west Omdurman, Alkadaro, Soba and Shambat respectively.

Tables

Table No (1) Physical and Chemical Properties West Omdurman

Sample	Depth Cm	SP%	pH	Ece ds/m	SAR	O.C %	CaCO3 %	Clay %	Silt %	C.S %	F.C %	CEC Meq/100g	K Meq/L	Ca +Mg Meq/L	Soluble Na meq/L	Ex Na meq/100g
1	0 - 20	22.7	7.51	0.8	1	0.12	7.4	17	23	40	20	6.2	0.14	6.0	2.3	0.9
2	20 - 45	26.3	7.01	0.6	1	0.11	6.6	21	25	39	15	5.3	0.11	4.0	1.9	0.9
3	0 - 20	23.7	7.65	0.5	1	0.10	6.8	19	23	45	13	6.2	0.13	4.0	0.9	0.9
4	20 - 45	23.7	7.51	0.6	1	0.13	6.3	19	24	41	16	6.0	0.12	5.0	0.6	0.9
5	0 - 20	23.7	7.38	0.5	1	0.13	7.2	19	24	40	17	5.3	0.14	4.0	1.1	0.9
6	20 - 45	27.8	7.18	0.6	1	0.12	7.3	22	25	40	13	4.4	0.11	5.0	1.0	0.9
7	0 - 20	26.8	6.95	0.3	1	0.12	5.5	21	24	39	16	6.2	0.14	2.0	0.7	0.9
8	20 - 45	28.9	7.07	0.3	1	0.12	5.3	24	25	40	11	4.0	0.12	2.0	0.8	0.9
9	0 - 20	23.7	7.44	1.0	2	0.11	7.7	19	26	40	15	5.0	0.18	7.0	4.6	1.3
10	20 - 45	35.1	7.38	0.9	2	0.14	7.4	27	25	33	15	4.4	0.14	6.0	3.6	1.3
11	0 - 20	28.3	7.7	0.78	3	0.34	1.0	26	2	51	21	5.3	0.3	3.0	3.2	1.3
12	20 - 45	25.0	7.8	2.4	6	0.11	0.7	28	2	41	19	7.0	0.3	8.5	2.1	1.3

Table No (2) Physical and Chemical Properties AlKadroo field

Sample	Depth Cm	SP%	pH	Ece ds/m	SAR	O.C %	CaCO3 %	Clay %	Silt %	C.S %	F.C %	CEC Meq/100g	K Meq/L	Ca +Mg Meq/L
1	0 - 20	46.8	8.6	1.3	5	0.3	25.9	35	20	37	8	45.8	1.0	5.4
2	20 - 45	47.0	9.1	1.4	21	0.1	44.1	38	15	30	17	45.3	0.5	0.8
3	0 - 20	33.6	8.7	1.9	30	0.2	23.8	25	22	30	23	33.9	4.8	0.8
4	20 - 45	28.8	8.9	1.5	26	0.5	24.9	32	18	33	17	26.8	4.5	0.6
5	0 - 20	32.8	9.0	1.2	22	0.3	23.9	40	3	33	24	45.8	0.5	0.5
6	20 - 45	41.6	9.0	1.8	56	0.6	28.7	38	3	36	23	31.2	4.0	0.2
7	0 - 20	33.7	9.0	1.2	29	0.5	22.0	30	12	33	25	39.6	0.5	0.3
8	20 - 45	25.6	9.0	1.3	40	0.3	23.9	30	15	33	22	42.7	0.8	0.2
9	0 - 20	32.8	8.8	1.5	43	0.4	25.9	40	8	32	20	42.7	2.5	0.2
10	20 - 45	32.8	8.9	1.5	37	0.4	35.4	30	13	33	24	44.9	0.5	0.3
11	0 - 20	40.5	8.8	1.6	34	0.1	21.1	43	6	32	19	31.2	0.3	0.4
12	20 - 45	42.5	8.7	4.4	68	0.2	22.0	30	10	33	27	29.5	0.3	0.4

Table No (3) Physical and Chemical Properties Soba Field

Sample	Depth Cm	SP%	pH	ECe ds/m	SAR	O.C %	CaCO3 %	Clay%	Silt %	C.S %	F.C %	CEC Meq/100g	Ca +Mg Meq/L
1	0 - 20	30.1	7.3	0.8	18	0.1	8.2	38	13	28	21	35.2	1.5
2	20 - 45	15.2	7.4	0.5	13	0.1	7.9	52	13	22	13	48.4	2.1
3	0 - 20	28.2	7.3	0.5	11	0.6	6.7	40	12	30	18	70	2.3
4	20 - 45	27.2	7.2	6.8	12	0.1	7.6	40	10	32	18	37	15.5
5	0 - 20	36.6	7.5	3.6	7	0.7	8.1	40	20	23	17	42.7	12.8
6	20 - 45	29.5	7.6	5.2	5	0.4	10.2	45	15	23	17	68.2	26.8
7	0 - 20	27.9	7.8	1.2	12	0.1	7.5	40	15	26	19	35.2	2.3
8	20 - 45	35.0	7.5	7.3	9	0.1	9.2	42	15	26	17	72.2	21.5
9	0 - 20	18.3	7.4	4.8	3	0.3	8.1	35	13	28	24	82.3	29.5
10	20 - 45	30.1	7.4	8.1	9	1.0	5.6	38	13	29	20	78.3	19.3
11	0 - 20	35.6	7.4	4.3	5	1.0	7.6	43	15	24	18	44.9	21.3
12	20 - 45	40.4	7.3	5.8	8	1.0	10.2	35	13	29	23	73.9	17.2

Table No (4) Physical and chemical Prosperities Shambat

Sample	Depth Cm	SP%	pH	ECe ds/m	SAR	O.C %	CaCO3 %	Clay%	Silt %	C.S %	F.C %	CEC Meq/100g	Ca +Mg Meq/L
1	0 - 20	61.0	8.2	1.4	37	0.8	6.9	55	38	2	5	61.2	20
2	20 - 45	84.5	8.0	0.9	19	0.1	6.1	65	26	3	6	67.8	12
3	0 - 20	63.1	8.0	1.4	12	0.3	5.2	70	20	4	6	70.4	10
4	20 - 45	69.7	8.0	3.1	17	0.2	5.4	65	27	2	6	68.2	5
5	0 - 20	58.7	8.0	1.5	12	0.3	4.4	58	35	2	5	75.0	7
6	20 - 45	59.3	7.9	0.5	10	0.1	6.9	60	32	3	5	94.2	2
7	0 - 20	73.2	7.7	0.9	7	0.4	6.1	58	35	2	5	79.2	14
8	20 - 45	64.6	7.9	0.5	8	0.2	6.1	65	27	3	5	84.0	13
9	0 - 20	73.3	7.8	1.9	15	0.4	5.0	58	35	2	5	80.0	6
10	20 - 45	78.5	7.8	5.9	24	0.02	6.3	65	27	3	5	79.2	13
11	0 - 20	68.6	8.0	1.5	35	0.5	5.9	53	37	4	6	85.8	2
12	20 - 45	78.5	8.0	1.0	15	0.1	7.7	58	35	2	5	73.5	16

Table No (5) Factors Effecting Soil Aggregate West Omdurman

Sample	Clay Content %	WDC %	CaCO3 %	O.M %	SAR	ESP meq/100g	LS%
1	17	14	7.4	0.12	1	15	18
2	21	14	6.6	0.11	1	17	33
3	19	14	6.8	0.10	1	15	26
4	19	14	6.3	0.13	1	15	26
5	19	14	7.2	0.13	1	16	26
6	22	14	7.3	0.12	1	20	37
7	21	14	5.5	0.12	1	14	33
8	24	14	5.3	0.12	1	23	42
9	19	14	7.7	0.11	3	26	26
10	27	14	7.4	0.14	2	19	49
11	26	14	1.0	0.34	3	25	45
12	28	14	0.7	0.11	6	19	50

Table No (6) Factors Effecting Soil Aggregate AlKadoroo

Sample	Clay Content %	WDC %	CaCO3 %	O.M%	SAR	ESP meq/100g	LS%
1	35	14	25.9	0.3	5	32	60
2	38	14	44.1	0.1	21	53	63
3	25	14	23.8	0.2	30	31	44
4	28	14	24.9	0.5	26	43	49
5	40	14	23.9	0.3	22	21	65
6	38	14	28.7	0.6	56	30	63
7	30	14	22.0	0.5	29	45	53
8	30	14	23.9	0.3	40	39	53
9	40	14	25.9	0.4	43	60	65
10	30	14	35.4	0.4	37	26	53
11	43	14	21.1	0.1	34	21	67
12	30	14	22.0	0.2	68	50	53

Table No (7) Factors Effecting Soil Aggregate Soba Field

Sample	Clay Content %	WDC %	CaCO3 %	O.M%	SAR	ESP meq/100g	LS%
1	38	14	8.2	0.1	14	20	63
2	53	14	7.9	0.1	10	12	73
3	40	14	6.7	0.6	9	6	65
4	40	14	7.6	0.1	60	19	65
5	40	14	8.1	0.7	3	4	65
6	45	14	10.2	0.4	48	4	69
7	40	14	7.5	0.1	20	14	65
8	43	14	9.2	0.1	217	14	67
9	35	14	8.1	0.3	27	5	60
10	38	14	5.6	1.0	73	11	63
11	43	14	7.6	1.0	37	9	67
12	35	14	10.2	1.0	62	13	60

Table No (8) Factors Effecting Soil Aggregate Shambat

Sample	Clay Content %	WDC %	CaCO3 %	O.M%	SAR	ESP meq/100g	LS%
1	55	14	6.9	0.8	37	15	75
2	65	14	6.1	0.1	19	19	78
3	70	14	5.2	0.3	12	9	80
4	65	14	5.4	0.2	17	21	78
5	58	14	4.4	0.3	12	7	76
6	60	14	6.9	0.1	10	7	77
7	58	14	6.1	0.4	7	4	76
8	65	14	6.1	0.2	8	3	78
9	58	14	5.0	0.4	15	11	76
10	65	14	6.3	0.02	24	27	78
11	53	14	5.9	0.5	35	8	73
12	58	14	7.7	0.1	15	24	76

Correlations

Pearson correlation (PC) is a measure of the linear correlation two variables X and Y
West Omdurman

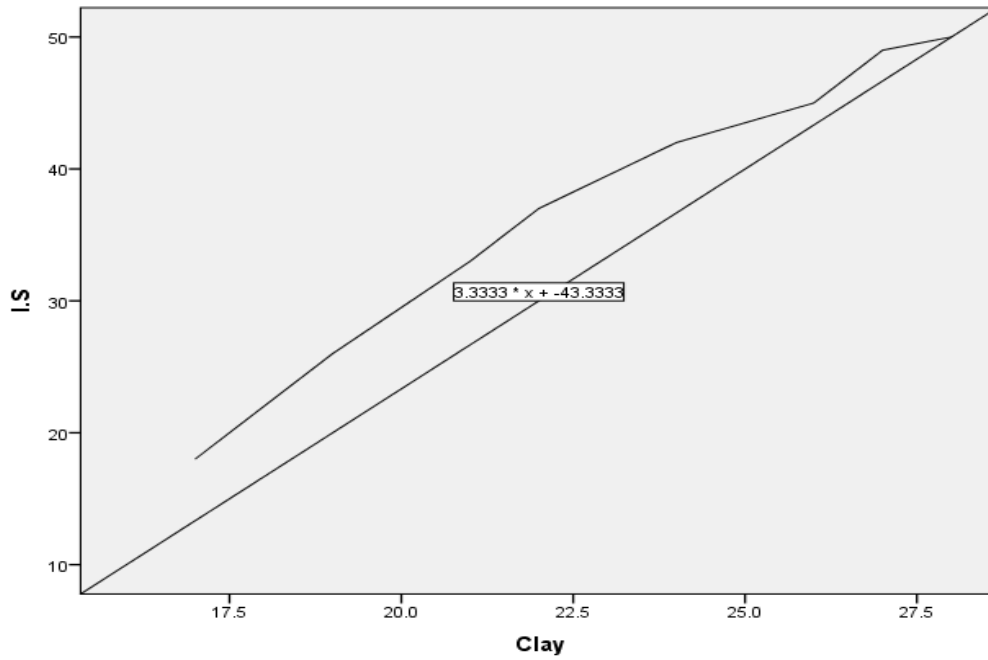


Figure (1) relation between I.S and Clay in west Omdurman.

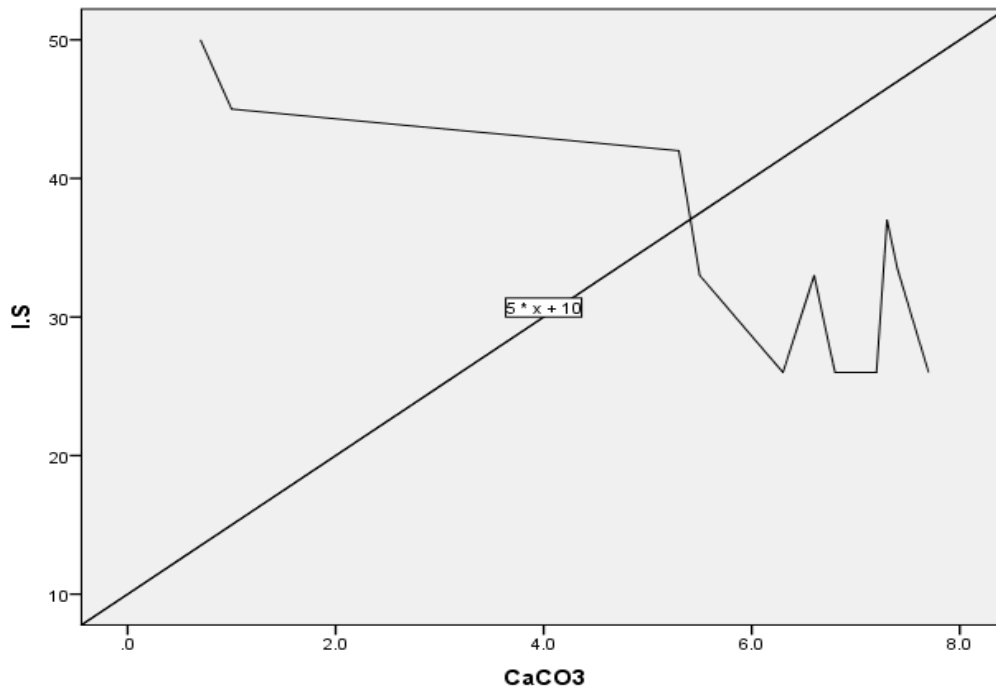


Figure (2) relation between I.S and CaCO₃ in west Omdurman.

Kadaroo

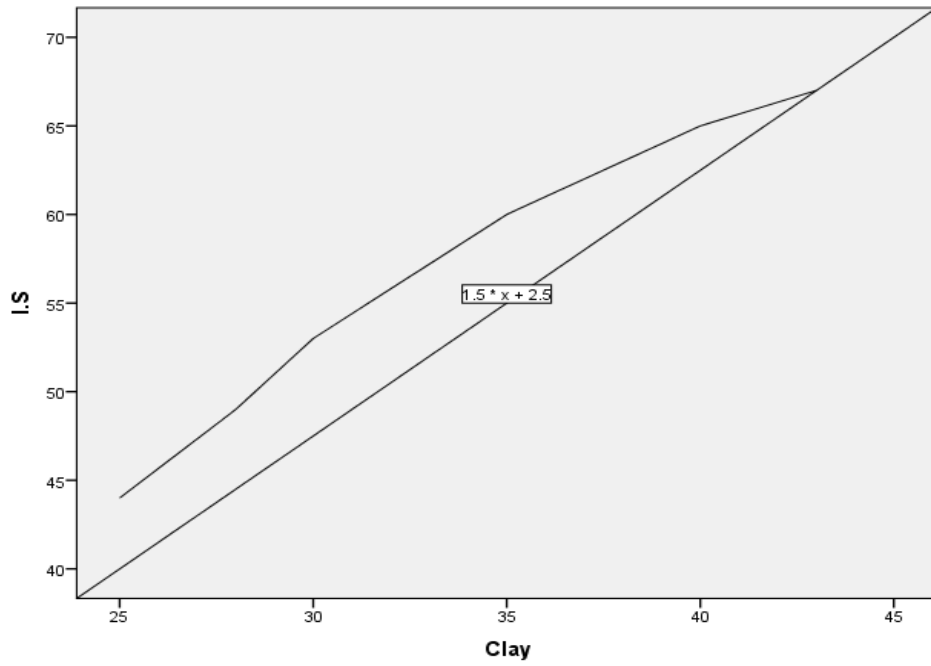


Figure (3) relation between I.S and Clay in Alkadaroo.

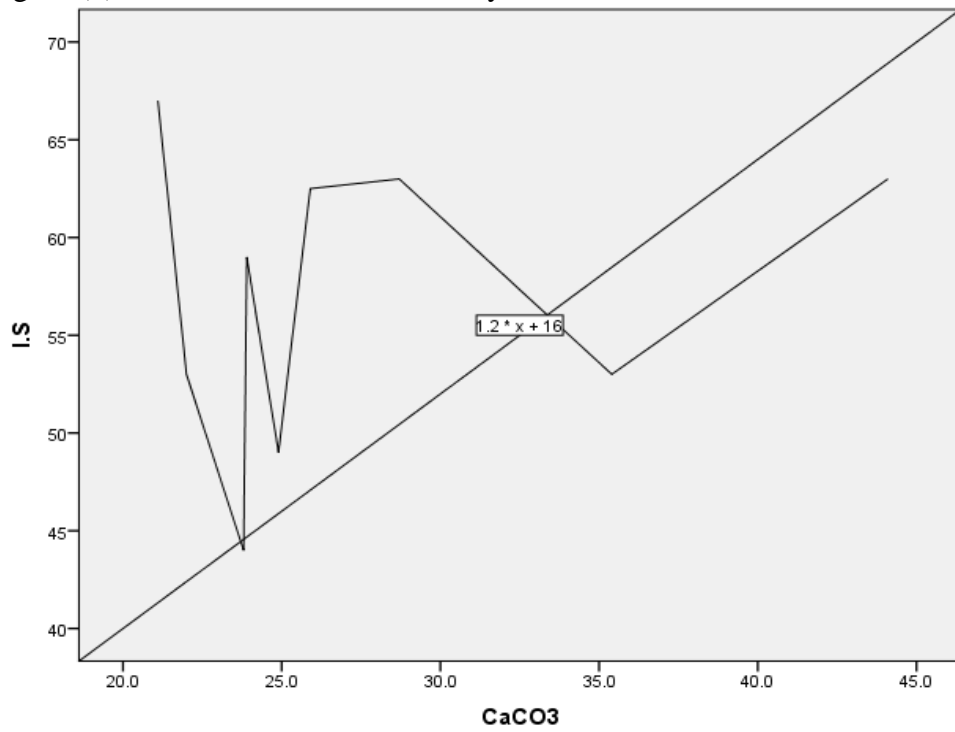


Figure (4) relation between I.S and CaCO₃ in Alkadaroo.

Soba

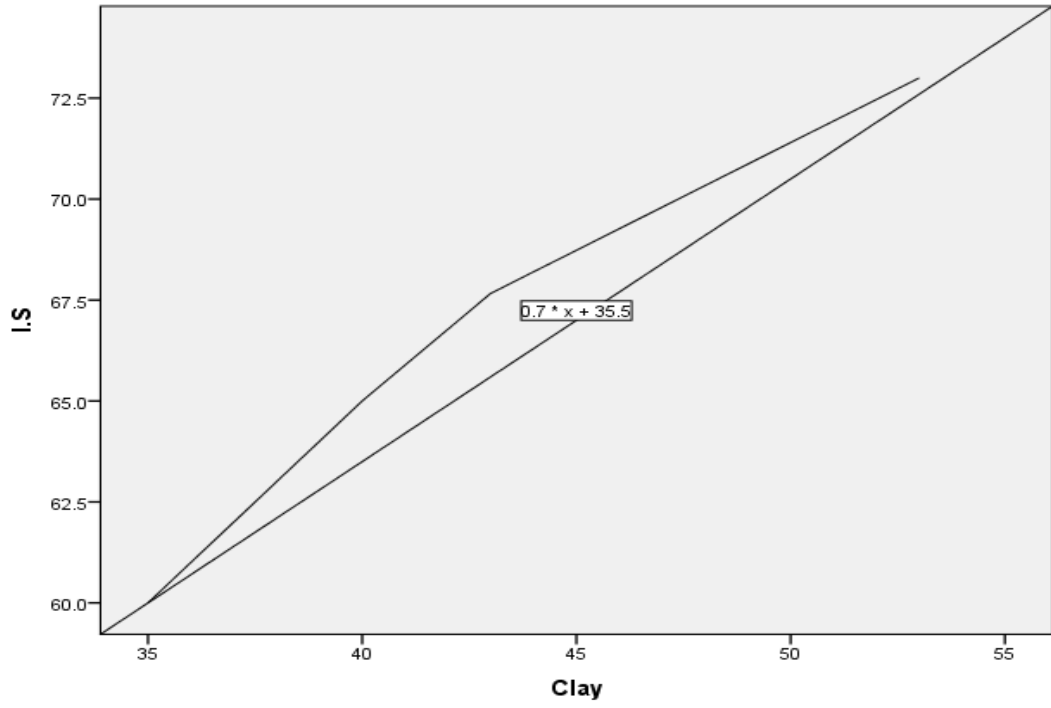


Figure (5) relation between I.S and Clay in Soba.

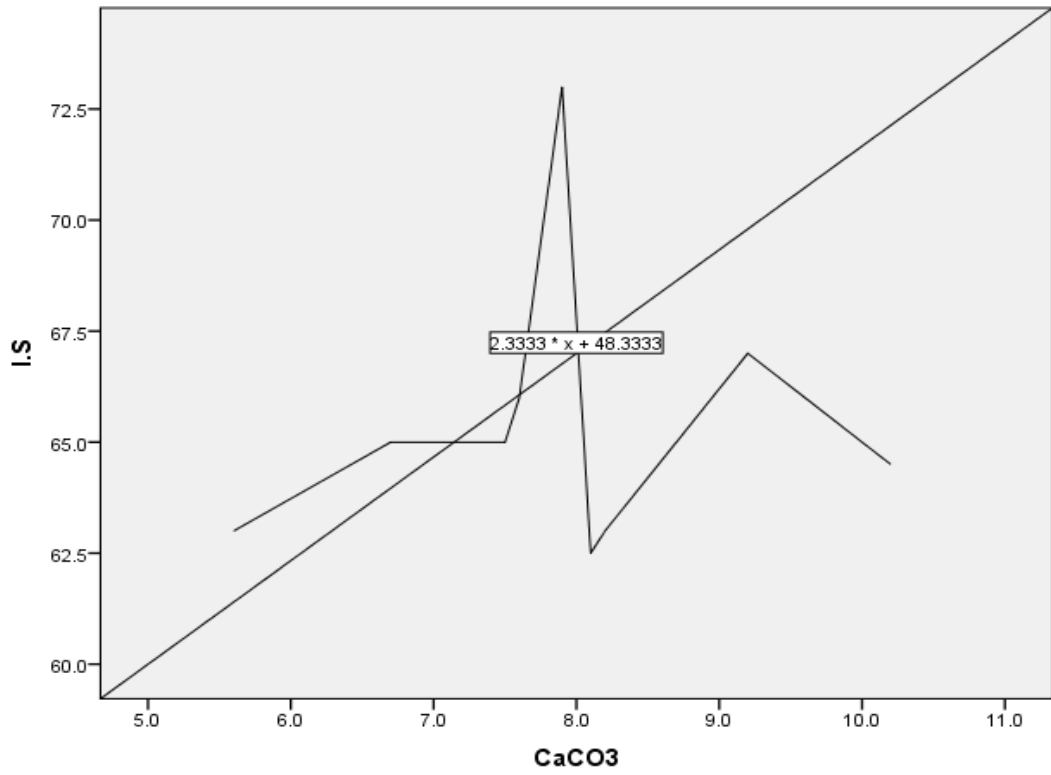


Figure (6) relation between I.S and CaCO₃ in Soba.

Shambat

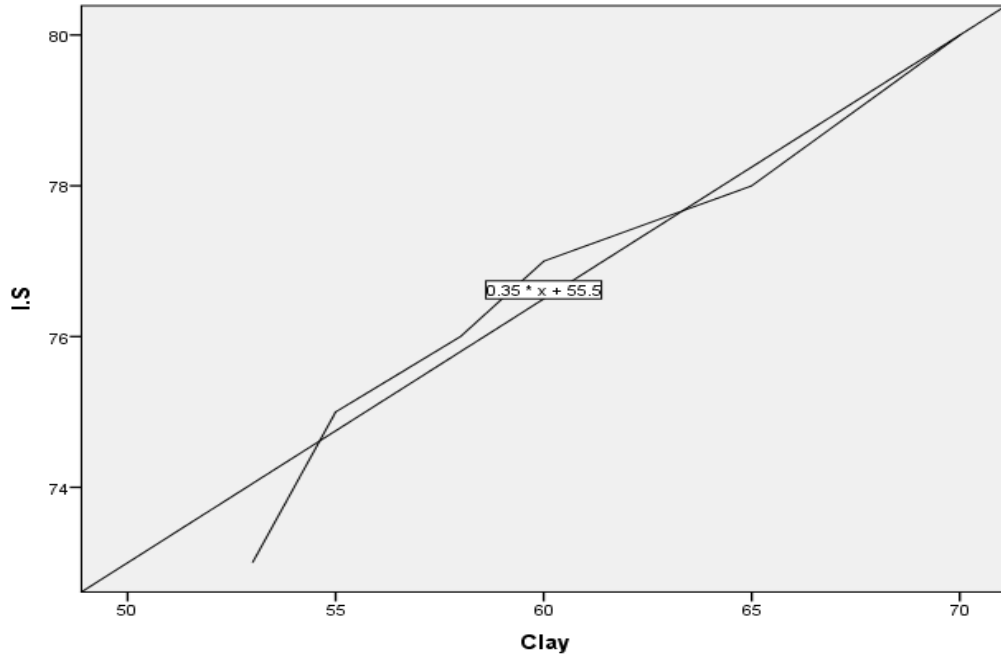


Figure (7) relation between I.S and Clay in Shambat.

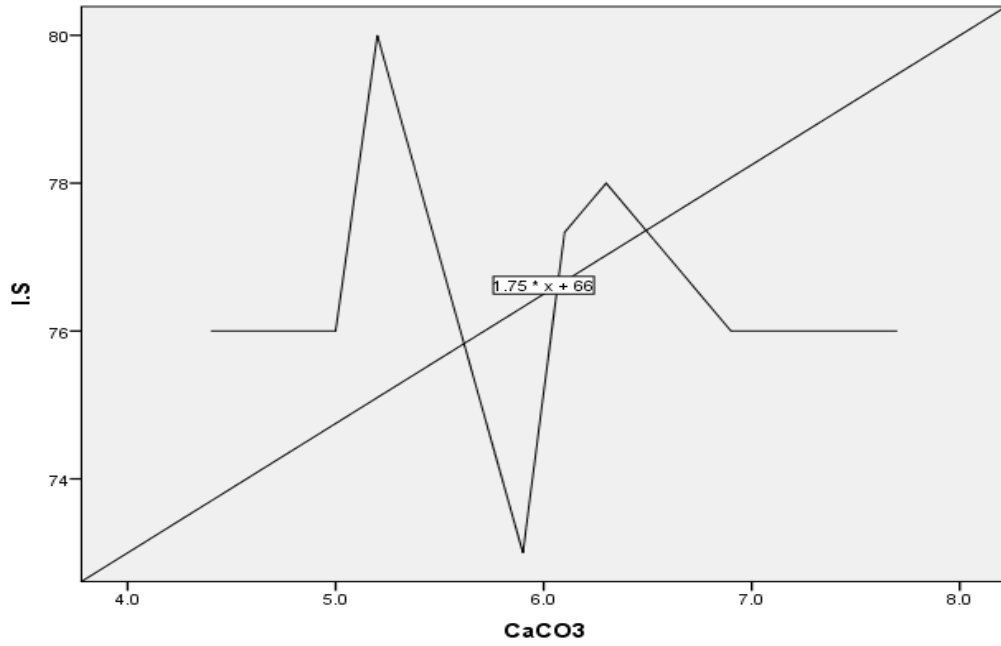


Figure (8) relation between I.S and CaCO₃ in Shambat.

All area

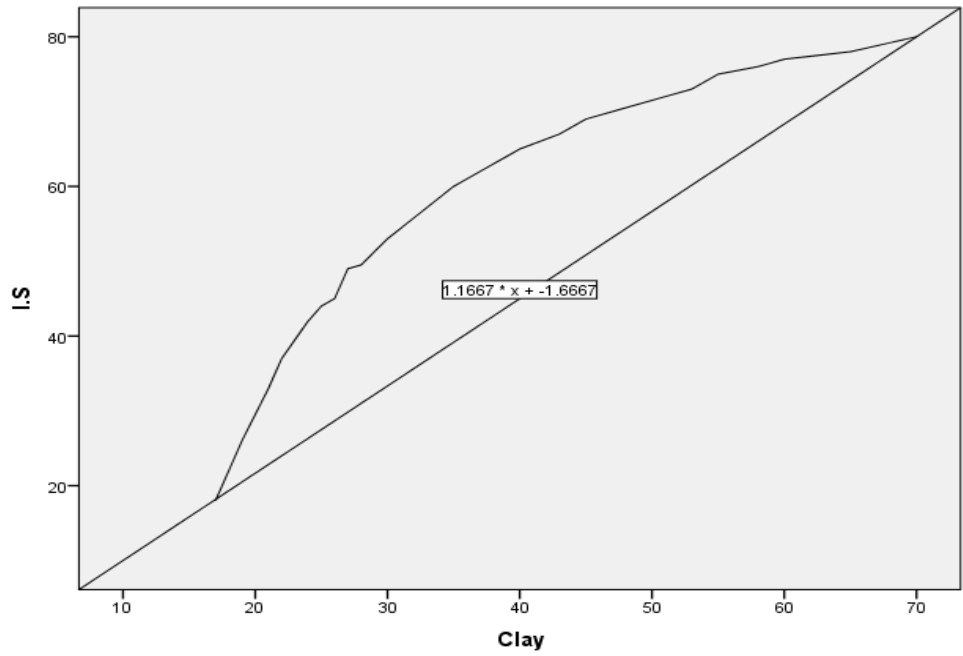


Figure (9) relation between I.S and Clay in all area.

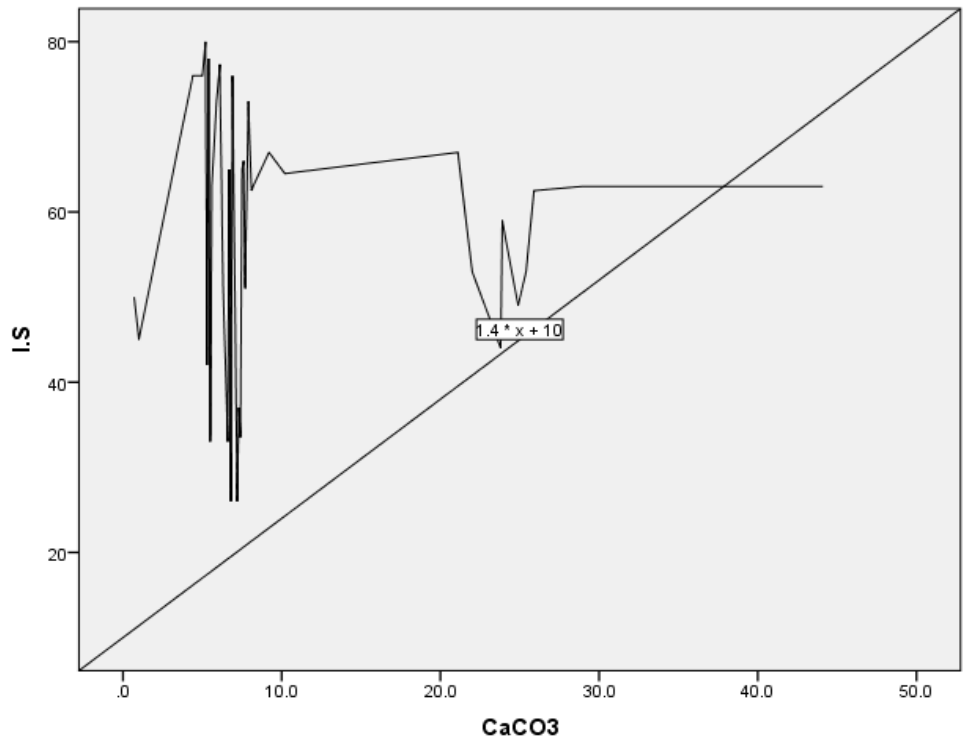


Figure (10) relation between I.S and CaCO₃ in all area.

5.2. Statistical Analysis:

The correlation coefficients are I.S Vs Each of the independent variables (clay and CaCO₃) and for each type.

The analysis of variation has indicated a highly significant (0.01) effect of clay content in soil aggregate. The effect of CaCO₃ is also significant (0.05) as their interaction

The effect of clay content on index of structure is highly significant (p=0.01) in all study area.

The effect index of structure on clay content of all area is highly significant (P=0.01) and effect index of structure of CaCO₃ of all area is not significant. Correlation is significant at the 0.01 level. $R=0.991, Y= 3.3 * X + -43.$ and is significant at the 0.05 level. $R=0.631, Y= 5 * X + 10$ at west Omdurman. Correlation is significant at the 0.01 level. $R=0.990, Y=1.5 * X + 2.5.$ and is not significant at level . $R=0.175, Y= 1.2 * X + 16$ at Alkadroo.

Correlation is significant at the 0.01 level. $R=0.970, Y= 0.7 * X + 35.5.$ and is not significant. $R=0.045, Y= 2.3 * X + 45.3$ at Soba.

Correlation is significant at the 0.01 level. $R=0.975, Y= 0.35 * X + 55.5.$ and is not significant . $R=0.170, Y= 1.75 * X + 66$ at Sambat.

Correlation is significant at the 0.01 level. $R=0.928, Y=1.17 * X + -1.7.$ and is not significant. $R=0.007, Y=1.4 * X + 10$ at all area.

5.3. Discussion:

The description of 48 sample of soil taken by auger from four different areas, they all meet the requirements of classification as vertisols and Entisols (USDA-NRCS).

The analysis done was physical and chemical analysis, but we are concentrating in two important factors that mostly affect soil aggregation; Clay Content and Calcium Carbonate.

Clay content in soil improved the aggregation. The three locations selected for this study are rich in clay content (Kadaro (25-43%), Soba (35-53%), and Shambat (53-70%)).

Two of these sites (AlKadaroo and Soba) are strongly calcareous, with CaCO_3 content of about (21-44.1, 5.6-10.2%), hence they develop more aggregate than other site in west Omdurman on Shambat.

Aggregation was most effective in the clay-rich soils. Soils with large organic amendments exhibited improved aggregation were most effective in the clay- rich soils.

Chapter Six

CONCLOSSION AND RECOMMENDATION

6.1. Conclusions:

This study was undertaken to determine the effect of clay content, CaCO_3 and ESP upon the structure of some Vertisols and Entisols in Khartoum state. Soil structure is referred to as the Index of Structure. Result of the statistical analysis revealed the following points.

1. Clay content was the most important single factor in relation to aggregation (R) it accounts for 0.861%; or it 86% (R^2) of the variation in Index of Structure (I.S).
2. CaCO_3 content has exhibited non significant effect and due to its association with sodicity Exchangeable Sodium Percent (ESP) has shown a negative effect is (0.00).

Sandy soils have low aggregation because of the high amounts of sand and the lack of binding agents. Shambat have higher clay content and thus better aggregation than west Omdurman. Alkadaro and soba have the most favorable structure. These soils have the most valuable aggregates due to the presence of numerous cementing agents. AlKadaro, Soba and Shambat contain more large aggregates (clods) because of their high clay content.

6.2. Recommendation:

I recommend that:

- Addition of Organic Matter and Clay to improve soil aggregate and physical properties of sand soil.
- Soil has calcium carbonate content more aggregate, the addition of Gypsum can improve the properties of this soil.
- Selection of crops that suit the condition of the soil.
- Irrigation with water has high content of Calcium to improve soil Physical Properties.
- Management of the soil at optimum moisture content.
- Some Crops has ability to increase soil aggregate such as Alfalfa

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Contact us: Prof. **Steven Banwart,** SoilTrEC Project Coordinator, and University of Sheffield. Email: s.a.banwart@sheffield.ac.uk

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