Sudan University of Sciences and Technology

College of Graduate Studies

Soil Characterization and Land Suitability Assessment Study for Farming Area at Al- Khojalab- Khartoum State

توصيف التربة و دراسة تقويم صلاحية الأراضي لمزرعة الخوجلاب. ولاية الخرطوم

dissertation Submitted to the Sudan University of Science and Technology in partial Fulfillment of the Requirements of the Degree of Master of science.

By

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الآية

قال تعالى:

(الَّذِي جَعَلَ لَكُمُ الْأَرْضَ فِرَاشًا وَالسَّمَاءَ بِنَاءً وَأَنْزَلَ مِنَ السَّمَاءِ مَاءً فَأَخْرَجَ بِهِ مِنَ الثَّمَرَاتِ رِزْقًا لَكُمْ فَلَا تَجْعَلُوا لِلَّهِ أَنْدَادًا وَأَنْتُمْ تَعْلَمُونَ)

صدق الله العظيم

سورة البقرة الآية (22)

Dedication

This work is dedicated to:

To the soul of my mother,

Father, husband andSun

brothers and sisters,

Teachers and colleagues

To my friends And the people I love…

Acknowledgements

Praise is to Allah who gave me the health strength and patience to complete this study.

This study would not have been possible without moral, academic and moral support rendered available from various institutions, individuals and friends.

I wish to express my sincere thanks to all who directly or indirectly contributed to the completion of this study.

First and for most, my deepest gratitude and appreciation are due to my supervisor **Dr. El-Abbas Doka Mohamed Ali** for his invaluable efforts exerted by way of advice, guidance and encouragement.

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I would never forget all the chats and beautiful moments I shared with my friends and classmates. They were fundamental in supporting me during these stressful and difficult moments.

Finally, my deepest gratitude goes to my family for their unflagging love and unconditional support throughout my life and my studies. They have made me life the most unique, magic and carefree childhood that have made me who I am now!

Special thanks warmly go to my father and my husband for supporting and helping me in this study.

List of Contents

List of Tables

List of Figures

Abstract

This study was conducted on a farm located in the state of Khartoum, in the northern side of Bahri town in Al- khojalab area, the total area of the farm about 72 feddan, and the study was conducted to evaluate the farm lands and determine suitability for agricultural use and crop production and estimate physical, chemical and biological soil properties. The description of soil samples were collected from the field and Auger and profile. The results of physical and chemical routine analysis of soil samples were getting in the College of Agricultural Studies - University of Sudan for Science and Technology laboratories.

Was identified two types of soils are: clayey loam soil and clay soil (which is the most prevalent in the study area). Soils that have been identified in the study area were described as saline and sodic soils, therefore the farm has been divided into two units: Section (1): contains amount of salinity and sodicity, Section (2): contains a high amount of salinity and sodicity and high percentage of clay, which was lead to low permeability. The land suitability was classified as Class II (S_{2sn}) for the first section, and Class III (S_{3snp}) for the second section.

The study recommended with land use planning in the farm based on the differences in soil units, Add sufficient amounts of organic matter (depending on the plant needed) to improve soil physical properties and chemical to ensure high crop productivity, grow the resistant plant to salinity (such as feed), apply the modern technology packages, follow the agricultural management and put in consideration the saline and sodic; the irrigation system and avoid using heavy machine. When planting trees in a pit; prefer using non-saline soils and finally, follow the crop rotation to reduce the strain of soil.

المستخلص

أجريت هذه الدراسة فى مزرعة تقع بولاية الخرطوم، في الجانب الشمالي لمحلية بحري بمنطقة الخوجلاب ، وتبلغ المساحة الكلية للمزرعة حوالى 72 فدان. وأجريت الدراسة لتقييم أراضى المزرعة وتحديد صلاحيتها للإستخدام الزراعي لإنتاج المحاصيل وتحليل الخواص الفيزيائية والكيميائية والحيوية للتربة . تم وصف التربة فى الحقل وجمعت عينات من الحفر والبريمة, تم التحليل الفيزيائي والكيميائي الروتيني فى معامل كلية الدراسات الزراعية – جامعة السودان.

حيث تم التعرف على نوعين من الترب هي: التربة الطينية اللومية والتربة الطينية وهي الأكثر إنتشاراً في منطقة الدراسة . الترب التي تم التعرف عليها في منطقة الدراسة توصف جميعها بأنها ملحيه وصودية ، وبناءاً على ذلك قسمت المزرعة إلى وحدتين : الوحدة الأولى بها نسبة ملوحة وصودية ، والوحدة الثانية بها نسبة عالية من الملوحة بالإضافة للصودية وارتفاع نسبة الطين مما أدى إلى انخفاض نفاذيتها. وتم تقييم درجة الصلاحيةمن الدرجة الثانية (S_{2sn}) ومن الدرجة الثالثة (S_{3snp}).

أوصت الدراسة بتخطيط استخدام الأراضي على مستوى المزرعة بناءا على اختلافات وحدات التربة داخل المزرعة ,إضافةكميات كافية من المادة العضوية (حسب حاجة النبات) لتحسين خواص التربة الفيزيائية والكيميائية لضمان إنتاجية عالية ، وزراعة محاصيل مقاومة للملوحة (مثل الأعلاف) ، تطبيق الحزم التقنية الحديثة، إتباع إدارة فلاحية والوضع في الاعتبار الملوحة والصودية مع مراعاة نظام الري وعدم إستخدام الآليات الثقيلة . وعند زراعة الأشجار يفضل عمل حفر تحتوي على ترب غير مالحة وأخيرا استخدام الدورة الزراعية للحد من إجهاد التربة.

CHAPTER ONE

INTRODUCTION

1.1 Background:

The sound planning of changes in land use requires a thorough knowledge of the natural resources, and a reliable estimate of what they are capable of producing, so that reliable predictions and recommendations can be made. In addition to production potential, the conservation of soil and water resources for use by future generations requires consideration in planning land development. Undoubtedly, a proper land management decreases soil erosion and increases agricultural yield. Land evaluation is an important step in the process of land use planning where the resources are limited. Land use programming for optimum use causes the maximum profitability so that, the land will be protected for the future land users. In this frame of programming, the land is evaluated and their suitability for the possible uses will be specified. Hence, the land base on their characteristics will be determined to the most profitable use. Sustainable agriculture comes true, provided that the land based on their suitability will be classified and utilized for different uses types (FAO, 1983). Quality assessment of land suitability is to estimate land use for specific uses without taking into consideration of yield and social-economic factors (FAO, 1976, 1983).

To know the land production capacity and to allocate the land to the best and to the most profitable use should be considered. Global concerns about food security, the quality of life for future generations and the growing awareness about environment degradation are posing penetrating questions to the world of sciences (De Bie, Van Lanen, andZuidema, 1996). Therefore, availability of proper land use information is required at various scales of planning. Agriculture is one of the world’s most important activities supporting human life. On a global scale, agriculture has the proven potential to increase food supplies faster than the growth of the population, a pattern to be expected in the foreseeable future (Davidson, 1992). Projections for the year 2000 and beyond suggest that, due to population increase and income growth, demand for food and other agricultural products will continue to rise by over 3% annually.

The work embodied in this thesis was carried out to study the soils of a private farm at Alkhojalab area.The farm area is situated on old alluvium deposits of the third terrace of the River Nile and makes about 72feddans. The study was set to characterize the soils and assess their suitability for some selected present and potential land uses. As well, the study will recommend on proper management practices to ensure proper and sustainable use of the land.

1.2 Problem definition:

Clearly, no systematic land suitability assessment and land use planning has been carried out in the area so far. A systematic inventory and analysis of present land resource and land use patterns is therefore required to be followed by a sound land suitability evaluation and land use planning.

Soil physical conditions, salinity and sodicity problems are among the major factors which limit crop production. They are primarily appearing in heavy soils associated with arid and semi-arid regions where climatic conditions are characterized by insufficient rain to leach soluble salts besides the prevailing high temperatures. Such harsh climates prevail in the northern and some central states of Sudan, where Khartoum state is one of them. Khartoum state lies in the tropical arid climatic zone which lead to the formation of saline and/or sodic soils especially on the high old terraces characterized by heavy textured soils (Nachtergaele, 1976).

The review of the limited research conducted in salt affected soils at Shambat and Soba research stations showed the beneficial effects of land preparation, irrigation frequency and organic amendments on management and production of forage Sorghum and Lucerne in salt affected soils (Karouri,1977; Mahagoub1979;Karouri*et al*.,1980; EL Amin 1980; Mustafa and A/ Magid 1982; Sokrab 1983; Gabir,1984; Dahab, and Mohamed,(2005); and Mustafa, 2007).

1.3 Hypotheses:

If the present land use is well matched with the determined soil properties and land suitability classes, it wouldindicate that there is no pressure on the land,if it is properly used. Accordingly, limitingfactors crop growth to the study area should be identified and proper management practices should be recommended. Consequently matching to rowaremmed of Land utilization types with land units characteristics and qualitiesare conformed in order to determine land suitability classes for kinds of land utilization type.

This research is directed to investigate the introduction of integrated management methods which could be recommended for the proper utilization of land use and increase crops production in this area.

1.4 Research Objectives:

1. Describe and characterize the major soil types occurring in the study area and map their distribution in the farm land.
2. Determine the physical, chemical and biological properties of the soil types in the farm.
3. Evaluate the suitability of the farm land for some selected cropping systems mostly adapted in Alkhojalab area and the response of the different soil types to management practices.
4. Advice on the proper management practices to be recommended for the local farmers to ensure high productivity and sustainable use of the land.

CHAPTER TWO

STUDY AREA

2.1. Environmental set up of the Area:

2.1.1. Location and extent:

The survey area lies north of Khartoum North within Khartoum State (Figure 2.1). Agriculture is the main occupation of the inhabitants around the study area which is part of alkhojalab Agricultural Cooperative Societythat was established in1951. The total size of the land area owned by the society is 1400 feddans and it includes 216 members from local farmers. The main activity of the society is confined tofarming of field crops which include cultivation of mainly fodder crops (alfalfa and maize).The cultivation includesminor cropping of vegetables in addition to wheat and broad beans.

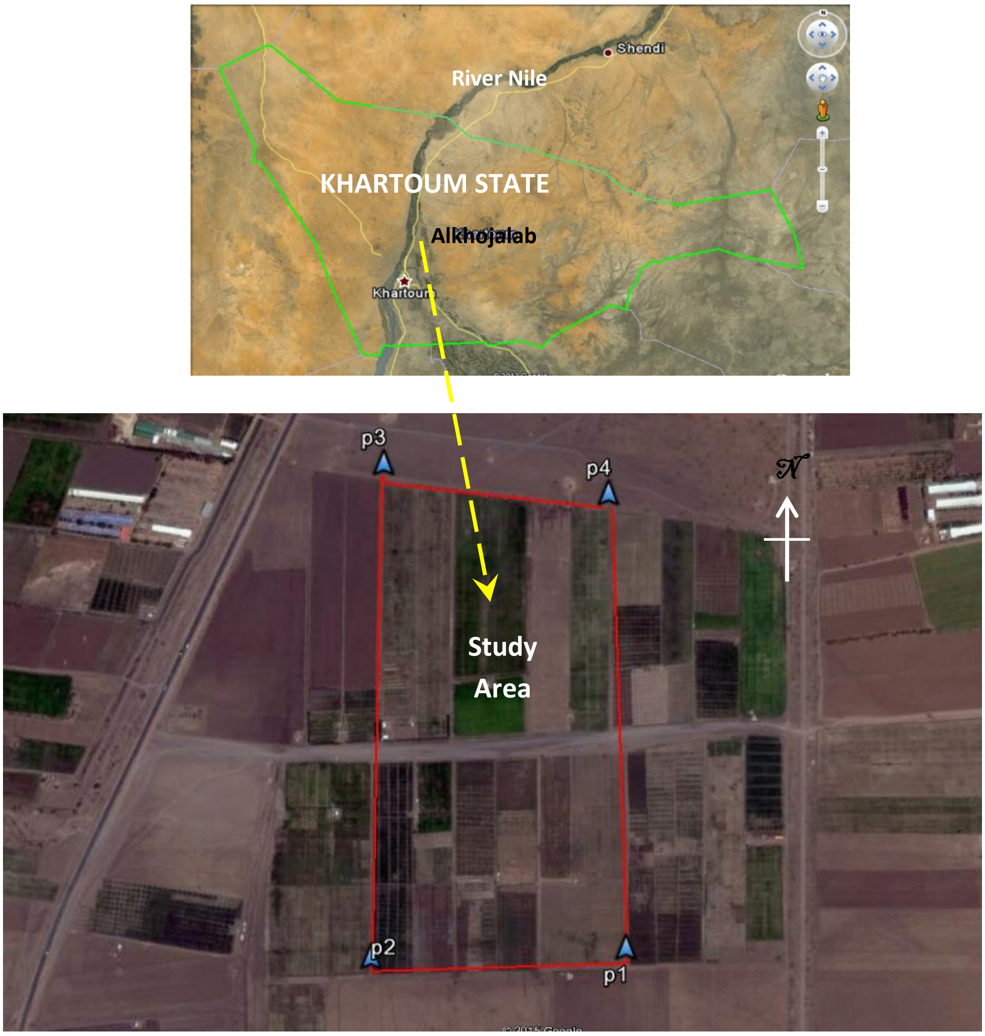


Figure 2.1: Showing the location of the area under study

2.1.2. Climate:

The Khartoum temperature regime in Papadakis classification falls within the semi-desert climate zone with summer rains, warm winter. The climate is hot almost throughout the year, except the cooler short winter season (December, January).Mean annual temperature is 28°C. Average maximum temperature in the hottest months (April– June) range from 40°C to 42°C, while the minimum temperature in that period are between 21°C and 26°C. During winter (December – January) the minimum temperature reaches 13°C. Relative humidity shows some variations with GMT during the year. At 06 00 GMT it ranges from 30 – 40 % during January – February; decreases to 20 – 27 % in March – June and increases 30 – 40 % from July to December table (2.1).

Table 2.1: Khartoum ClimatologicalNormals for the Years 1991 – 2001

Month	Mean relative Humidity	Total rainfall (mm)	Potential Evapo-ration (mm)	Mean Wind speed	Mean daily maxi-mum	Mean daily mini-mum	Mean daily Temperature(c)	Bright sunshine duration (%)
January	26	00	143	4.5-N	30.7	15.6	23.2	86
February	21	00	147	4.9-N	32.6	16.8	24.7	85
March	16	01	196	4.5-N	28.4	20.3	28.4	82
April	17	01	165	4.9-N	40.4	24.1	32.7	84
May	15	00	198	4.9-N	37.0	27.3	34.6	74
June	20	39	198	4.5-SW	41	27.6	34.4	68
July	26	43	205	4.5-SW	41.3	26.2	32.3	63
August	42	29	202	4.5-SW	38.5	25.6	31.6	66
September	48	48	189	4.5-SW	39.3	26.3	32.5	71
October	41	29	177	4.5N	35.7	25.9	32.6	83
November	29	78	162	3.4-N	31.7	21.0	28.1	91
December	29	01	140	4.5-N	31	17.0	24.4	90
Year	18	121.1	2065	4.9-N	40.4	22.8	29.9	**79**

(Doka M. Ali. El-Abbas 2003, Soil Survey of WadiALmogadam)

2.1.3 Geology:

The solid geology of the area is composed of ancient formations of cretaceous age, outcropping on the western bank of the Nile, with a regional easterly dip of 0-5 with common high local dips. In Lithological terms, this formation, which is given the name of Nubian series, is mostly sandstones and mudstones. Ferruginous sandstones are also present. From a structural point of view, the area is considered to be a gently dipping monocline with an easterly dip. There might be some local variations. The Nubian series components of sandstones, mudstone and ferruginous sandstone are interbedded. The beds, however, are not uniform, and they are discontinuous, usually fading into each other in an interdigitating manner. The solid geology of this area is covered by recent deposits composed of Nile silts and sands. The silts are formed as relatively thick continuous formation, consequently giving wide flood plain. The expanses of superficial deposits occurring on an elevated position to the east of this area and a bit far from the river, has been classified as Gezira clay. This

Gezira clay together with the recent deposits have been investigated by the geological survey during the thinking of wells and boreholes. Although there is a considerableFig (2.2)

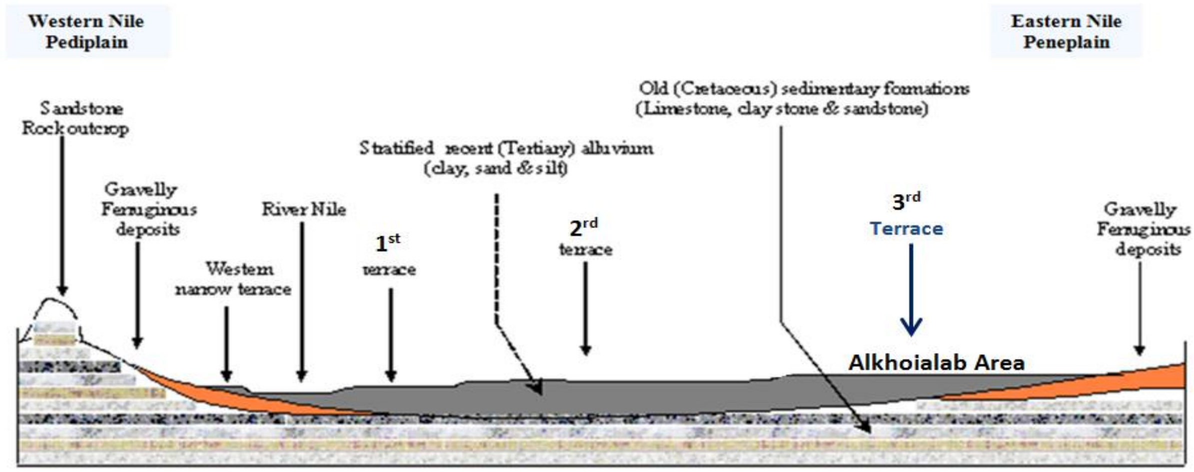


Figure 2.2: Schematic diagram showing different depositional formation along east-west transect across Alkojalab area

2.1.4 Topography:

From a topographical point of view, most of the area under study is field. The land is being made more flat by the practice of leveling, before sowing of seeds, usually carried out in these fields. Variations in level were found to be very small.

2.1.5Natural Vegetation and Land Use:

i. Natural Vegetation

Over a hundred of naturally occurring plant species have been identified at Alkhojalab locality. As this area is continuously under cultivation, the natural vegetation cover is disturbed. Dense populations of plants growing naturally are only located in the idle land along the canals and in the very small areas that have not been brought under cultivation for many years. It is here that the tree species are concentrated as the following: Acacia seyal (Talh), Acacia melifera (Kitir), Acacia albida (Haraz), Prosopischilensis (Haraz),Ziziphusspina-christi (Nabag), Balanitesaegyptiaca (Laloub).

ii. Land Use:

There are three cropping seasons in this area during which the land is used for growing the following crops:

Winter season (shetwi) November – February

The most active season, arable crops include wheat, broad beans, onions and vegetables include tomatoes, eggplant, potatoes, and carrots, beans, in addition to spices (chillies, garlic, kasbara and kamoun).

Flood season (Damera) July – September

Arable crops include sorghum, maize, fodders and summer vegetables.

Summer season (sayfi) March – June

Fodder crops.

CHAPTER THREE

LITERATURE REVIEW

3.1 The Soil as a basis for Crop Production

Soil is the medium which supports the growth of plants. It provides mechanical support, the water and oxygen supply to plant roots as well as the plant nutrients .Soil fertility is the capacity of soil to supply plant nutrients, water and oxygen in adequate amounts for optimum growth of the plant. The term soil fertility includes the chemical make-up and availability of nutrient elements to plants, the physical arrangements and properties of the soil particles and organic matter, which control water and oxygen availability, and the nature and activity of soil microorganisms. The fertility of a soil is an important factor determining fertilizer requirements as well as the level of crop production that can be obtained mineral matter, air, water and organic matter are the main constituents of soil. The size of the mineral particles varies from coarse materials, such as stones, gravel and coarse sand to very fine particles of silt and clay. The organic matter is formed by the decay of plant and animal residues. The air and water occupy the empty spaces in the soil. For proper crop growth the soil must be in a good physical, chemical and biological condition, the main requirements for which are described in the following sections (FAO,1995).

3.2 Soil Physical and Chemical Properties

Physical properties are those that can be observed without changing the identity of the substance. The general properties of matter such as color, density, hardness, are examples of physical properties. Properties that describe how a substance changes into a completely different substance are called chemical properties. Flammability and corrosion/oxidation resistance are examples of chemical properties.

The difference between a physical and chemical property is straightforward until the phase of the material is considered. When a material changes from a solid to a liquid to a vapor it seems like them become a difference substance. However, when a material melts, solidifies, vaporizes, condenses or sublimes, only the state of the substance changes. Consider ice, liquid water, and water vapor, they are all simply H_2O. Phase is a physical property of matter and matter can exist in four phases – solid, liquid, gas and plasma.

3.2.1 Soil Physical Properties

3.2.1.1 Soil texture: Soil texture refers to the proportion in which different sized mineral particles (2.0 mm and below in diameter) are present in the soil. The soil particles are generally divided into three basic textural classes (as per USDA) known as sand (2 to 0.05 mm in diameter), silt (0.05 to 0.002 mm) and clay (less than 0.002 mm). Soils are classified on the basis of the relative proportion of these particle sizes into texture groups such as sand, sandy loam, clay loam, clay, etc.

Soil physical properties such as ease of cultivation, nutrient and moisture holding capacity, aeration, drainage and to some extent suitability for cultivation, are much influenced by soil texture. Sandy soils provide good aeration and drainage and are generally loose and friable, and their cultivation is therefore easy. Soils with high clay content, having internal surface areas, have high absorptive capacity and retain nutrients and moisture well. Clayey soils generally have fine pores, are poorly drained and aerated and tillage operations are relatively difficult. Silty soils are intermediate between sandy and clayey soils and are suitable for most crops.

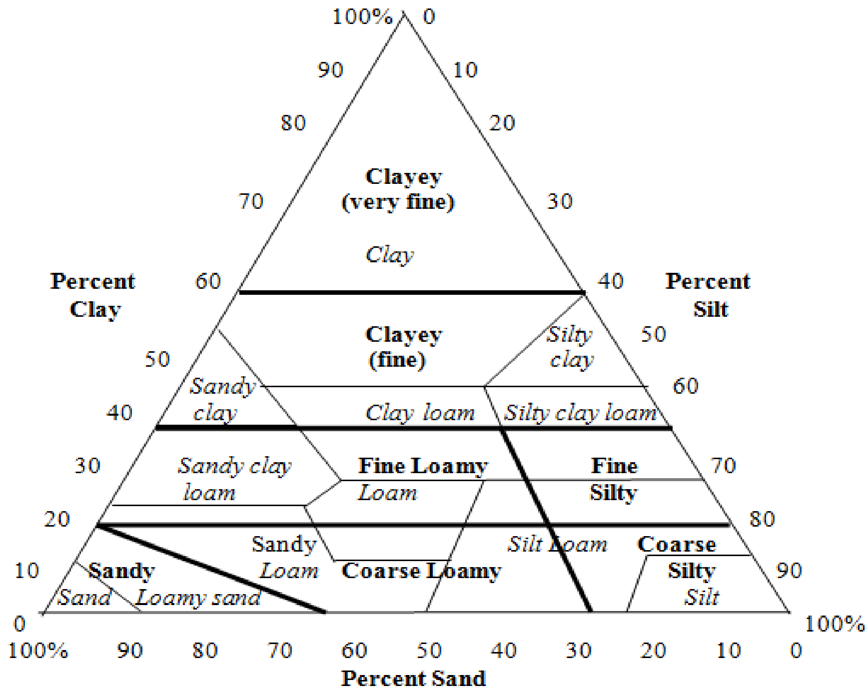


Figure 3.1:Texture in different soil textural classes and groupings (1995).

The mineral components of soil consist of a mixture of sand, silt and clay. In the illustrated textural classification triangle (Fig 3.1) the only soil that does not exhibit one of those predominately is called "loam." While even pure sand, silt or clay may be considered a soil, from the perspective of food production a loam soil with a small amount of organic material is considered ideal. The mineral constituents of a loam soil might be 40% sand, 40% silt and the balance 20% clay by weight. Soil texture affects soil behavior, including the retention capacity for nutrients and water.

Sand and silt are the products of physical weathering, while clay is the product of chemical weathering. Silt is finely powdered parent material. Clay on the other hand is a product of chemical weathering and forms as a secondary mineral from dissolved minerals that precipitate out of solution. It is the specific surface area of soil particles and unbalanced ionic charges in the soil particle that determine their role in the cation exchange potential of soil hence its fertility. Sand is least active followed by silt; clay is the most active. Sand has its greatest benefit to soil by resisting compaction. Silt, with its higher specific surface area, is more chemically active than sand and the clay content, with its very high specific surface area and generally large number of negative charges, gives clay its great retention capacity for nutrients and water. Clay soils resist wind and water erosion better than silty and sandy soils, as the particles are bonded to each other.

Sand is the most stable of the mineral components of soil; it consists of rock fragments, primarily quartz particles, ranging in size from 2.0 mm to 0.05 mm. Sand is largely inert but plays an important part in holding open soil. Silt ranges in size from 0.05 mm to 0.002 mm. Silt is mineralogically like sand but is more active than sand due to its larger surface area. Clay is the most important component of mineral soil due to its net negative charge and ability to hold cations. Clay cannot be resolved by optical microscopes; it ranges in size from 0.002 mm or less. In medium-textured soils, clay is often washed downward through the soil profile and accumulates in the subsoil. Components larger than 2.0 mm are classed as rock and gravel and are removed before determining the percentages of the remaining components and the texture class of the soil but are included in the name. For example, a sandy loam soil with 20% gravel would be called gravely sandy loam. When the organic component of a soil is substantial, the soil is called organic soil rather than mineral soil. The limits are as follows:

1. Mineral fraction is 0% clay and organic matter is 20% or more.
2. Mineral fraction is 0% to 50% clay and organic matter is between 20 - 30%.
3. Mineral fraction is 50% or more clay and organic matter 30% or more.

3.2.1.2 Soil structure:

Soil particles (sand, silt and clay) usually remain grouped together in the form of aggregates. The aggregation of soil particles in a definite pattern is known as soil structure. It can be best studied in the field under natural conditions.

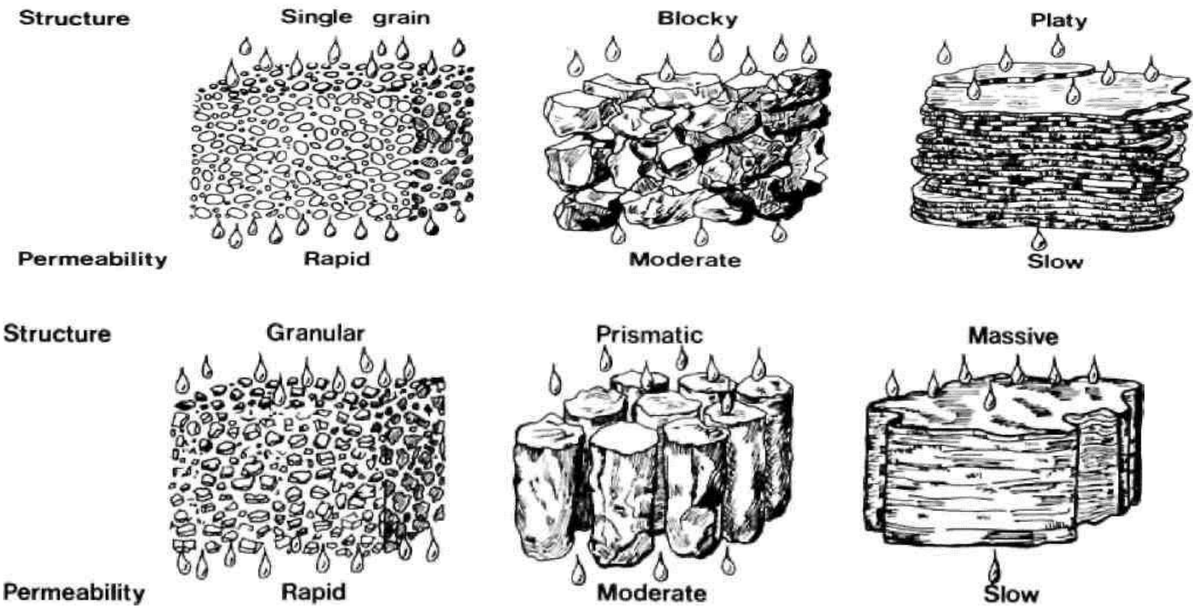


Figure 3.2: Types of soil structure and permeability

The types of structure (Fig 3.2) are determined by the size, shape and build up of soil aggregates. Granular structure having rounded porous particles is considered to be the best for crop growth. Soils with a granular structure usually have satisfactory porosity, moisture retention capacity, aeration and drainage characteristics and are said to have a good tilth. Tilth is promoted by timely tillage operations and by the maintenance of an adequate soil organic matter content, e.g., by application of organic manures (FAO,1995).

The soil structure affects aeration, water movement, resistance to erosion and plant root growth. Soil structure often gives clues to texture, organic matter content, biological activity, past soil evolution, human use, and chemical and mineralogical conditions under which the soil formed. While texture, defined by the mineral component of a soil, is an innate property of the soil and does not change with agricultural activities, soil structure can be improved or destroyed by our choice and timing of farming practices, (Soil Survey Division Staff 1993).

3.2.1.3 Soil Density

Density is the weight per unit volume of an object. Particle density is the density of the mineral particles that make up a soil i.e. excluding pore space and organic material. Particle density averages approximately 2.65 g/cc (165lbm/ft^3). Soil bulk density,is a dry weight, includes air space and organic materials of the soil volume. A high bulk density indicates either compaction of the soil or high sand content. The bulk density of cultivated loam is about 1.1 to1.4 g/cc (for comparison water is 1.0 g/cc). A lower bulk density by itself does not indicate suitability for plant growth due to the influence of soil texture and structure(Tables 3.1, and Table 3.2)(Soil Survey Division Staff 1993).

Table 3.1: Representative bulk densities of some treated soils.

Soil treatment and identification	**Bulk density g/cc**	**Pore space %**
Tilled surface soil of a cotton field	1.3	51
Trafficked inter-rows where wheels passed surface	1.67	37
Traffic pan at 25 cm deep	1.7	36
Undisturbed soil below traffic pan, clay loam	1.5	43
Rocky silt loam soil under aspen forest	1.62	40
Loamy sand surface soil	1.5	43
Decomposed peat	0.55	65

Source: (Arshad*et al*., 1996)

Table 3.2: Management factors influencing bulk density

Increases bulk density	**Decreases bulk density**
• Continuous tillage	• Continuous cropping
• Removing or burning Residue	• Adding organic amendments
• Trafficking on wet soils	

Source: (Arshad *et al*., 1996)

3.2.1.4 Soil air

The composition of soil air is about the same as that of the atmosphere but it contains more carbon dioxide and water (moisture) and less oxygen. The composition of soil air can change very quickly. A proper balance between soil water and air is necessary for the normal growth of plants. Rainfall, irrigation, drainage and tillage operations are the main factors governing the share of the pore spaces that are filled with water and air. Maintenance of adequate aeration is more difficult on clayey than on sandy soils, FAO. (1995)

3.2.1.5 Soil Porosity

Pore space is that part of the bulk volume not occupied by either mineral or organic matter but is open space occupied by either air or water. The air space is needed to supply oxygen to organisms decomposing organic matter, humus and plant roots. Pore space allows the movement and storage of water and dissolved nutrients. There are four categories of pores:

1. Coarse pores: 0.2 mm -200 microns
2. Medium pores: 200-20 microns
3. Fine pores: 20-2 microns
4. Very fine pores: < 2 microns

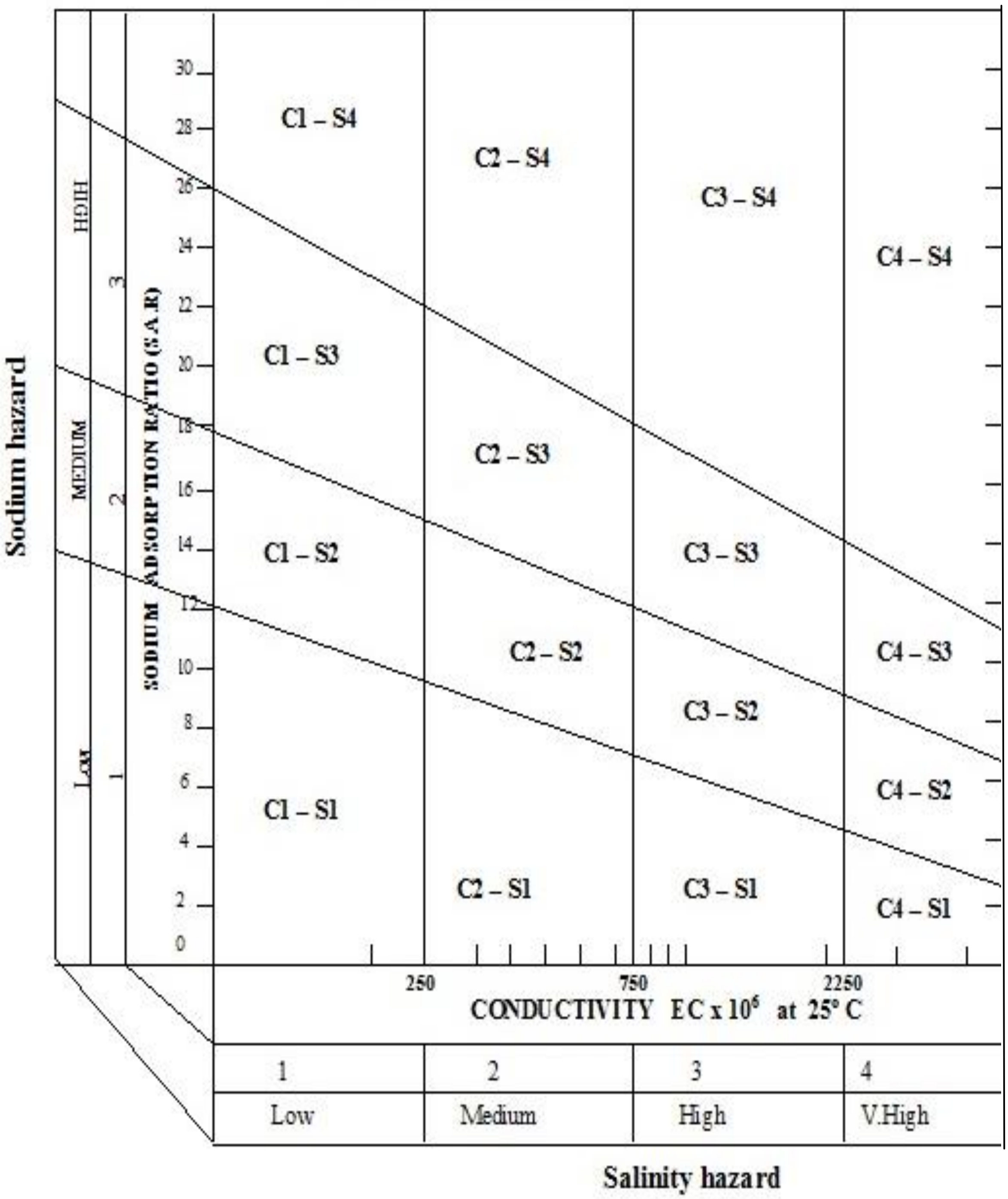
When pore space is less than 30 microns, the forces of attraction that hold water in place are greater than those acting to drain the water. At that point, soil becomes water logged and it cannot breathe. For a growing plant, pore size is of greater importance than total pore space. A medium textured loam provides the ideal balance of pore sizes. Having large pore spaces that allow rapid air and water movement is superior to total percentage pore space, (Soil Survey Division Staff 1993).

3.2.1.6 Soi1 water:

The space between soil particles is known as "pore space" and is filled by water and air in varying proportion, depending upon the moisture content of the soil. Fertile soils should supply plant roots with water and with oxygen from the soil air. The soil receives water in the form of precipitation or irrigation and loses it by drainage through the profile, by evaporation from the soil surface and by uptake and transpiration by plants. After a good rain or irrigation, all or almost all the pore space will be filled with water and the soil is said to be saturated. Some of this water can be lost by drainage, while some is held by and around the soil particles; when the free water has drained out (over a period of days, in some soils weeks) the soil is said to be at field capacity.

Much of the water held in the soil at field capacity can be used by plants, but a proportion is too firmly held by the soil for crops to take it up. When crops have exhausted soil water to this level, the soil is said to be at wilting point. The amount of water between field capacity and wilting point is that available to crops ,(Figure 3.3) . It varies very much, mainly In relation to soil texture and where rainfall is inadequate or sporadic is an important determinant of soil productivity(FAO,1995).

Figure 3.3 : Classification of Irrigation Water (U.S. Salinity Laboratory)



Source: Richard, 1954

3.2.1.7 Soil Color

In general, color is determined by organic matter content, drainage conditions, and the degree of oxidation. Soil color, while easily discerned, has little use in predicting soil characteristics. It is of use in distinguishing boundaries, as an indication of wetness and waterlogged conditions, and as a qualitative means of measuring organic and salt contents of soils. Soil color is primarily influenced by soil mineralogy. Many soil colors are due to various iron minerals. The development and distribution of color in a soil profile result from chemical andbiological weathering, especially redox reactions. As the primary minerals in soil parent material weather, the elements combine into new and colorful compounds. Iron forms secondary minerals with a yellow or red color, organic matter decomposes into black and brown compounds, and manganese, sulfur and nitrogen can form black mineral deposits. These pigments can produce various color patterns within a soil.

3.2.2 Soil Chemical properties

Plant Nutrient Sources: Plant nutrient sources in the soil may be divided into native and added components. Native sources are those derived from soil minerals and also those derived from decomposition of plant residues and soil organic matter. Added sources are those directly added in fertilizers or organic manures. All nutrients are subject to processes of immobilization and re-mobilization into plant-available form; the processes involved vary from nutrient to nutrient, and are both biological and chemical in nature. The biological processes are mainly uptake into soil microflora and release on its death and decomposition; they are particularly important in relation to nitrogen supply and moderately so for sulphur and phosphorus. Chemical processes include precipitation as insoluble compounds, to which phosphorus is especially subjected, and immobilization of cations. It is important to note that, for almost all nutrients the proportion of total soil nutrient content that is available to plants at any one time is very small (FAO,1995).

3.2.2.1 Soil Reaction and its Effect on Nutrient Availability:

Suitability of a soil as a medium for the growth of plants and desirable microorganisms depends considerably on the soil reaction. The degree of acidity or alkalinity is expressed in terms of pH and it is conveniently expressed in the form of a scale (Fig.3.3). The degree of acidity or alkalinity is largely controlled by the ratio of H ions (acidic) to basic cations, mainly Ca , Mg , K and Na – very acid soils are dominated by H ions, less acid and neutral soils by Ca (with Mg , K and H) , (Tables 3.1and 3.4) while the presence of considerable Na gives an alkaline reaction.

Table 3.3: Cation Exchange Capacity (CEC) and Exchangeable Cations Ratings and Interpretation

Analysis	Methods	Units	Rating	Range	General Interpretation
CEC	a) Un-buffered 1 M KCl at pH of soil b) Na or NH_4 acetate at pH 8.2, 7.0	me/100 gm soil	Very high High Medium Low Very low	> 40 25 – 40 15 – 25 5 – 15 < 15	Normally good agricultural soils **O**nly small quantities of lime and K fertilizers required. **N**ormally satisfactory for agriculture, given fertilizers. **M**arginal for irrigation (FAO, 1979a quoted low is 8-10 me/100 g soils). **F**ew nutrient reserves. Usually unsuitable for irrigation, except rice
Ca	As CEC	me/100 gm soil	High Low	> 10 < 4	Response to Ca fertilizer expected at levels < 0.2 me/100 g soil. If high Na levels, response occurs with higher Ca levels.
Mg	As CEC	me/100 gm soil	High Low	> 4.0 < 0.5	Mg deficiency more likely on coarse, acidic soils. With high Ca, Mg is less plant available
K	As CEC	me/100 gm soil	High Low	> 0.6 < 0.2	Response to K fertilizers unlikely> High K effects often similar to high Na, but depends on soil type –especially texture. Response to K fertilizer likely
Na	AS CEC	me/100 gm soil	High	> 1	} Alkali or Sodic soils
			High	> 15%	
ESP	Calculation: Na/CEC	%	High	> 15%	50% yield reduction for sensitive crops
				15 – 25%	50% yield reduction for semi-tolerant crops
				25 – 35%	50% yield reduction for tolerant crops

(Source: Adapted from Landon, 1991)

Available phosphorus (ppm):

Table 3.4: General interpretation of available phosphorus analysed by Olsen's method

Characteristic crop demand	Examples	Indicative available phosphorus values		
		Deficient	Questionable	Adequate
Low P	Grass, cereals, soybean, maize	< 4	5 – 7	>8
Moderate P	Lucerne, cotton,sweetcorn, tomatoes	< 7	8 – 13	>14
High P	Sugar beet, potatoes, celery, onions	< 11	12 – 20	>21

(Source Landon, 1991)

Soil reaction has a great influence on the availability of plant nutrients which is generally highest between pH 6,5 and 7.5 (Fig. 3.4), In particular, phosphorus is rendered unavailable in very acid soils because of precipitation as insoluble iron and aluminum phosphates, and in high pH soils by precipitation of insoluble forms of calcium phosphate. Biological activity is also greatest at intermediate pH levels (around pH 7) so that the breakdown of soil organic matter and release of nutrients such as nitrogen, phosphorus and sulphur to plant available forms is enhanced. Acidic soils can be limed and alkaline soils can be reclaimed by application of gypsum or sulphur to bring the pH nearer to 7.0 (neutral) (FAO 1995).

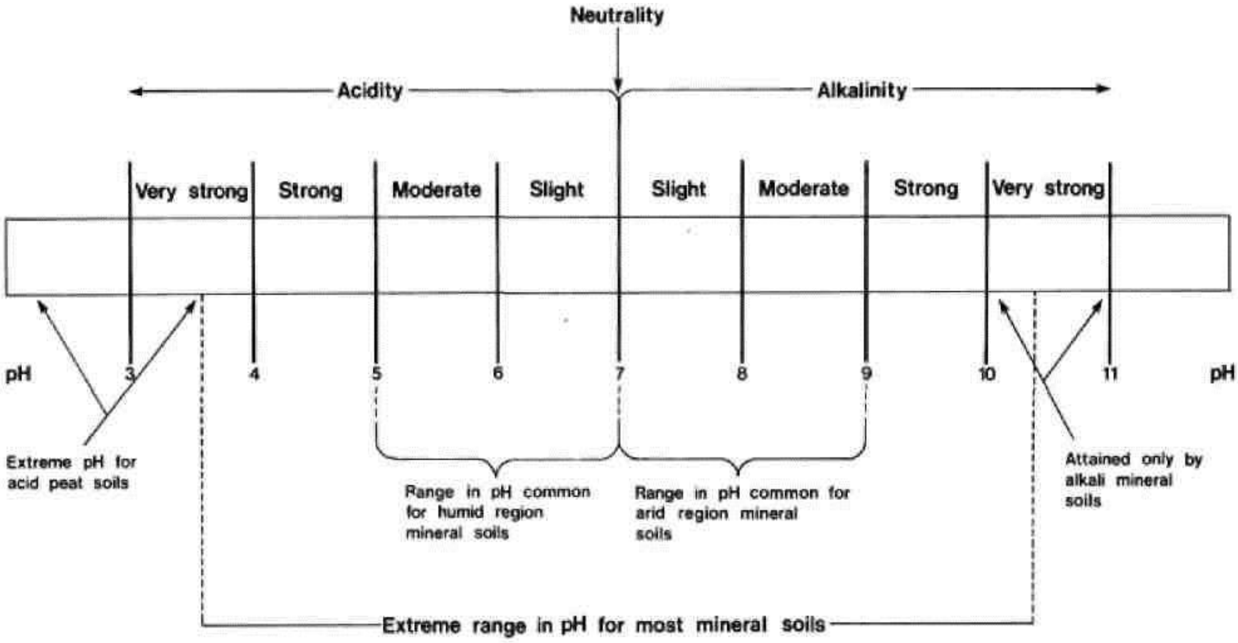


Figure 3.4: Scale of soil pH levels (misplaced).

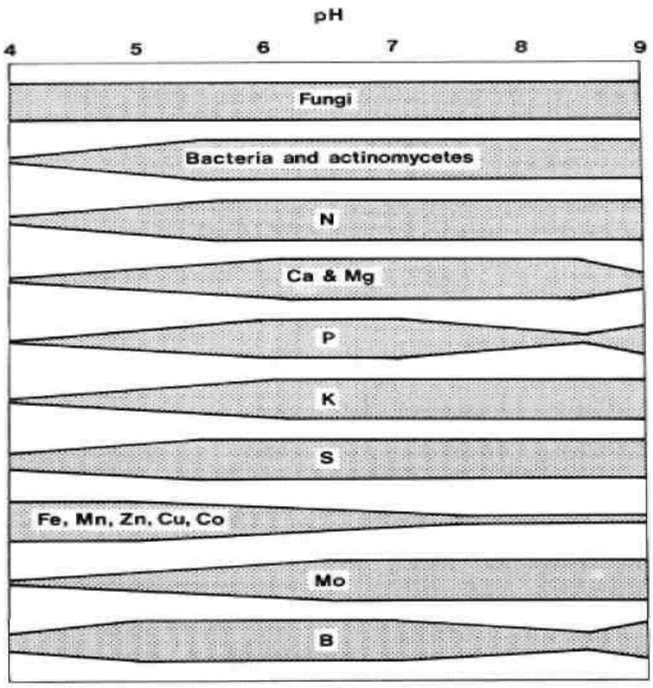


Figure 3.5: Soil pH and relative availability of plant nutrients

3.2.2.2 Soil Organic Matter

Generally, soil contains a variable but relatively small percentage of organic matter in intimate mixture with its mineral components and derived from the remains of plants and animals, including roots, stubble and other residues of harvested crops, and soil micro-organisms such as bacteria, fungi, earthworms. The type and amount of organic matter present in the soil are determined by a number of factors including soil reaction, type of vegetation, the kind of soil microbes present, drainage, rainfall, temperature, and management practices. Under field conditions, crop residues, green manure, straw, compost and other organic manures contribute to the replenishment of soil organic matter. All these materials are decomposed by soil organisms of different kinds and finally converted into a fairly stable amorphous brown to black material known as "humus", not resembling in any way the materials Table 3.6:and 3.7from which it originated (FAO 1995).

3.2.2.2.1important functions of Soil organic matter:

- It helps in binding fine particles together into structural units (soil aggregates), thus helping to maintain the soil in a loose and open granular condition and to improve its tilth.
- It improves soil aeration and the percolation and downward movement of water and thus reduces risk of soil erosion.
- It increases the water and nutrient holding power of the soil and in this way many nutrients are protected from losses due to leaching.
- It increases the amount of available water in sandy and loamy soils.
- it provides a reserve of plant nutrients. Most of the soil nitrogen and much soil phosphorus and sulphur exist in organic forms which, when the organic matter decomposes, are made available to growing plants.
- it supplies a number of micronutrients and growth promoting substances such as hormones; raw organic matter acts as a source of food for soil microbes and thus maintains microbial activity and release of nutrients from organic to plant-available form; organic acids, which are breakdown products of soil organic matter, solubilize soil phosphorus and other micronutrients and make them available for crop growth.

- **Organic Carbon**

Table 3.5: Broad Ratings of Organic Carbon Measurements

Organic carbon content Walkley-Black method (% of soil by weight)	Rating
< 2	Very low
2 – 4	Low
4 – 10	Medium
10 – 20	High
> 20	Very high

(Source: Adapted from Landon, 1991)

- **Organic Nitrogen**

Table 3.6: Broad Ratings of Nitrogen Measurements

N content Kjeldahl method (% of soil by weight)	Rating
< 0.1	Very low
0.1 – 0.2	Low
0.2 – 0.5	Medium
0.5 – 1.0	High
> 1.0	Very high

(Source: Adapted from Landon, 1991)

3.2.2.3 Micronutrients

The micronutrients, which are required by plants in very small quantities, are iron, zinc, copper, manganese, boron, molybdenum and chloride**FAO. (1995**)..

Requirement for Micronutrients:

Micronutrients are required by crops in very small quantities, usually in terms of grams per hectare, but these few grams may make all the difference between securing high yields and the complete failure of the crop. The amounts of micronutrients required to produce one tone of dry matter in a few selected crops are given in Table (3.8).

Table 3.7: Micronutrient uptake by different crops (g/t Dry matter)

Crops	Fe	Mn	B	Zn	Cu	Mo
Cotton	106	14	15	16	8	0.77
Sorghum	360	27	27	36	3	0.98
Castor	223	41	31	14	9	1.01
Pearl millet	264	23	27	22	9	0.84
Groundnut	499	39	44	9	5	1.32
Wheat	232	26	18	21	8	0.87
Potato	160	12	50	9	9	0.80
Tobacco	692	132	96	21	11	0.60

Source: FAO, 1995

Deficiencies of micronutrients produce characteristic symptoms in plants, but taking corrective measures after the symptoms appear may be too late, since the damage has already been done. Application of the necessary micronutrient at this stage may not fully compensate for earlier deficiency and consequently yield may suffer.

It is therefore desirable to establish whether the soil in which the crop is to be grown has sufficient available micronutrients for proper growth and development or whether it is deficient in one or more micronutrients, and to take where the existence of a deficiency has been established there are usually a number of ways of correcting it, which will differ from element to element. For some nutrients, e.g. copper, a soil application of a copper salt will be effective on most soils, because if enough copper is applied it will remain available in the soil for a number of years. For other nutrients, e.g. boron, soil application is effective but short-lived because boron is readily leached from soils. For others, e.g. manganese and iron, soil applications of their salts are relatively ineffective because of rapid conversion to unavailable form. In these cases, the elements may be applied to the soil in the form of chelates, a chemical combination that protects them from immobilization in the soil but allows them to be taken up by crops. Foliar sprays of salts or chelates are effective for most micronutrients, but only if applied early in crop growth. General recommendations on materials and rates of use are given in Table (3.9). Organic manures provide appreciable amounts of most micronutrients and help to maintain them in the soil if applied regularly.

Table 3.8: The forms and rates of application of micronutrients.

Micro-nutrient	Soil application	Spray application
Iron	Ferrous sulphate, 10 kg/ha	0.4 percent ferrous sulphate + 0.2 percent lime
Zinc	Zinc sulphate, Zinc oxide, 10-50 kg/ha	0.5 percent zinc sulphate + 0.25 percent lime
Manganese	Manganese sulphate, 10-50 kg/ha	0.6 percent manganese sulphate + 0.25 percent lime
Copper	Copper sulphate, 10-50 kg/ha	0.1 percent copper sulphate + 0.05 percent lime
Boron	Borax, 5-20 kg/ha	0.2 percent borax
Molybdenum	Sodium molybdate, 0.1-0.5 kg/ha	0.1-0.2 percent solution of ammonium molybdate

Source: FAO, 1995

3.3. Agriculture Sustainability

The concept of agriculture sustainability has been submitted to many definition essays (Farshad and Zink, 1994).Sustainability is the ability of an agricultural system to meet evolving human needs without destroying and, if possible, by improving the natural resource base on which it depends (USAD, 1988).Sustainability concerns the long-term productive performance of systems and is primarily a function of the environmental quality, economic viability and socio- economic well being of the farming population (Conway, 1987).

Karlen*et al*. (2006) have mentioned that basedon the definition issued by the American society of Agronomy a sustainable agriculture is one that over the long term enhances environmental quality and the resources based on which agriculture depends; provides for basic human food and fibre needs; is economically viable; and enhances the quality of life for farmers and society asa whole. In general definition of sustainability indicates that there is a relationshipbetween sustainability and suitability, stability, land degradation, and land use.

Land suitability refers to use of land on a sustainable basis. It means that land evaluation should take account of the hazards of soil erosion and other types of soil degradation(FAO, 1983).To attain sustained food production, agriculture ecosystems must be made stable otherwise land becomes degraded and its productivity declines(Blaike and Brookfield, 1987).

According to (Farhad and Zink, 1994) an average definition of sustainability would include such elements as soil fertility and productivity (rotations, integrated pest management and biological control, tillage methods, crop sequences), controlling pesticide and fertilizer pollution, management strategies) choice of hybrids and varieties,low cost input, etc.), human needs (demand for basic food and fibres), economic viability,ecological soundness, time span (long term as opposed to short term profitability), andphilosophical ethics (implying satisfaction of spiritual and material goals and mankind).

3.4. Land Evaluation

Burrough, *et al*. (1996) states that we need to look more at the interactions between how the various tools for land evaluation can be used in different circumstances, and howphysical, economic and social factors can be combined. A demand driven approach to selecting a land evaluation method would help to reveal what predictions are really needed and at what level of certainty.The process of land evaluation could be improved in several ways.

Firstly, by involving local users in the plan formulation, so that their preferences and constraints are taken into account This would include both the assessment of the impact of interventions by market or government, for example, and of inputs (input supply, extension, credit), as well as the economic, social and environmental outputs of the implementation of the land use plans.Secondly, using existing data but changing the methods of data processing by the use ofmore flexible data processing methods. Thirdly, by the optimal use and better integration of the existing data like remote sensed data and field data. Finally, by a clear presentation of land evaluation and land use plans in non-technical terms .

Land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. The process of land suitability considered in its present condition or after improvements. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses (FAO, 1976).

Land evaluation is concerned with the assessment of land performance when used for specific purposes. It involves the execution and interpretation of basic surveys of climate,soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. To be value in planning, the range of land uses considered has to be limited to those which are relevant within the physical, economic and social context of the area considered, and the comparisons must incorporate economic considerations.

Land evaluation is the process of estimating the potential of land for alternative kinds of use (Dent and Young, 1981). Land evaluation can also be defined as the assessment or prediction of land quality for aspecific use, in terms of its productivity, degradation hazards and management requirements (Austin and Basinski, 1978), has mentioned that agriculture land evaluation fulfils two main tasks:

- •Identifying the most suitable location for a specific agriculture use
- •Identifying the most suitable agriculture use for a specific location

(many uses- single location).

Land evaluation assesses the suitability of land for specified land uses (Beek*et al*. 1999).In general, land evaluation is a process of matching, based on a series of selected land qualities and comparison of them with land use requirements.Land evaluation can also be defined as the assessment or prediction of land quality forspecific use. Assessment is made in terms of production, sustainability, the inputs neededto obtain that production, and (in the case of quantitative land suitability classification)economic return. This process includes:

identification, selection and description of land use types relevant to the area under consideration; mapping and description of thedifferent types of land that occur in the area and the assessment of the suitability of thedifferent types of land for the selected land use types (FAO, 1976).

Land evaluation may be concerned with present land performance. Frequently, however, it involves change and its effects: with change in the use of land and in some cases change in the land itself. Evaluation takes into consideration the economics of the proposed enterprises, the social consequences for the people of the area and the country concerned, and the consequences, beneficial or adverse, for the environment (FAO, 1976).Rossiter (1996) discusses a theoretical framework for the classification of land evaluation models and concludes that there is no single land evaluation modeling approach.

The choice of technique affects the reliability and scope of the application, and also the predictions and purpose. Rossiter added that predictions on land performance are useful only if they are used by decision-makers to make better decisions, we should take a stepback, away from the question "what predictions can we make with the data we have?" i.e.a data – driven approach, to the question " who are the decision- makers, who actually affect land use, how are they making their decisions, and how could their decision bebetter informed? i.e. a demand-driven approach '(Rossiter, 1996).Burroughetat (1996) states that in the top-down approach to land evaluation, the direction of reasoning is always from resource base to land utilization, a perfectly adequate approach where there is plenty of land, and the market is unconstrained.

In general the conditions for agriculture will be initially created by the modification of the natural physical resources. Irrigating, fertilizing and other practices may do this; as the cost of inputs increases, however, physical land resources become less important and factors such as access to the market, infrastructure, skilled labour and organization are more important Added to this are other aspects concerning social habits and traditions. For example inMexico, almost all farmers grow maize because their culture requires it any maize isbetter than none..

Land evaluation provides essential information on land resources. However this information is often not used in the planning and implementation of better land use systems or land use practices, for a number of reasons. Firstly, the information produced is frequently incompatible both to government's objectives and/or the preferences of thelocal people. Secondly, data processing is in adequate, resulting in low quality information. Thirdly, land evaluation is based on a top-down approach; such an approach does not take sufficiently into account the aspirations, capabilities are constraints of the local land users. Added to which, land use plans tend not to consider sufficiently the limitations of interventions (subsidies, policy prices, input supply, extension, credit etc.)(Bronsveld*et al*, 1994).Land evaluation is defined as the process of assessing.

This approach is based on the matching of qualities of different land units in a specific area, with the requirements of actual or potential land use. The results of land evaluation should be useful for rational land use planning (FAO, 1993).

The aim of land evaluation is to determine the suitability of land for alternative, actual or potential, land uses that are relevant to the area under consideration. The suitability assessment is based on the productivity, stability and sustainability of land use systems (Huizing*et al*, 1995).Land suitability is assessed and classified with respect to specified kinds of use and is made in terms relevant to the physical economic and social context of the area concerned (FAO, 1984).

Land evaluation surveys started in 1950 and the most important of these surveys, was land capability classification carried out by soil conservation service (S.C.S) of the United States, which major kinds of land use were determined by soil information. When human being knowledge promotion, it was specified that other factors are effective in land utilization. in this regard, the scientists paid more attention to land characteristics and qualities.

3.5. Land Resources

Land comprises the physical environment, including climate, relief, soils, hydrology and vegetation, to the extent that these influence potential for land use. It includes the resultsof past and present human activity, e.g. reclamation from the sea, vegetation clearance, and also adverse results, e.g. soil Salinization. Purely economic and social characteristics, however, are not included in the concept of land; these form part of the economic and social context (FAO, 1976).Land is an area of the earth's surface, comprise the physical environment, including climate, relief, soils and underlying geology, hydrology, plant and animal population, and the results of past and present human activity (FAO, 1976, Dent and Young, 1981).

FAO (1995) defines land as : any delineable area of the earth's terrestrial surface, involving all attributes of the biosphere immediately above or below this surface including those of the near-surface climate, the soil, the terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps),near-surface layersand associated ground water and geohydrological reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water shortage or drainage structures, roads, buildings, etc.).

FAO (1995) give a complete definition including some socio-economic aspects as well. In this regard Land resources consist of two main categories:

- Natural land resources.
- Artificial land resources including the product of human activities such as dikes and plodders (Dent and Young, 1981).

Land use is the result of a continuous field of tension created between available resources and human needs and acted upon by human efforts (Vink, 1975).Land use carried out in many different ways. The broadest categories include:

- Rural land use; including agriculture, forestry and wildlife.
- Urban and industrial land use including towns, villages and industrial complexes

In this study the emphasis is put on the rural and especially on the agricultural uses.

3.5.1 Land Utilization Types

A kind of land use described or defined in a degree of detail greater than that of a majorkind of land use.

3.6. Land Characteristics

Attributes of land that can be measured or estimated, examples are slope, rainfall, soiltexture, available water capacity, biomass of the vegetation, etc.

3.6.1 Land Mapping Units

A land-mapping unit is a mapped area of land with specified characteristics. Landmapping units are defined and mapped by natural resource surveys, e.g. soil survey,forest inventory.

3.7. Land Capability and Land Suitability Classification

McRae and Burnham (1981) indicated that suitability and capability are not the same but they have often been confused or even regarded as identical. Suitability is always used for specific production e.g. onion production, while capability is used in a broader sense, such as agriculture or urban development. Thus suitability assessment has sharp focus , looking for areas possessing the positive features associated with successful production or use, where as capability must be vaguer, and is often defined in terms of negative limitations which prevent some or all of the individual activities being considered.

In developing a suitability and capability classification, technical data from agronomy, forestry and others are used. And as well socio-economic factors are very important to consider. These range from easily quantifiable geographical circumstances (position in relation to settlement, transportation, and other human activities) to political and administrative decisions like eligibility for planning permission and such unquantifiable factors such as the availability of managerial skill or the existence of religious constraints(Dent and Young 1981).

3.7.1 Land Capability Classification

Capability refer to general kinds of land use and used to allocate land rationally to the different kinds of land use required i.e. rotational, permanent grazing, woodland. The main product of land capability classification is a map in which areas of land are put into capability classes ranging from I (best) to VIII (worest) (Rossiter,1994).

It was first developed by in the USA and is mainly conservation oriented. The reason why an area is allocated to a given class is indicated by a letter suffix: thus sub-class IIe indicates an erosion hazard, IIw a problem of excess water. Each class of land has the potential, or capability, for use in a prescribed number of ways,or which specified management techniques. Thus class 1 land can be put to arable use without soil conservation measures whilst classes II to IV require increasingly costly conservation practices; classes VI to VIII should not be used for arable use (Dent and Young,1981).

3.7.1.1 Concepts and Assumptions

There are two concepts that are basic to the system. These are capability and limitations. The potential of the land for use in specified ways or with specified management practices is called capability (Davidson, 2006).There is a sequence of assumed uses built into the system. These are as follow (a) arable use for any crops and without soil conservation practices; (b) arable use with restrictions on choice of crop/or with soil conservation practices ;(c) grazing of improved pastures;(d) grazing of natural pasture or, at the same level, woodland; (e) and at the lowest level, recreation, wildlife conservation, water catchments and aesthetic purposes (Dent and Young, 1981).

Land that is allocated to any particular capability class has the potential for the use specified for that class and for all classes below it, Thus class 1 land , whilst excellent for arable use, can equally be put to any of uses below it whilst class v1 land is suited for improved pasture but also be any of the uses below it, whilst class v111 land can be used only for recreation. The capability class does not indicate what is the best use for land , nor the most profitable, it only indicates the range of uses to which each could be put (Dent and Young , 1981).

Limitation are land characteristics, which have an adverse effect on capability (McRae and Burnham,1981).Permanent limitations are those which cannot easily be corrected. Temporary limitations can be corrected, at least by minor land improvements. Land is classified mainly on the basis of permanent limitations(FAO,1976).
The general rule is that if any one limitation is of sufficient severity to lower the land to a given class it is allocated to that class, no matter how favorable all other characteristics might be. Thus it is useless to have level land, well drained and free from flooding, if it only has 10 cm of soil which is too shallow to practice any crop production. Dent and Yong (1981) indicated that this type of classification emphasizes the negative features of land, which are taken into account in assigning different types of land to capability classes. Soil erosion hazard, and hence conservation requirements, normally gets more attention.

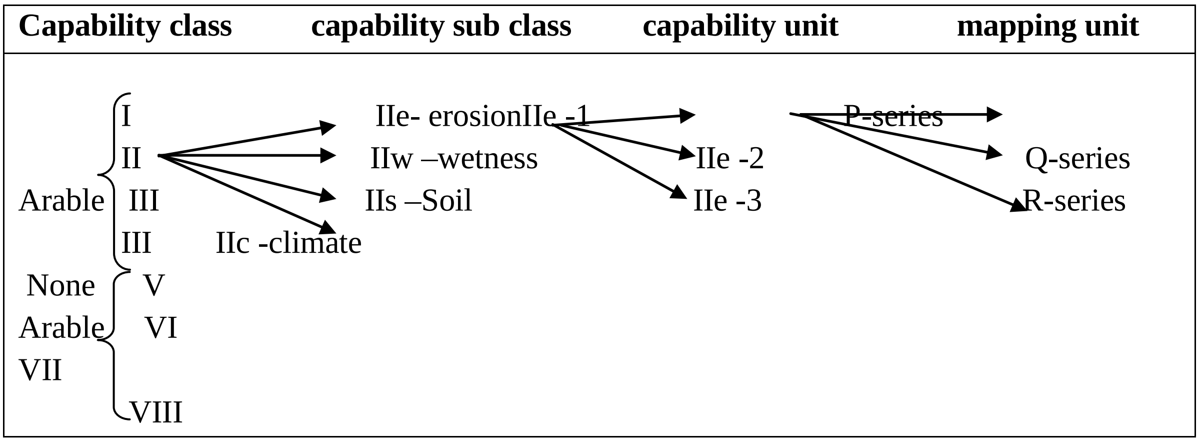
3.7.1.2 Structure of Classification

Three categories are used i.e. capability classes, sub classes and units (Davidson,1992). If the classification is based on soil survey, that is, not upon direct survey for capability, the capability units are themselves grouping of the soil mapping units and most of the time the system is oftenapplied without identifying capability units (FAO,1976).

a- Capability Class

A general degree of (goodness) in the sense of(possible intensity of use):
I (best), VIII (worest). Roman numerals I, II, VIII are used to indicate the capability from class Table 3.10 and the restriction on kinds of land use andmanagement needs increases from class I to class VIII (Rossiter,1994).

Table 3.9: Structure of land capability classification



Source (Davidson,1992)

The risk of soil erosion increases through class I to IV, progressively reducing the choice of crops and requiring more expensive practices and more careful management (Dent and Young, 1981). Class I-IV can conveniently be thought of as " very good ", " good "," moderate " and " marginal " arable land respectively . Class IV should only be used for arable purpose if very carefully managed. Class V is allotted to land rendered unsuitable for cultivation by reasons other than erosion hazard, e.g. wetness or excessive stoniness.

Classes VI-VIII are precluded from arable use by severe permanent limitations (McRae and Burnham, 1981). For most part they have steeply sloping land. Class VI can be managed under improved pasture, class VII only under rough grazing or woodland, whilst class VIII cannot be used for commercial plant production of any kind, except recreation

b- **Capability Subclasses**

Indicates the major limitations, by the use of one or more letters. USDA subclasses: 'e' = erosion hazard, 'w' = excess water, 's' = soil limitations within the rooting zone (includes shallowness, stones, low native fertility difficult to correct, salinity), 'c' = climatic limitations (temperature or rainfall). Class I has no subclasses (Rossiter, 1994).

c- **Capability Unit**

A division of the subclass that have nearly identical potential, limitation and management requirements The degree and general type of limitations are the same in a subclass, but there may be important management . The goal of soil survey is to increase production and to help farmers for optimum use of land. Up to now the lands for general utilization such as rainfed agriculture, irrigated agriculture, grassland, forestry, or recreation have been classified however land evaluation for different agriculture cropsand horticulture crops have not been employed. Thus; the concept of soil survey is only meaningful when applied aspects are considered after carrying out a project, that is, in spite of determination of soil type and preparation of map, we should be able to presentan optimum cultivated pattern to the farmers, to predict crop yield, and to conduct themin management.

3.7.2 Land Suitability Classification

Land suitability is the fitness of a certain area of land for a specific use (Vink, 1975) differences in the degree of suitability are determined by the relationship (actual or potential) between inputs required and outputs gained from a particular land used for a specific use. For the purpose of judging ،land suitability both for land use and for land improvement, a systematic land evaluation is necessary. Land evaluation, therefore, links the gap between the physical, biological and technological means of land use and its social and purpose. land evaluation is not economic, but neither is it a purely physical disciplines, it is utilization of social and economic parameters in evaluating physical data. In its most quantitative from ,land suitability is expressed in economic term of input and output ,or in its result as net income.

Land suitability can be defined as the fitness of a given tract of land for a defined kind of land use. The land suitability classification system used here is the current system under use in Sudan since 1976 (Van der Kevie, 1976) . It was adopted by the former Soil Survey Administration, Wad Medani. Recently this administration was restructured and named as Land and Water Research Center (LWRC) and eventually affiliated to the Agricultural Corporation for Research and Technology Transfer. The Land suitability is based on the suggested Land Evaluation system outlined by FAO (1976).

Vink (1975) stated that two main sets of assumptions about land conditions could be used to interpret land suitability from land resource maps. These are

a- the suitability of land unit for the use in question in its present condition without major land improvement, i.e actual land suitability.
b- the suitability of land unit for the use in question at some future data after major land improvement have been effected where necessary, potential land suitability.

3.7.2.1 Categories of the System

The system uses well defined hierarchical subdivision into orders, classes, subclasses and units.

The four categories with decreasing generalization are:

- The land suitability orders :
  Order S - Suitable land

  Order N – Unsuitable land

- The land suitability classes
  Class 1 – Highly suitable land

  Class 2 - Moderately suitable land

  Class 3 - Marginally suitable land

Class N1 -Currently unsuitable land

Class N2 - Permanently unsuitable land

- The land suitability subclasses
- The land suitability *units*

3.7.2.2 Structure of the Classification

According to the FAO (1976) there are four categories or levels of classification :land suitability orders,classes,sub-classes and units (Table 3.11). These suitability classes are classed separately for each land-mapping unit in the survey area.

Table 3.10: Structure of Land Suitability Classification:

Order	class	sub-class	unit
S(suitable) S2me	S1 S2 S3S2e	S2m	S2e-2	S2m-1
Sc (conditionally suitable)		Sc2m	
N(not suitable)	N1 N2 N1e	N1m	

Source (FAO,1976)

a- Suitability Order

This separates land assessed as suitable (s) from that which is not suitable (N) for the use under conditions (FAO, 1976). According to Dent and young (1981), there are three main reasons why land may be classified as not suitable. these are ,the proposed use could be technically impracticable. e.g cultivating very shallow or rocky soils, or is environmentally undesirable, e.g would lead to severe soil erosion, or is economically unprofitable ,the income from estimated production being less than the cost of the required inputs.

b- Suitability Classes

These are divisions of suitability orders that indicate the degree of suitability i.e. highly suitable (S1),moderately suitable (S2),marginally suitable(S3),Table 3.12 . unsuitable for economic reasons but otherwise marginally suitable (N1), unsuitable for physical reasons(N2).N2 implies limitations that cannot be corrected at any cost within the context of the land combined into S3\N1 because the distinction between these is purely S1and S2,S2 andS3\N1are arbitrary or based on single-factor yields reductions. In economic evaluations, the limits between S1andS2,S2andS3,andS3andN1are made on the basis of predicated economic value (Rossiter, 1994).

Table 3.11: Salinity and Sodicity Limits for Land Suitability Classes

		Non-Vertisols				Vertisols			
Salinity	cm	**S1**	**S2**	**S3**	**N1**	**S1**	**S2**	**S3**	**N1**
ECe, ds/m	0-30	< 4	4-8	9-12	> 12	< 4	4-8	9-12	> 12
	30-90	<6	6-12	13-16	>16	< 6	6-12	13-16	> 16
< 4 - non-saline 4 - 8 - slightly saline 9 -12 - Moderately saline 13 -16 - Strongly saline >16 - very strongly saline									
		Non-Vertisols				**Vertisols**			
Sodicity	Cm	**S1**	**S2**	**S3**	**N1**	**S1**	**S2**	**S3**	**N1**
ESP/SAR	0-30	< 10	10-15	15-25	> 25	< 10	10-20	21-35	> 35
	30-90	< 15	15-25	26-35	> 35	< 20	20-35	36-50	> 50
< 15 -Non-Sodic 15 - 25 - slightly Sodic 26 - 35 - moderately Sodic 36 - 50 - strongly Sodic > 50 - very strongly Sodic									

Source: Osman Eltoum, 1976

c- Suitability Subclasses

These are divisions of suitability classes which indicate not only the degree of suitability (as in suitable class) but also the nature of the limitations that make the land less than completely suitable .So, suitability class S1 has no subclasses. The subclass code consist of the suitability class code, followed by suffix, which indicates the nature of the limitations. There is a suggested list of suffixes in some the guidelines(FAO,1976 and Mc Rea and Burnham,1981).E.g.S3e; marginally suitable (S3) because of erosion hazard (e),S3w; marginally suitable (S3) because of wetness (w).

d- Suitability Units

There are divisions of subclasses designated by numbers within subclasses e.g. S3e-3, which are meant to be managed similarly. These have different management requirements, but the same degree of limitation and the same general kinds of limitation (because they are divisions of subclasses). E.g. moderate fertility limitations, but one management unit may require extra K and another extra P. The hierarchical nature of the suitability classification Figure (3.5) can be presented as follows (Rossiter,1994).

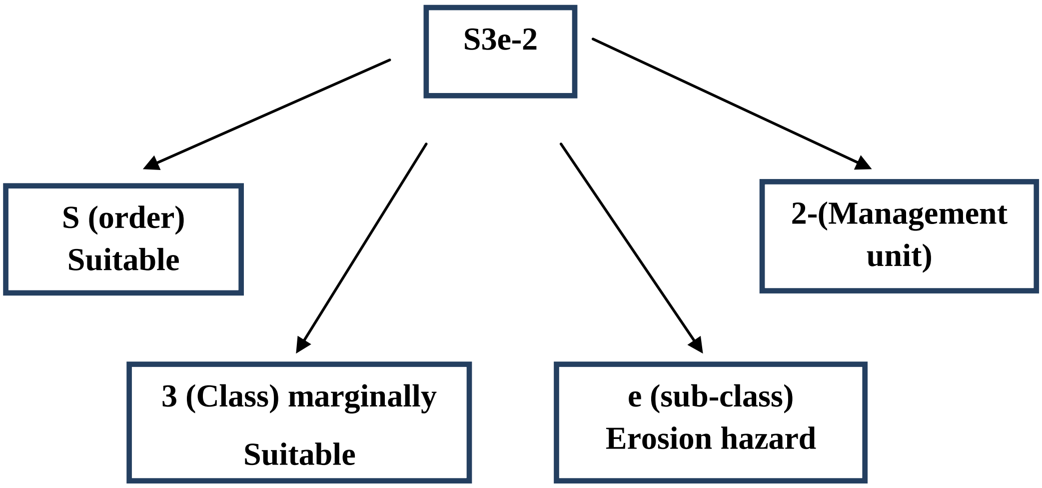


Figure 3.6: The hierarchical nature of the suitability classification

3.8 Land Qualities

The suitability of a tract of land is determined by a number of land qualities. These qualities are combinations of individual land characteristics, and are distinct from other land qualities in their influence on the suitability of the land for a specific kind of land use .Each land is determined by a small number of land characteristics, and is related to one a few specific limitations to profitable use of the land. For instance moisture availability is a land quality, determined by rainfall, potential evapotranspiration, soil depth, runoff and water holding capacity of the soil material and related to either a climatic limitation (c) if caused by a very low water holding and (d) if cased by shallowness of the soil. A list of land qualities that may be used in the assessment of land suitability is given in table (3.13)

The use of land qualities as an intermediate step in the determination of land suitability has the advantage that one can link land suitability with only a limited number of qualities instead of with a large number of interrelated land characteristics . At the same time it becomes clear which are the major limiting factors and to what degree are they limiting. The land qualities cannot be measured such as most the individual land characteristics, but they can be rated good, moderate, poor or very poor, based on the measured land characteristics which determine them. In rating the land qualities each quality is given a number ,1, 2, 3, or 4 which corresponds with good, moderate, poor, or very poor for agriculture in general.

Table 3.12: Major land qualities for agricultural production with individual land characteristics and related limitations:

Land quality	Major land characteristics	Limitations
Moisture availability for the plant	Soil depth, available water capacity, texture, structure, O.C, degree of runoff, climatic moisture regime.	d ,c, m
Chemical fertility	Content of N, P and K, micronutrients, CEC, base saturation and PH.	F
Conditions for seedling establishment	Texture, structure, aggregate stability, consistence, bulk density, stoniness, surface gravel.	p or g
Possibilities for Mechanization	Slope, relief, bearing capacity (n-value), consistence (texture, type of clay), stoniness , availability of shallow pans and rocks.	d, g
Erosion hazards	Slope, infiltration rate(texture, structure, bulk density, soil depth and aggregate stability).	E
Climate regime	Temperature regime, air humidity, storm hazards.	c
Occurrence of pests and diseases	Frequency and severity of pests and diseases, caused by birds, insects, nematodes, etc…	X

Source (Doka 2003)

CHAPTER FOUR

MATRERIALS AND METHODS

4.1 Materials

4.1.1 Location of the Study Area:

Farm is located atAlkhojlab area; the farm was located at 20 Km north of Bahari town with an area of about 72 feddans (60 fields). . Field survey was located by GPS and the teams adhered to a basic 780m x 390m grid

4.1.2 Remote Sensing Data and satellite image:

The using of Google earth**.**

4.1.3 Equipment and Tools for profile description:

- Profile description sheets
- HCL (Hydrochloricacid)
- Water battle
- Meter
- GPS
- Color book
- Hammer
- Plastic bags
- markers
- camera

4.2 Methods

4.2.1 Soil sampling methods:

Soil samples may be taken by two methods which involve either digging profiles oraugering method at the different site in the field.

4.2.1.1 The open of profile pit method:

Open test pits are the only means available actually to see and be able to examine a soil profile in its natural state.The basic steps to follow when digging an open pit are:

Dig a pit with very straight sides 1 x 1.50 m and 2 m deep or, less, until you reach the parent rock; the upper part of the pit should be wide enough for you to see the bottom easily (the drawing shows you how); When you have finished digging, examine one of the well-exposed sides of the pit carefully to determine the different soil horizons: this is called a soil profile; it should be examined when freshly dug. Make a drawing of this soil profile for each pit you dig and measure and write the depths of each soil horizon. Carefully write on your drawing the location of the site where each sample was taken.

4.2.1.2 The auger boring method

The auger boring method is a way to obtain soil samples from different depths (0-30, 30-60 and 60-90cm) by drilling (auger), without having to dig a pit. The auger boring method is cheap and fast, you can quickly check the soil at several places of your site, but it provides only disturbed samples.

4.3 Laboratory determination of soil samples:

A total of soil 23 samples were collected from the soil profile pits and these samples were analyzed in the SUST laboratories at the College of Agricultural Studies .

Different determinations were carried out on the soil samplesin the laboratory with the aim of studying some of the most important physical and chemical properties of the soi1. Special interest was given to those indicating the conditions of salinity, alkalinity and potential soil fertility.

4.3.1 Physical measurement carried out on pit soil samples, includ the following:

- Particle-size distribution (sand, silt and clay).
- Particle density.
- Bulk density.
- Porosity.
- Saturation percentage.

4.3.2 The chemical characteristics determined of pit samples were as follows:

- pH soil paste.
- pH 1:5 soil water suspension.
- Electrical conductivity of the saturation extract ds/m.

Soluble cations and anions on saturation extract:

- Calcium plus Magnesium (Milliequiv./1)
- Calcium
- magnesium
- sodium
- potassium
- Carbonate
- Bicarbonate
- Chloride
- Sodium

Ammonium acetate extractable sodium (milliequiv. /l00g)

- Soluble sodium
- Exchangeable sodium
- Sodium adsorption ratio.
- Exchangeable sodium percentage.
- Carbonates as incorporated calcium carbonate (%).
- Organic carbon (%).
- Organic nitrogen (%).
- C/N (Carbon to Nitrogen ratio).

4.4 Analysis of Soil Samples:

4.4.1 Preparation of Soil Samples:

The laboratory ,the disturbed samples, collected from both is pites and surface soil, were dried under shade by spreading on sheets of stout paper placed inside wooden trays. Each sample was then divided into two unequal portions. The smaller portions were stored in polythene bags. The major portions were ground and sieved (2 mm.). The fine earth of each subsample was thoroughly mixed and placed inside labeled glass jars with screw tops.

The coarse material of each pit sample remaining on the sieve was washed and dried to be calculated as a percentage of the total soil before it was discarded, percent moisture of the air—dry fine earth was also determined

4.4.2 Methods of Analysis:

In the analysis of soil samples adoption was made, in most cases, of the official routine methods especially those employed by the United States Soil Survey (Agriculture Handbook No, 6o, U.S..D.A Deptof Agric.).

4.4.2.1. Physical Analysis

- **Particle—size distribution:**

All results refer to oven dry soil. The soil was treated with HCl acid to destroy calcium carbonate, washed to remove soluble salts, dispersed with calgon and boiled. Pipette method used to determine the clay fraction and wet sieving for the separation of the fine and coarse sand fractions. The silt fraction was obtained by subtraction from 100 %. Coarse and medium sand 2.0 - 0.25 mm; fine sand 0-25 - 0.05 mm; silt 0.05 - 0.002mm; clay < 0.002mm.

- **Soil Textural Class,** The FAO textural triangle was used to determine the different textural classes of soils.
- **particle density:**

This was determined according to Black (1965) using a pycno— niter.

- **Dry Bulk Density (BD), g/cc**

Determined using natural soil clods (Brasher, 1966).

- **Porosity:**

Porosity, which is an expression of the pore space as a percentage of the total volume of soil, was calculated from density measurements:

$$Porosity = PD-BD/PD*100$$

Where PD = particle density

BD= bulk density.

4.4.2.2. Chemical Analysis

- **Preparation of saturated soil paste and determination of saturation percentage:**

In the preparation of saturated paste, the procedure described in the Agriculture Handbook No. 6o, (U.S.D.A.) was used.

Percent moisture at saturation was determined in a small portion of the paste.

- **Soil reaction:**

For each sample pH was determined on the saturated paste, using a Metrohrn pH Meter equipped with glass electrode. The standard used was a saturated solution of potassium hydrogen tartrate (PH 3.57).

pH was also measured in a 1:5 soil water suspension (prepared by mixing 10 grams of fine soil with 50 ml. of distilled water in a beaker) after stirring, standing for two hours and stirring again.

- **Extraction of the saturated pastes:**

The saturated pastes used for pH measurement were transferred to a set of Buchner funnels connected to a vacuum system. The vacuum pump was then operated and about 50 ml. of extract were obtained from each sample. . The pH was read by a glass/calomel electrode (concentrated KCL) system.

Analysis of saturation extract:

- **Electrical Conductivity (ECe) dS/m at 25OC**

Saturated soil paste prepared by adding soil to a known quantity of water to paste consistency. Saturation extract was sucked off using a vacuum pump. EC of the saturation extract read from a battery-operated conductivity meter.

- **Percent salt and Osmotic pressure:**

The following formulae, given by Richards (1954), were used to c-.calculate percent salt in the saturation extract and soil, as well

- **Calcium(Ca^{++})plus Magnesium (Mg^{++}):**

Calcium plus Magnesium were determined volumetrically by the titration of 10 m1 aliquots of the saturation extract against 0.01 N disodium dihydrogen ethylendiaminetetraacetate (Versenate), in a 10 ml. microbureffe, using Eriochrome Black ‘i as indicator. According to (Richards 1954).

- **Calcium:**

For the determination of calcium a suitable aliquot of the saturation extract was titrated with 0.01 N disodium dihydrogen EDTA solution against Ammonium purpurate (Murexide) indicator. As the end point of titration against this indicator varies with dilution, the same volume of extract was used for all the samples to avoid this variation (Richards 1954).

- **Magnesium:**

The concentration of Magnesium in the saturation extract was obtained by subtracting the concentration of calcium from that of calcium plus Magnesium.

- **Sodium and Potassium:**

These cations determined directly using an EL Flame Photometer on appropriately diluted portions of the saturation extract.

- **Carbonate and Bicarbonate:**

Were determined together by titration with standardized 0.0l N sulphuric acid, using phenolphthalein .indicator for the first and methyl orange indicator for the second according to (Richards, 1954).

- **Chloride:**

A suitable aliquot was pipetted into a porcelain evaporating dish and the chloride content determined according to Richards (1954) using 5 percent potassium chromate as indicator, and titrating with 0.005N silver nitrate solution.

- **Ammonium acetate extractable sodium and potassium:**

The method used was given by Richards (1954).

- **Exchangeable sodium:**

Calculated by subtracting the concentration of soluble sodium in milliequiv. /l00g. From the ammonium acetate extractable sodium.

Soluble sodium in meq/100 gm. was calculated by multiplying the number of milliequivalents sodium in 1 m1 of saturation extract by the saturation percentage.

- **Exchangeable Potassium**:

The procedure used in the calculation of exchangeable sodium was also followed with potassium.

- **Cation exchange capacity:**

The procedure was that of Richards (1954) in which the soil was saturated with sodium acetate, washed with ethanol and the adsorbed sodium was extracted by ammonium acetate.

- **Exchangeable sodium Percentage (ESP):**

This percentage was calculated as follows:

ESP = (Exchangeable Na ÷ CEC) × 100

- **Sodium Adsorption Ratio (SAR):**

This ratio was calculated according to Richards's formula:

SAR = Na / (√ Ca+ Mg/2); Soluble Na, Ca and Mg substituted in the equation, are in meq. /litre.

- **Carbonates as incorporated calcium carbonate:**

Calcium carbonate was determined gasimetrically in Collins calcimeter. (Collins, S.H. 1906). The volume of Co2 generated from a known weight of soil was reduced to standard conditions, and calculated as if the total volume was derived from calcium carbonate only.

- **Organic carbon:**

Wet oxidation of organic matter by Weakley and Black rapid method.

- **Organic Nitrogen:**

This property was determined by Kjeldahl digestion, followed by distillation of the freed ammonia into 2% boric acid solution and titrated with 0.05 N HC1.

4.5 Water analysis:

The methods used for analysis of water are essentially those used for the analysis of water extracts of soil obtained at saturation. The methods described in FAO 1984Bulletin No.10 "Physical and Chemical Methods of Soil and Water Analysis".

4.6 Soil Classification:

Based on the morphological, physical and chemical properties the soils were classified up to family level following USDA Soil Taxonomy.

4.7 Land Suitability Classification for Crops:

Most of the plant species need well drained, moderately fine to medium texture soils, free of salinity and having optimum physical environment. Soil resource maps based on several parameters, can aid in predicting the behavior and suitability of soils for growing field crops, horticultural crops, forest species and other plantation crops once the suitability criteria is established. Within limits, it may also find application in transfer of technology to other areas with comparable soil-site characteristics (FAO, 1976).

CHAPTER FIVE

RESULTS AND DISCUSSIONS

5.1 Physical properties

5.1.1 Texture:

The results of mechanical analysis of pit samples are tabulated in appendix1.

Clay content ranged between the extreme values of 73 %(pit 1=60-80cm) and 24 %(pit 3=0-15cm).The general trend for clay is to increase with depth because it's a clayey soils. The texture in certain profiles remains variable with depth whilst an increase in clay content with depth is observed in all profiles. Silty ranged between the extreme value of 24 % (pit 4= 45-80) and 12% (pit 1/pit 2 = 60-80), silty increase with depth is observed in the subsoil in all profiles. Two main textural classes of the topsoil were found to exist, namely clay and clay loam (auger 8=0-30cm), (auger 9= 0-30 cm) (auger 10= 0-30). The textural of the subsoil is homogeneous. This is in addition to the sandy layer, fine sand ranged between the extreme values of 56=pit 3 0-15cm) and 13% (pit 1=15-40/40-60cm).

5.1.2. Particle density:

23 determinations of particle density have been made. Detailed results of particle density measurements are tabulated in appendix 1.Variations between the values were insignificant and the average particle density was found to be 1.4 g/cm3 in subsoil (pit 3= 85-115/115-150) and 1.8 g/cm3 in all the depth of (pit 1, 2, 4)(Table 5.2). Particle density is the density of the mineral particles that make up a soil i.e. excluding pore space and organic material.

Table 5.1:Particle density

W1	
Depth (cm)	Bd
0-5	1.6
5-15	1.8
15-40	1.8
40-60	1.7
60-80	1.8
80-150	1.6

W2	
Depth (cm)	Bd
0-5	1.7
5-25	1.8
25-60	1.7
60-80	1.7
80-100	1.8
100-150	1.6

W3	
Depth (cm)	Bd
0-15	1.6
15-35	1.7
35-55	1.6
55-85	1.5
85-115	1.4
115-150	1.4

W4	
Depth (cm)	Bd
0-25	1.5
25-45	1.6
45-80	1.8
80-105	1.7
105-150	1.7

5.2. Chemical properties

PH determinations were made on samples. The reaction of the soils is alkaline; PH (1:5) ranges from 7.9 to 8.1 in topsoil and 8.1 to 8.4 in subsoil. Variations throughout the profile are quite significant and PH tends to rise with increasing depth. This is mainly due to the increase in the content of soluble plus exchangeable sodium in soil. Results of PH measurements are tabulated in appendix (1).

5.2.1 Saturation extracts:

The saturation extracts obtained from the samples were analysed for the estimation of salinity and determination of soluble salts composition. The results of analysis are shown in appendix1.

Table 5.2: Soil Chemical Analysis

Soil properties	Depth	**TOPSOIL**	**SUBSOIL**
Clay	*Average*		
%	*Range*	24 - 51	33 – 73
pH	*Average*		
Paste	*Range*	7.9 – 8.0	8.1 – 8.4
CEC	*Average*		
cmol(+) kg-1	*Range*	35– 57	39 – 70
Exchangeable Na	*Average*		
cmol(+) kg-1	*Range*	3.0 – 16.0	6.0 – 31.0
Ex. K	*Average*		
cmol(+) kg-1	*Range*	0.8 – 1.0	0.3 – 1.3
Ca + Mg	*Average*		
	Range	27.0 – 46.0	11.6– 42.7
Total N	*Average*		
%	*Range*	0.02 – 0.03	0.02 – 0.03
Organic Carbon	*Average*		
%	*Range*	0.3 – 0.4	0.2 – 0.3
$CaCO_3$	*Average*		
%	*Range*	3.0 – 8	2 – 10
Available P	*Average*		
ppm	*Range*	4 – 6	3 – 4
ECe	*Average*		
dS/m	*Range*	4.0– 9.28	5.46-13.57
ESP	*Average*		
	Range	6.0 – 36.0	12.0 – 67.0

5.2.2. Salinity:

This property was determined on all of the disturbed pit samples, being measured as the electrical conductivity of the saturation extract in dS/m.at 25c.Percent salt and osmotic pressure were calculated from the electrical conductivity figures and tabulated in appendix (1).The results indicate that in certain profiles salt concentration increases with depth, but in the majority of the pits percent salt concentration increases with depth, but in the majority of the pits percent salt in soil rises with increasing depth and the salt accumulation layer usually lies about 30-150cm below the surface. There appear thus to be a definite leaching process at work enriching the deeper subsoil at the expense of the topsoil.

The electrical conductivity of the saturation extracts ranges between 4.0 to 13.57 dS/m. For topsoil the range is from 4.0 to 9.28 dS/m. For subsoil the range is from 5.66 to 13.57 dS/m. according to the approximate limits of salinity classes as given in the U.S. Soil survey manual, the soils of the area are belonging to class 2 and class 3.The general pattern is one of slightly saline on topsoil; the subsoil is strongly saline in all pits.

5.2.3. Composition of soluble salts:

Twenty nine analyses were made to determine the ionic composition and concentration of soluble salts in the saturation extract each showed a range of values as can be seen from appendix1. Only four cations and four anions were investigated. Sodium was found to be the dominating cation in the majority of the samples.

Among the anions determined chloride and bicarbonate are equally important. The bicarbonate range (1.3- 2.9); whilst chloride range is (16– 94).

5.2.4. Cation exchange capacity:

Cation exchange capacity of samples was determined and the results are shown appenendix1. Values of CEC ranged from 35-70 in related to clay texture..the values for both are nearly identical in may samples. CEC was calculated for all samples the average value was 50 meq/100g soil because the montmorillonite is the dominant clay mineral.

5.2.5. Soluble sodium:

The results as tabulated in (appendix1) indicate that there is a wide range in the concentration of soluble sodium in samples. Concentration as low as 16.0meq. /l and as high as 96.0 meq./l has been recorded.

5.2.6. Exchangeable sodium:

Exchangeable sodium was determined in samples due to the influence of this property on the permeability of soil to water and hence on soil fertility. The results expressed in (appendix1) show a general tendency for exchangeable sodium to increase markedly with depth. The values are relatively high ranging from 3.0 to 31.0 meq /100grams soil.

5.2.7. Exchangeable sodium percentage:

This property was determined for estimation of the alkali status of the soil. The results are shown in appendix1. They show a remarkable increase with depth. According to the standards of the U.S. Soil survey manual, the result for the Profiles indicates that the soils are alkali in the deep layers. Areas surrounding pits 1, 2, 3 and 4 definitely include alkali soils.

5.2.8. Sodium adsorption ratio:

This property has been determined for all samples. The results are shown in (appendix1) they show a positive correlation with exchangeable sodium percentage.of highest sodium adsorption ratios are obtained values all soil sampled of pits.

5.2.9. Exchangeable Potassium:

The results for exchangeable potassium are tabulated in (appendix 1), the values are relatively high ranging from 0.3 to 1.3 meq/100grams soil. Exchangeable potassium due to the influence of this property on the permeability of soil to water and hence on soil fertility. High K effects often similar to high Na, but depends on soil type –especially texture.

5.2.10. Calcium carbonate:

Except for the soils very recently deposited by the river (gerif) calcium carbonate was detected in all the profiles in the form of white nodules ad concretions of various sizes . White calcium carbonate concretions usually occur throughout the profile with their sizes sometimes increasing with depth. Usually they are concentration of calcium carbonate ranged from 2.0%to 10.0%. They are tabulated in (appendix1).

5.2.11. Organic carbon:

This analysis was carried out in 23 samples. The results (appendix1) are more or less uniform and markedly decreasing with depth. The highest recorded content is 0.4% and lowest is 0.2%. Average organic carbon content for topsoil is 0.28%.

5.2.12. Organic nitrogen:

The results of organic nitrogen are tabulated in (appendix1). The content of nitrogen in the soil is low. The topsoil has an average content of 0.24%.
The highest value of organic nitrogen in the soil is 0.03% and the lowest is 0.02%. A notable decrease in organic nitrogen in the soil with depth is indicated by the results.

5.2.13. Available phosphorus (ppm):

The results of available phosphorus are tabulated in (appendix1). The available phosphorus in the soil is low. The topsoil has an average value of 4.12.
The highest value of available phosphorus in the soil is 6.0 and the lowest is 3.0.

5.3. Mapping Units

Main concepts:
Depending on the purpose of a survey, a number of soil and land characteristics need to be determined. For surveys for irrigation projects, these include topography, texture, drainage, permeability, reaction, maximum tolerance of salinity for different crops and ESP. Soils can then be grouped in delineations (map units) according to similarities and differences in key characteristics in relation to irrigation, and accordingly a soil map is being produced.

5.3.1.The main purposes of the alkhojalab soil characterization study area:

1. Define the main soil properties and show their distribution.
2. Assess the land suitability.
3. Recommend suitable soil management and agricultural practices.

5.3.2. Description of soil mapping units

The soils of the area under investigation are not uniform, they are developed on materials laid down by water, and hence the profile is characterized by different textural layers bearing no relationship with each other. Features of genetically profile development are usually lacking or faintly expressed. The differentiation between soils was based mainly on profile characteristics and some properties of the soil as determined in the laboratory have also been utilized in the separation of soil mapping units. These include mechanical analysis of topsoil and subsoil, salinity and alkalinity.

5.3.3Two type of soil mapping units were identified at the Al Khojalab area:

1- Unit 10
2- Unit 20

The soil map is composed of following soil units:

1- Soil unit 10:

According to the results in appendix1, this unit includes pit 1 and pit 2; and auger (11-16) based on the differences in the soil characteristics as below:

- Texture: the clay content (33 – 73), this highest content in clay leads to decreasing in permeability level in the soil.
- Soil reaction (pH): 7.9-8.4
- Salinity: high salinity EC (4 -13.57).
- Sodicity: strongly sodicity ESP (6 – 46).SAR(12-25)

2- Soil unit 20:

According to the result in appendix1, this unit include pit 3 and pit 4; and auger (1-10) based on the differences in the soil characteristics as below:

- Texture: the clay content is (24 - 61), this highest content in clay leads to decreasing in permeability level in the soil.
- Soil reaction (PH): 7.9-8.2
- Salinity: high salinity EC (4.0 -13.53).
- Sodicity: strongly sodicity ESP (6 - 69)SAR(9-23)

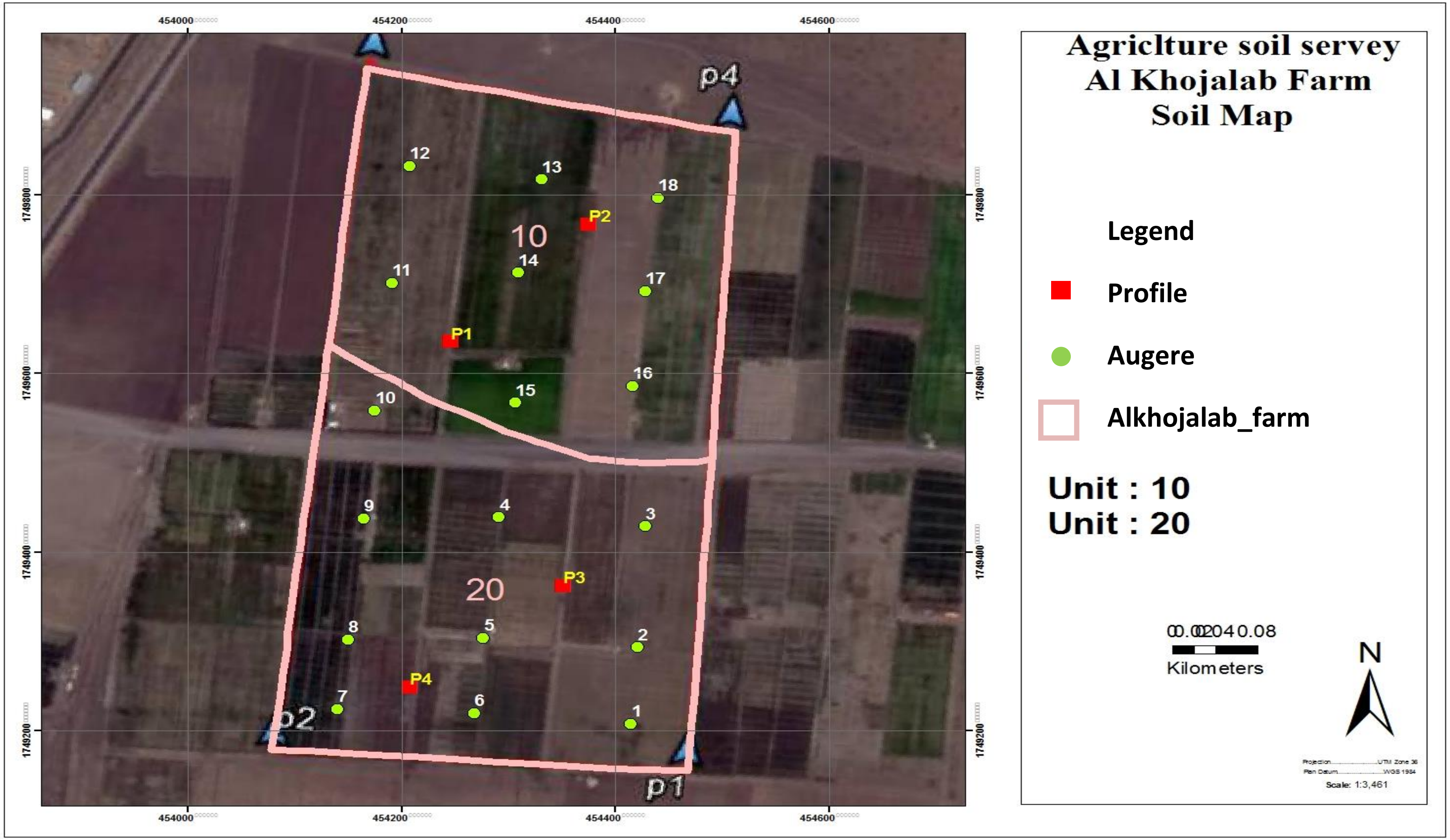
5.4. Land suitability map:

The farm is composed of two suitability class S2 and S3 and subclass. S2sn and S3snp.

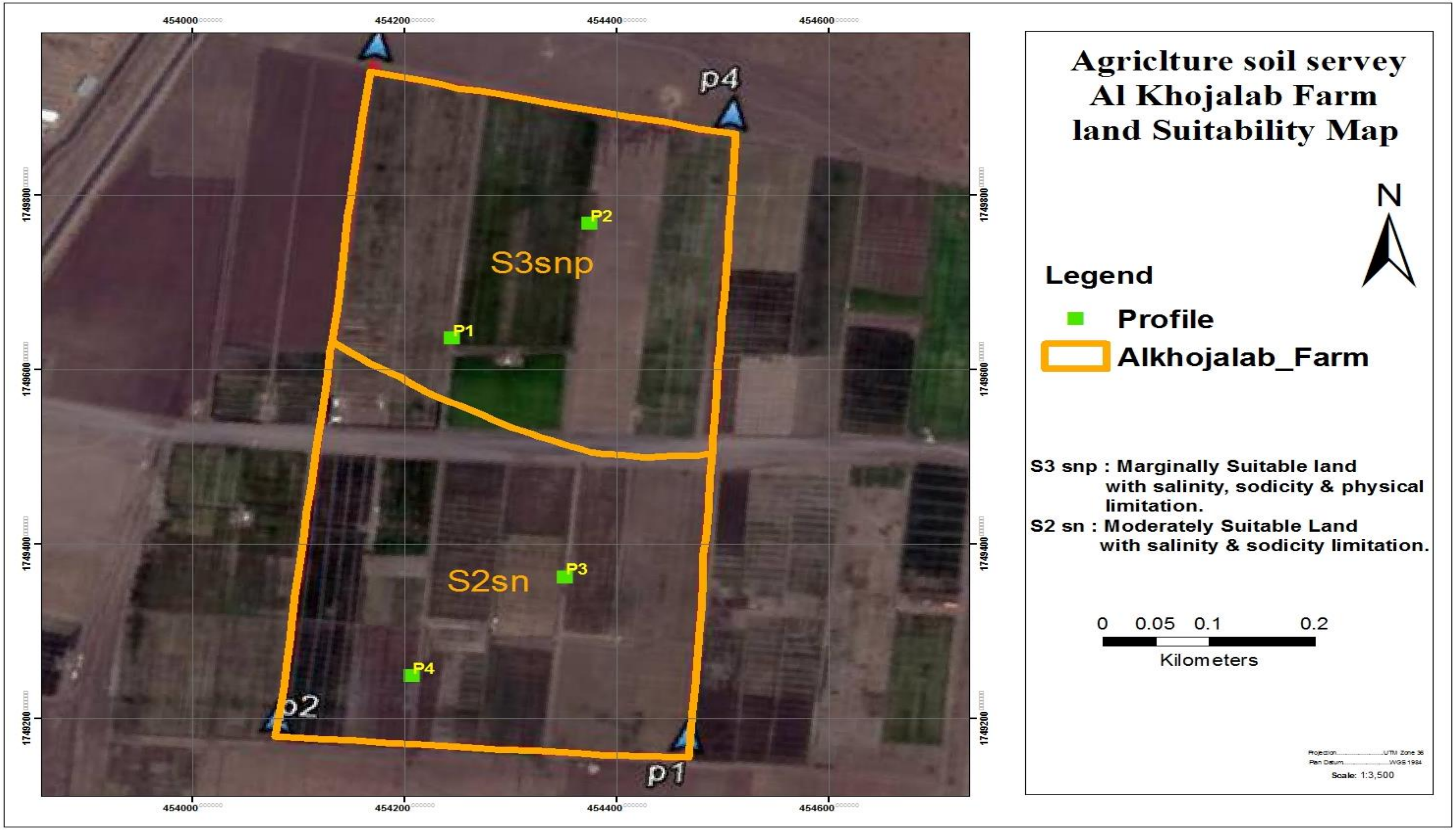
S_{3snp} Unit 10 was classifying as marginally suitable land with main limitations of salinity sodicity and physical properties as permeability.

S_{2sn} Unit 20 was classifying as moderately suitable land due to salinity and sodic limitation

Agriculture soil survey Al Khojalab Farm Soil Map



Agriculture soil survey Al Khojalab Farm Land Suitability Map



5.3. Water analysis:

Table 5.3: The water analysis of Al Khojalab farm.

Water NO.	EC micromas	pH	Na	Ca+Mg	k	SAR	Class
WS_1	1.0	7.2	6.9	3.1	0.4	6	C1-S1
WS_2	1.0	7.3	7.0	3.2	0.4	6	C1-S1
WS_3	0.9	7.3	5.7	3.1	0.3	5	C1-S1
WS_4	0.9	7.2	6.9	2.2	0.3	7	C1-S1
WS_5	0.1	7.2	6.2	3.7	0.3	5	C1-S1

WS (1-5) are water samples which were taken from 5 wells allocated in Alkhojalab farm. The results showed that all the water samples are classified as class C1-S1 as show table 5.7.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The soils of al-khojalab farm have a high levels of salinity and sodicity which made these factors appearing on the top of the main hazards limiting the use of these soils.
2. Salinity, sodicity, imperfect drainage, nutrients availability and seasonal flooding are the main limitations to the use of these soils. The soils are extremely depleted from nutrients. The texture is clay.
3. The field observations and laboratory findings were used for the study of soil genesis and the compilation of a detailed soil map of the area. For this purpose surface soil samples have been analyzed for soil reaction, salinity, sodium adsorption ratio and exchangeable sodium percentage.
4. The results of mechanical analysis of pit samples are tabulated in appendix1. Clay content ranged between the extreme values of 73 %(pit 1=60-80cm) and 24 % (pit 3=0-15cm).The general trend for clay is to increase with depth because it's a clayey soils. The texture in certain profiles remains variable with depth whilst an increase in clay content with depth is observed in all profiles. Siltranged between the extreme value of 24 % (pit 4= 45-80) and 12% (pit 1/pit 2 = 60-80), silt increase with depth is observed in the subsoil in all profiles. Two main textural classes: clayey soils and clayey loamy soils.
5. The soil was divided into two units: 20 and 10; and the suitability are S2 and S3. The subclass is S2sn and S3snp. Both units have a salinity and sodicityclasslimitation, but unit 10 have the highest level of saline and physical limit based on clay content affected on soil permeability.
6. The soil was moderate permeability; it was mildly alkaline throughout the profile and high in exchangeable sodium percentage. Both pH and ESP tend to increase slightly with depth.

Recommendations:

1. Add organic matter to improve soil physical and chemicalproperties.
2. Grow the crops that resistant to salinity as food crops.
3. Follow the agricultural operation in the farm to increase the crop productivity and avoid use the heavy machine in the land preparation and blowing the field.
4. Follow the peasant administration take into consideration the saline and sodic in the region to reduce the negative effects.
5. In the irrigation system takes into account the physical and chemical properties of the soil and water.
6. In the case of planting trees preferred use of the drill has a non-saline soils.

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APPENDICES

Appendix 1

Soil Profile descriptions

And

Laboratory data (profiles and Augare)

Informatiom on the site:

Profile No.: W - 01

Classification: FluventicHaplocambids, fine loamy , mixed, isohyperthermic

Date of examination:JAN 2015

Authors of description Wesal

Location: 0454247 E -1749628 N North Khartoum Bahry Town along the road of Khartoum – Shendi highway.

Elevation:about 463 m

Landform: Plain

Physiographic position: flat site

Lanform of surrounding country: Plain

Micotopography:

Vegetation/Landuse: scattered. Grasses/ grazing/ Sorgum/Alfa Alfa

Climate: tropical semi desert.

General information on the soils:

Parent material: Alluviun

Permeability of subsoil: well drainage

Moisture conditions in the soil : dry almost

Depth of ground water : Very deep not affected the profile

Presence of surface stones: Nil

Evidence of erosion: Nil.

Human influence: Agricultural land

Depth		**Description**
0 – 5	cm	Brownish block (10YR 3/2) dry; clay laom; strong , fine sub angular blocky; slightly sticky; slightly plastic wet, friable and very friable moist, slightly hard dry, very fine tubular pores; common fine and medium roots; modrate calcareous; clear wavy boundary; pH 7.9
5 – 15	cm	Brownish block (10YR 3/2) dry; silty clay laom; strong , fine and medium sub angular blocky; slightly sticky; slightly plastic wet, friable moist, hard dry, very few fine tubular pores; few fine roots; slightly calcareous; clear wavy boundary; pH 8.
15 – 40	cm	Dry dark brown (10YR 3/3) dry; clay; strong , moderate and medium sub angular blocky; sticky plastic wet, firm moist, hard dry, very few fine roots; slightly calcareous; gradual wavy boundary; pH 8.1
40 – 60	cm	Brownish block (10YR 3/1) moist; clay; weak, medium and coarse angular blocky; sticky plastic wet, very firm moist, hard dry; slightly calcareous; gradual wavy boundary; pH 8.2
60 – 80	cm	Brownish gray (10YR 4/1) moist; clay; massive; very sticky and very plastic wet, very firm moist,very hard dry; pH 8.2
80 – 150	cm	Brownish gray (10YR 4/1)moist; clay; massive; very sticky and very plastic wet, very firm moist, very hard dry; pH 8.4

Pit No	Depth Cm	clay %	Silt %	sand %	pH 1:5	ECe dS/m	Exchcations cmol(+) /kg-1				CEC Cmol/kg-1	S.P %	OC %	Total N%
							Ca+ Mg	K	Na	Sum				
1	0-5	33	19	48	7.9	9.14	33.7	1.3	8		43	43	0.4	0.02
	5-15	51	17	32	8.0	9.28	28.2	0.8	16		45	68	0..3	0.03
	15-40	67	20	13	8.1	11.39	29.2	0.8	17		47	71		
	40-60	69	18	13	8.2	11.30	20	1	28		49	73		
	60-80	73	12	20	8.2	13.57	33.2	0.8	27		61	76		
	80-150	57	15	28	8.4	13.57	29	1	26		56	68		

Pit No	Depth Cm	C:N	$CaCO_3$ %	Olsen p ppm	ESP	SAR	Soluble cations ($mmoll^{-1}$)				Soluble anions ($mmol^{-1}$)				
							Ca+ Mg	Na	K	sum	CO_3	HCO_3	Cl_2	SO_4	sum
1	0-5		4	5	19	17	29	64	1.5			2.2	22		
	5-15		4	3	36	17	30	66	1.5			1.6	40		
	15-40		4		36	20	34	84	2.5			2.2	42		
	40-60		3		57	20	33	82	2.5			2	59		
	60-80		2		44	20	45	94	2.5			2.9	94		
	80-150		8		46	9	7	16	0.3			2	38		

Profile No.: W - 02
Classification: FluventicHaplocambids, fine loamy , mixed, isohyperthermic
Date of examination: JAN 2015
Authors of description Wesal
Location: 0454379 E - 1749761 N North Khartoum Bahry Town along the road of Khartoum – Shendi highway.
Elevation: about 463 m
Landform: Plain
Physiographic position: flat site
Lanform of surrounding country: Plain
Micotopography:
Vegetation/Landuse: scattered. Grasses/ grazing/ Sorgum/Alfa Alfa
Climate: tropical semi desert.

General information on the soils:

Parent material: Alluviun
Permeability of subsoil: well drainage
Moisture conditions in the soil : dry almost
Depth of ground water : Very deep not affected the profile
Presence of surface stones: Nil
Evidence of erosion: Nil.
Human influence: Agricultural land

Depth		**Description**
0-5	cm	Brownish block (10YR 3/2) dry; clay laom; strong ,very fine and fine sub angular blocky; slightly sticky; slightly plastic wet, very friable moist, slightly hard dry,; few fine and medium roots; clear wavy boundary; pH 8.1
5-25	cm	Brownish block (10YR 3/2) dry; silty clay laom; moderate , fine and medium sub angular blocky; slightly sticky; slightly plastic wet, friable moist, slightly hard dry,very few fine pores; very few fine roots; clear wavy boundary; pH 8.2
25-60	cm	Brownish gray (10YR 4/1) moist; clay; weak , fine and medium sub angular blocky; slightly sticky ,slightly plastic wet, fairm moist, hard dry; slightly calcareous; very few fine roots. gradual wavy boundary; pH 8.2
60-80	cm	Brownish gray (10YR 4/1) moist; clay; weak, fine and medium angular blocky and sub angular blocky; sticky plastic wet, fairmmoist,very hard dry; gradual wavy boundary; pH 8.2
80-100	cm	Brownish gray (10YR 4/1) moist; clay; massive; sticky plastic wet, firm moist, very hard dry; pH 8.2
100-150	cm	Graysh yellow brown (10YR 4/2) moist; clay; massive; sticky and plastic wet, firm moist, very hard dry; pH 8.3

Pit No	Depth Cm	clay %	Silt %	sand %	pH 1:5	ECe dS/m	Exchcations, cmol(+) kg-1				CEC cmol kg-1	S.P %	OC %	Total N %
							Ca+ Mg	K	Na	Sum				
2	0-5	28	22	50	8.1	4.	46	1	3		50	39	0.3	0.02
	5-25	43	23	34	8.2	8.6	42	1	14		57	55	0.2	0.03
	25-60	45	23	32	8.2	11.75	35	1	27		63	59		
	60-80	63	12	25	8.2	11.8	30.2	0.8	28		59	67		
	80-100	65	15	20	8.2	11.57	42.2	0.8	27		70	69		
	100-150	55	15	30	8.3	13.48	38	1	26		65	65		

Pit No	Depth cm	C:N	$CaCO_3$ %	Olsen p ppm	ESP	SAR	Soluble cations ($mmoll^{-1}$)				Soluble anions ($mmoll^{-1}$)				
							Ca+ Mg	Na	K	sum	CO_3	HCO_3	Cl_2	SO_4	Sum
2	0-5		4	4	6	12	12	29	1.5			1.3	25		
	5-25		3	4	28	22	18	67	1.6			2.2	40		
	25-60		5		43	25	28	88	2.5			1.9	38		
	60-80		3		47	24	29	91	2.5			2	64		
	80-100		3		39	23	27	85	2.5			1.9	36		
	100-150		7		40	9	17	26	0.7			1.6	38		

Profile No.: W - 03

Classification: FluventicHaplocambids, fine loamy , mixed, isohyperthermic

Date of examination: JAN 2015

Authors of description Wesal

Location: 0454355 E - 1749358 N North Khartoum Bahry Town along the road of Khartoum – Shendi highway.

Elevation: about 463 m

Landform: Plain

Physiographic position: flat site

Lanform of surrounding country: Plain

Micotopography:

Vegetation/Landuse: scattered. Grasses/ grazing/ Sorgum/Alfa Alfa

Climate: tropical semi desert.

General information on the soils:

Parent material: Alluviun

Permeability of subsoil: well drainage

Moisture conditions in the soil : dry almost

Depth of ground water : Very deep not affected the profile

Presence of surface stones: Nil

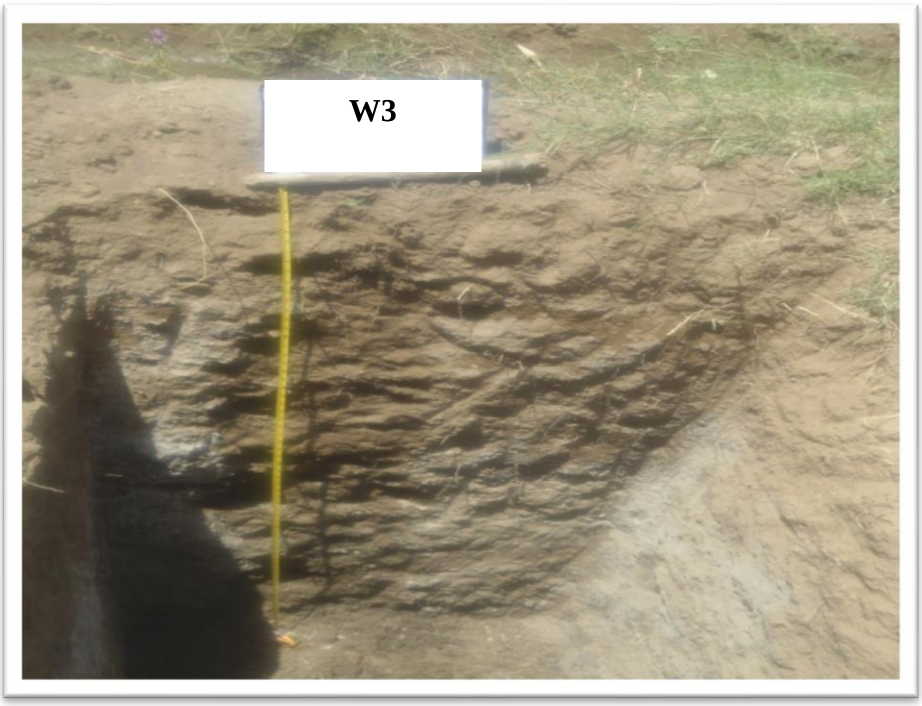
Evidence of erosion: Nil.

Human influence: Agricultural land

Depth		**Description**
0-15	cm	Yellowsh brown (10YR 4/3) moist; clay laom; weak ,very fine and fine sub angular blocky; slightly sticky; slightly plastic wet, friable moist, slightly hard dry,; common fine and medium and coars roots; strong calcareous. ,gradual wavy boundary; pH 7.9
15-35	cm	Yellowsh brown (10YR 4/3) moist; clay laom; weak , fine sub angular blocky; slightly sticky; slightly plastic wet, friable moist, slightly hard dry ,very few fine pores; common fine and medium and coars roots; strong calcareous. gradual wavy boundary; pH 8
35-55	cm	Yellowsh brown (10YR 4/3) moist; silty clay loam; weak ,very fine sub angular blocky; slightly sticky ,slightly plastic wet, friable moist, hard dry; moderate calcareous; very few fine and medium roots. gradual wavy boundary; pH 8.2
55-85	cm	Yellowsh brown (10YR 4/3) moist; silty clay loam; massive, slightly sticky slightly plastic wet, firiable moist, very hard dry; slightly calcareous. Few fine roots .clear wavy boundary; pH 8.2
85-115	cm	Graysh yellow brown (10YR 4/2) moist; clay; massive; sticky plastic wet, friable moist, very hard dry; slightly calcareous, few fine roots . clear wavy boundary; pH 8.2
115-150	cm	Graysh yellow brown (10YR 4/2) wel ; clay; massive; sticky and plastic wet, firm moist, very hard dry 8.2

Pit No	Depth Cm	clay %	Silt %	sand %	pH 1:5	ECe dS/m	Exchcations, cmol(+) kg-1				CEC cmol kg-1	S.P %	OC %	Total N %
							Ca+ Mg	K	Na	Sum				
3	0-15	24	20	56	7.9	4.	43	1.0	3		47	42	0.4	0.02
	15-35	27	22	51	8	5.33	42.2	0.8	5		48	45	0.2	0.02
	35-55	33	23	44	8.2	5.66	42.7	0.3	6		49	47		
	55-85	37	22	41	8.2	10.54	35.7	0.3	16		52	49		
	85-115	44	19	37	8.2	11.83	11.6	0.4	27		39	53		
	115-150	50	17	33	8.2	12.1	14.7	0.3	28		43	58		

Pit No	Depth Cm	C:N	$CaCO_3$ %	Olsen p ppm	ESP	SAR	Soluble cations ($mmoll^{-1}$)				Soluble anions ($mmol^{-1}$)				
							Ca+ Mg	Na	K	sum	CO_3	HCO_3	Cl_2	SO_4	sum
3	0-15		7	6	6	10	15	27	0.4			2.9	20		
	15-35		6	4	10	14	16	40	1.4			1.5	32		
	35-55		6		12	14	17	41	1.5			1.6	25		
	55-85		6		31	17	36	74	2.5			1.8	21		
	85-115		10		69	22	31	88	2.5			2.0	16		
	115-150		4		65	23	34	96	2.5			2.3	22		

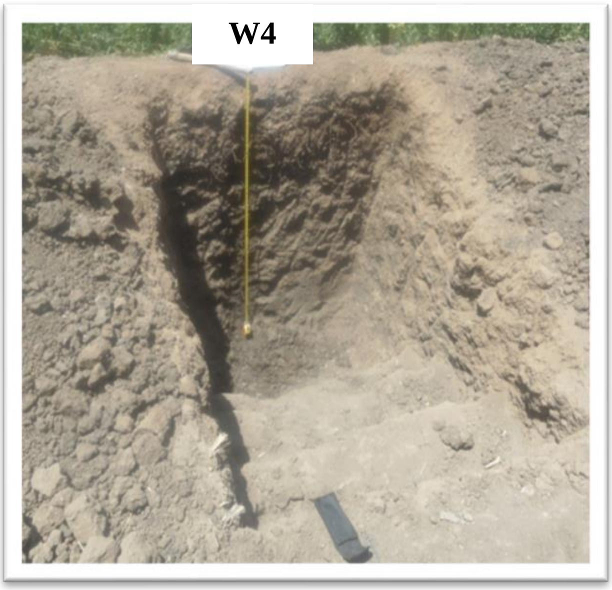


Profile No.: W - 04
Classification: FluventicHaplocambids, fine loamy , mixed, isohyperthermic
Date of examination: JAN 2015
Authors of description Wesal
Location: 0454212 E - 17499252 N North Khartoum Bahry Town along the road of Khartoum – Shendi highway.
Elevation: about 463 m
Landform: Plain
Physiographic position: flat site
Lanform of surrounding country: Plain
Micotopography:
Vegetation/Landuse: scattered. Grasses/ grazing/ Sorgum/Alfa Alfa
Climate: tropical semi desert.
General information on the soils:
Parent material: Alluviun
Permeability of subsoil: well drainage
Moisture conditions in the soil : dry almost
Depth of ground water : Very deep not affected the profile
Presence of surface stones: Nil
Evidence of erosion: Nil.
Human influence: Agricultural land

Depth		**Description**
0 – 25	cm	Red (5YR 5/6) wet; clay loam; strong ,very fine and fine sub angular blocky; slightly sticky; slightly plastic wet, very friable moist, slightly hard dry,; common fine and medium and cores roots; very few fine pores; gradual wavy boundary; pH 8
25 – 45	cm	Brownish block (10YR 3/2) wet; silty clay loam; strong , fine sub angular blocky; slightly sticky; slightly plastic wet, very friable moist, slightly hard dry, very few fine pores; few fine and medium roots; slightly calcareous; gradual wavy boundary; pH 8.1
45 – 80	cm	Brownish block (10YR 3/2) wet; clay; weak , fine and medium sub angular blocky; slightly sticky ,slightly plastic wet, very friable moist, hard dry; slightly calcareous; very few fine roots. Gradual smooth boundary; pH 8.2
80 – 105	cm	Brownish block (10YR 3/2) moist; clay; massive; sticky plastic wet, fairm moist, very hard dry; slightly calcareous; gradual smooth boundary; pH 8.2
105 – 150	cm	Brownish block (10YR 3/2) wet; clay; massive; sticky plastic wet, firm moist, very hard dry; slightly calcareous pH 8.1

Pit No	Depth Cm	clay %	Silt %	sand %	pH 1:5	ECe dS/m	Exchcations, cmol(+) kg-1				CEC cmol kg-1	S.P %	OC %	Total N %
							Ca+ Mg	K	Na	Sum				
4	0-25	35	18	47	8.0	4.44	31	1.0	3		35	47	0.3	0.03
	25-45	45	20	35	8.1	5.46	27	1.0	8		36	63	0.2	
	45-80	50	24	26	8.2	13.20	13.2	0.8	28		42	65		
	80-105	52	22	26	8.2	13.51	13.7	1.3	29		44	67		
	105-150	61	19	20	8.1	13.55	18	1.0	31		50	71		

Pit No	Depth cm	C:N	$CaCO_3$ %	Olsen p ppm	ESP	SAR	Soluble cations ($mmoll^{-1}$)				Soluble anions ($mmol^{-1}$)				
							Ca+ Mg	Na	K	sum	CO_3	HCO_3	Cl_2	SO_4	sum
4	0-25		8	4	9	9	16	26	1.5			1.8	29		
	25-45		6	3	22	13	18	38	1.6			2.1	24		
	45-80		5		67	22	36	92	2.5			2.1	42		
	80-105		4		66	19	47	93	2.5			2.2	55		
	105-150		3		62	20	47	96	2.8			2.2	58		



Ag No.	NO.	Clay	Silt	Sand	TEX.	PH	EC	Mois
1	1	51	14	35	CL	7.2	3	3
	2	55	14	31	CL	7.4	5	4
	3	49	20	31	CL	7.6	6.7	4
2	4	47	15	38	CL	7.6	2.8	3
	5	57	19	24	CL	7.8	4.1	4
	6	53	24	23	CL	7.9	3.3	3
3	7	45	14	41	CL	8	3.2	3
	8	55	21	24	CL	8.2	6.8	3
	9	47	25	28	CL	7.5	8.1	4
4	10	46	21	33	CL	7.4	3.4	4
	11	48	19	33	CL	7.5	5.1	4
	12	51	20	29	CL	7.7	6.8	4
5	13	45	22	33	CL	7.9	3	3
	14	50	23	27	CL	8	2.1	4
	15	48	28	24	CL	8.1	2.2	3
6	16	62	19	19	CL	8.2	3.7	4
	17	59	17	24	CL	8.4	6.1	3
	18	64	22	14	CL	8.5	8	4
7	19	61	20	19	CL	8.3	3.7	3
	20	66	19	15	CL	8.5	7.4	4
	21	69	17	14	CL	8.6	8.8	4
8	22	33	27	40	CL L	8.3	3.8	2
	23	63	22	15	CL	8.6	7.9	4
	24	47	29	24	CL	8.7	8.8	3
9	25	35	25	40	CL L	8.3	2.8	2
	26	44	27	29	CL	8.5	6.2	3
	27	41	29	30	CL	8.6	7.5	3

Ag No.	NO.	Clay	Silt	Sand	TEX.	PH	EC	Mois
10	28	37	22	41	CL L	7.8	3.6	3
	29	43	23	34	CL	7.8	4.9	3
	30	69	17	14	CL	7.9	9.7	4
11	31	60	21	19	CL	7.8	3.6	4
	32	72	14	14	CL	8	7.7	4
	33	77	14	9	CL	7.9	9.1	4
12	34	61	15	24	CL	7.8	3.8	4
	35	73	13	14	CL	8	3.7	4
	36	75	13	12	CL	7.9	6.1	4
13	37	63	12	25	CL	7.8	3.6	3
	38	67	14	19	CL	7.9	4.6	3
	39	71	14	15	CL	7.9	7.2	3
14	40	65	12	23	CL	7.9	3.8	4
	41	69	17	14	CL	7.9	6	3
	42	75	13	12	CL	8.1	8.4	4
15	43	67	15	18	CL	7.9	4.1	4
	44	70	19	11	CL	8	7.2	3
	45	72	15	13	CL	8	7.5	3
16	46	63	12	25	CL	8	4.6	3
	47	71	17	12	CL	8.2	8.5	3
	48	77	15	8	CL	8.3	9.2	4
17	49	53	17	30	CL	8.2	1.9	3
	50	67	13	20	CL	8.1	5.3	3
	51	65	20	15	CL	8.1	6.6	3
18	52	63	19	18	CL	8.2	1.9	3
	53	65	21	14	CL	8.1	5.9	3
	54	69	22	9	CL	8.2	7.4	3