بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

An Enhanced Soil Health Card Method for Soil Quality Assessment towards Improving Land Management Practices

Case study: Khartoum State. Sudan

تعزيز طريقة أورنيك صحة التربة بغرض تقييم جودتها لتحسين عمليات إدارة الأراضي

منطقة الدراسة ولاية الخرطوم - السودان

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الآيـــة

قال تعالي:

{وَتَرَى الْأَرْضَ هَامِدَةً فَإِذَا أَنزَلْنَا عَلَيْهَا الْمَاءَ اهْتَزَّتْ
وَرَبَتْ وَأَنبَتَتْ مِن كُلِّ زَوْجٍ بَهِيجٍ}

صدق الله العظيم

سورة الحج - الآيه رقم
(5)

Dedication

MY PARENTS, FATHER AND MOTHER

THE SOUL OF MY BROTHER LOAIY ABD ELRAHIM KHOJALY

MY KIDS AND HUSPAND.

MY BROTHERS AND SISTERS.

MY TEACHER ELABBAS DOKA

I HOPE ALLAH OFFER THEM HEALTH AND PROSPERITY.

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Finally my great thank to Department Of soil Survey \Ministry Of Agriculture \Khartoum State.

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Glossary of Special Terms and Abbreviations

NRCS	Nautral Resources Conservation Service (USDA)
USDA	United State Department Of Agricultuer
SQI	Soil Quality Institue
ARC	Agricultural Researchers Corporation
USA	United state Of America
FAO	Food and Agricultuer Organization
NT	No Tillage
CT	Conservation Tillage
IRRI	International Rice Research Institue
EC	Electrical Conductivity
ESP	Exchangeable Sodium Percent
CEC	Cation Exchange Capacity
SAR	Sodium Adsorption Ratio
CHM	Chicken Manure
PSI	pound\ $inch^2$

ABSTRACT

Soil quality is the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries to sustain plant and animal productivity; maintain or enhance water and air quality and support human health and habitation. Soil function describes what the soil does. The terms soil quality, soil health, and soil condition are all interchangeable. Soils vary naturally in their capacity to function; therefore, ***quality is specific to each kind of soil.*** This concept encompasses two distinct but interconnected parts: ***inherent*** quality and ***dynamic*** quality. Characteristics, such as texture, mineralogy, etc., are innate soil properties determined by the factors of soil formation climate, topography, vegetation, parent material, and time. Collectively, these properties determine the inherent quality of a soil. They help compare one soil to another and evaluate soils for specific uses. For example, all else being equal, a loamy soil will have a higher water holding capacity than a sandy soil; thus, the loamy soil has a higher inherent soil quality. This concept is generally referred to as soil capability. Map unit descriptions in soil survey reports are based on differences in the inherent properties of soils.

More recently, soil quality has come to refer to the dynamic quality of soils, defined as the changing nature of soil properties resulting from human use and management. Some management practices, such as the use of cover crops, increase organic matter can have a positive effect on soil quality. Other management practices, such as tilling the soil when wet, adversely affect soil quality by increasing compaction. In this research, soil quality refers to the dynamic quality of soil those properties that are affected by management. Soil quality evaluation is a tool to assess management-induced changes in the soil and to link existing resource concerns to environmentally sound land management practices.Soil quality assessments are thus used to evaluate the effects of management on the health of the soil.

Having such concept into consideration, the Natural Resources Conservation Service in USDA (NRCS, 2001) has produced guidelines for soil quality assessment in order to monitor, manage and prevent soils from incidence of deghradation hazards. Within this context, NRCS has developed a health card intended to be utilized in collaboration with the farmers, scientists, agriculture research centers and extension especialists. This health card is a collection of procedures that assess changes in in soil qualities through identifying relevant soil indicators that are affected by different aspects of field mannagement. These indicators can be of physical, chemical or biological soil properties and/ or crop conditions related to soil characteristics.

The aim of this study is to present procedures to provide information for performing soil quality assessments at Khartoum State, Sudan. Khartoum state was chosen to apply the procedure for designing ,adapting and producing soil ***health card*** based on accumulated information by farmers and researchers on soil properties, their use and management at different parts of Khartoum State. This will enable assessing the impact management on soil qualities and to identify and diagnoses reason problems in addition to monitor hazards caused by mismanagement .The complete procedures of the health card could be used for informal

soil quality assessment but the included rating chart could be used for quick assessment. The soil health card is composed of four parts in one leaflet. The first part shows the farmer important of soil health and quality and how to maintain it. The second part contains indicator that found in the area to advance soil management. The third part contains the results of laboratory soil analysis. The fourth part shows how to take the field soil sample and some of the observations on management practices (tillage, fertilizer, irrigation, crop system) and eventually allows space for remarks and recommendation for soil conservation. The health card is intended to be used by farm managers and knowledgeable farmers with some support from local extension officers. Other States in Sudan could modify Khartoum health card for soil quality assessment to suit their soil conditions that might have different indicators.

المستخلص

جودة التربة هو مقدرة التربة لأداء وظيفتها داخل حدود النظم الإيكولوجية الطبيعية أو تتم ادارتها للحفاظ على انتاجية النباتات والحيوانات وايضا المحافظة وتحسين جودة الماء والهواء ودعم صحة الانسان واستقراره. وتعكس وظيفة التربة مهام التربة. المصطلحات جودة التربة او صحة التربة او حالة التربة مترادفات، اذ ان التربة تختلف بطبيعة الحال في قدرتها لا داء وظائفها؛ ولذلك الجودة هي التي تميز بين انواع الترب. هذا المفهوم يشتمل علي جزئيين مترابطين: وهما جودة التربة الوراثية و الديناميكية (المتغيرة). الخصائص مثل القوام والمعادن، إلخ، خصائص وراثية تحددها عوامل تكوين التربة، المناخ، والتضاريس، والغطاء النباتي، مادة الأصل، والزمن. هذه الخصائص مجتمعة تحدد الجودة الوراثية للتربة وهي تساعد في المقارنة والتقييم بين الترب لاستخدامات المحددة. على سبيل المثال، اذا تساوت كل الخصائص في تربتين، فان التربة الطمئية قدرتها على الاحتفاظ بمياه أعلى من الرملية؛ وهذا يعني ان، التربة الطمثية أعلى جودة من ناحية تربة الأصل. هذا المفهوم هو عموما يرجع إلى صلاحية التربة و خريطة التربة و تقارير مسح التربة تستند إلى الاختلافات في الخصائص الوراثية للتربة.

في الآونة الأخيرة ظهر مفهوم جودة التربة للإشارة إلى الجودة الديناميكية وتعرف بأنها التغيير الطبيعي لخصائص التربة الناتج عن الإدارة و استخدام الإنسان. بعض الممارسات الإدارية، مثل استخدام محاصيل التغطية، تؤدي الى زيادة المواد العضوية وبالتالي جودة التربة أيضا البعض الأخر، مثل حراث التربة عندما تكون رطبة، يؤثر سلبا على جودة التربة عن طريق زيادة الانضغاط. في هذه الدراسة تشير جودة التربة إلى الجودة الديناميكية لتلك الخصائص التي تتأثر بالإدارة. تقييم جودة التربة أداة لتقييم التغيرات الناتجة من إدارة التربة وأيضا لربط مفهوم المحافظة علي الموارد القائمة بممارسات الإدارة السليمة بيئياً للأراضي. وتستخدم تقييمات جودة التربة لتقييم آثار الإدارة على صحة التربة.

وبأخذ هذا المفهوم في الاعتبار ,انتجت ادارة الموارد الطبيعية في الولايات المتحدة الامريكية دليل لتقييم وقياس جودة التربة وكيفية ادارة وحماية التربة من التدهور .ومن هذا السياق تم تطوير كرت صحة التربة بالتعاون مع المزارعين والباحثين والمرشدين والخبراء ,وهذا الكرت عبارة عن اجراءات تجمع لتقييم التغيرات التي لجودة التربة من خلال التعرف مؤشرات التربة التي تأثرت بمختلف اوجه العمليات الفلاحية لإدارة الحقل ,وهذه المؤشرات قد تكون فيزيائية ,كيمائية وحيوية لها علاقة بخصائص التربة.

الهدف من هذه الدراسة تقديم إجراءات لتوفير المعلومات لإجراء تقييم جودة التربة في ولاية الخرطوم، السودان. تم اختيار ولاية الخرطوم لتطبيق الإجراء لتصميم واقلمة كرت صحة التربة استناداً إلى المعلومات المتراكمة من المزارعين والباحثين عن خصائص التربة، لاستخدامه وإدارته في أجزاء مختلفة من ولاية الخرطوم .و هذا الكرت 'يمكن من تقييم مخاطر ادارة التربة علي جودتها وايضا تشخيص الاسباب التي ادت للمشكلة بالإضافة الي قياسها .الإجراءات الكاملة للبطاقة الصحية التربة يمكن استخدامها لمعرفة جودة التربة ولكنها تضمن علامات يمكن استخدامها بطريقة تقديرية للتقييم السريع في الحقل.

كرت صحة التربة يتكون من أربعة أجزاء في منشور واحد, ويبين الجزء الأول للمزارع اهمية صحة التربة وجودتها وكيفية المحافظة عليها والجزء الثاني يعرض المؤشرات الموجودة في المنطقة لتحسين إدارة التربة، أما الجزء الثالث يحتوي على نتائج تحليل التربة في المختبر. الجزء الرابع يوضح كيفية أخذ العينة من تربة الحقل وبعض الملاحظات على الممارسات الفلاحية مثل (الحرث، والأسمدة، والري، الدورة الزراعية)، وفي نهاية الصفحة يتيح مساحة للملاحظات والتوصيات للمحافظة علي التربة. البطاقة التربة الصحية تم اعدادها للاستخدام من قبل مديري المزارع والمزارعين ذوي المعرفة مع بعض الدعم من موظفي الإرشاد المحليين. يمكن للولايات الأخرى في السودان تعديل بطاقة التربة الصحية لولاية الخرطوم لتقييم جودة التربة لتلائم خصائص التربة المحلية للولاية المعنية حيث قد يؤدى تباين الخصائص الى اختلاف مؤشرات جودة التربة.

CHAPPTER ONE
INTRODUCTION

1.1 Background

More than four decades of research and development work in Africa have not resulted in the 3-5% annual increase in agricultural growth necessary for most African countries to ensure sustainability of agriculture and the promise of food security in the next decade (Badiane and Delgado, 1995). With the new emphasis on sustainable agriculture comes a reawakening of interest in soil health. Early scientists, farmers, and gardeners were well aware of the importance of soil quality. As soil quality has emerged as a leading concept in natural resource conservation and protection, stronger emphasis is now being placed on the relationship between specific dynamic soil properties and soil performance. Enhancement of these dynamic soil properties is the goal of soil quality management. Achievement of water quality, air quality, and carbon sequestration goals rely on improving soil quality. For example, one typical method for improving soil quality by increasing organic matter involves reducing tillage, a fundamental practice for reducing erosion. Decreasing erosion improves water quality by reducing sediment runoff. In areas subject to wind erosion, conservation tillage reduces the amount of particulate matter in the air. Thus, reducing tillage to improve soil quality also benefits erosion control, air quality, and water quality goals.

Soils around Khartoum being part of semi-arid environment are subjected to problems of soil salinity and sodicity that are associated with various physical, chemical and biological soil limitations that restrict the productivity of the land. More than 80% of south Khartoum lands belong to class S3 (marginal agricultural lands) due mainly to fore mentioned limitations (Van der Kevie and Eltom. (2004) As well most of the old alluvium deposits on the eastern upper terraces of the Nile north of Khartoum suffer from same limitations beside the relatively high content of calcium carbonate ($CaCO_3$). The higher terraces on the western side of the River Nile are composed mostly of residual gravelly yellow reddish soils formed on Nubian sandstone. Limited depth, moisture deficiency and lack of fertility are the main limitations.

Some management practices, such as the use of crop residues to increase organic matter can have a positive effect on soil quality. Other management practices, such as tilling the soil when wet, adversely affect soil quality by increasing compaction. In recent years there has been increasing interest in the concept of soil health, which consider all aspects of soil, that is, physical structure, chemical components and biological life, rather than looking at each of these separately. A soil does not have to be agriculturally productive to be healthy. However, many agricultural practices can make soils less healthy than they were in their natural state.

By managing physical, chemical and biologica soil properties, farmers can work soils within their capabilities so that the soils are able to recover from agricultural disturbance without being degraded. Many countries that devolped agriculture and increased crop production per unit area have created amendment tools, one of these tools is careful management of soil quality. United State of America (USA) is one of these countreis that have early discusse on soil health. Naural Resources Conservation Service (NRCS) unit of the United States Departement of Agriculture (USDA), established Soil Quality Institute (SQI) to assess, manage and maintain the soil from degradation (NRSC 2001). The SQI has developed a health card that is intended to be utilized collaboratively by local farmers, ARC scientists and extension specialists. The Health Card is used to assess changes in soil quality that are affected by field management. Soil quality assessments are conducted by evaluating *indicators*. Indicators can be physical, chemical, and biological properties, processes, or characteristics of soils. They can also be morphological or visual features of plants. Indicators are measured to monitor management induced changes in the soil.

1.2 Soil Quality Assessment

In this study, Khartoum state was chosen to design soil health card depending on results of research studies that were carried to advance and managing agriculture practice. It attempts to upgrade and sustain agriculture in Khartoum State so as to meet the increasing demand for agricultural products in the expanding urban towns and to improve the socio-economic status of the rural population in the State. Therefore, tools to increasing the yield per unit area through creating good soil condition to the plant and maintain the soil for coming generations. In this regard, the enhancing of soil health - in all its aspects, not just nutrient levels - is probably one of the most essential strategies in developing countries to ensure the provision of nutritious food for the people and as well maintaining the soil resources for next generations.

Qualitative assessments have an element of subjectivity and, thus, are best done by the same person over time to minimize variability in the results. Indicators measured with a quantitative method have a precise, numeric value. Therefore, different people conducting the same measurement should be able to produce very similar results. Qualitative assessments usually can be done simply and quickly, and producers can complete them unassisted. If tools are required, they are usually simple and easily obtained. However, because of the subjective nature of the qualitative assessment, results can not be compared to any .target. levels for soil properties, nor should results be compared among different users or different farms. Although more time consuming and sometimes more complex, quantitative assessments are more appropriate to use when different people will be conducting the assessment over time or when there is interest in comparing soils to some target level based on soil surveys or other data.

A variety of methods or approaches are currently used to measure and assess soil quality in USA. The methods discussed range from primarily qualitative to purely quantitative. They are as follows:

- Soil Health Card
- NRCS Soil Health Card Template (NRCS Template)
- Soil Quality Test Kit
- Laboratory analysis

These methods provide important information about soil quality, whether the goal is to determine changes in soil health over time or to compare management effects on soil quality in different fields or pastures. Various combinations of these methodologies may be used. No single one is inherently better or more effective(NRCS 2001) .In this the health card was adapted as a combinations of these methodologies.

1.3 Research problem

Many agricultural practices can make soils less healthy than they were in their natural state, this lead to decreases in the yield. By managing physical, chemical, and biological characteristics in the soil, farmers can work soils within their capability so that the soils are able to recover from agricultural disturbance without being degraded more .

1.4 Research objectives

1. To design, adapt and produce soil health card for Khartoum State to assess the impact of field management on soil quality and to identify soil resource problems.
2. The produced soil health card will enable monitoring trends in one or more fields over time due to impact of management. As well, this will keep records of soil quality and detect soil quality changes over time.
3. The assessment of soil quality procedures leads to diagnosing causes of problem areas.
4. The health card will help in communicating the management practices and associated soil quality problems with specialists at ARC, universities, and agricultural industry professionals.

CHAPTER TWO
STUDY AREA

2. Environmental set up:

2.1 Location and extent:

Khartoum state lies between longitudes 31.5 -34 east and latitude 15-16 north in an area about 28.165 square kilometers. It is bordered on the north, and the east sides by the River Nile State, on the northwestern side by the Northern State, and on the eastern and southern sides by Kassala, Gedaref and Gezira States figure(1). (www.mhd.gov.sd/english/index.php?option=com...id

Figure 1:The location of the study area

2.2 Climate:

The climate data was taken from Shambat Meteorological Observatory Station (Tables) which is the centrale to the location of site. . Potential evapotranspiration figures are generated by programme of FAO (Adam, 2005). The classification of climate by Papadakis which is based on water balance, using monthly rainfall and potential evapotranspiration is adopted by Kevie (1976) for classifying climatic zones of khartoum state Temperature regime in Papadkis classification falls in the semi-desert climate with summer rain (average annual rain fall 100-225), warm winter . Table(1).

Table 1. Climatic Zones in the Sudan

Symbole	Climatic zone	Humid months	Dry months	Growing season	Average annual rainfall (mm)	Mean max. temp. in hot. Month	Mean min. temp. in col. Month	Diagnostic characteristic
D3.1	Semi-desert, summer rain , warm winter.	0	12	0	100-225	40-42	13-16	Rw=0.2-0.5E Tc >13.
A1.1	Arid, summer rain, warm winter .	0	10-11	1-2	225-400	40-42	13-17	Rw=0.5.-1.0WTc< 13.

Ssource\ Van der Kevie, and Eltom.(2004).

According to Abu Sin and Davies, (1991) there arc four seasons in the year. The first is the cooler winter season covering the period mid - November to March. By the end o f March daily mean maximum temperature is 40 C and the hot dry season is well in placc. By the quintile (5-day period) beginning 23 may the temperatures peak is 44.1 C and odd days with temperature over 45 C must be expected. In most years the weather stays mainly dry until the end of June, and indeed throughout the period March to June relative humidity remains typically below 30%. On relatively infrequent occasions showers occur as early as April or May, but in many years it is June before any significant, precipitation is noted. The growing instability can lead to dust storms (haboobs) and earosion hazard. Table (2): Khartoum

Table 2. Climatic Data for the Years 1971 to 2000. (Lat.: 15º 36 N; Long.: 32º 33 E; Alt. 380 m.)

Month	Mean relative Humidity (%)	Total rainfall (mm)	Potential Evapo-transpiration (mm)	Mean wind speed and direction (m/s)	Air temperature		Mean daily temp.(ºC)	Bright Sun shine duration (%)
					Mean daily maximum	Mean daily minimum		
January	26	0.0	143	4. 5 –N	30.7	15.6	23.2	86
February	21	0.0	147	4. 9-N	32.6	16.8	24.7	85
March	16	0.1	196	4. 9-N	36.5	20.3	28.4	82
April	15	0.0	198	4 .5 –N	40.4	24.1	32.7	84
May	20	3.9	205	4 –N	41.9	27.3	34.6	74
June	26	4.2	201	4. 5 - SW	41.3	27.6	34.4	68
July	42	29.6	189	4. 9 - SW	38.5	26.2	32.3	63
August	48	48.3	177	4. 5 -SW	37.6	25.6	31.6	66
September	41	26.7	162	4. 0-SW	38.7	26.3	32.5	71
October	29	7.8	167	3. 6 –N	39.3	25.9	32.6	83
November	26	0.7	150	4. 5 –N	35.7	21.0	28.1	91
December	29	0.0	140	4. 5-N	31.7	17.0	24.4	90
Year	28	121.4	2065	4. 5	37.0	22.8	29.9	79

The average annual rainfall is about 147.5 mms, with most of the rain falling in June – October. The amount is quite variable and distribution is rather erratic and irregular

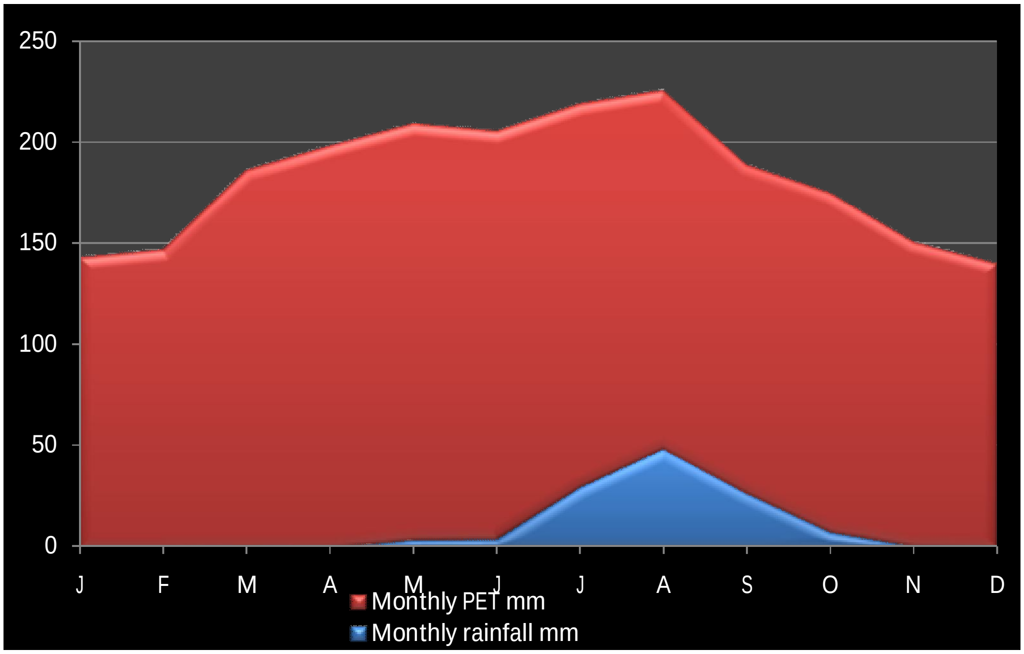


Figure 2. Monthy rainfall and potential evapotranspiration for Khartoum town

The combined effect of high temperature strong solar radiation caused the potential evapotranspiration to be very high and significantly exceeds the rainfall in all months (Fig1.). This means that the soil water available for the plan growth is deficient and crop production must be based on irrigated farming system. The average wind speeds is about 11m/s and increases to maximum in the hot dry summer (April-May) causing dust storms (Haboob) and erosion hazards. The winds occur frequently in northerly direction from October to May. By late June the wind move to south westerly direction due to the approach of inter-tropical convergence zone causing slight and variable rainfall. As a control measure, wind breaks and shelter belts are prerequisites to protect the rangelands, agricultural lands and crops (Table 2).

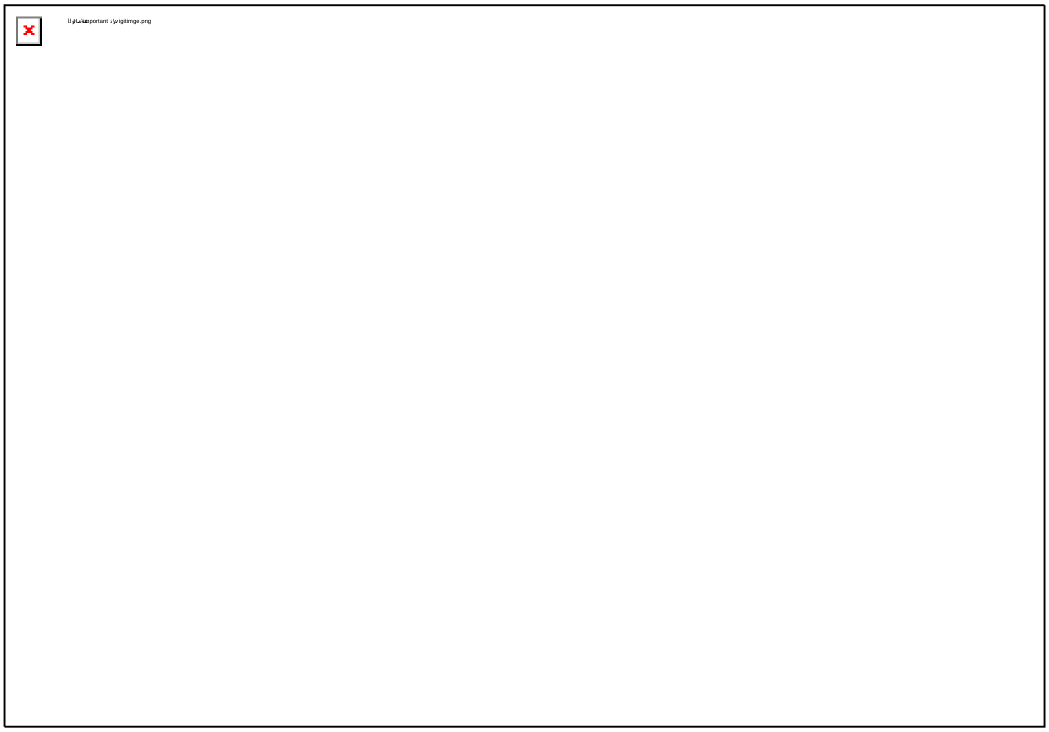
2.3Vegetation

The whole area of Khartoum state falls in the semi-desert ecological zone as depicted by Jackson and Harrison (1958) in their vegetation map of the Sudan produced (prepared by Hydrogeological Information Center Ground Water&Wadies Administration M.O.I& Water Resources. three minor subdivision of the semi-desert ecological zone prevail namely ;

1. Acacia tortilis-Maerua, crass folia desert scrub; this is occupying more than 90% of state area.

2. Avery small portion exists that lies in the extreme North West named semi desert grass land on sand.
3. 3-Another very small portion of the state lying on the South East is named semi-desert grassland on clay (part to the Butaan plain).

The natural grazing area in the state is estimated as 40% of the total area. The annual grasses about 75% of the natural vegetation. Perennial grasses and shrubs trees cover about 5% and 20% respectively Figure (3) .



Source\-ministry of agriculture of Khartoum

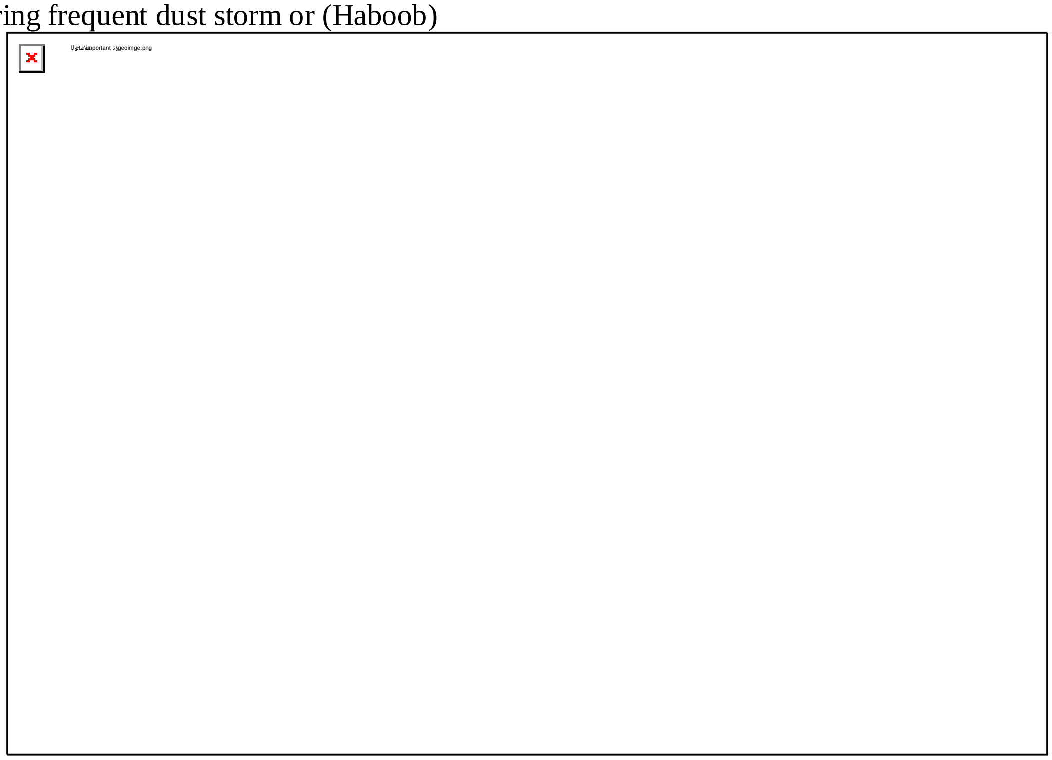
Figure 3. Vegetation map of Khartoum state

2.4 Geomorphology and Soil

The geological map (Whiteman, 1971) shows that geologic setting is composed of Basement Complex, Omdurman formation, and the Gezira Formation. The basement complex consists of acid grey gneisses and granite. Omdurman Formation is composed of a sequence of sandstone, conglomerate and mudstone, of more than 400 m thick, which rests uncomfortably on the Basement complex. Gezira formation covers the area between the Blue and White Nile, and small strip east of the Blue Nile. It consists of a sequence of unconsolidated interceded clay, silt, sand and gravel layers. Calcarete and Salt rocks are Characteristic features of the upper part of Gezira and Omdurman formation. The Thickness of Gezira formation ranges from few meters to more than 80 m. Omdurman and Gezira formations encompass the minor aquifer systems Figure (4) The soils arc natural resources and constitute one o f the fundamental basis of both urban and rural life. The soils in the area have been formed in moisture regime, which may be described as dry (tropic) and a soil temperature regime, which is hot (hypothermic) according to the soils survey (Soil Survey Division, 1976).

The lack of vegetation indicates that little organic matter will be available and in most cases profile development will be limited, although salt accumulation can be troublesome under certain condition. However, in and around the major centre of population in Sudan, the effect o f human beings on these soils, and the anthropogenic factor, are strong. The geological substrata for these soils are presented in Figure (4).

-The Nubian sandstone.
- The Gezira clays.
-The sand o f Qoz Abu Dulu.
-The alluvia o f the Nile and their terraces.
-Small rocky outcrops o f the Basement Complex.
-Various local alluvial deposits in the wadis.
These geological units weather to produce the parent materials for the formation o f soils. The strong difference in character between them is reflected in the morphology of the land forms o f the area. So these relationships may be used on the analysis of the soil pattern of the capital region. In addition, a significant amount of wind-blown materials is added to the soil during frequent dust storm or (Haboob)



Source:Ministry of Agriculture of Khartoum

Figure 4. The Geological map of Khartoum state

2.5 Human activity and infrastructure .

2.5.2 Land use

Crop production in the Khartoum State is oriented towards the major kind of land use which is irrigated agriculture. The main agricultural land use categories are:

1. Horticultural crops: Intensive cropping of fruits (citruses, dates, mangoes and guava) and vegetables (tomatoes, potatoes, cucumbers, beans, peas, chick peas, onions etc…).
2. Arable crops: Mainly field crops (wheat, sorghum or maize) and fodder crops (Alfalfa or Abu Sabeain).

3. Mixed farming: A combination of arable farming with animal production (poultry and dairy) and recently protected houses farming are all increasingly practiced around Khartoum state.

The two main categories (Horticulture and arable farming) have different soil requirements both physical and chemical. The infrastructure and services to support agricultural activities is well established, especially for agricultural activities on riverain lands. Extension, pest and disease control, protection and treatment of animal diseases are widely known services around the Khartoum State. There are three cropping seasons in this area:

1. Winter season (Shetwi) November – February:
   The most active season, Arable crops include wheat, broad beans, onions and vegetables include tomatoes, egg plant, potatoes, carrots and beans, in addition to spices (chilies', garlic, kasbara and kamoun)
2. Flood season (Khareef or Damera near the river) July – September: Arable crops include sorghum, maize, fodders and summer vegetables.
3. Summer season (Sayfi) March – June : Fodder crops

Khartoum area is considered as one of potential agricultural areas in Sudan for the production of different kinds of tropical fruits beside most winter vegetables and field crops. As well fodders crops are widely grown throughout the year. All these agricultural products, particularly vegetables, fruits and fodders are profitably exportable to the close neighboring Middle East demanding countries.

2.5.3 Economic opportunities

Lack of infrastructure has had a negative impact on food security, for example by limiting the marketing possibilities for moving food from surplus to food-deficit areas. Economic opportunities are also restricted by:

- Economic assets: Limited roads infrastructure, bridges, water sources, agricultural and livestock markets, and other farm assets have direct and indirect negative impacts on economic opportunities for the people of North Sudan. Basic infrastructure is crucial for accessing markets, collecting agricultural inputs, and selling surplus produce which are important for agricultural growth and the improvement of household economies.

- Loss of opportunities: Insecurity and risk of landmines restrict human movement, resulting in less investment and limited use of fertile agricultural land. In many locations, households are confined to limited land areas, cultivating only for subsistence, while large fertile fields remain uncultivated for years. Opportunities are also lost because of a lack of transparency and good governance, lack of or inadequate funds and micro-credit facilities, or dominance of traditional production systems with weak technical, managerial and financial capacities. In addition, the lack of appropriate adaptive research and technology transfer, resulting in adoption and use of out dated production technologies in the agriculture sector, needs to be resolved.

- Disruption of trade routes and communication: This is reflected in high transport costs, which inhibit trade and the distribution of food and production inputs. Poor market access and market infrastructure, as well as weak physical infrastructure (rural roads network) increase the cost and reduce the efficiency of agricultural recovery and development programmers.

CHAPTER THREE
LITREATURE REVIEW

3.1 Background

Some soils are exceptionally good for growing crops, and others are inherently unsuitable; most are in between. Many soils also have limitations, such as low organic matter content, texture extremes (coarse sand or heavy clay), poor drainage, or layers that restrict root growth. Most of Sudan alluvium-derived clay and loamy soils (i.e. old cracking clays and recent alluvium deposits), are naturally blessed with a combination of silty clay – clay loam textures and high base saturation. By every standard for assessing soil health, these soils-in their virgin state-would rate moderately high and very high. The way we care for a soil modifies its inherent nature. A good soil can be abused through years of poor management and turn into one with poor health, although it generally takes a lot of mistreatment to reach that point. On the other hand, an instinctively challenging soil may be very "unforgiving" of poor management and quickly become even worse. For example, a heavy clay loam soil can be easily compacted and turn into a dense mass. Both naturally good and poor soils can be productive if they are managed well. However, they will probably never reach parity, because some limitations simply cannot be completely overcome. The key idea is the same that we wish for our children-we want our soils to reach their fullest potential (Doran .*et al.* 1996).

It should come as no surprise that many cultures have considered soil central to their lives. After all, people were aware that the food they ate grew from the soil. Our ancestors who first practiced agriculture must have been amazed to see life reborn each year when seeds placed in the ground germinated and then grew to maturity. In the Hebrew Bible, the name given to the first man, Adam, is the masculine version of the word "earth" or "soil" (*adama*). The name for the first woman, Eve (or Hawa in Hebrew), comes from the word for "living." Soil and human life were considered to be intertwined. A particular reverence for the soil has been an important part of the cultures of many civilizations, including American Indian tribes. Although we focus on the critical role soils play in growing crops, it's important to keep in mind that soils also serve other important purposes. Soils govern whether rainfall runs off the field or inter the soil and eventually helps recharge underground aquifers. When a soil is denuded of vegetation and starts to degrade, excessive runoff and flooding are more common. Soils also absorb, release, and transform many different chemical compounds. For example, they help to purify wastes flowing from the septic system fields in your back yard. Soils also provide habitats for a diverse group of organisms, many of which are very important-such as those bacteria that produce antibiotics. Soil organic matter stores a huge amount of atmospheric carbon. Carbon, in the form of carbon dioxide, is a greenhouse gas associated with global warming. So by increasing soil organic matter, more carbon can be stored in soils, reducing the global warming potential. We also use soils as a foundation for roads, industry, and our communities (Magdoff and van Es.2000).

3.2 Healthy Soil

Soil consists of four important parts: mineral solids, water, air, and organic matter. Mineral solids are sand, silt, and clay and mainly consist of silicon, oxygen, aluminum, potassium, calcium, and magnesium. The soil provides nutrients and it is the main source of water for plants. Essential nutrients are made available to the roots of plants through the soil solution. The air in the soil, which is in contact with the air above ground, provides roots with oxygen and helps remove excess carbon dioxide from respiring root cells. When mineral and organic particles clump together, aggregates are formed. They create a soil that contains more spaces, or pores, for storing water and allowing gas exchange as oxygen enters for use by plant roots and soil organisms and the carbon dioxide (CO_2) produced by the organisms leaves the soil.

Farmers sometimes use the term *soil health* to describe the condition of the soil. Scientists usually use the term *soil quality*, but both refer to the same idea- how good is the soil in its role of supporting the growth of high-yielding, high-quality, and healthy crops? How would you know a high-quality soil from a lower-quality soil? Most farmers and gardeners would say that they know one when they see one. Farmers can certainly tell you which of the soils on their farms are of low, medium, or high quality. They know high-quality soil because it generates higher yields with less effort. Less rainwater runs off, and fewer signs of erosion are seen on the better quality soils. Less power is needed to operate machinery on a healthy soil than on poor, compacted soils (Magdoff and van Es.2000).

The first thing many might think of is that the soil should have a sufficient supply of nutrients throughout the growing season. But don't forget, at the end of the season there shouldn't be too much nitrogen and phosphorus left in highly soluble forms or enriching the soil's surface. Leaching and runoff of nutrients are most likely to occur after crops are harvested and before the following year's crops are well established. We also want the soil to have good tilth so that plant roots can fully develop with the least amount of effort. A soil with good tilth is spongier and less compacted than one with poor tilth. A soil that has a favorable and stable soil structure also promotes rainfall infiltration and water storage for plants to use later. For good root growth and drainage, we want a soil with sufficient depth before a compact soil layer or bedrock is reached. We want a soil to be well drained, so it dries enough in the spring and during the following rains to permit timely field operations. Also, it's essential that oxygen is able to reach the root zone to promote optimal root health-and that happens best in a soil without a drainage problem. Keeping in mind that these general characteristics do not hold for all crops, for example, flooded soils are desirable for cranberry and paddy rice production.)

We want the soil to have low populations of plant disease and parasitic organisms so plants grow better. Certainly, there should also be low weed pressure, especially of aggressive and hard-to-control weeds. Most soil organisms are beneficial, and we certainly want high amounts of organisms that help plant growth, water, also called the soil solution, contains dissolved. Figure (1).

Source: Cornell soil health assessment training manual

Figure 5 The Healthy soil that show Biological activities and Good mass roots growth

3.3 Building Healthy Soils for Better Crops

Some characteristics of healthy soils are relatively easy to achieve-for example, an application of limestone will make a soil less acid and increase the availability of many nutrients to plants. But what if the soil is only a few inches deep? In that case, there is little that can be done within economic reason, except on a very small, garden-size plot. If the soil is poorly drained because of a restricting subsoil layer of clay, tile drainage can be installed, but at a significant cost (Magdoff, *et al*. 1998).

Soil organic matter has a positive influence on almost all of the soil characteristics. Organic matter is even critical for managing pests-and improved soil management should be the starting point for a pest reduction program on every farm. Although the details of how best to create high-quality soils differ from farm to farm and even field to field, the general approaches are the same and for example the following (Hudson,. 1994):

- Implement a number of practices that add organic materials to the soil.
- Add diverse sources of organic materials to the soil.
- Minimize losses of native soil organic matter.
- Provide plenty of soil cover crops and/or surface residue to protect the soil from raindrops and temperature extremes.
- Minimize tillage and other soil disturbances.
- Whenever traveling on the soil with field equipment, use practices that help develop and maintain good soil structure.
- Manage soil fertility status to maintain optimal pH levels for your crops and a sufficient supply of nutrients for plants without resulting in water pollution.
- In arid regions, reduce the amount of sodium or salt in the soil.

3.4 Soil Quality

Quality is the essential character, distinguishing feature or property of an object. It identifies that feature which makes the thing useful or perform a task in a beneficial way. Most persons refer to soil quality in a similar way and look for attributes that enable the soil to perform its functions in an acceptable manner. It is the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries to:

1. Sustain plant and animal productivity
2. Maintain or enhance water and air quality (Larson.1991).

A more formal definition, of Conservation and enhancement of soil quality. and many others is, "the capacity of the soil, as an integral part of the ecosystem to perform the functions of enabling life to thrive in or on it.

1. acting as an ecosystem source, sink, and a filter reducing contaminants affecting water and other resources
2. providing the foundation for buildings and other structures, and space for rooting and support for plants
3. buffering the life support system against thermal, chemical, gaseous, and/or other stresses
4. regulating microclimate through its hydrological function of controlling water flowing over or in it.

Soils vary naturally in their capacity to function; therefore, quality is specific to each kind of soil. This concept encompasses two distinct but interconnected parts; these are *dynamic* and *inherent* soil qualities.

3.4.1 Inherent soil quality

It related to soil properties that change as a result of soil use and management over the human time scale. Characteristics, such as texture, mineralogy, etc., are innate soil properties determined by the factors of soil formation .climate, topography, vegetation, parent material, and time. Collectively, these properties determine the inherent quality of a soil. They help compare one soil to another and evaluate soils for specific uses. For example, all else being equal, a loamy soil will have a higher water holding capacity than a sandy soil; thus, the loamy soil has a higher inherent soil quality. This concept is generally referred to as soil capability. Map unit descriptions in soil survey reports are based on differences in the inherent properties of soils. More recently, soil quality assessments are thus used to evaluate the effects of management on the health of the soil (Sarrantonio,. 1994.***)***

3.4.2 Dynamic soil quality

It is defined as the changing nature of soil properties that result from human use and management. Some management practices, such as the use of cover crops, increase organic matter and can have a positive effect on soil quality. Other management practices, such as tilling the soil when wet, adversely affect soil quality by increasing compaction. In this research, soil quality refers to the inherent quality of soil. Those properties that are affected by management Soil quality assessments are thus used to evaluate the effects of management on the health of the soil (http://attra.ncat.org/)

3.5 Soil Quality Objectives

Some producers may be seeking assistance to improve overall soil quality, because they recognize the direct impact this will have on the profitability and health of the operation. Other producers may have recognized soil quality degradation in specific fields and request assistance only in those fields. Some may require assistance in troubleshooting small problem areas. Generally, their goals will fall into one of the following areas(Doran, *et al.* 1996.)

1. Improve soil quality.
2. Maintain soil quality.
3. Stop or reverse soil quality degradation.
4. Troubleshoot problem areas.

Results of comparisons of different management systems in different fields or in problem areas can often be obtained quickly. A few sets of measurements from each field or area can often provide important insight into the direct effects of management. Results of evaluations of new practices or information about long-term trends will not be available immediately (Larson, and Pierce. 1994). It is important to explain to the producer that the first set of results provides baseline values that are specific to that farming system. Subsequent evaluations later in the season and in following years will be necessary to reach definite conclusions about the trends and levels of soil quality. Comparing results with .established or target levels, as determined by a soil survey, can be done, but it requires caution. If this is the producers' goal, be sure to use quantitative measurements (Doran, *et al*. 1994)

3.6 Soil Quality Assessment Indicators

Soil quality is an assessment of how well soil performs all of its functions now and how those functions are being preserved for future use. It cannot be determined by measuring only crop yield, water quality, or any other single outcome. Soil quality cannot be measured directly, so *we evaluate indicators*. ***Indicators*** are measurable properties of soil or plants that provide clues about how well the soil can function. Indicators can be physical, chemical, and biological properties, processes, or characteristics of soils. They can also be morphological or visual features of plants. Useful indicators:

- Are easy to measure,
- Measure changes in soil functions,
- Encompass chemical, biological, and physical properties,

- Are accessible to many users and applicable to field conditions, and
- Are sensitive to variations in climate and management.

Indicators can be assessed by qualitative or quantitative techniques. After measurements are collected, they can be evaluated by looking for patterns and comparing results to measurements taken at a different time or field.

Table :Examples of soil quality indicators:

Soil Properties (Soil health indicators)	**Relationship to Soil Health**
Soil organic matter (SOM)	Soil fertility, structure, stability, nutrient retention; soil erosion
Physical: soil texture, soil structure, depth of soil, infiltration and bulk density; water holding capacity	Retention and transport of water and nutrients; habitat for microbes; estimate of crop productivity potential; compaction, plow pan, water movement; porosity; workability
Chemical: pH; electrical conductivity; extractable N-P-K	Biological and chemical activity thresholds; plant and microbial activity thresholds; plant available nutrients and potential for N and P loss
Biological: microbial biomass C and N; potentially mineralizable N; soil respiration.	Microbial catalytic potential and repository for C and N; soil productivity and N supplying potential; microbial activity measure

Source: NRCS (2001)

3.7 Soil Physical Properties

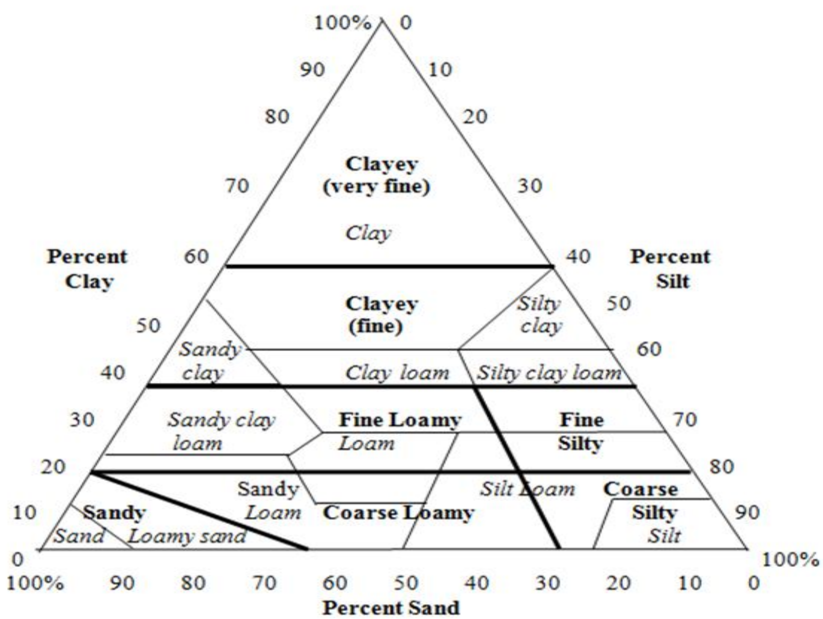
3.7.1 Soil Texture

Soil texture refers to the weight proportion of the separates for particles less than 2 mm as determined from a laboratory particle-size distribution (Soil Survey Manual2009 USA). The principal textural classes are figure (6) Clay, sandy clay, silty clay, clay loam, sandy clay loam, silty clay loam, loam, sandy loam, silt loam, sand, loamy sand and silt. Subclasses of sand are subdivided into coarse sand, sand, fine sand, and very fine sand. Subclasses of loamy sands and sandy loams that are based on sand size are named similarly. The textural classes differ not only in the particle size analysis, but also in their bearing on some of the important factors affecting plant growth, such as:-

- The move ability and availability of water
- Aeration
- Workability
- The content of plant nutrients.

Texture affects many basic properties. Soils with higher clay contents generally have higher ability to retain nutrients (more cation exchange capacity, or CEC) and can bind more organic matter. The size distribution of the particles also defines the size of the pore spaces between the particles and also between aggregates. These are just as important as the sizes of the particles themselves, because the relative quantities of variously sized pores—large, medium, small, and very small—govern the important processes of water and air movement. These in turn affect processes like water infiltration, permeability, water retention, aeration, nitrate leaching, and DE nitrification. Also, soil organisms and plant roots live and function in pores. When the soil lacks small pores, roots cannot grow and many organisms have difficulty surviving. Most pores in a clay are small (generally less than 0.002 mm), whereas most pores in a sand are large (but generally still smaller than 2 mm).

The pore sizes are affected not only by the relative amounts of sand, silt, and clay in a soil, but also by the amount of aggregation. On the one extreme, we see that beach sands have large particles (in relative terms) and no aggregation due to a lack of organic matter or clay to help bind the sand grains. A good loam or clay soil, on the other hand, has smaller particles, but they tend to be aggregated into crumbs that have larger pores between them and small pores within. Although soil texture doesn't change over time, the total amount of pore space and the relative amount of variously sized pores are strongly affected by management practices—aggregation and structure may be destroyed or improved (Swift and Woomer 1994) . Using a texture triangle such as the one shown in figure (2), will aid in determining the soil texture class when percentages of sand, silt and clay are plotted in lab. Soil texture is virtually unchangeable for a particular soil and is therefore not scored as part of a soil health assessment. Information on soil texture, however, is very valuable by itself for improving management practices. Moreover, soil textural information is being used to score most of the other soil health indicators, because interpretations cannot be made without it.



Source: FAO (1995)

Figure 6. Proportions of sand, silt and clay in different soil textural classes and groupings

3.7.1.1 Identifying the texture class in the field

By carrying out a number of simple tests, you can determine the texture class of a soil. In the field a ball of about 2.5 cms diameter is formed from approximately 1 tablespoon of fine earth. Water is slowly dripped onto the soil until it approaches the sticky point, i.e. the point at which the soil just starts to stick to the hand. Figure (7)

-
- Describe how the soil feels: is it gritty, smooth or sticky?
- Try to make a firm square of soil.
- Try to roll up the square. If that works, moisten the roll and then look at its surface; is it shiny or dull?
- Try to bend the roll into a ring.

Based on the appearance of the ring, determine whether the soil is sticky, brittle or completely loose, when it is both wet and dry. You can then use Table (3) to identify which texture class corresponds to your soil.

Source: Adam. H (2005)

Figure 7. Field methods to determinate soil texture

Table 3.Texture classes

Soil texture Classes	Feel of Soil	Can form a firm square	Can form a thin roll	Can form a ring	Moist	Dry
Sand	very gritty, does not make fingers dirty	No	No	No	loose and single grained	Loose
Loamy Sand	very gritty	no, forms weak square	No	No	somewhat cohesive	Loose
Silt loam	smooth, fine powder	Yes	yes, poor shape and dull surface	No	feels soapy	soft, dusty
Loam	gritty and sticky	Yes	Yes	No	feels soapy and is more-or less plastic	soft, dusty
Clay loam	smooth and sticky	Yes	yes, good shape, shiny surface	No	firm	somewhat hard to hard, no dust
Light clay	no gritty parts anymore only sticky	Yes(firm)	yes, good shape, shiny surface	yes (showing cracks at outside)	very firm	hard to very hard, no dust
Heavy clay		Yes(very firm)	yes, good shape, shiny surface	yes, without cracks	very firm	hard to very hard, no dust

Source\ Soil Survey Manual (2009).

Khartoum state texture differ from clay, clay silty loamy to silt clay loamy and sandy ,sandy loam (Soil Survey Division staff .1976).

3.7.2 Availabe water capacity

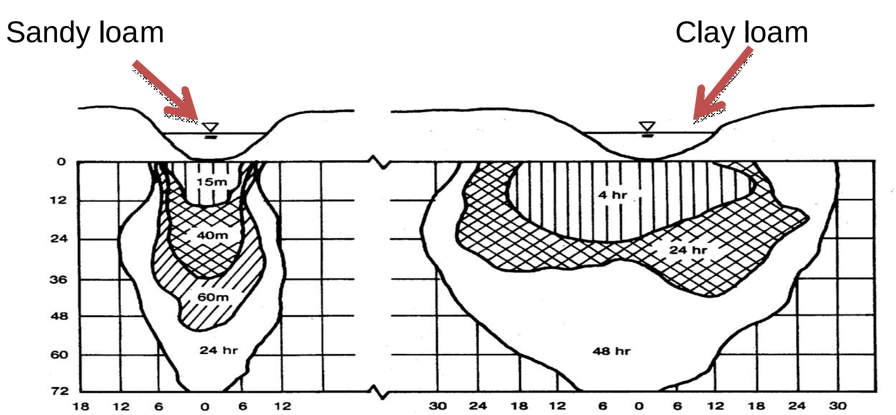
It is The amount of water in soil based on rainfall amount, what proportion of rain infiltrates into the soil, and the soil's storage capacity. Available water capacity is the maximum amount of plant available water a soil can provide. It is an indicator of a soil’s ability to retain water and make it sufficiently available for plant use. Available water capacity is the water held in soil between its field capacity and permanent wilting point. Field capacity is the water remaining in a soil after it has been thoroughly saturated and allowed to drain freely, usually for one to two days. Permanent wilting point is the moisture content of a soil at which plants wilt and fail to recover when supplied with sufficient moisture. Water capacity is usually expressed as a volume fraction or percentage, or as a depth (in or cm) . FAO 1995.

The important of AWC in the soil:

Soil is a major storage reservoir for water. Water availability is an important indicator because plant growth and soil biological activity depend on water for hydration and delivery of nutrients in solution. Runoff and leaching volumes are also determined by storage capacity and pore size distribution and soil depth. In areas where rain falls daily and supplies the soil with as much or more water than is removed by plants, available water capacity may be of little importance. However, in areas where plants remove more water than is supplied by precipitation, the amount of water held by the soil may be critical. Water held in the soil may be necessary to sustain plants between rainfall or irrigation events. By holding water for future use, soil buffers the plant – root environment against periods of water deficit. Available water capacity is used to develop water budgets, predict doughtiness, design and operate irrigation systems, design drainage systems, protect water resources, and predict yields. (http://soils.usda.gov/technical/handbook/) .Figure(37).

3.7.3 Infiltration Rate

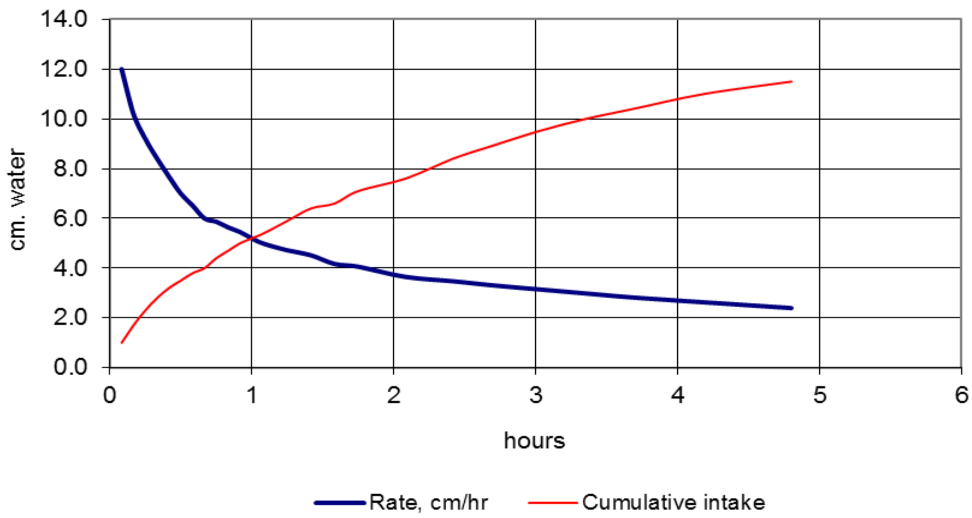
The infiltration rate is the velocity or speed at which water enters into the soil. It is usually measured by the depth (in mm) of the water layer that can enter the soil in one hour. An infiltration rate of 15 mm/hour means that a water layer of 15 mm on the soil surface will take one hour to infiltrate. In dry soil, water infiltrates rapidly. This is called the initial infiltration rate. As more water replaces the air in the pores, the water from the soil surface infiltrates more slowly and eventually reaches a steady rate. This is called the basic infiltration rate (FAO. 1976). The infiltration rate depends on soil texture (the size of the soil particles) and soil structure (the arrangement of the soil particles) (Figure.8.) and is a useful way of categorizing soils from an irrigation point of view



Source: soil survey manual division staff

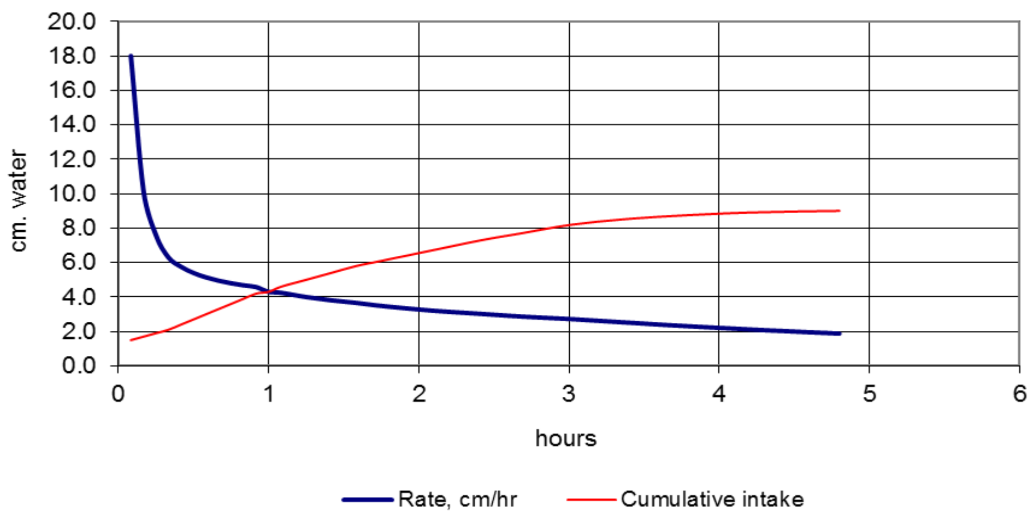
Figure 8. Distance from furrow center (inches)

Saeed (1968)studied some physical and chemical properties of certain Shambat soils and produced soil map units and saline-alkali maps. He described the soil units as; Recent Alluvium, clay loam over silt loam, Silty clays and Clays. The soils are slowly permeable, well aerated and characterized by deep root penetration. The fine cracking clay is ranging in colour from dark brown to very dark grayish brown. The range of colour in the deep silt loam subsoil is same as that of the clay loam topsoil. These soils are calcareous. Also Haj Hamad (2010) carries The detailed description of the most important physical and chemical properties of the shambat soils under investigation, especially those concerning salinization and alkalization processes and potential soil fertility including the soil water regime. Figure (9) ,(10)



Source \ Haj Hamad(2011)

Figure 9. Infiltration Rates of Sub recent Alluvium levees



Source\ Haj Hamad (2011)

Figure 10. Infiltration Rates of Old Alluvium clay

The number, lengths, and diameters of pores determine water movement and retention in soils. Large pores (greater than 1/16th inch in diameter) are responsible for most of the flow through soils. Water infiltration is also subject to factors such as texture and slope. Sandy soils in general will have higher infiltration rates than silty or clayey soils Table (4). Water tends to drain more quickly from positions higher on the landscape Soil structure is an important factor that controls water infiltration. Unstable soil aggregates disintegrate when wet and release small clay particles that clog pores. Compacted soils restrict water movement into deeper sub-soil layers where water could be stored for plant use.

Table 4. Soil type and Infiltration Rate.

Soil type	**Steady infiltration rate (inches per hour)**
Sands	>0.8
Sandy and silty soils	0.4-0.8
Loams	0.2-0.4
Clayey soils	0.04-0.2
Sodic clayey soils	<0.04

Source: Hillel, (1982)

The most common method to measure the infiltration rate is by a field test using a cylinder or ring infiltrometer. Figure(11) (Young, 2001)

A one inch layer of water is added to a six inch diameter ring to measure infiltration rate.

Source: Magdoof and Van Es (2009)

Figure 11. Measure infiltrtion rate in the field

Several studies show that AWC improves when other physical soil properties, such as SOM, the infiltration rate, bulk density, soil structure, and penetration resistance, improve (Dao, 1993; Li *et al*., 2008; Villamil *et al*., 2006). Analyses of penetration resistance, compaction, crusting/sealing, and infiltration in studies of NT systems showed that these properties exhibit more improvement under NT systems than CT systems (Table 5). Brock (1999) summarized various several NT studies in the southeastern part of the United States and noted that long-term no-till resulted in reduced crusting/sealing and increased infiltration and water holding capacity and significantly reduced runoff. Infiltration, penetration resistance, and/or crusting/sealing improved more under all NT systems studied, as compared to CT systems, in all areas where these properties were analyzed, except one (Villamil *et al*., 2006; So *et al*., 2009; Li *et al*., 2008; Dao, 1993; Franzluebbers, 2002; Sasal *et al*., 2010). In Table 5 the percentage pore space was calculated using 2.7 g/cc for particle density except for the peat soil, which is estimated. Arshad *et al*, (1996)

Table 5. Representative Bulk Densities for Different Kinds of 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 (estimated)

Source: Arshad *et al*, (1996)

Wortmann and Walters (2006) observed that repeated manure application can lead to improve water infiltration and help to minimize runoff. Ahmed (2008) found that hoeing is generally the best treatment for managing crust in the soil. Performing tillage operations at optimum water contents and/or including deep tillage operations in seed bed preparation after every two years can control soil compaction. Deep tillage techniques in soils with low permeability, can improve infiltration of water into the soil, allowing them to be leached (American Society of Civil Engineers, 1990). Dahab (1984) found that the application of organic matter on the soil surface or mixed with soil surfaces improved the soil structure, inhibited evaporation and increased infiltration rate and water holding capacity

3.7.4 Soil Compaction

Soil compaction occurs when soil particles are pressed together, reducing the pore space between them. Compaction occurs when farm machinery repeatedly passes over the same area of soil. The weight of the equipment, the number of trips across the field, and the type of soil determine the degree of compaction (Palouse and Nezperce Soil Quality Indicator Card 2004) .

When a soil is compacted, the amount of pore space is reduced, and the weight of a given volume of soil is increased. Density values can predict how well plant roots are able to extend into the soil. Equally important as bulk density are soil strength and loss of Particle density averages approximately 2.65 g/cc (165 lb/ft^3. Soil bulk density, 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 Figure (12). A lower bulk density by itself does not indicate suitability for plant growth due to the influence of soil texture and structure (Soil Survey Division Staff (1993).

Compaction that restricts crop roots to the upper few inches of soil layers increases production costs by increasing runoff, erosion, seedling mortality and susceptibility to crop damage during periods of drought. Compaction counter measures are frequently not cost effective so one of the best strategies is to avoid creating conditions which may cause compaction;

A three inch diameter ring is hammered into the soil to collect bulk density samples.

Source: Arshad et al, (1996)

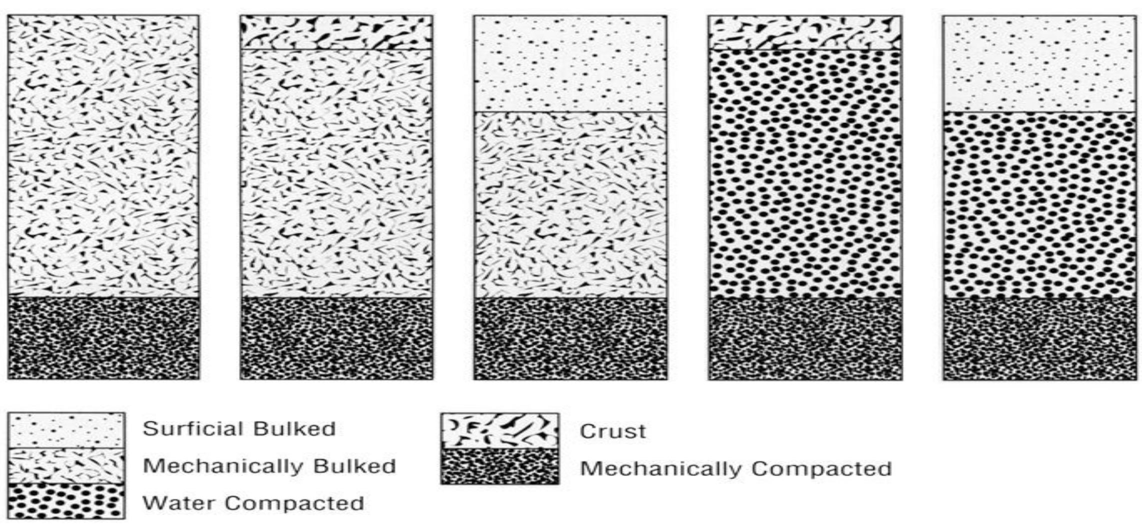
Figure 12: Collection of bulk density samples in field

3.7.4.1 Reasons for development of compaction

The morphology of the uppermost few centimeters is subject in many soils to strong control by antecedent weather and by soil use. A soil may be freshly tilled today and have a loose surface. Tomorrow it may have a strong crust because of a heavy rain. Or, in one place soil may be highly compacted by livestock and have a firm near surface even though over most of its extent the same uppermost few centimeters are little disturbed and very friable. There is a need for a set of terms to describe subzones of the near surface and, in particular, the near surface of tilled soils. Five subzones of the near surface are recognized in Figure (13).

First, the mechanically bulked subzone has undergone through mechanical manipulation a reduction in bulk density and an increase in discreteness of structural units, if present. Usually the mechanical manipulation is the consequence of tillage operations. Rupture resistance of the mass overall, inclusive of a number of structural units, is loose or very friable and occasionally friable. Individual structural units may be friable or even firm. Mechanical continuity among structural units is low. Structure grade, if the soil material exhibits structural units < 20 mm across, is moderate or strong Strain that results from contraction on drying of individual structural units may not extend among structural units. Hence, internally initiated desiccation cracks may be weak or absent even though the soil material in a consolidated condition has considerable potential extensibility. Cracks may be present, however, if they are initiated deeper in the soil

Second; the mechanically compacted subzone has been subject to compaction, usually in tillage operations but possibly by animals. Commonly, mechanical continuity of the fabric and bulk density are increased. Rupture resistance depends on texture and degree of compaction. Generally, friable is the minimum class. Mechanical continuity of the fabric permits propagation of strain that result on drying only over several centimeters. Internally initiated cracks appear if the soil material has appreciable extensibility and drying has been sufficient. In some soils this subzone restricts root growth. The suffix "d" may be used if compaction results in a strong plow pan. The water-compacted subzone has been compacted by repetitive large changes in water state without mechanical load except for the weight of the soil. Repetitive occurrence of free water is particularly conducive to compaction. Depending on texture, moist rupture resistance ranges from very friable through firm. Structural units, if present, are less discrete than for the same soil material if mechanically bulked. Structure generally would be weak or the condition would be massive. Mechanical continuity of the fabric is sufficient that strain which originates on drying propagates appreciable distances.



Source:: Soil Survey Manual (2009)

Figure 13: Five subzones of the near surface are recognized.

As a consequence, if extensibility is sufficient, cracks develop on drying. In many soils, over time the water-compacted subzone replaces the mechanically bulked subzone. The replacement can occur in a single year if the subzone is subject to periodic occurrence of free water with intervening periods when slightly moist or dry. The presence of a water-compacted subzone and the absence of the mechanically bulked subzone is an important consequence of no-till farming systems.

Third: the surficial bulked subzone occurs in the very near surface. Continuity of the fabric is low. Cracks are not initiated in this subzone, although they may be present if initiated in underlying more compacted soil. The subzone is formed by various processes. Frost action under conditions where the soil is drier than wet is a mechanism. Wetting and drying of soil material with high extensibility is another origin; certain Vertisols are illustrative

Fourth, crust is a surficial subzone, usually less than 50 mm thick, that exhibits markedly more mechanical continuity of the soil fabric than the zone immediately beneath. Commonly, the original soil fabric has been reconstituted by water action and the original structure has been replaced by a massive condition. While the material is wet, raindrop impact and freeze-thaw cycles are mechanisms leading to reconstitution. Crusting related to raindrop-impact and freeze thaw are recognized

Fifth: a fluventic zone may be formed by local transport and deposition of soil material in tilled fields. Such a feature has weaker mechanical continuity than a crust. The rupture resistance is lower, and the reduction in infiltration may be less than for crusts of similar texture. A rain drop impact crust may occur on a fluventic zone (Soil Survey Divisions Staff 1993).

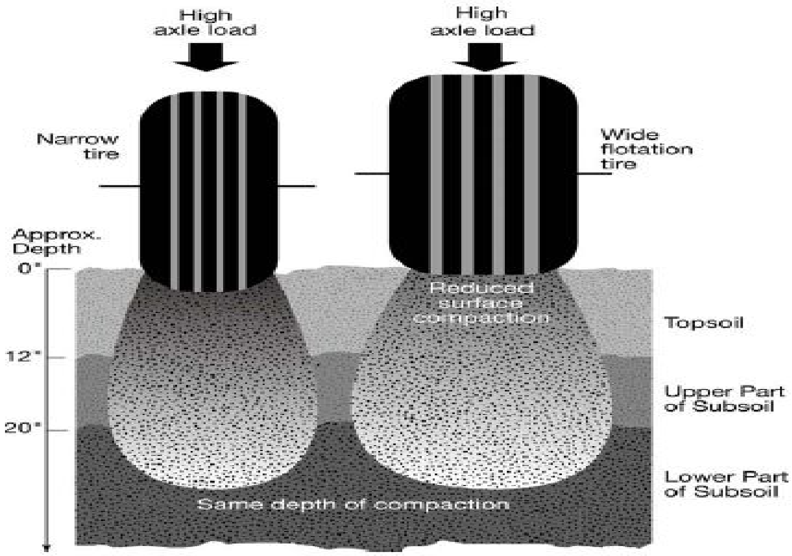


Figure 14: Surface compaction is caused by high contact pressures. Using flotation tires instead of narrow tires reduces surface contact pressure, but does not reduce subsoil compaction. (Source: photo from Doka)

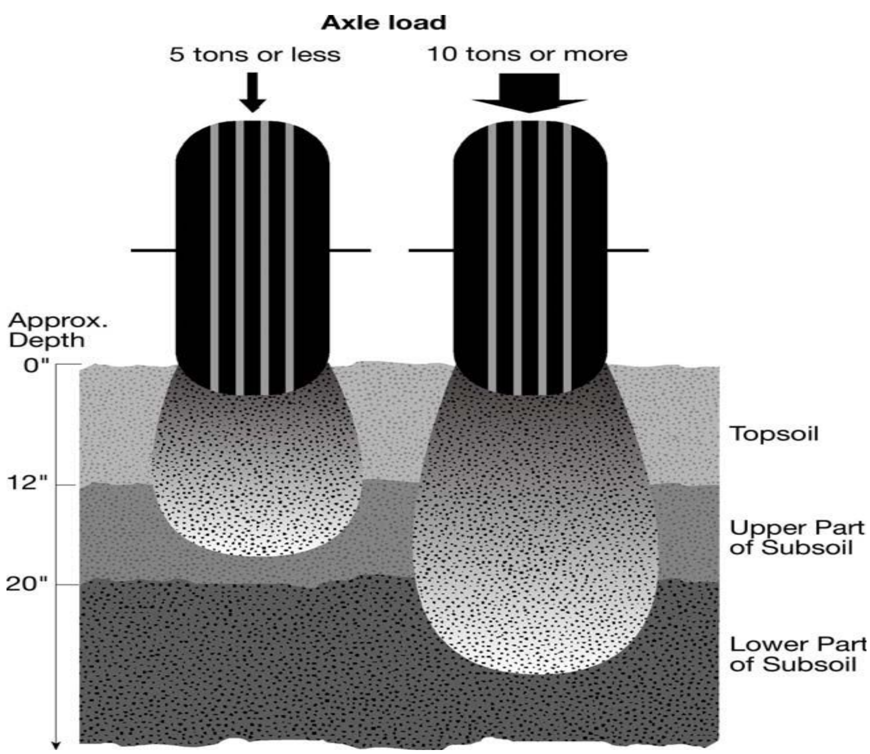


Figure 15: Axle load determines subsoil compaction. Reduction of axle load reduces subsoil compaction. (source:photo from Doka)

Figure 16: Two types of modern subsoilers that break through subsoil compaction while conserving surface residue cover. (Source:GIZ\Weber(2005)

3.7.4.2 Measure Compaction in the field

Field penetration resistance is a measurement of the soil’s strength measured (in psi) with a field penetrometer pushed through the soil profile. Measurements should be taken when the soil is near field capacity. It is measured for two depth increments in the field (0 to 6 in. and 6 to 18 in.) and used to assess surface and subsurface soil compaction Figure (17)

Source:Cornell soil health manual training (2009).

Figure 17. Field penetrometer pushed through the soil profile

3.7.4.3 When we use the penetrometer in the field

The level of soil moisture can greatly affect the ease with which the probe penetrates the soil. It is recommended that penetration reading be taken when the soil is at field capacity (several days after free drainage). If the soil conditions are not ideal, it is important to note conditions at the time of measurement so proper interpretation of the reading can be made. Although apply slow even pressure so penetrometer advances into the soil at a rate of 4 seconds per 6 inches or less. Record the highest pressure reading measured for each of the two depths on the grower and field information sheet. There are some study concern to amendment soil compaction if it is on the surface or sub surface (Andrews, *et al* 2004)

3.7.4.4 Compaction Management

There are some study concerns to amendment soil compaction if it is on the surface or subsurface. Dahab (1984) found that the application of organic matter on the soil surface or mixed with soil surfaces improved the soil structure, inhibited evaporation and increased infiltration rate (Ahmed 1995, Fuad 1999). Most studies show that bulk density have increased slightly in the early stages of implementation of a no-till system after conventional tillage has been used (Stipesevic and Kladivko, 2002; Schwen et al., 2011). Some studies also show that bulk density may increase more with long-term use of No-tillage systems than with Conservation Tillage (Evett et al., 1999; Blanco-Canqui et al., 2004; Rhoton et al., 1993; Franzluebbers and Stuedemann, 2008). Mahmoud (1985) found that chisel plough normally stirs the soil and break through deep hard compacted layers, also he found that deep plowing has an effective on plant height.

In Australia Pillai and Garry (1996) study structure repair of a compacted Vertisol with wet-dry cycles and Crops We hypothesized that the four rotation crops: wheat (Triticum aestivum L.), sorghum [Sorghum bicolor (L.) Merr.], lablab [Lablab purpureus (L.) Sweet] and mung bean [Vigna radiata (L.) R. Wilczek] differ in their ability to repair soil structure. all crops improved soil structure over the initial field condition but lablab and Mung bean gave improvements to greater depths and more rapidly than wheat and sorghum. Mung bean and lablab caused up to a threefold increase in clod porosity in the 0.1- to 0.4-m soil layer after only three wet-dry cycles, whereas sorghum required nine wet-dry cycles to increase clod porosity in only the 0.2- to 0.3-m layer, and wheat gave no improvement even after nine wet-dry cycles. Image analysis of soil structure showed that lablab and Mung bean rapidly (by three wet-dry cycles) produced smaller peds with more interconnected pore space than wheat and sorghum. By nine wet-dry cycles, sorghum achieved deep cracking of the soil but the material between the cracks remained large and dense. Evapotranspiration was double under lablab and Mung bean compared with wheat and sorghum. their indicate greater cycles of wetting and drying under lablab and Mung bean than wheat and sorghum that have led to rapid repair of soil compaction.

Ahmed and Abbas (2012) have studied the effect of incorporated groundnut stover on the soil physical properties, biological activity and sorghum growth and yield. They found that the increased soil biological activity as monitored by the microbial count (fungi, total count and azotobacter) resulted in higher microbial activity, as measured by high CO_2 release. Moreover, the treatment increased water infiltration rate, reduced bulk density and increased water availability. Regarding the soil chemical aspects, the I treatment increased soil N, P and organic carbon, All quantities of ground nut straw added resulted in significantly higher sorghum yield in the two seasons. 616 kg/F of groundnut straw gave highest seed yield compared to the control and all other treatments. These results recommend the addition of 616 kg/F of groundnut straw as new technology to sustain agricultural production.

3.7.4.5 Tillage effects

Soil tillage may be defined as the mechanical manipulation of soil for any purpose. However, one of the main objectives of tillage according to Kepner et al, 1982, is to control weeds. They also indicated that minimum tillage is a broad principle that can be applied in many ways. They also mentioned that the major objectives of minimum tillage are to reduce mechanical energy and labor requirements and to perform only the operations necessary to improve the soil condition for each type of soil within a field. Moreover, they added that experience has indicated that minimum tillage, under suitable conditions, and with some row crops, is a practical way to conserve resources and reduce production costs, usually without reducing yields. Tilth is a quantitative term describing the physical state of the soil. It indicates the ease of tillage, seedbed preparation, seedling emergence and root growth (Bradey, 1984). In fact, tilth represents a combination of physical properties, which include texture, structure, strength, organic matter content and consistency. It is a dynamic characteristic and thus subject to changes due to natural forces as well as modifications by artificial means such as plowing and cultivation. Although an experienced person may tell by sight and feel if a soil is in good or poor tilth, there is no available method to quantify and measure it. Therefore, gaining a quantitative understanding of soil tilth and evaluating the effect of the tillage system, crop condition and seasonal variation on soil tilth is needed.

Croplands are tilled at least once and in most cases, several times. There are many machines available for tilling the soil, and large amounts of money are spent annually for tillage equipments and their operation. Efforts have been made to measure tillage induced soil condition .

Dafalla**,** *et al* (2010) studied the determination of suitable tillage system for Sorghum production under different field conditions in New Halfa Scheme. They found that in weed infested fields, chiseling, disc ploughing and disc harrowing resulted in significantly higher ($P \leq 0.05$) percentage of big clod size in primary seedbed compared to the other two tillage treatments and high significant difference ($p \leq 0.01$) among treatments in fuel consumption during the two seasons for both perennial-weed free and infested fields. However, deep tillage systems consumed more fuel than minimum tillage systems, irrespective of field condition. In the perennial weed – free field chiseling consumed significantly higher fuel in comparison with re-ridging (414%,), split ridging (159%) and disc harrowing (147%), with respective values of (428%, 169%, and 135%) in infested field in perennial weed–free field. On the other hand, disc ploughing consumed fuel significantly more than re-ridging, split ridging and disc harrowing, with respective percent values of 366, 135 and 125, and by (343%), (125%) and (96%) in the infested fields. Chiseling and ploughing resulted in very highly significant eradication (percent by weight) of Nageel (Cynodon dactylon, L) over re-ridging, split ridging and disc harrowing. The respective percentage values of Nageel reduction with chiseling amounted to 78, 72 and 72%, while for disc ploughing the respective values were 79, 78 and 78%. Chiseling and ploughing systems reduced annual weeds by 48, 50 and 44% compared to re-ridging, split ridging and disc harrowing, respectively.

3.7.5 Land leveling

Land leveling is a measure used in surface irrigation, such as basin and furrow irrigation. It consists of:

- preparing the irrigation plot in a way that no high and/or low spots disturb the uniform distribution of irrigation water on the field, and
- ensuring the optimal slope for water movement across a field when irrigated.

Leveling results in more efficient irrigation and, if fertilizer are applied, in more efficient use of fertilizers and pesticides. In an unlevelled field, high spots might not be covered by irrigation water, and the dissolved nutrients and/or pesticides might percolate unused into the soil. In case of low spots, water and the dissolved nutrients and chemicals might accumulate there and create zones of water logging and nutrient or pesticide the uniformity of the crop cover is disturbed and yields might decrease**(.**FAO 1989)

3.7.5.1 Technical parameter

Leveling can be done manually or with machinery and corresponding equipment. Heavy earth movement should be avoided in order to keep the natural soil structure undisturbed, thus maintaining good growing conditions for the crop roots and keeping costs low. Experienced farmers often do land leveling according to visual assessment, e.g. on small plots with hoes, or with draft animals and equipment such as ploughs and bars or scrapers. Equipment such as grading blades and hydraulically operated levelers mounted on wheels are used with tractors, More advanced and sophisticated leveling equipment is operated with a laser emitter, a laser sensor or receiver, and a scraper pulled by a tractor after the desired level or slope of the field and/or the difference of the high and low spots have been surveyed, the emitter is set to send a rotating laser beam creating a plane of laser light above the field surface. The laser light is used as the leveling reference. It directs the hydraulic system of the moving tractor and scraper, and thereby controls the leveling. figure (18).

Source: GIZ/ Weber (2005)

Figure 18: Laser leveler

3.7.5.2 Effect and benefits of land leveling

The International Rice Research Institute (IRRI, see International Organizations) provides the following data regarding the costs for land leveling during rice cultivation in Cambodia from 1996 - 1999. As shown in the Table (6)

Table 6. The total cost of leveling depends on the technology used.

Equipment Used	Animal leveling board	2-wheel tractor harrows	4-wheel tractor blade
Total costs ($/ha)	33.00	46.00	50.00

Source\
http://www.knowledgebank.irri.org/factsheetsPDFs/Land_Preparation/landLeveling.pdf

In summary, the main benefits of levelling are:

- improved crop establishment,
- even water coverage of the field,
- even crop stand and maturation,
- reduction of weeds up to 40 % (thereby 75 % decrease of labour required for weeding),
- increase of farming area by 5-7 %,
- reduction of farm operation times by 10-15 %,
- within rice production, the possibility of changing from planting and transplanting to direct seeding which results in reduced labour of 30 person-days per ha, and
- average yield increase of 10- 20 %

3.7.5.3 Cost and net profit –example (Egypt)

In Egypt, the Egyptian-German Water Resource Management Reform Programme quantified the costs and benefits (in Egyptian Pound (LE) per feddan and year) of land levelling. As most farmers in Egypt do land levelling, the data did not compare plots where no levelling had been conducted. Highest yield increase and cost savings were achieved by using a laser unit. Moreover, land levelling by laser method is done only every 4th year, whilst the other methods require annual leveling.

Table 7. The costs and benefits of land leveling as for most farms in Egypt

	Benefits	Costs (LE/fed)	Additional revenue (LE/fed)	Net profit (LE/fed)
Alternative 1 (manually operated shield)	Yield increase by 10% Saved pumping cost by 15% Saved irrigation labour cost by 15%	75	448	373
Alternative 2 (hydraulically operated shield)	Yield increase by 10% Saved pumping cost by 15% Saved irrigation labour cost by 15%	62.5	448	385,5
Alternative 3 (laser land levelling unit)	Yield increase by 20% Saved pumping cost by 20% Saved irrigation labour cost by 20%	150	864	714

Source :FAO (1989)

The highest net profit can be obtained with precision laser levelling, but it is not commonly used. This can be due to a variety of factors: limited access to laser units (the few units available cannot be used all year round, but only during a limited period before planting rice or wheat); infrastructural problems (too narrow roads, too high water tables for the heavy machinery); or gender constraints. Other important issues are the relatively high costs compared to regular leveling (although they arise only once in four years) and the increase of costs per unit when used on small, individual plots of less than one feddan (FAO (1989).

Bakhiet (2015) evaluate the performance of laser land leveling and its effect on sugarcane production, operation costs and some soil physical properties at Assalaya Sugar Scheme during September – November 2013, Low values of both theoretical and actual field capacities were recorded for laser land leveling (1.24 fed/h and 0.88 fed/h) as compared to the scraper (traditional) leveling (1.99 fed/h and 1.64 fed/h). Laser machine recorded low value of field efficiency (71.23 %), whereas the scraper leveling recorded 82.4%. High fuel consumption rates were recorded for laser land leveling (21.3 l/fed and 18.67 l/h), while scraper leveling showed low rates of fuel consumption (9.1 l/fed and 13.5 l/h). High mean values of sugarcane production (56 ton/fed) were recorded by laser land leveling as compared to the production (40 ton/fed) when using scraper machine. High operation cost (381 SDG/fed) was encountered when using laser machine as compared to the cost of scraper leveling (212 SDG/fed). Laser land leveling resulted in a decrease in the soil moisture content (4.6%) as compared to the mean values before the operation of leveling (5.4%). Soil bulk density decreased from 1.36 to 1.27 g/cm3 after the laser leveling operation, this was coupled with an increase in the soil porosity from 47.93% to 52.15%.,

Ramesh and Ogbazghi(2015) study tillage and irrigation requirements of sorghum (Sorghum bicolor L.) at Ha melmalo, Anseba Region of Eritrea Single preplanting tillage 4 days after heavy rainfall was sufficient for optimum yield of sorghum in well bounded and level fields. Soil bundling and leveling for rainwater conservation can raise rain fed sorghum yields to more than 2400 kg ha^{-1}. Irrigations cannot bring significant increases in yield unless fields are level and bounded.

3.7.6 Crop Condition

Crop condition use as an assessment of crop health and development to minimize farm inputs and to maximize production. Farmers measure the condition of the crop by asking questions such as: is the crop vigorous, is there an even stand in the field, is the color strong and uniform?

Plant vigor is indicated by the health of individual plants in the field. The uniformity of growth shown by all crop plants in a particular field also suggests good plant vigor. With similar management, plants that emerge at about the same time should be ready for harvest about the same time. The plant is dependent on the root system to collect and transport nutrients and water essential to normal growth and development. Healthy plants often have root growth as extensive as above ground plant growth figure (19)

Good soil structure promotes plant vigor by providing suitable porosity, water regulation, and nutrient cycling throughout the growing season and encouraging development of an extensive root system that explores as much of the soil as possible. Compacted subsoil layers that reduce the effective root zone or that perch water for long periods can restrict root system development. Soil organisms can inhibit the proliferation of certain root diseases caused by fungi, bacteria and nematodes. Diverse populations of soil organisms are associated with good structure (Brady, and Weil 1996.)

Source: \soil survey manual (USA)

Figure 19: Healthy plant in healthy soil

3.7.6.1 Management Consideration

It is important to determine whether the crop is under optimal management. If management was less than optimal (late planting, insufficient irrigation or rainfall, etc.), then plant vigor may not be a good soil quality indicator. The crop should be examined for pest or disease damage. It is important to determine if the disease problem is related to soil quality. For example, root borne diseases may be in part caused by poor soil quality in the form of compacted soil that remains saturated for long periods. Management that encourages good soil structure will help promote root growth. Cultivation and compaction can inhibit root growth. Factors that contribute to good plant vigor will be reflected in Agriculture Researches center recommended that to added100kg\hec P_5O_2 super phosphate and irrigated every 7days in Khartoum state to a paw sapiens for high yield and fresh plant.

Abdel Rahim (1985) studied the effects of irrigation regimes and some soil amendments on salt redistribution and production of forage sorghum. The result indicated that irrigation every 7 days intervals improved salt removal and de-alkalization of the soil and increased yield, leaf area index, plant height, and leaf nutrients up-take.

3.7.7 Soil Erosion

Erosion is defined as the movement of topsoil and nutrients from production areas to sites where they are not wanted. Erosion is a serious threat to water quality; sediment is the primary cause of water pollution, nutrient runoff, the second. Soil erosion is detrimental to farmers as it leads to a loss of the most productive part of the soil figure (20). (Brady and Weil 1996).

Natural Erosion is the relatively slow sculpturing of landscapes by climatic factors over geologic time. Accelerated Erosion is the rapid alteration of landscapes due to land disturbing activities such as urbanization, tillage, grazing, or timber cutting etc. These activities increase erosion rates by exposing the soil surface to wind and rain fall. Erosion is the result of the combination of an erosive force (water, wind, or gravity), a susceptible soil, and several other management- or landscape-related factors. A soil's inherent susceptibility to erosion (its erodibility(is primarily a function of its texture (generally, silts more than sands and clays), its aggregation (the strength and size of aggregates, which are related to the amount of organic matter), and soil water conditions. Many management practices can reduce soil erosion, although different types of erosion have different solutions , The ability of wind to erode a soil depends on how that soil has been managed, because strong aggregation makes it less susceptible to dispersion and transportation. In addition, many soil-building practices like mulching and the use of cover crops protect the soil surface from both wind and water erosion .(Langdale, 1992)

In the absence of shelter belts and wind breaks soil becomes vulnerable to erosion due to the removal of the vegetation cover and ploughing at the steeper areas. In such conditions, soil erosion factors become active. All these require the essential proper management of soil and its components, hence the gained result will be a good environment for social and economic benefits (Ibrahim, 1988). Wind erosion hazards in the Sudan occur mainly in the dry northern part of the country, where the vegetation is scanty, soils are dry most of the time and the wind velocity is rather strong, though it varies relatively little within the area. Variation in erodibility of unprotected soils in this area is thus mainly related to soil texture. The term wind erosion hazards as used here refer both to removal of soil by wind as well as to deposition of wind blown material (formation of dunes, hummocks or sand sheets). (Van de kevi and eltoom2004). Table (8) gives ratings for wind erosion hazards on unprotected soils in those areas of the Sudan that have semi-arid, arid and semi-desert climates. (Van de kevi and Eltoom2004)

The researcher' (Mahgoob 2110) study the wind erosion in Khartoum. The study showed inverse ,and linear relationship between distance and intensity of wind erosion according to location and the site and it showed wind erosion in of Khartoum state in order of: north Khartoum > south Khartoum > east Khartoum. Also in order of February > April > January > March > November >December and in spite of Khartoum state faced wind erosion hazard (map soil classification of Khartoum state), there's no research or study to show the effect of erosion on farm yield and how to manage it.

Table 8. Gives ratings for wind erosion hazards

Rating	Evidence of wind erosion or deposition	Textural class of surface soil /1/
1	No evidence of significant erosion and deposition; well developed A-horizons.	None calcareous loam and silt loam; none calcareous clay loam and silty clay loam with 35 % clay ; silt ; sandy clay loam; sandy clay.
2	Unsterilized hummocks, 20-100 cm high and more than 20 m apart or less than 20 cm high and less than 20m apart; and/or "A" horizon partly eroded, tillage implements may reach underlying horizon.	Sandy loam; calcareous loam and silt loam; calcareous clay loam and silty clay loam with 35 % clay; non calcareous clay loam and silty clay loam with 35 % clay; clay and silty clay.
3	Many unsterilized hummocks, 20-100 cm high and less than 20 m apart; and/or "A" horizon partly or wholly eroded.	Loamy sand; loamy fine sand
4	Unsterilized dunes of more than 100 cm high or continuous unsterilized sand sheet of more than 20 cm thick.	Very fine, fine and medium sand

Source: Adapted from data of wind erosion laboratory, Kansas State University, USA. SUORC\(Van de kevi and Eltom2004)

Soures: Soil Survey Manual U.S.A (2009)

Figure 20: Soil erosion

3.7.8 Crops residues

Crop residue is another important source of organic matter. As it decomposes, the organic matter is going back into the soil and improving soil tilth. Crop residue left on the surface will protect against erosion and improve surface aggregation, thereby reducing crusting and surface compaction figure (21). However, diseased crop debris can harbor inoculum that can become a problem during the next season if a susceptible crop is planted. Crop rotation with non-host crops belonging to different plant families will reduce pathogen inoculum. Removal and composting of crop debris may be an option in some situations. Incorporation or plowing down of crop debris to encourage the decomposition process may be an option depending on the tillage system and crop rotation sequence being employed. (Etahir, 1996) found, Incorporation of cover crops and other organic residues can help build soil organic matter, which can be important in counteracting compaction

Source: Photo by Jeff Vanuga USDA-NRCS

Figure 21: Show corn residues covering the soil

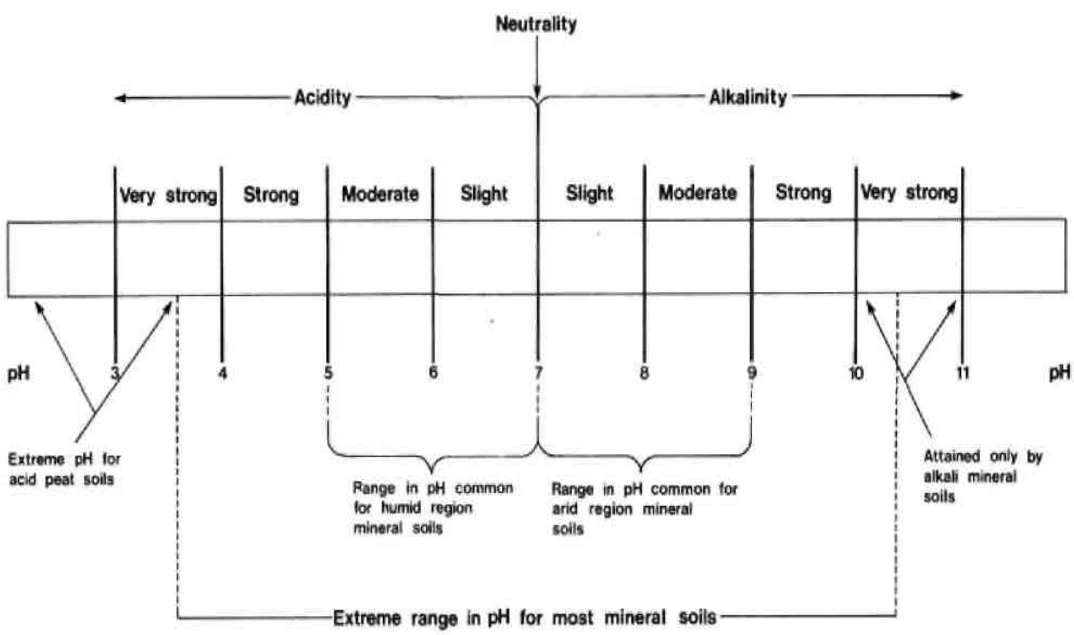
3.8 Chemical Indicators

3.8.1 Soil reaction (pH)

The acidity level refers to the extent to which the moisture in the soil is acidic or alkaline (= not acidic). An extremely acidic soil can be compared to vinegar, an extremely alkaline soil to soap. Clearly, soil acidity thus influences the growth of plant roots. The acidity level is indicated with the symbol pH. Acidic soil has a pH lower than7. A soil is acidic if a lot of H^+ is present. An alkaline soil (i.e. a soil that is not acidic) has a pH higher than 7. Soil that has a pH 7 is neutral. A pH of 4 or 10 is extreme, most soils have a pH between 5 and 9. Both high and low pH levels can result in nutrient deficiencies. A low pH also results in an excess of iron (Fe, at pH levels < 4.5), aluminum (Al, at pH levels < 5), and manganese (Mn, at pH levels < 4.5) in the soil. Excessive amounts of these nutrients are very poisonous for plants (FAO 1995).

Soil acidity also has an important influence on the availability of nutrients for the plant, such as can be seen in Figure (21). Microorganisms are also less active in soils that have a high or low pH: they decompose less organic matter, which results in fewer available nutrient. Soil reaction has a great influence on the availability of plant nutrients which is generally highest between pH 6,5 and 7.5 , 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 sulfur to plant available forms is enhanced, FAO (1995).

Plants differ in their sensitivity to a low or high pH and to aluminum, iron and manganese toxicity. Some plants can withstand or even prefer a somewhat low pH level, others a higher one. Most soils range in pH from slightly less than 2.0 to slightly more than 11.0, although sulfuric acid forms and pH may decrease to below 2.0 when some naturally wet soils that contain sulfides are drained Table (9)



Source: FAO. (1995).

Figure 22; Scale of soil pH levels (misplaced)

Table 9. Classification of PH value

Soil Ph	PH value
Ultra acid	< 3.5
Extremely acid	3.5-4.4
Very strongly acid	4.5-5.0
Strongly acid	5.1-5.5
Moderately acid	5.6-6.0
Slightly acid	6.1-6.5
Neutral	6.6-7.3
Slightly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Very strongly alkaline	> 9.0

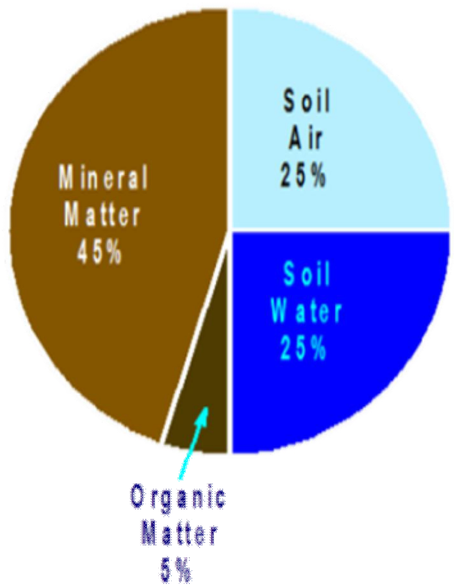
Source: Soil Survey Manual 2009

Both colorimetric and electrometric methods are used for measuring pH. Colorimetric methods are simple and inexpensive. Reliable portable pH meters are available.(Soil Survey Manual USA). Haj hammed (2011.) Study physical properties in shambat soil he found pH ranges from 7.3 to 7.9 in the top soil, Hessen (2009) studied sodic and salinity in soba area he found that pH of soil rages from7.2 to 8.2., Mohamadin (20012)study some physical properties in soil of west east Omdurman ,he found the pH rang(7.3-7.9) ,All them agree that the organic matter is the best amendment to solve the problem that related to pH ,and it is the key to build better soil (Agricultural Research Corporation (2004), Yousif (1982), Doran, *et al* 1996.)

3.8.2 Soil organic matte

Organic matter is a very small part of the soil, only 1 – 5% of most soils figure(23). but it consider in various forms greatly impacts of the physical, chemical and biological properties of the soil. It contributes to soil aggregation, water-holding capacity, provides nutrients and energy to the plant and soil microbial communities, etc Figure (24) It has been argued that organic matter management is soil health management. Increasing the percent organic matter in the soil takes time and patience. It is unlikely that a single incorporation of a green manure or compost will noticeably increase the percent organic matter.

However repeated use of organic amendments in combination with reduced tillage (depending on the constraints of the production system) will build soil organic matter levels. The selection of organic matter will depend on the management goal .



Source :Fred Magdoff and Weil (2004)

Figure 23. Distribution of solids and pores in soil.

Soil organic matter has a positive influence on almost all of the characteristics ,physical or chemical in the soil .The organic matter in the soil consists of fresh organic material and humus. Fresh organic material is plant and animal waste that has not yet decomposed, such as roots, crop residues, animal excrement an cadavers. The fresh material is transformed by soil organisms into humus, which is also called soil organic matter. In the process, nutrients are released (Figure24) organic matter thus makes nutrients available to the plants. Humus, i.e. soil organic matter, is material that has been broken down so far that the original fresh material is no longer distinguishable. It gives the soil a dark color. Humus itself is also broken down by the soil organisms, which releases even more nutrients, but this process takes much longer time. Humus can also retain a lot of water and nutrients. Organic matter can retain a lot of water, which means that in dry periods more water is available for the plants for a longer time. This is also especially important in sandy soils, which retain little water (Swift.and,Woomer 1994).

Organic matter aids aggregate formation and can thus improve the soil structure. This is important for both sandy and clay soils, because they have a poor structure. Organic matter can bind H+ and thus prevent soils from becoming acidic organic matter stimulates the growth of soil organisms, which helps make the nutrients in the organic matter available to the plants.(Schöll, and Nieuwenhuis.2004)

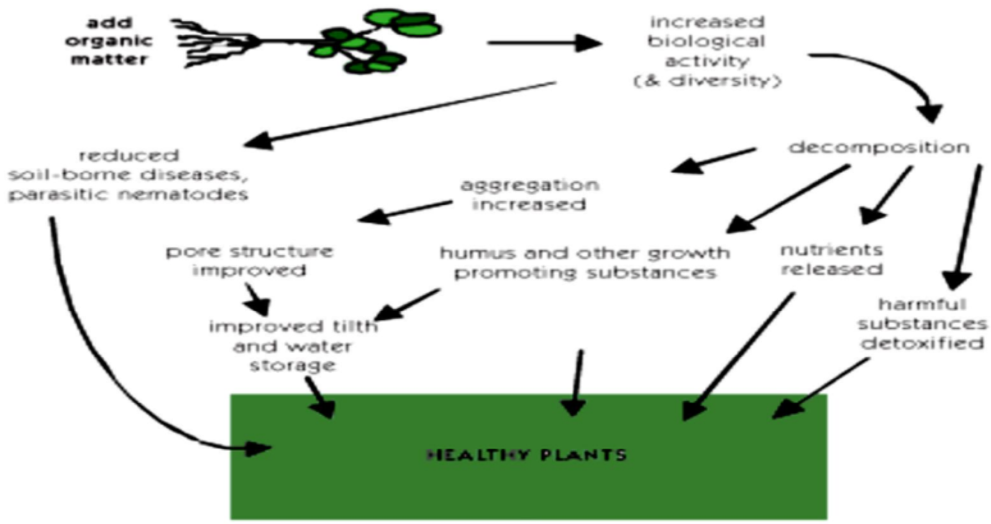


Figure 24. Adding organic matter results in a cascade of changes within the soil. Source: Better Crops, 2nd edition, Sustainable Agriculture Network - USDA*)*

The addition of fresh organic matter that is easily degradable by the soil microbial population will lead to improvements in soil aggregate stability, nutrient cycling, and increased microbial diversity and activities Table(9). The addition of more stable organic matter such as compost will improve water infiltration and retention. Also, organic matter in the form of rotational and cover crops, green manures, and composts have a major impact on the population and damage of soil borne pathogens, plant-parasitic(Müller *et al*1994.)

Table 10. 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

In Khartoum Generally, all the soils of the semi desert region have low organic matter and nitrogen contents <2% (all the study show that). The Agricultural Research Corporation (2004) recommended that to addition organic manure as the flowing Table (11).

Table 11. Organic matter value in the soil

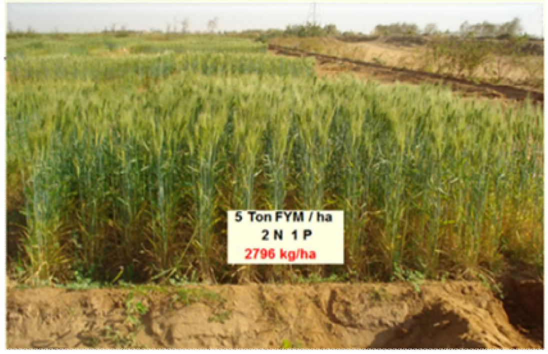
Organic manure\ton\Fedan	Chemical fertilizer\kg\fadan	Cases
4.5 ton	27kg nitrogen(60kg urea)	the farmer buy
8.4ton	18kg nitrogen(40kg urea)	The farmer owns animals
10ton	Non	Any cases

Source: Agricultural Researshes Corporation

numerous studies concerned about the effect of organic matter on yield and soil condition Elagib (1997) studied the effect of organic fertilizers on the uptake of different chemical element. The result of his two experiments showed that the organic fertilizer especially Chicken manure gave higher fresh weight of Zea maize, and increased calcium, magnesium, nitrogen and sodium contents . Dahab (1984) found that the application of organic matter on the soil surface or mixed with soil surfaces improved the soil structure, inhibited evaporation and increased infiltration rate.

Langdale *et al.* (1992) found during a 5-year study in restoring eroded Ultisols in the southeastern part of the United States that decomposition of residue significantly increased soil carbon. Restoration processes were initiated by increasing the average soil carbon content, representing slight, moderate, and severe soil erosion classes, from 0.97 to 2.37 percent in the upper 1.5cm of the soil. Accompanying the soil carbon responses were increases in soil N, water-stable aggregation, and infiltration. Ahmed (1995) found that the application of chicken manure in Shambat soil significantly reduced crop germination percentage; while FYM and water hyacinth increased crop germination percentage. Jokela *et al.* (2009) concluded that additions of manure and starter fertilizer have a significant effect on extractable P and K in areas under cover and companion crops. Use of liquid dairy manure alone did not improve any soil quality indicator.

Awad Elkarim and Younis (2008)study Effects of Farm Yard Manure, Nitrogen and Phosphorus Fertilization on Growth and Productivity of Wheat under New Hamdab Conditions they found that 5 tons farm yard manure/ha + 86 kg N/ha + 43 kg P2O5 is recommended for wheat production in the desert plain soils followed by 10 tons FYM / ha + 86 kg N/ha without phosphorus figure (24).



Source:Awad Elkarim and Younis (2008)

Figure 25. Show effects of farm yard manure, nitrogen and phosphorus fertilization on wheat grain yield (kg/ha)

3.8.3 Soil Fertility

Most agricultural problems that directly or indirectly involve soil fertility problem.Lack of soil fertility causes decreased yields but many plant diseases are also related to poor soil fertility. If the soil fertility is not good, the crops are not in optimal condition, and are thus more susceptible to diseases and pests. The presence of diseases and pests lowers productivity levels, again threatening further the livelihoods of the rural communities. Such conditions can be avoided by improving the condition of the soil.(Hand book(4) Soil Fertility Management).

3.8.3.1 Nutrient Deficiency Symptoms

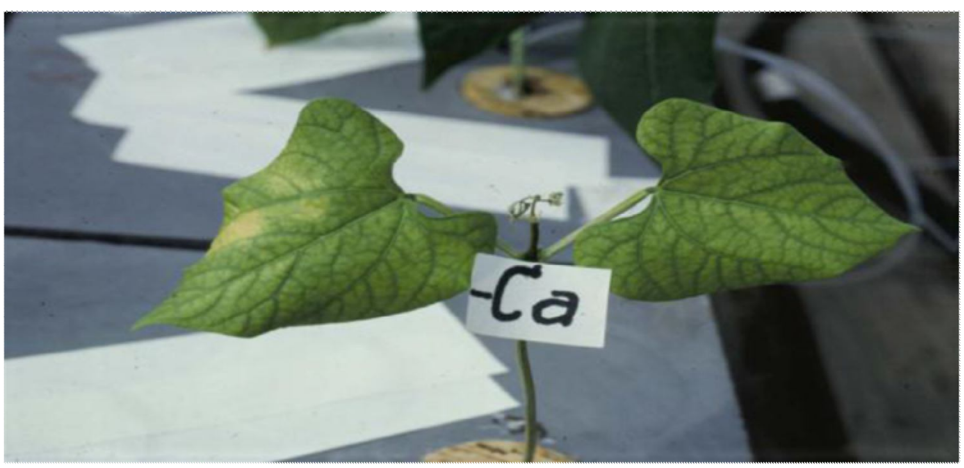
With very little data, Firman Bear and his coworkers decided that the "ideal" soil was one in which the CEC was 10 me/100g; the pH was 6.5; and the CEC was occupied by 20% H, 65% Ca, 10% Mg, and 5% K. And the truth is, for most crops that' s not a bad soil test. It would mean that it contains 2,600 pounds of Ca, 240 pounds of Mg, and 390 pounds of K per acre to a 6-inch depth in forms that are available to plants .Determining whether a plant has a nutrient deficiency by means of an analysis of its deficiency symptoms can thus be very complicated figure (26). A lot of experience is needed to perform the analysis well (Prasad, *et al* 1997)

Nitrogen deficiency in corn(necrosis)

phosphate deficiency in corn

Sulfur deficiency in. corn

Ferrous deficiency in corn



calcium deficiency in soya bean

Mg defecincy in onions
Source: Swift and Woomer (1994)

Figure 26. General Nutrient Defecincy. Symptoms

Farmers' view nutrient holding capacity as a process in which the soil acts as both a sink, and a source of nutrients. Important considerations for farmers are the capacity of the storage, the rate of release, and the ability of the soil to replenish itself and provide nutrients to following crops. 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 sulfur 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).

3.8.3.2 Relationship between texture and nutrient adsorption

The difference between sand, silt and clay is of course not visible to the naked eye. But it is important to distinguish between them, because each of the textural groups has its own characteristics . Clay particles are the smallest soil particles. They have the ability to adsorb nutrients and to ‘hold’ them. The pores between the clay particles are very small. Clay expands when it gets wet. Clay sticks together very well. Dry clay is solid and very hard. Both the size and characteristics of silt particles fall between those of clay and sand particles. The pores are smaller than in sand, but larger than in clay. Silt particles can adsorb few nutrients. Silt particles are not very sticky; they rather feel like talcum powder when dry, or soap when wet. Sand particles are big enough to distinguish with the naked eye. They feel very gritty. Sand particles adsorb nutrients very poorly. Because they are rougher than clay and silt particles, the pores between the sand particles are larger. Sand particles do not stick together. Gravel and stone are not useful for plants. They do not retain any nutrient or water, and where a stone is present it takes the place of clay or silt which can retain water or nutrients. The plant roots also have to waste energy on growing around the stones. Table (12).

Table 12. CEC Values for different Soil Textures

Soil texture	CEC (meq/100g soil)
Sands (light-colored)	3-5
Sands (dark-colored)	10-20
Loams	10-15
Silt loams	15-25
Clay and clay loams	20-50
Organic soils	50-100

3.8.3.3 Soil Reaction (pH) and its Effect on Nutrient Availability

Factors important to nutrient holding capacity are pH, amount and kind of organic matter, soil texture, and clay type. Soil reaction has a great influence on the availability of plant nutrients which is generally highest between pH 6,5 and 7.5 figure (27).

Generally ,Khartoum state soil pH is more than 7,5 and it site in semi-arid zoon the temperature more than 40degree centigrade in summer season, phosphor element faced problem to be insoluble .(PH more than 7.3).

3.8.3.4 Nutrient Management

Management practices are all related. The key is to visualize them all as whole-farm management, leading to the goals of better crop growth and better environmental quality. If a soil has good tilth, no subsurface compaction, good drainage, adequate water, and a good supply of organic matter, plants should be healthy and have large root systems. This enables plants to efficiently uptake nutrients and water from the soil and to use those nutrients to produce higher yields.

Table 13. Rating chemical fertility

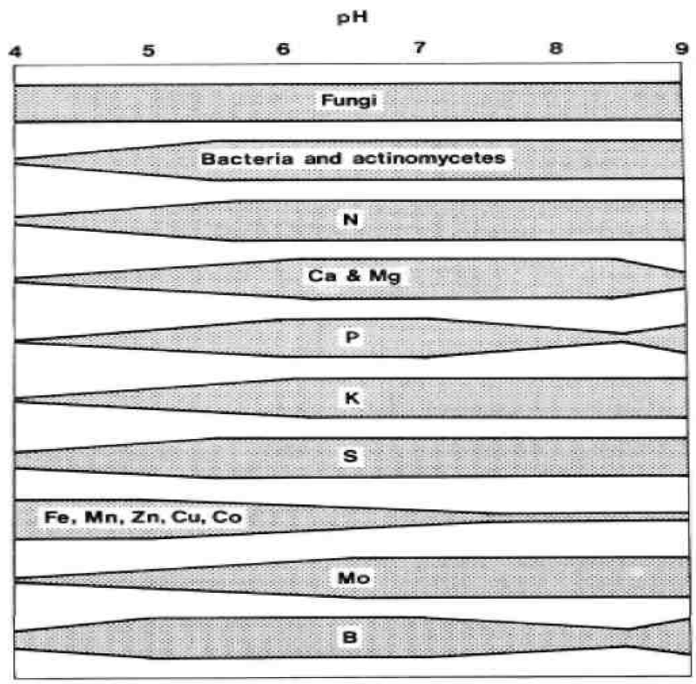
Rating	pH paste	O.C %	N %	P (4) mg/kg	CEC Cmol (+)/ kg	K Cmol (+)/ kg	Base Sat.	Micro-nutriments
1	6.0-8.0	>2.25	>0.15	>24	>20	>0.4	>70	Adequate
2	8.0-9.0, 5.0-6.0	0.75-2.25	0.05-0.15	16-24	10-20	0.2-0.4	40-70	Low
3	4.5-5.0	0.15-0.75	0.01-0.05	8-16	3-10	0.1-0.2	10-40	Deficient
4	<4.5	<0.15	<0.01	<8	<3	<0.1	<10	Toxic

Element	Limit (mg/kg)	Method of Determination
Zn	0.75	DTPA
Mn	5.00	"
Cu	1.50	"
Fe	2.00	Ammonium acetate

Source:van dar kevi and Eltom (2004)

There are many study show the effect of element on chemical and physical properties of soil.

Zahra (1986) study the effect of elemental sulfur on chemical properties of tow alkaline soils (Khartoum state)and on the performance of vicia faba and triticum aestivum ,she found that The application of sulfur decrease pH and increase availability of phosphorous the end increase the uptake of copper but uptake of zinc decrease and so soil ESP ,also sulfur increase the nitrogen utilization by plant.



Source: FAO. (1995).

Figure 27: Soil pH and relative availability of plant nutrients and activity of soil microfloa

Nazar (1997)found nitrogen fertilizer +chicken manure significantly increased all measured parameters ,the best results were obtained when10tons chicken manure and 100kg nitrogen\ha were applied. The results show significant in lenses ,leafs number .Seif (1992) found the application of sulfur fertilizer in western state (sandy clay ,sandy loamy soil, Sulfure deficiency in most Sudan soil) advance yield quantity and quality .

Recently Agriculture Research's corporation recommended addition of five (5) tons FYM /ha plus 43 kg P_2O_5 /ha or (10) tons FYM /ha without P for high terrace soil. Most study recommended that super phosphate fertilizer alone was not enough especially in our soil because the nitrogen level is low there for we add nitrogen fertilizer.

3.8.4 Salinity and sodicity

Salinization and sodication are considered major desertification processes in irrigated lands of the world because they are widely spread and have serious adverse impacts on the productive capacity of agricultural lands, forestlands, and rangelands (Mustafa 2007). Soil salinization is the increase of the total soluble salt concentration at the root zone in the soil profile .When plants grow under saline conditions, they are subjected to three types of stress, water stress caused by the osmotic pressure, mineral toxicity stress caused by the salt and disturbances in the balance of mineral Salinity becomes a problem when enough salts accumulate in the root zone to negatively affect plant growth. Excess salts in the root zone hinder plant roots from withdrawing water from the surrounding soil. This lowers the amount of water available to the plant, regardless of the amount of water actually in the root zone.. Sodication or alkalization is the increase of the exchangeable sodium percentage at the root zone in the soil profile (Mustafa, 2007).

Both of them are known as salt affected soils and they occur naturally, but they may be accelerated by some adverse human activities. Salt affected soils occur in all continents and under almost all climatic conditions. However, their distribution is more extensive in the arid and semi arid regions particularly, after watering. Melon (1984) concluded that the occurrence of salinity under natural conditions can be explained from a study of the geo-hydrology of the area. Such investigations, also the base for predicting the changes introduced by irrigations, the natural factors which cause evolutions of salt affected soils are: Salts movement, transport, diffusion and dispersion (Kovda, 1984). Previous research showed that the world is losing at least ten hectares of arable land every minute, five because of soil erosion, three from salinization and one from other degradation processes and one from non-agricultural uses

It was estimated that 50% of the irrigated land in arid and semi-arid regions have some degree of soil salinization problems. Thus, combating salinity and sodicity stresses through protection, correction, and reclamation scenarios of salt-affected soils is essential to secure future food security. In Sudan, it was estimated that 4.874 million hectares are salt-affected. This area constitutes a small portion of the total area which is expected to be salt-affected in a large country (2.5 x 106 km2) dominated by arid and semi-arid zones that favors the formation of salt-affected soils .The main source of all salts in the soil is the primary minerals of the earth's crust (Prasad and Power, 1997). The majority of rocks found in the upper strata of the earth's crust are formed under extreme conditions of high temperature and pressure. Because of this, the minerals making up of these rocks, known as primary minerals, are thermodynamically unstable and readily react to form more stable minerals in the presence of water, oxygen and carbon dioxide. The availability of these reagents will affect the rate and the degree of weathering that occurs in a region (American Society of Civil Engineers, 1990). Where there is a large amount of organic matter, weathering is enhanced as a result of the high levels of CO2. Due to the lack of moisture in arid and semi-arid regions, the soils are generally are not subject to wealth. These conditions provide an excellent source of nutrients for plants but at the same time constitute a renewable source of salinity.

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Salty soils have no structure and a lot of salt. Often white spots appear on the surface where salt has accumulated figuer (28). These soils occur in dry areas where the groundwater is not very deep. For agricultural use they must have a good irrigation and drainage system(American Society of Civil Engineers (1990) reported that saline seas have covered large areas of the present day continents. These have left behind deposits of sedimentary rocks as well as entrapped aquifers with their saline solution, both of which are substantial sources of salinity. The man made factors of salinization and sodication are closely related to soil and water managements, quality and use, and to the lack of awareness of the problems of salt affected soils, where condition permit their formation, beside some other factors (Massoud, 1984). Their characteristics are that: they depend on man's role according to his management to improve or worsen the condition, they have different weighted values and importance, and functionally they are interrelated, and consequently should not be evaluated separately but in an integrated approach

Source: Adam, (2012)

Figure 28: Plate Oily appearance in sodic \ saline soil

The human activities such as irrigation also result in an increase of salts in soils (American Society of Civil Engineers, 1990) A form of irrigation will have an effect on the salinity of the soils as all irrigation water contains some form of salts and because the extra moisture increases the rate of mineral weathering. Sodic soils are so-called because they have sodium ions attached to clay particles. When these soils are wet, the particles disperse and move away from each other, which is seen as cloudy water. When the water evaporates, these individual particles settle in a solid mass, causing waterlogging and hard-setting soil crusts. It is difficult for roots to move through these soils. Gypsum can help ameliorate these soils, but this is not economical for large areas.

3.8.4.1 Parameters for diagnosis of salinity and sodicity

Salinity is most commonly measured with an electrical conductivity (EC) meter that estimates the concentration of soluble salts in soil or water by passing an electrical current through the medium (McCauley and Jones, 2005). The ability of a solution to conduct electricity increases with increasing salt content. The more accurate assessing of soil sodicity can be quantitatively tested in laboratory by determining the portion of exchangeable sodium (ESP) percent in the cation exchange capacity (CEC).

$$ESP = (ES/CEC) \times 100$$

Where, ESP and CEC (exchangeable Na^+, K^+, Ca^{2+}, and Mg^{2+}) are in meq/100g soil.

Sodicity is measured by calculating the exchangeable sodium percentage (ESP) and/or the sodium adsorption ratio (SAR) (McCauley and Jones, 2005). SAR is commonly used to determine the sodium hazard of irrigation water (Prasad and Power, 1997). ESP is the percentage of soil exchange sites occupied by Na^+, and is calculated by dividing the concentration of Na^+ cation by the total cations exchange capacity (CEC). Units of concentration for ESP are milliequivalents per 100 g(meq/100g). (Table (14).

SAR,on the other hand, expresses the proportion of Na^+ relative to the proportions of Ca^{2+} and Mg^{2+} where cations concentrations are in milliequivalents per liter (meq/l). This provides an ESP (exchangeable sodium percentage) value which determines the sodicity of the soil. If the ESP is more than 15, the soil is sodic. Sodic soil soils have a tendency to swell on wetting

Table 14. Salt affected soil definition:

Soil classification	**EC (dS/m)**	**SAR**	**ESP**	**pH**
Saline	>4.0	< 12	< 15	< 8.5
Sodic	< 4.0	>12	>15	>8.5
Saline-sodic	>4.0	>12	>15	< 8.5

(Source: Husaein (2008). - Mc Cauley and Jones, 2005).

The ESP is also calculated through a standard formula using the sodium adsorption ration values (SAR) obtained from the ionic (Na^+, Ca^{2+}, Mg^{2+}) concentrations in the soil saturation extract (Prasad and Power, 1997) then SAR can be calculated by the equation below:

$$SAR = \frac{Na}{\{(Ca + Mg)/2\}^{1/2}} \text{ (moles/l)}$$

Where, the concentration of Na^+, Ca^{2+} and Mg^{2+} are in meq/l.
The values of SAR are then used to calculate ESP (Richard, 1954).

EC, ESP and SAR are routine analyses for most soil or water testing laboratories, with the exception of ESP; which is not analyzed for water samples. Soil sampling depths for EC, ESP and SAR should be taken from the 0 - 0.15 m and/or 0.15- 0.30 m soil depths (McCauley and Jones and Jones, 2005). Ions which commonly occur in salt affected soils are given by American Society of Civil Engineers (1990) as shown in Table (15).

Table 15. Ions commonly found in salt affected soils

Cations		Anions	
Na^+	Sodium	Cl^-	Chloride
Ca^{2+}	Calcium	SO_4^{2-}	Sulfate
Mg^{2+}	Magnesium	HCO^{3-}	Bicarbonate
K^+	Potassium	CO_3^{2-}	Carbonate
Na^+	Sodium	NO^{3-}	Nitrate

(Source: ASCE, 1990)

Soil reaction pH is one of the most variable characteristics of soil solution. It is influenced by the soil moisture content, the total concentration and ionic composition of the soil solution, the temperature of the soil layer and by several other factors. The pH of saline-sodic soils is generally less than 8.5. However; this can increase with the leaching of soluble salts unless concentration of Ca and Mg^{2+} are high in the soil or irrigation water (Brady R. Weil, 2002). Soils with a pH greater than 8.5 are said to be alkaline (Prasad and Power. 1997).

3.8.4.2 Sodicity Problems

High sodicity causes clay to swell excessively when wet. The clay particles move so far apart that they separate (disperse). This weakens the aggregates in the soil, causing structural collapse and closing-off of soil pores. For this reason water and air movement through sodic soils is severely restricted. In vegetable crops, sodic layers or horizons in the soil may prevent adequate water penetration when during irrigation, making the water storage low. Additionally, waterlogging is common in sodic soil, since swelling and dispersion closes off pores, reducing the internal drainage of the soil. Sodicity of the surface soil is likely to cause dispersion of surface aggregates, resulting in surface crusts.

- **Self-mulching clays**
  These soils are well structured and non-sodic at the surface. There is generally more calcium rather than sodium attached to the clay particles; this is why self-mulching clays are well structured. The deeper subsoil of these soils can be sodic, so waterlogging is possible.

- **Non-self-mulching clays**
  These soils are sodic at or near the surface; the sodicity increases with the depth. Therefore, these soils are likely to have water storage and waterlogging problems. Establishment of crops is often difficult due to crusting and poor tilth

3.8.4.3 Distribution of salt-in khartoum state soils

Saline and/or sodic soils occur in Khartoum State, the northern States along both banks of the Nile, South of Khartoum between the Blue and White Niles Table(16) ,and on both banks along the White Nile north of Kosti, Kasala, Red Sea, Al Gizera, and in Al Gadarif (Adam, 1975; Nachtergaele, 1976; Ministry of Agriculture of Khartoum State, 2000; Doka, 2002; Lahmeyer, 2005; Mutafa 2007;).

Some of these soils are used by private and co-operative growers for producing vegetables, fruit and fodder crops for neighboring markets. The established farms have the advantage of good Nile water and good roads to local markets. The declining yields of irrigated crops have accentuated the need for more research of the efficient use and management of such soils.

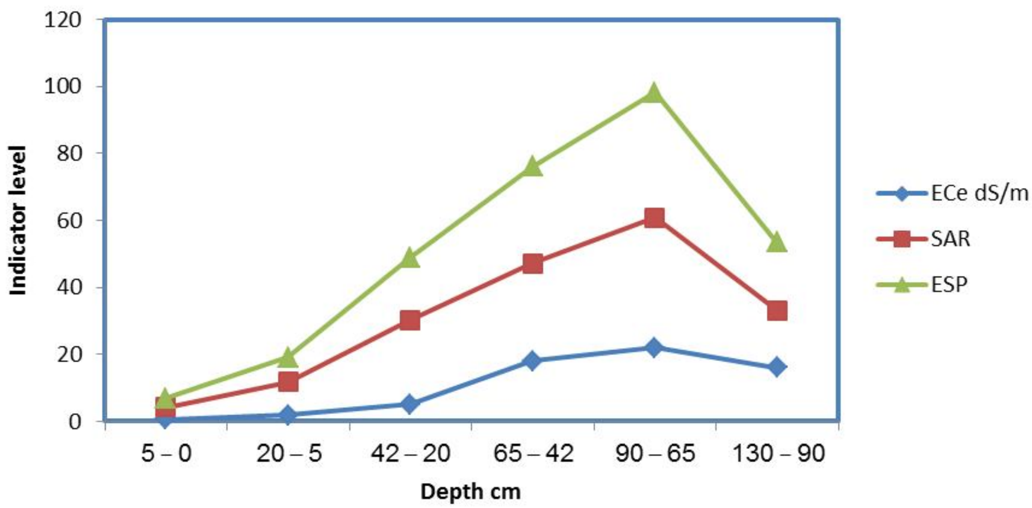
Table 16. The area covered by soalt hazard in khartoum state.

Soil Series	**Depth (cm)**	**pH**	**Mean**	**EC**	**Mean**	**ESP**	**Mean**	**Clay**	**Mean**	**Type of salt**
	0-30	8.4		3.2		42		29		
Kadro	30-60	8.3	8.3	7.7	6.2	50	47	39	36	S a
	60-90	8.3		7.8		50		39		
	0-30	8.1		2.6		26		38		S a
Kuku	30-60	8.	8	6.1	7.5	16	25	45	43	
	60-90	7.8		13.5		33		45		
Bageir	0-30	8.6		1.7		37		31		
(South	30-60	8.5	8.5	4	3.1	50	48	29	29	a
Khartoum)	60-90	8.5		3.5		57		27		
Eseilat	0-30	8.7		1.7		31		37		a
(South	30-60	8.7	8.7	4.2	3.2	49	43	39	41	
Khartoum)	60-90	8.6		3.8		48		47		

Salinity (s) and sodicity (a). (Source: Farah, 2008)

Source:Adam (2012)

Figure 29: Plate Surface crust and flakes appearance in sodic \saline soil ;



Source:Hessen Adam(2012)

Figure 30: Salt distribuation in diffrent horizon(Elsielat area)

3.8.4.4 Management of Salinty and sodicty

- **Using manure and irrigation**

Little scattered research conducted in Soba research station and Khartoum University has given less attention to integrated management practices. Yousif (1982) found that in Soba saline-sodic soils, the faba bean significantly responded to application of manure. Chicken manure associated with nitrogen yielded higher than both farm yard manure alone and nitrogen alone. But sewage addition was intermediate between the above. Dahab (1984) found that the application of organic matter on the soil surface or mixed with soil surfaces improved the soil structure, inhibited evaporation and increased infiltration rate. Ahmed,

(1995) found in saline-sodic soil, that chicken manure is the better effective soil amendment in production of dry matter and fresh yield of Lucerne leaves and sorghum, respectively compared with other soil amendments. Although Ahmed (1995) found that the application of chicken manure in Shambat soil significantly reduced crop germination percentage; while FYM and water hyacinth increased crop germination percentage.

Gabir (1984) conducted an experiment at Soba Agricultural Research Station to investigate the impact of irrigation interval (7 and 14 days) and soil amendments (gypsum, sulpher, dry sewage, chicken manure (CHM) and chicken manure plus gypsum) on lucerne growth in a saline-sodic clay soil. Irrigating every 7 days and adding CHM was found to be the superior treatment.

Dahab (1984) agree with Ezzeldeen (1995) that the application of organic matter on the soil surface or mixed with soil surfaces improved the soil structure, inhibited evaporation and increased infiltration rate. El Amin (1980)and Abdel Rahim (1985) and Hessen (2012)) studied the effects of irrigation regimes and some soil amendments on salt redistribution and production of forage sorghum. The result indicated that irrigation every 7 days intervals improved salt removal and de-alkalinization of the soil and increased yield, leaf area index, plant height, and leaf nutrients up-take. 0maima 2003) study the effect of different levels of salinty on growth ,yield and quality of barly (Hordeum ualgare) ,she found significant effect of salinty on seedling emegernce ,all growth and yield parameter and seed quality and reduced days to50% heading.

❖ **Using Tolerance crop**

Sabir Ali *et al(2014)* studies Salt tolerance and effects of Salinity on someAgricultural Crops in the Sudan ,thy found that The salt tolerance of the five tested plants was as follows: *Portulaca oleracea* “purslane” was the most tolerant plant followed by Abu Sabeen, pearl millet, Roselle and okra “most sensitive”. Superiority of purslane was mainly related to its being a succulent plant that contains large amounts of water in its shoot system that contributes to moderating the effects of salinity.

❖ **Using gypsum**

Gypsum contains calcium sulfate. Calcium sulfate is a salt, but unlike sodium chloride (the main component of salt in saline water tables) it is not toxic to plants. Gypsum will help to reduce swelling and dispersion of the soil through two mechanisms. These are:

- Gypsum slightly increases the salinity of the soil solution, and hence reduces swelling. The same effect can be seen when using saline bore water, but this often contains high levels of sodium and chlorine that are toxic to plants. Gypsum will slightly increase salinity without any detrimental effect on plants.
- Calcium from the gypsum will swap with the sodium that is held on the clay surfaces. This reduces the sodicity of the soil and is called cation exchange.

Gypsum can have its most beneficial effect at sowing time. It can provide better soil tilth, and can reduce crusting in sodic surface soils, hence improving establishment. If you use gypsum where the surface soil is sodic, time the application so that rain or irrigation does not leach the gypsum from the surface soil by sowing time.

Cultivation practices on sodic soils should be aimed at preserving soil organic matter in the surface soil. This is usually achieved by less aggressive, reduced tillage. Non-inversion tillage is useful for leaving the more sodic subsoil at depth. In many soils, the topsoil is non-sodic and of reasonable depth (10 to 40 cm). However, these soils will often have sodic sub-soils. Gypsum applications to these soils will have little effect on the topsoil but will increase the structure, aeration and permeability of the sub-soils. This is likely to increase water storage and reduce waterlogging(Table 17). The depth of the non-sodic topsoil is an important consideration in the likely response of sodic subsoil to gypsum improvement. Since a non-sodic topsoil is usually a better environment for plant growth anyway than a sodic topsoil, responses to gypsum will be low or unlikely when there is good depth of topsoil—the existing soil structure will allow optimum plant growth. As a rough guide, if the non-sodic topsoil is greater than 15 to 20 cm deep, then a gypsum response may be unlikely.

Table 17. Gypsum application rate with respect to soil ESP

Exchangeable sodium percentage (ESP) of cut area	**Gypsum application rate t/ha**
Greater than 5, less than 10	2–5 t/ha
Greater than 10	5 t/ha

❖ **Using saline irrigation water**

Many farmers are now using bore water to irrigate crops and pastures. However, be careful with this as you may experience problems, including:

- A build-up in soil salinity and therefore a decrease in crop production
- An increase in soil salinity in some districts. As figure (31)indicates, a sodic soil can be well structured if the soil is saline enough to prevent dispersion. This is why saline water or gypsum (a calcium salt) improves soil structure on sodic soils. However, avoid using saline water for irrigation, since:
- Soil sodicity is likely to increase. If the sodicity increases and soluble salts are leached out (washed out) of the soil by fresh water, the soil will become poorly structured.
- Soil salinity will increase. However, careful irrigation does have its place (figure 27).

http://www.dpi.nsw.gov.au/-dataassets/pdf_file/0007/127258

http://www.fao.org/docrep/x5871e/x5871.htm

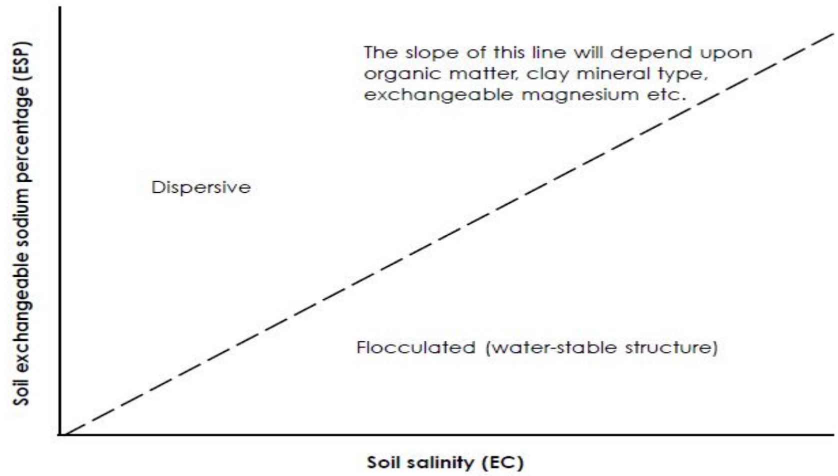


Figure 31: Soil structure as affected by salinity (EC) and sodicity (ESP)

3.8.5 Calcium carbonate

Calcium carbonate, or CaCO3, comprises more than 4% of the earth's crust and is found throughout the world. Its most common natural forms are chalk, limestone, and marble, produced by the sedimentation of the shells of small fossilized snails, shellfish, and coral over millions of years. Although all three forms are identical in chemical terms, they differ in many otherrespects, including purity, whiteness, thickness and homogeneity. (https://en.wikipedia.org/wiki/).

The major soils in Sudan can be divided geographically into three categories: the sandy soils of the northern and west central regions, the clay soils of the central and eastern regions, and the laterite soils of the southern regions (Elfaki *et al.*, 2015). Carbonate is a natural constituent of many soils in the world; most carbonate minerals found in soils of arid regions of Sudan are calcite ($CaCO_3$) and dolomite (Ca Mg, CO_3) minerals and exist mainly in the soils of the northern Sudan (Ibrahim, 2008).

Calcium and magnesium carbonate occur naturally in some soils and sediments notably on calcareous soils and sediments notably on calcareous lithologies, and where the shell fragments are present, their presence may also be the result of human activity. Naturally, occurring carbonate such as limestone, dolomite and shell will also contribute to the total carbonate of the soil and their potential presence should be considered when interpreting the data. Carbonates may also be precipitated from the ground water in hard water areas (El Mahi *et al.*, 1987)

3.8.5.1 Calcium carbonate measure

Calcium carbonate concentration is determined by dissolution of carbonate is on excess of 1N HCl, followed by back titration of the remaining acid using 1N NaOH. Calcimeter instrument is used to estimate carbon dioxide (CO_2) volume obtained from the reaction between soil carbonate with hydrochloric acid (HCl) at room temperature and atmospheric pressure. The volume of gas should be corrected to standard temperature and pressure, and these amounts of carbonate can be calculated according to the statement; one mole of gas occupies 22.41 liter at standard temperature and pressure (Horváth, *et al*., 2005)

3.8.5.2 Effect of calcium carbonate in the soil

Calcareous soils (pH > 7 .0) which cover more than 25% of the earth surface are very common in semi-arid and arid climates; their content of free calcium carbonate in the upper 30-40 em is between a few percent to 95%. Pedogenic carbonates such as calcium affect soil chemistry and structure via decreased water penetrability, a well-buffered pH range of 8.0 to 8.4. Such a relatively high pH decreases the availability of micronutrients such as manganese, copper, iron and zinc. Calcium carbonate can control P levels in soil solutions through ion-pairing with calcium, physical sorption onto calcium carbonate .The lowered crop response to P fertilization is attributed to the fixation of phosphorus by pedogenic $CaC0_3$. (McCalsin and Gledhill, 1980).

3.9 Soil Health Cards

The soil health, or soil quality, assessment card is a qualitative tool designed by and for farmers. The cards contain farmer-selected soil quality indicators and associated ranking descriptions typical of local producers. Generally, indicators listed, such as soil tilth, abundance of earthworms, or water infiltration, can be assessed without the aid of technical or laboratory equipment (Table18). All cards have a scoring system, which usually includes either a range of poor to good or a numerical scale from 1 to 10 for each indicator. Individual indicator scores are generally not combined or totaled, and there is usually space on each page to record results for each field (Doran *at el.* 1996.)

In United State of America (USA) soil quality assessment cards are obtained from the local National Resource Conservation Service (NRCS) Conservation District, or Cooperative Extension Service Office in those states that have produced cards. Health cards integrate physical, biological, and chemical properties in ways that are familiar to producers. For example, the cards use terms like tilth, which refers to the physical structure of soil and which also depends on biological properties.

Table 18. Best time to assess different indicators

Indicator	**Best assessed**
Organic Matter Roots/Residue	Anytime
Subsurface Compaction	Best pre-tillage or postharvest Good soil moisture
Soil Tilth // Friability	Good soil moisture
Erosion	After heavy rainfall
Water Holding Capacity	After rainfall During growing season
Drainage Infiltration	After rainfall
Crop Condition	Growing season Good soil moisture
pH	Anytime, but at same time of year each time
Nutrient Holding Capacity	Over a four year period, always at same time of year.

Source :USDA Guidelines for Soil Quality Assessment (2001).

Soil health cards are producer friendly, quick, and require only basic tools such as a shovel and wire flag. Results are obtained immediately, allowing the user to evaluate numerous fields quickly Table(19) Directions for use are found on each card. To use the card, simply pick an area information with other important data, including management practices, fertilizer rates, pest management, manure application, etc. Soil quality changes are best interpreted by having the same person assess the field under approximately the same conditions (time of the year).(Romig, *at el.* 1995).

Health cards can be used to conduct assessments with producers, and the information gained from health card assessments should be used to discuss soil quality. Producers should be encouraged to utilize the information gathered with the card. However, the card and results should be left with the producer. Only if the producer agrees can a summary of the health card results be included in the conservation plan (Doran *at el.* 1996)

Table 19: The Steps of Soil Health Card Assessment

STEP	SUMMARY
1. Identify Problems and Opportunities	Contact farmer. Identify general resource problems, opportunities, and concerns. Collect information on general needs of farmer. Consult Conservation District long-range plans, soil maps, other resources.
2. Determine Objectives: Assessing Soil Quality Goals	Define producer. objectives for soil quality. Identify whether producer wants to improve or maintain soil quality or to troubleshoot problem or low productivity areas
3. Inventory Resources: Assessing Soil Quality	Collect background information. Determine which methods/indicators best meet the needs of the producer. Do soil quality assessment. Record data.
4. Analyze Resource Data: Evaluating and Integrating Results	Look for patterns and trends in results. Compare results from different methods. Evaluate discrepancies carefully. Reevaluate soil quality if necessary. Provide general summary of soil quality assessment to producer.
5. Formulate Alternatives: Implementing Steps to Improve Soil Quality	Formulate alternatives to meet the farmer goals, address natural resource problems, and improve or protect resource conditions. Integrate inherent properties and capabilities of system with results of soil quality evaluation and features of the cropping systems. Use Suggested Management Solutions to Soil Quality Problems in Resources, Soil Quality Test Kit Guide, interpretive information from soil testing labs, Soil Quality Thunder book, NRCS Field Office Technical Guide, personnel from Cooperative Extension Service, Conservation Districts, Certified Crop Advisors, and private consultants for ideas. Involve producers in discussions about results and formulating solutions.
6. Evaluate Alternatives	Consider side effects of alternatives, including ecological, natural resource, social, cultural, and economic impacts; size of farm; type of operation; and resource availability. Predict consequences of various practices and operations. Give special attention to any ecological values protected by law or executive order
7. Make Decisions	Help producer with final decision. Work together to sketch out a timeline for implementation. Prepare necessary documentation

Source: Guidelines for Soil Quality Assessment in Conservation Planning (2001)

3.9.1 Soil health card Application in United State of America

Soil health card provides assistance to Natural Resources Conservation Service (NRCS) staff and its conservation partners to collaboratively develop Soil Quality Cards with local farmers. Partners such as Soil and Water Conservation Districts (SWCD), Cooperative Extension Service, state conservation agencies, and local groups assist in producing Cards that farmers and other land managers can use to assess soil quality on their land and implement management practices that ensure long-term soil productivity (**http://soils.usda.gov/sqi**)

There are many examples to soil health card that develop with farmer and designed by the University of state or region in collaboration with the USDA-NRCS Soil Quality Institute. It was developed to help users evaluate changes in soil quality as affected by field management:-

- Maryland soil quality assessment card is a locally adapted field tool designed by the University of Maryland in collaboration with the USDA-NRCS Soil Quality Institute and 17 Maryland farmers. It was developed to help users evaluate changes in soil quality as affected by field management. Regular use will allow you to record long-term changes in soil quality among different fields and various farming systems. The book is designed for farmers, but can also be used by agricultural support professionals such as soil conservationists, soil scientists, Cooperative Extension agents, and agriculture industry representatives.(figure 32)

- Palouse and Nezperce Prairies Soil Quality Card Guide was developed by A group of North Idaho and Eastern Washington growers identified 10 soil quality indicators for the Palouse and Nez Perce Prairies, which will assist in assessing the impacts of agricultural activities on soil management(Table 20 .).

- Nebraska soil quality assessment was developed by farmers in collaboration with the Natural Resources Conservation Service (NRCS), Natural Resources Districts (NRD), and the University Nebraska Lincoln. It has been locally adapted by Nebraska NRCS as a field tool for Nebraska farmers, educators, and agricultural support professionals such as soil conservationists, Cooperative Extension educators, or agriculture industry personnel (figure 33).

- Northeastern Illinois soil quality card Developed by farmers for farmers to evaluate soil quality in their fields, Farmers worked with the USDA-Natural Resources Conservation Service and Extension to develop a simple tool to evaluate soil quality in the field. The land users wanted a non-technical way to assess current conditions of their soil and to measure changes as management systems were updated. Upper-Midwest farmers and producers all the way to the east coast followed their example (.Figure 34).

- Willematte valley soil quality card was developed by farmer in collbration with soil Conservation Service, local soil and wate conservation districts and Oregon state university. The Willamette Valley Soil Quality Assessment Card is a standard paper size (8.5” x 11”) pad, which includes user instructions, an assessment calendar, and multiple soil assessment cards (printed on Ritein- the-Rain paper). The card was also produced as a fold-out brochure for convenient display and distribution (figure 35)

- Cornell soil health assessment card was developed and designed by College of Agriculture and Live Sciences staff in University of Cornella. figure (36)

Assessment Calendar					
Indicator	**Before planting Early spring**	**Active crop growth Spring Summer/Fall**		**Late Fall**	**Winter**
1. Infiltration					
2. Compaction					
3. Tilth and Structure					
4. Organic Matter					
5. Plant Residue					
6. Worms					
7. Erosion					
8. Seedling Emergence					
9. Plant Growth					
10. Rooting Systems					

FIELD NOTE

Farm I.D………………. Field I.D…… . Date……………..

Crop……………………. Acres………………………..

Inputs Type Quantity Price

Fertilizer……………………………………………………………………………………….

Lime………………………………………………………………………………………….

Manure……………………………………………………………………………………….

Cover………………………………………………………………………………………….

Crops………………………………………………………………………………………….

Pesticides……………………………………………………………………………………..

Other……………………………………………………………………………………………..

Equipment Used……………………………………………………………………………..

Problems, Comments, Weather Conditions……………………………………………………

Yield

Amount…………………………….. Units……………………………….

Moisture……………………………..

Price……………………………………..

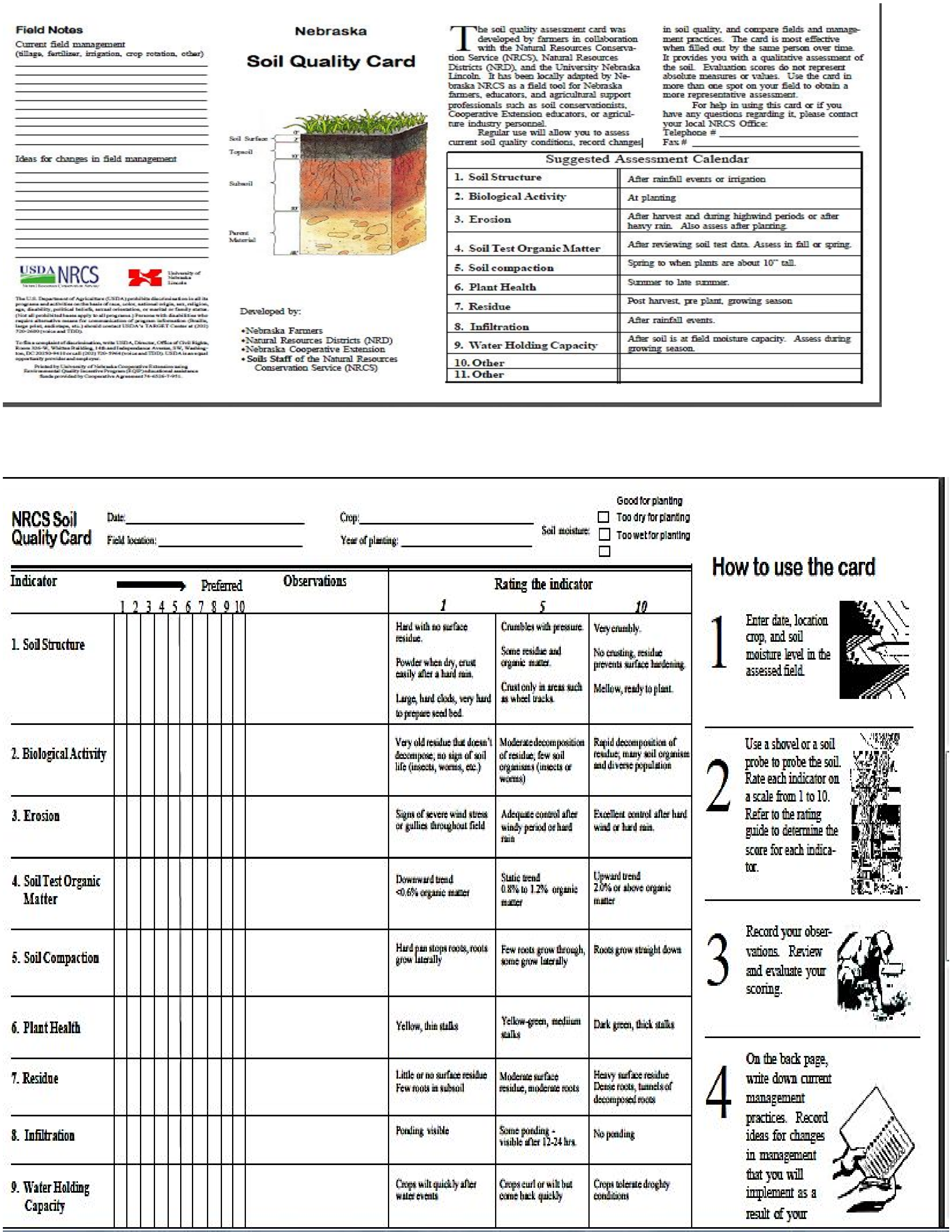
Source: Guideline for soil quality assessment in conservation planning

Figure 32: Maryland Soil Quality Assessment Card

Table 20: Palouse and Nezperce Prairies soil quality card

Assessment Calendar					
Indicator	**Before planting Early spring**	**Active crop growth Spring**	**Summer/Fall**	**Late Fall**	**Winter**
1. Infiltration					
2. Compaction					
3. Tilth and Structure					
4. Organic Matter					
5. Plant Residue					
6. Worms					
7. Erosion					
8. Seedling Emergence					
9. Plant Growth					
10. Rooting Systems					

Source: Palouse and Nezperce Prairies soil quality assessment card



Field Notes

Current field management
(tillage, fertilizer, irrigation, crop rotation, other)

Ideas for changes in field management

Nebraska

Soil Quality Card

Soil Surface
Topsoil
Subsoil
Parent Material

Developed by:

- Nebraska Farmers
- Natural Resources Districts (NRD)
- Nebraska Cooperative Extension
- Soils Staff of the Natural Resources Conservation Service (NRCS)

The soil quality assessment card was developed by farmers in collaboration with the Natural Resources Conservation Service (NRCS), Natural Resources Districts (NRD), and the University Nebraska Lincoln. It has been locally adapted by Nebraska NRCS as a field tool for Nebraska farmers, educators, and agricultural support professionals such as soil conservationists, Cooperative Extension educators, or agriculture industry personnel.

Regular use will allow you to assess current soil quality conditions, record changes in soil quality, and compare fields and management practices. The card is most effective when filled out by the same person over time. It provides you with a qualitative assessment of the soil. Evaluation scores do not represent absolute measures or values. Use the card in more than one spot on your field to obtain a more representative assessment.

For help in using this card or if you have any questions regarding it, please contact your local NRCS Office:
Telephone # ______
Fax # ______

Suggested Assessment Calendar	
1. Soil Structure	After rainfall events or irrigation
2. Biological Activity	At planting
3. Erosion	After harvest and during highwind periods or after heavy rain. Also assess after planting.
4. Soil Test Organic Matter	After reviewing soil test data. Assess in fall or spring.
5. Soil compaction	Spring to when plants are about 10" tall.
6. Plant Health	Summer to late summer.
7. Residue	Post harvest, pre plant, growing season
8. Infiltration	After rainfall events.
9. Water Holding Capacity	After soil is at field moisture capacity. Assess during growing season.
10. Other	
11. Other	

NRCS Soil Quality Card Date: ______ Field location: ______ Crop: ______ Year of planting: ______ Soil moisture: ☐ Good for planting ☐ Too dry for planting ☐ Too wet for planting ☐

Indicator	Preferred → 1 2 3 4 5 6 7 8 9 10	Observations	Rating the indicator 1	5	10
1. Soil Structure			Hard with no surface residue. Powder when dry, crust easily after a hard rain. Large, hard clods, very hard to prepare seed bed.	Crumbles with pressure. Some residue and organic matter. Crust only in areas such as wheel tracks.	Very crumbly. No crusting, residue prevents surface hardening. Mellow, ready to plant.
2. Biological Activity			Very old residue that doesn't decompose, no sign of soil life (insects, worms, etc.)	Moderate decomposition of residue, few soil organisms (insects or worms)	Rapid decomposition of residue, many soil organisms and diverse population
3. Erosion			Signs of severe wind stress or gullies throughout field	Adequate control after windy period or hard rain	Excellent control after hard wind or hard rain.
4. Soil Test Organic Matter			Downward trend <0.6% organic matter	Static trend 0.8% to 1.2% organic matter	Upward trend 2.0% or above organic matter
5. Soil Compaction			Hard pan stops roots, roots grow laterally	Few roots grow through, some grow laterally	Roots grow straight down
6. Plant Health			Yellow, thin stalks	Yellow-green, medium stalks	Dark green, thick stalks
7. Residue			Little or no surface residue Few roots in subsoil	Moderate surface residue, moderate roots	Heavy surface residue Dense roots, tunnels of decomposed roots
8. Infiltration			Ponding visible	Some ponding - visible after 12-24 hrs.	No ponding
9. Water Holding Capacity			Crops wilt quickly after water events	Crops curl or wilt but come back quickly	Crops tolerate droghty conditions

How to use the card

1 Enter date, location crop, and soil moisture level in the assessed field.

2 Use a shovel or a soil probe to probe the soil. Rate each indicator on a scale from 1 to 10. Refer to the rating guide to determine the score for each indicator.

3 Record your observations. Review and evaluate your scoring.

4 On the back page, write down current management practices. Record ideas for changes in management that you will implement as a result of your

Source: http://soils.usda.gov/sq

Figure 33: Nebraska soil quality card

NORTHEASTERN ILLINOIS SOIL QUALITY CARD

Developed BY farmers FOR farmers to evaluate soil quality in their fields

FIELD ____ **DATE** ___________________________

LOCATION ____

SOIL NAME/MAP UNIT________________________ **TODAY THE SOIL IS**: ☐Dry ☐Moist ☐Wet

CROP/PLANTS __________________________ **VARIETIES**________________**YIELD**____

FIELD CHARACTERISTICS

Characteristics of the field which need to be checked less frequently. Check the box that best describes your field.

Tpography	DESCRIPTION			NOTE
	☐Rolling to hilly	☐Gently rolling	☐Flat, more options for management	
Color	☐Light, low organic mater	☐Some organic Matter	☐Dark, high organic matter	
Soiltype	☐Clay, non-porous	☐Loam	☐Sandy, porous	
Darinage	☐Non-porous, poorly drainag	☐Moderately drained	☐Porous, well drained	

ON-GOING INDICATORS

Rate the present condition of your soil from poor to preferred. For each indicator, circle the number (on a scale of 1-9) that best describes your soil.

NDICATOR	RATING THE INDICATOR. Poor	Medium	Preferred	NOTE	SITE
Fall compaction	Severe. Root growth restrictions in top layers 1 2 3	Some or few Restrictions 4 5 6	Little to none below tillage layer 7 8 9		
Structure	Hard, slabby, aggregates hard to break 1 2 3	Somewhat blocky 4 5 6	Crumbly , loose, Mellow 7 8 9		
Earthworms per shovel	0-1 Worms 1 2 3	2-10 worms 4 5 6	> 10 worms 7 8 9		
Drainage/ moisture	Ponding prevents crop growth in some years 1 2 3	Wet spots prevent timely work but can be farmed later 4 5 6	Entire field can be workwd on same day 7 8 9		
Erodibility	Many gullies 5-10 cm deep or more, wind erosion, ditches full of soil, crop damage, siltation 1 2 3	Beginning signs of gullies, gullies < 2" 4 5 6	No visible signs of Erosion 7 8 9		
Other	1 2 3	4 5 6	7 8 9		

Source: http://www.aces.uiuc.edu/~asap/resources/isqi/isqi-resources.htm

Figure 34: Northeastern Illinois Soil Quality Card

Willamette Valley
Soil Quality Card
EM 8711

Date: ____________ Crop: ____________ Soil moisture ☐ Good for planting ☐ Too dry for planting ☐ Too wet for planting
Field location: ________ Year of planting: ________

Indicator	1 → 10 Preferred	Observations	Rating the indicator 1	5	10
1. Does the soil have good structure and tilth?			Cloddy, powdery, massive, or flaky	Some visible crumb structure	Friable, crumbly
2. Is the soil free of compacted layers?			Wire flag bends readily; obvious hardpan; turned roots	Some restrictions to penetrating flag and root growth	Easy penetration of wire flag beyond tillage layer
3. Is the soil worked easily?			Many passes and horsepower needed	Medium amount of power and passes needed	Tills easily; requires little power to pull tillage implements
4. Is the soil full of living organisms?			Little or no observable soil life	Some (moving) soil critters	Soil is full of a variety of soil organisms
5. Are earthworms abundant in the soil?			No earthworms	Few earthworms, earthworm holes, or casts	Many earthworms, earthworm holes, and casts
6. Is plant residue present and decomposing?			No residue or not decomposing for long periods	Some plant residue slowly decomposing	Residue in all stages of decomposition; earthy, sweet smell
7. Do crops/weeds appear healthy and vigorous?			Stunted growth, discoloration, uneven stand	Some uneven, stunted growth; slight discoloration	Healthy, vigorously and uniformly growing plants
8. Do plant roots grow well ?			Poor root growth and structure; brown or mushy roots	Some fine roots; mostly healthy	Vigorous, healthy root system with desirable root color
9. Does water infiltrate quickly?			Water on surface for long periods after light rain	Water drains slowly; some ponding	No ponding after heavy rain or irrigation
10. Is water available for plant growth?			Droughty soil, requires frequent irrigation	Moderate degree of water availability	The right amount of water available at the right time
Other					

Flip to back for field notes *Printed on Rite-in-the-Rain paper*

Source: soil quality card designe appendix (NRCS)

Figure 35: Wilamette valley soil quality card

Source: Corenll soil health manual (2009)

Figure 36: Corenll soil health card

3.10 The main soil types in Khartoum state

The country is characterized by variable soil types, which reflect the modifying effects of local factors such as topography and parent material. According to USDA soil taxonomy the main soil types include:

1. **Aridisols (Yermosols: according to WRB includes Calcisols, Gypsisols, Solonetz and Solonchack):** These are common in the desert and semi-desert zones where rainfall is generally less than 200 mm/annum; mostly produced under conditions of desert erosion; three distinct groups:
   - skeletal soils of eroded desert mountains
   - gravel (pavement) where the topsoil has been blown away leaving a layer of flat polished gravel, and
   - windblown sands.

   Entisols :according to WRB includes Arenosols and FLuvisols): **Arenosols** : are sand plains covering large areas in western Omdurman. The sand deposits are coarse-textured, buff to red in colour becoming paler with depth with a low cation exchange capacity; profile is generally structure less and pH ranges from 5 to 9; content of organic matter and mineral nutrients is naturally low; characterized by high permeability to water and relatively high water availability during the dry season (which is why, under the same rainfall regime, the sand deposits supports better perennial vegetation than heavy cracking clays). The sand deposits are highly susceptible to erosion by wind and water; are easy to cultivate using hand tools hence most of the traditional production activities are practiced on these soils. Long years of cultivation exhaust these soils causing a sharp drop in fertility and declining productivity; important wet season grazing areas as they are free from biting insects and muddy conditions that encourage hoof diseases among livestock.

   Fluvisols :are the soils of recent alluvium located along the Nile and its tributaries, along major water courses and inland deltas of the Gash and Tokar; prime agricultural land for basin, flood and pump irrigation.

2. **Vertisols (same name according to WRB):** These are the dark cracking clays, which are often referred to as black cotton soils; mostly alluvial in origin from material transported by the Blue and White Nile, but some might have been formed in situ from basaltic rocks, such as the cracking clays of Gedarif State. These soils are characterized by clay contents of 60% or more, are alkaline in pH and have gypsum and calcium carbonate concretions, particularly in the lower horizons. Areas with Vertisols have impeded drainage and their vegetation is the result of edaphic rather than climatic factors. Vertisols support mechanized farming as well all large scale irrigated farming. Although areas like the Butana plains are used for wet season grazing, most lands covered with heavy cracking clays are utilized for grazing after the rainy season and are important for the supply of crop residues, particularly sorghum stokes.

3. **Alfisols (Ferralsols: according to WRB).** These are the red yellow tropical old soils formed at past pluvial periods on reddish sandy loams sand stone materials overlying a layer of more consolidated ironstone; in some cases the topsoil is completely eroded to form a flat ironstone pavement; slightly acid to neutral (pH 5-7) and of relatively low fertility.

Adam and Ahmed (2010) study the assessment of soil texture and vegetation cover in three Sites in the Eastern Nile Locality, Khartoum State. The results showed that the highest clay and silt contents (34.9% and 16.4% respectively) were found in Alsileit area which had more wadis and water courses compared to the other two areas. The highest mean sand content was found in Algaili and Eilafoon areas (65.6% and 66.2% respectively) compared to Alsileit. Soil moisture content was very low in the study area ranging between 2.6% and 4.3% recorded at Algaili and Eilafoon areas, respectively. The study area was, generally, poor in vegetation cover, which ranged between 7.4% and 27.6% recorded for Algaili and Eilafoon areas, respectively. In general, most of the available vegetation was concentrated in wadis and water courses with few scattered trees and herbaceous plants in other elevations

Mohamadin (2014) studied the physical soil properties that affects soil moisture conditions and plant, and predict which is the best irrigation system for the study area in western state soils based on the soil physical properties, The Research problem there is a large amount of gravel (10-25%) and coarse sand in the soil surface and deep in the soil that affect the soil moisture characteristics and irrigation practices, he found that the proportion of gravel affect soil physical properties affected the movement of water within the soil that has been chosen for the irrigation system approves of these properties even of is pivot irrigation is controlled and maintained on soil physical properties.

Figure 37: Soil profile from farm in Al-Matamh

Sourc: Soil Survuy Divition (1976)

Figure 38: Soil profile from Wad Omar area

Source: Soil Servuy Divition (1976)

Figure 39: Soil profile from Wadi Almugadam (Sowg area)

Source: Haj hamd (2010)

Figure 40: Soil profile from Shambat area

Source: Adam, (2010)

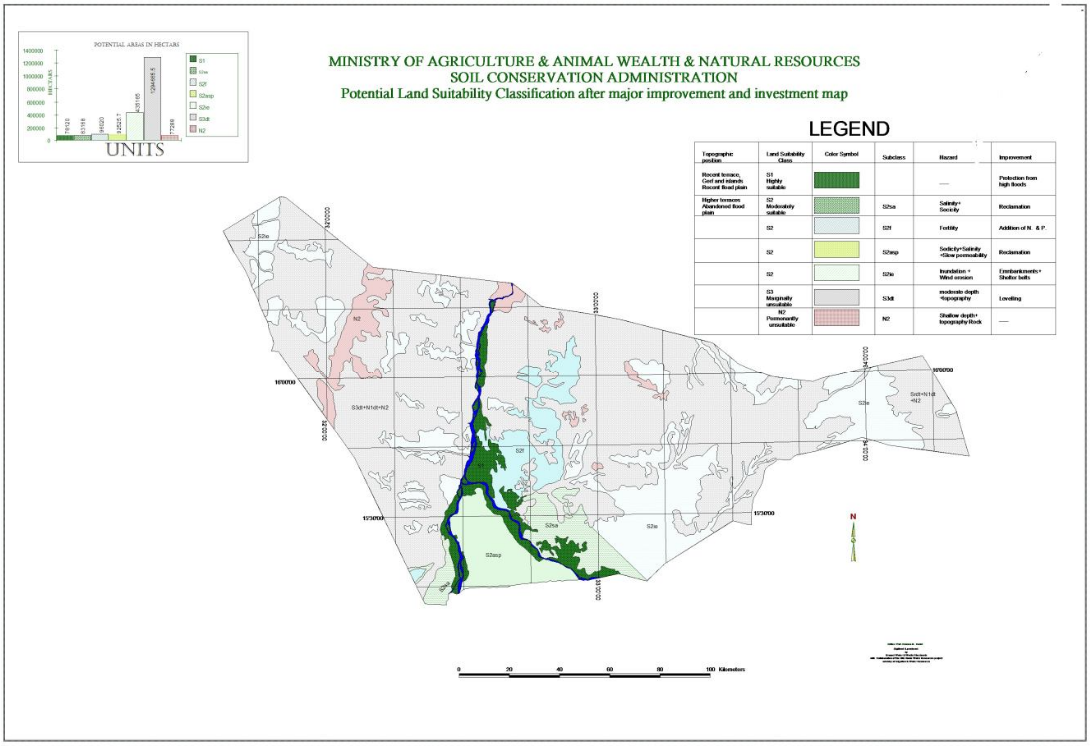
Figure 41: Clod soil in Elseilt area makes poor seedbed

3.10.1 Previous soil studies in Khartoum state

Many studies and reseaches were concerned about soil quality and how to enhance, maintant and managing farme practice to keep the soil helthy to sustainable agriculture aprodecte and good condetion to the plant growth. Now in this study _quality are chosen in khartuom state soil accroding to the studies ,researshes and land suitability classification map, the map show more than halfe regoin (1294665,5) hectar classified as marginal land (S3) from(207,966.4) hectar . It faced modreat depth and topogravy hazerd. although (706,878.7)hectar classifited as (S2) it faced limitation like fertility ,salinity and sodic, wind earotion,permeability.(Figure42)

Many research studies and field practices give signifant effort to improve soil management inorder to get best yield. These practices might include following exaamples:

- Implement a number of practices that add organic materials to the soil by considering diverse sources of organic materials to the soil
- Minimize losses of native soil organic matter.
- Provide plenty of soil cover—cover crops and/or surface residue—to protect the soil from raindrops and temperature extremes.
- Minimize tillage and other soil disturbances.
- Whenever traveling on the soil with field equipment, use practices that help develop and maintain good soil structure.
- Manage soil fertility status to maintain optimal pH levels for your crops and a sufficient supply of nutrients for plants without resulting in water pollution.
- In arid regions, reduce the amount of sodium or salt in the soil



Source: Ministry Of Agriculture Khartoum Staste

Figure 42: potentialland suitability classification after major improvement and invesment map.

3.10.2 Soil quality at Khartoum State

According to the above review of previous studies and research results it could be concluded that the main indicators in khartoum state fall into two categories of Soil physical and chemical indicators. These are as follows:

- **Soil physical indicator:**
  Soil Texture, Soil Compaction in soil layers, Soil Erosion, Water infiltration, Water, tillage and land leveling

- **Soil chemical Indicators:**
  Soil pH, soil organic matter, soil fertility, calcium carbonate, soil salinity and sodicity

- **Crop condition and crop residues:** These could be included if availabe.

CHAPTER FOUR
MATERIALS AND METHODS

4.1 Materials

4.1.1 Identifying Soil quality indicators

These are the resource information collected to identify general resource problems, opportunities, and concerns and general needs of the farmers. Agricultural research recommendations on soil properties taken from local research institutions (ARC, Agriculture colleges, Research Centers etc.), international agricultural research trials and local farmer's experiences constitute the baseline for the information needed.

Consultations were also being carried considering extensionest, long range plans and policies, soil maps and other resources. Resource problems related to soil limitations that could affect soil quality and hence its role to function properly in the environment. In this regard the objectives for soil quality are to improve or maintain soil quality and as well to troubleshoot problem at low productivity areas. Considering this, the following soil quality indicators were selected for Khartoum State as outstanding soil aspects which if maintained properly through management will enhance productivity and conserve the resources. These are listed as follows and the recommended measures are explained immediately after the list:

1. Available Water Capacity (AWC)
2. Soil texture
3. Infiltration
4. Compaction
5. Land Leveling
6. Soil erosion
7. Plant growth condition
8. Crop Residues
9. Soil Reaction
10. Soil Organic Matter
11. Soil Fertility
12. Salinity and Sodicity
13. Calcium Carbonate concentrations

4.1.1.1 Available Water Capacity (AWC)

Available water capacity is the maximum amount of plant available water a soil can provide. It is an indicator of a soil's ability to retain water and make it sufficiently available for plant use. Available water capacity is affected by soil texture, presence and abundance of gravels and rock fragments, and soil depth and layers. Soil texture contributes to the inherent soil quality, the characteristics of the soil that result from soil forming processes. These characteristics are difficult to change through. An "ideal" soil is generally defined as a soil composed of a mixture of sand, silt and clay - all of which have their unique effect on the chemical or physical aspects of the soil. The FAO textural triangle was used to determine the different textural classes of soils. Available water capacity is also affected by organic matter, compaction, and salt concentration of the soil. Figure(43).

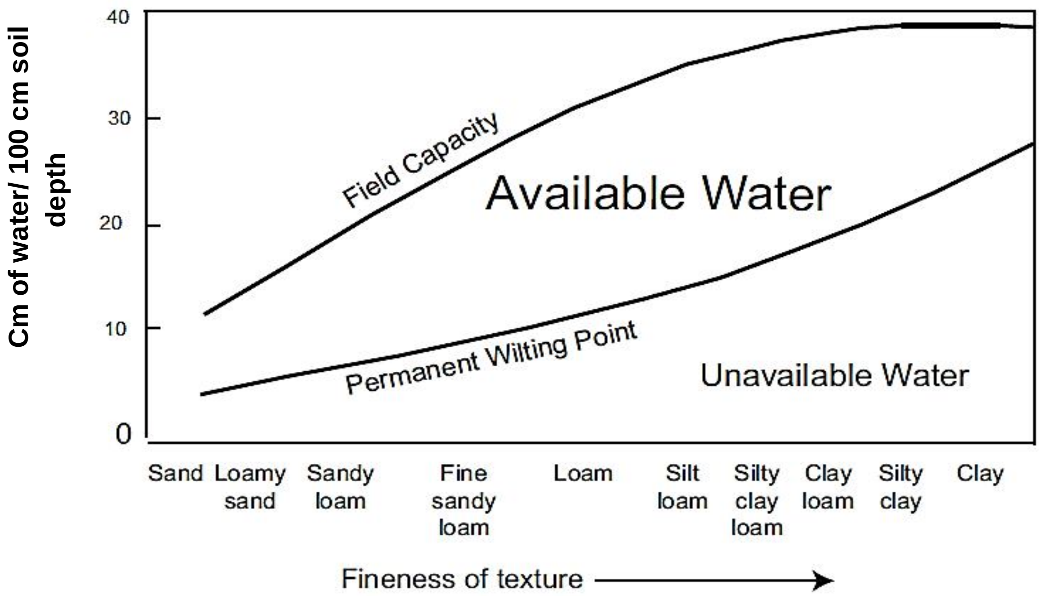


Figure 43: Available Water Capacity in relation to Texture

4.1.1.2 Infiltration

measured using the same cylinder as in the soil respiration test. Infiltration is important to reducing runoff and storing water in the soil for plant growth

Height infiltration rate: Excessive runoff or ponding, Very low water holding capacity.
Medium infiltration rate: Some runoff or ponding. Poor water holding capacity
Low infiltration rate: Very little runoff or ponding, Good water holding

4.1.1.3 Soil texture

poor texture : Soil surface is hard clumps and does not break apart, very powdery
Medium texture : Soil crumbles in hand, few Aggregates
Good texture : Soil surface has many soft small aggregates which crumble easily

4.1.1.3 Compaction

It is expression by bulk density and it is determined using natural soil clods in laboratory (Brasher, 1966) or by using soil penetrometer to measure compaction in the field. Bulk density is related to seed and root growth, biological activity, and movement of water and air in the soil. In the field it is rated as follows:

High Compaction : Cannot push probe or wire flag (16mm) into soil; crusting is prevalent
Medium compaction :Can push probe or wire flag(16mm) in soil with force; some soil crusting
Low compaction : Probe or flag enters soil easily; no soil crusting.
Bulk density is a soil property determined in the laboratory

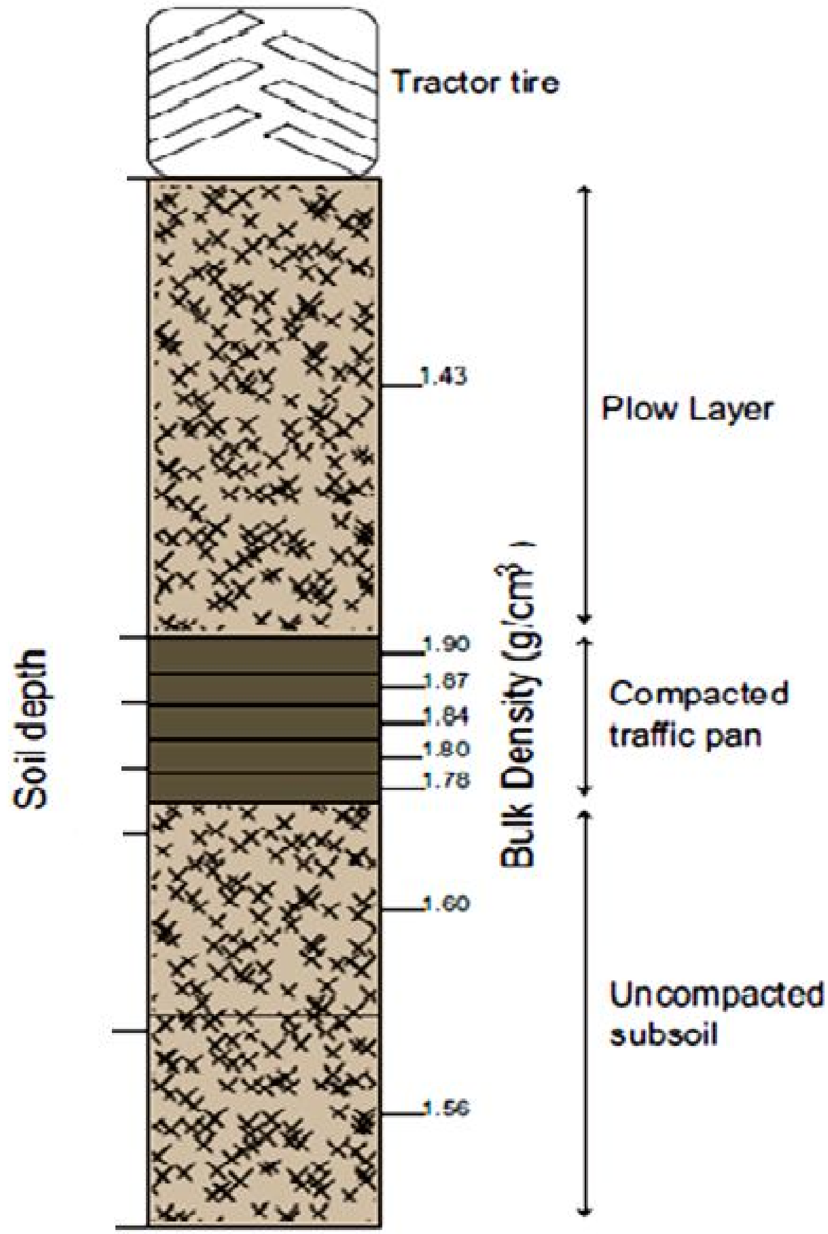


Figure 44. the compaction of tractor tiro in the soil

4.1.1.4 Land Leveling

It is a measure used in surface irrigation, such as basin and furrow irrigation according to conventional methods or using laser equipment. The advanced method to level or grade the field is to use laser-guided leveling equipment. Laser leveling is a process of smoothing the land surface (± 2 cm) from its average elevation using laser equipped drag buckets to achieve precision in land leveling. Precision land leveling involves altering the fields in such a way as to create a constant slope of 0 to 0.2%. This practice makes use of large horsepower tractors and soil movers that are equipped with global positioning systems (GPS) and/or laser-guided instrumentation so that the soil could be moved by either cutting or filling to create the desired slope/level. (Walker, Timothy *et al*. 2003). Producers should pay attention to the high cost of the equipment/ laser instrument, the need for skilled operator to set/ adjust laser settings and operate the tractor and also it's less efficiency in irregular and small sized fields.

4.1.1.5 Soil Erosion

It measured by the movement of the soil ,wind erosion effect soil texture and soil fertility
The US Soil Conservation Service sets limits of tolerable erosion in the range of 2.2-11.21 ha-1 yr-1 (lower figures for shallow soils over hard rock and higher figures for deep soils). These limits are based on two notions: first, erosion is acceptable up to the rate at which soil is renewed by natural processes, and secondly, these rates are assumed to be practicable under common farming conditions.

However, Young (2001) argues that tolerance limits for soil erosion "should be set on the basis of sustained crop yields, translated into terms of maintenance of organic matter and nutrients. Specifically, the capacity of agroforestry practices to supply organic matter and recycle nutrients needs to be integrated with losses of these through erosion, in order to determine whether a system is stable. "Some recorded erosion rates under agroforestry practices and other relevant forms of land use are shown in Table 18.1. If rates of erosion are classified as low (<21 t ha-1 yr-1), moderate (2-101 t ha-1 yr1), and high (>101 t ha-1 yr-1), the results may be summarized as follows:

Low:

Natural rain forest
Forest fallow in shifting cultivation
Multistory tree gardens
Most undisturbed forest plantations
Tree plantation crops with cover crop and/or mulch

Moderate or high:

Cropping period in shifting cultivation
Forest plantations with litter removed or burned

Table 21. Rates of soil erosion in tropical ecosystems

Erosion (t ha yr-1)			
Land-use system	Minimum	Median	Maximum
Multistory tree gardens	0.01	0.06	0.14
Natural rain forest	0.03	0.30	6.16
Shifting cultivation, fallow period	0.05	0.15	7.40
Forest plantation, undisturbed	0.02	0.58	6.20
Tree crops with cover crop or mulch	0.10	0.75	5.60
Shifting cultivation, cropping period	0.40	2.78	70.05
Taungya, cultivation period	0.63	5.23	17.37
Tree crops, clean weeded	1.20	47.60	182.90
Forest plantations, litter removed or burned	5.92	53.40	104.80

Source: Wiersum (1984).

Height wind erosion: Excessive soil movement by wind
Medium wind erosion: Some visible soil movement by water and or wind
Low wind Erosion: Little or no soil erosion by water or wind

4.1.1.6 Plant Growth Condition

Good growth: Even stand; vigorous and uniform crop growth
Medium growth: Some uneven stand; stunted growth; slight discoloring
Poor growth: Uneven stand; unvigorous and stunted crop growth

4.1.1.7 Crop Residues

Low 0-30 percent of soil surface is covered with crop residue
Medium 50-70 percent of soil surface is covered with crop residue
good >70 percent soil surface covered with crop residue

4.1.1.8 Organic matter

In Khartoum generally, all the soils of the semi desert region have low organic matter and nitrogen contents <2% (all the studies show that). The Agricultural Research Corporation (2004) recommended that addition organic manure as the flowing Table 22

Table 22. Organic matter value in the soil

Organic manure\ton\fadan	Chemical fertilizer\kg\fadan	Cases
4.5 ton	27kg nitrogen(60kg urea)	the farmer buy
8.4ton	18kg nitrogen(40kg urea)	The farmer owns animals
10ton	Non	Any cases

Source\ Agricultural Researshes Corporation

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

Low : Less than1% on the top depth 5 cm
medium :1-2 in surface of soil 5cm
Good : More than 2%in 1n the surface 5 cm

4.1.1.9 Soil Reaction

Refers to the degree of soil acidity or alkalinity. Soil reaction is important because it affects nutrient availability, microbial activity and plant growth It is measured in units of pH, which is approximately defined as:

$pH = -\log [H+]$

Most plant species perform best in pH range 5.5 to 6.5 or 7.0 but some prefer extremes. For example azaleas and blueberries grow best under more acidic conditions. In contrast alfalfa does best under somewhat alkaline conditions.

Low: pH 1.0 lower than needed
Medium: pH 0.5 lower than needed
Good: Proper pH for the crop

4.1.1.10 Concentration of $CaCO_3$

Calcium carbonate concentration is determined by dissolution of carbonate on excess of 1N HCl, followed by back titration of the remaining acid using 1N NaOH. Calcimeter instrument is used to estimate carbon dioxide (CO_2) volume obtained from the reaction between soil carbonate with hydrochloric acid (HCl) at room temperature and atmospheric pressure. The volume of gas should be corrected to standard temperature and pressure, and these amounts of carbonate can be calculated according to the statement; one mole of gas occupies 22.41 liter at standard temperature and pressure (Horváth, *et al*., 2005)

Low: more than 12% $caco_3$
Medium : 5-12% $caco_3$
Good : less than 5% $caco_3$

4.1.1.11 Soil fertility

- **Tomato recommendation**

Source: Abu Sara, et al 2001

Area	Fertilizer	Dose
Khartoum (Silate Project) and Gezira	Manda 31	0.05 % every seven days + chicken manure or urea

Area	Fertilizer	dose	Yield\f
Rahad	3N NPK	300 Kg\fed	8.7& 10.03t\fed
	2N ASN	138 Kg\fed	7.47
	2N urea+1P	78Kg urea+39 TSP	6.9
Gezira	2N ASN	139Kg\fed	17.79
	2N AS	172Kg\fed	11.2
	1N ASN	69Kg\fed	8.3
	1N AS	86kg\fed	7.95

Source: Mohamed T. Yousif et al 2009

- **Onions**

Area	Fertilizer	Dose\fed	Yield t\fed
Rahad	2N ASN	138kg	5.2 & 9.43
	2N AS	172Kg	4.8 the second season 9.17
	1N ASN	79 Kg	3..94 &8.92
Gezira	2N AS	172Kg	9.3
	2N Urea+1P TSP	87kg urea +39kg TSP	2.25 Up to 8.28
	1N AS	86Kg	1.14 up to 6.84
Sennar	1N AS	86Kg	1.85 up to 4.6

Source: Abu Sara, A.F. et al 2001, ARC Vegetables improvement Program

- **Wheat**

Area	Fertilizer	Dose kg\fed
Gezira	1N NPK	100 Kg
	2N ASN	138 Kg
	2N AS	172Kg
Ranad	2N ASN	138Kg

New halfa	1N NPK	100Kg
	2N AS	172Kg

Source: Naiem, A. Ali et al 2001

Area	**Fertilizer(Urea+DAP)**	**Dose kg\fed**
Gezira	54 kgN + 18kgP_2O_5	101 kg Urea+39 kg DAP
	54kgN + 9 kgP_2O_5	110kg urea+20kgDAP
	36kgN+18KgP_2O_5	63kg urea+39kg DAP
	36kgN+9kgP_2O_5	71kg urea+20kg DAP

Source: Naiem, A. Ali et al 2007

4.1.1.12 Salinity and Sodicity

Cultivation practices on sodic soils should be aimed at preserving soil organic matter in the surface soil. This is usually achieved by less aggressive, reduced tillage. Non-inversion tillage is useful for leaving the more sodic subsoil at depth. In many soils of Khartoum State, the topsoil is non or slightly sodic and of reasonable depth (10 to 40 cm). However, these soils will often have sodic sub-soils (Table 18). Gypsum applications to these soils will have little effect on the topsoil but will increase the structure, aeration and permeability of the sub-soils. This is likely to increase water storage and reduce waterlogging.

The depth of the non-sodic topsoil is an important consideration in the likely response of sodic subsoil to gypsum improvement. Since a non-sodic topsoil is usually a better environment for plant growth anyway than a sodic topsoil, responses to gypsum will be low or unlikely when there is good depth of topsoil—the existing soil structure will allow optimum plant growth. As a rough guide, if the non-sodic topsoil is greater than 15 to 20 cm deep, then a gypsum response may be unlikely. Remember, it may take a few months before gypsum leaches into the subsoil and begins to take effect.

Table 23: Salinity and Sodicity ratings adapted for salt affected soils in Sudan

	Depth	**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**									
	Depth	**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**									

Sources: Van der Kevie and Tom 1976

The following farming management practices gave better yields on Saline –Sodic soils (S2, S3 lands) and therefore are recommended for such soils that are usually used for fodder production (Abu Sabien) at Khartoum State.

- Irrigating every 7 days with application of organic amendments (FYM and CHM) – 5 ton/ feddan
- Application of chisel and harrow only.

4.2 Methods

A variety of methods or approaches are currently used to measure and assess soil quality. The methods range from primarily qualitative to purely quantitative. Most comprehensive efforts to assess soil quality worldwide were conducted at USA and these are as follows:

- Soil Health Card
- NRCS Soil Health Card Template (NRCS Template)
- Soil Quality Test Kit
- Laboratory analysis

These methods provide important information about soil quality, whether the goal is to determine changes in soil health over time or to compare management effects on soil quality in different fields or pastures. Various combinations of these methodologies may be used. No single one is inherently better or more effective.

Qualitative on-farm, in-field measures of soil health involve no special analyses, only the informed scoring or rating of soil characteristics. This is usually done by visual assessment, but the smell and feel of soil may also be involved. While this approach is subjective and therefore can reflect user bias when detailed guidelines and training have been provided the results can compare well to quantitative laboratory measurements. Some specific soil indicators, such as penetrometer resistance in the root zone, are always measured better directly in the field than in a laboratory.

The method developed in this study to assess soil quality at Khartoum state is a combination of a qualitative and quantitative procedures that are outlined in the four methods developed at USA. Local extensionest could explain the different procedures of the card, interpret field tests and feature and show them how to collect soil samples. Final rating of soil quality and explaining the management plans in the card could be done in the presence of the extension officer.

4.2.1 Collection of soil samples to evaluate soil qualities

The procedures for collecting soil samples to evaluate soil qualities are explained in the card. Soil scientists could explain the procedures to the farmers to collect soil samples from their fields according to the shape and size of the fields

A participatory process in developing qualitative soil health monitoring procedures locally has considerable educational value and opens up communication among farmers and between farmers and other agriculture professionals
Extinction can play an important to transferring how to take sampl and how to rate indicator throw farmers school .

Field condition

Fields should be divided into sampling units when there are differences in:

- soil type,
- management practices
- crop growth and yield

General guidelines on soil sampling for soil quality include:

- ❖ Collect samples from areas that have similar soil map units (soil types) if making comparisons.
- ❖ Sample at approximately the same time of year, from year to year, and under similar soil moisture conditions.
- ❖ Take samples or make observations from representative areas of the field. Avoid non-representative

areas such as those that are uncharacteristically wet or dry, extremely hilly, or eroded. Also avoid field borders, fertilizer bands, and spots close to a road.

- ❖ If the objective is to evaluate a specific problem, collect samples from specific .problem areas. and, for comparison, from nearby .normal areas. within the same soil map unit (soil type).

Equipment required for taking soil sample

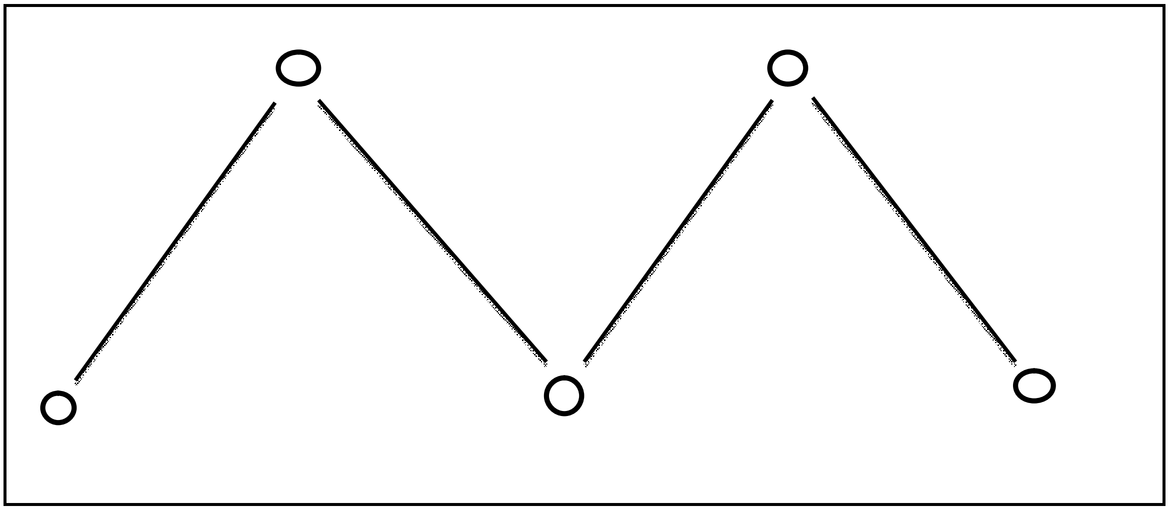
1. Shovel
2. Pen or pencil+ white paper
3. Plastic bags

Method to take a sample :

The shovel used to take a sample (figure40) in 20 cm depth from 2-5 location in regular farm in M uniform (figure41) this shape can cover a farm in good way.

Source\ photo by lubna

Figure 44. how to use and collected soil samples using shovel in the field



M Uniform to take a sample)

○ **L**ocation of the sample

Figure 45: How to take a sample by a shovel in the field

4.2.2 Laboratory analysis of soil samples

Which methods (unify methods to enable comparison of results) ……

4.2.3 Rating of soil qualities in Soil Quality Card (SQC)

The rating scales used in soil health score cards vary from just a few categories ("poor, fair, or good") to scales of 1 to 10. The descriptions that define categories or rating scales are best based on local terminology and preferences. High quality photographs are an excellent way to train users and standardize scoring.

4.2.4 How the SQC could be used by farmers

A soil health Card is primarily designed to be used by farmers to make soil quality assessments in the fields they manage. Soil health card provides assistance to Natural Resources Conservation Service (NRCS) staff and its conservation partners to collaboratively develop Soil Quality Cards with local farmers. Partners such as Soil and Water Conservation Districts (SWCD), Cooperative Extension Service, soil conservation administration, and local groups assist in producing Cards that farmers and other land managers can use to assess soil quality on their land and implement management practices that ensure long-term soil productivity

The Steps of Soil Health Card Assessment

1. **Identify Problems and Opportunities**: Contact farmer.. Collect information on general needs of farmer. The information collected during sampling is presented in this section. This includes the farm name and contact information, the sample number, the date of sampling, the local extension educator name, current crop and tillage and their history over the past 2 years, .
2. **Determine Objectives Assessing Soil Quality Goals**: Define producer. objectives for soil quality. Identify whether producer wants to improve or maintain soil quality or to troubleshoot problem or low productivity areas
3. **Indicator list:** gives a list of the physical, biological and chemical indicators that were measured for soil health assessment.
4. **Indicator values:** This presents the values of the indicators that were measured either in the laboratory or field.
5. **Ratings:** the ratings of the soil quality indicators. are scored on a scale of 1-10 based on scoring functions developed for individual indicators. In addition, the indicators are rated with numbers depending on their scores. Generally, a score of less than 5 is regarded as poor A score from 5 to 7 is considered medium A score value higher than 7 is regarded as good value .
6. **Constraints:** If the rating of a particular indicator is poor the respective soil health constraints will be highlighted in this section. This is a very useful tool for identifying areas to target their management efforts. Suggested management practices to address the identified constraints can be found
7. **Evaluate and recommended:** write the current management practices and suggest ides to change in management that you will implement as a result of assessment

CHAPTER FIVE
RESULT AND DISCUSSION

5. Khartoum state soil health card

Soil quality assessment is a useful process to evaluate and improve the soil resource as it provides an integrated method for assessing multiple aspects of the soil and their connections. By linking biological, physical, and chemical properties of soil all of the components and interactions of a soil system are viewed together. This integrated approach leads to more comprehensive solutions as compared to assessing each soil property independently. Soil health card of khartoum state was developed to help users evaluate changes in soil quality as affected by field management. Regular use will farmers and farm managers to record long-term changes in soil quality among different fields and various farming systems. The card is designed for farmers, but can also be used by agricultural support professionals such as soil conservationists, soil scientists, cooperative extension agents, and agriculture industry representatives. The card constitute four parts:

5.1 The first part

The first part includes general information for the farmer. It define a healthy soil and the important of its properties and how to improve soil management and soil function to be sustainable for agricultural use. It shows how ths card can be used to assess the soil and enhance their yield. Some recommendation were outlined on the period of evaluate and how to keep the card on file for future reference (Figure 48)

5.2 The Second part

This part includes the soil quality indicators that are selected because of their relationship to specific soil properties and soil quality. For example, soil organic matter is a widely used indicator, because it can provide information about a wide range of properties such as soil fertility, soil textuer, soil stability, and nutrient capacaty. Similarly, plant indicators, such as crop health can provide information about the fertility or water capacity of the soil., Indicators can be assessed by qualitative and/or quantitative techniques. A qualitative assessment is the determination of the nature of an indicator. A quantitative assessment is the accurate measurement of an indicator. For example, if erosion is the indicator being evaluated, a qualitative assessment would be the observation of rills and gullies in the field, indicating that erosion is occurring. A quantitative assessment would measure the amount of erosion occurring in the field. In another example, a qualitative assessment of infiltration would be the observation of excessive runoff water from a field. A quantitative assessment would measure the infiltration rate. Qualitative assessments have an element of subjectivity and, thus, are best done by the same person over time to minimize variability in the results. The rating scales used in soil health score cards vary from just a few categories ("poor, meduim, good") to scales of 1 to 10. The descriptions that define categories or rating scales are best based on local terminology and preferences .Cards developed to date have utilized 7 physical indicators and 6 chemical, and crop indicators of soil health . Periodic assessments in a field shouldbe done by the same person, during the same season and under similar soil moisture conditions as possible. (Table 22).

5.3 The Third part

Soil testing laboratories for many soil properties that are useful for soil quality evaluation The biggest advantage of a lab analysis is assurance that the results are obtained with quality control and that they are numerically reliable for long-term comparisons. Also, results from fertility related tests are often returned with interpretations and with specific recommendations to help make management decisions.., The most standard tests performed by soil testing labs are for chemical and physical properties. Chemical tests include pH, ECe, cation exchange capacity, ESP $CaCO_3$. Macronutrients include nitrogen, phosphorus, potassium, calcium,. Physical include soil textuer ,infiltration rate,bulck density ,water holding capacity, when the sample taken from the field (the method in part four) sample location, date, and depth should be recorded for every set of samples or observations to ensure long-term consistency in sampling. In other hand the analysis of the soil will enable the farmer to apply the proper fertilizer doses to avoid high doses which lead to soil salinization. The laboratory results will be interpretated and reported in recommendation.Table(26)

5.4 The fourth part

This part Include guideline steps for the farmer showing how to take soil samples from the field the steps and the equipment is very simple and easy to use. The soil sampling depending on the size of the field ,soil map is consider also the Knowledge of soil types and their distribution and uses is a fundamental and necessary step performed always before any use of the land.. Soil samples were taken is 30 cm depths (in M shape). The field equepment that are needed are normally avialable in most farms or local shops ; like shovel, empty sac, plastic page, markers + ball pens. One half Kg soil sample in plastic bag should be send to laboartory for analysis and the other half kg will be kept in the farm in save place for 3 years as refrence.Figure (49)

5.5 Minimum Data Sets and Indicators

Since it is impractical to measure every ecosystem or soil property, many researchers have proposed a minimum data set, which is the smallest set of soil properties or indicators needed to measure or characterize soil quality. Identifying key soil properties or attributes that are sensitive to change in soil functions establish a minimum data set. Table 1 is an example of a minimum data set, which shows the relationship of each indicator to soil health concerns.

A minimum data set does not usually encompass all relevant properties for a region or farming system. It is an example of a minimum set of indicators required to obtain a comprehensive understanding of the soil evaluated.

Each minimum data set is tailored to a particular region or soil map unit (soil type) and includes only those properties relevant to the soil types, farming system, and land uses of the areas being evaluated. For example, a minimum data set for the East amd South Darfur State would probably not include such indicators as salt accumulation and electrical conductivity, while a data set for areas with arid and semi-arid soils (Khartoum, Nile and Northern States) would include these indicators. Compiling a minimum data set helps to identify locally relevant indicators and to evaluate the link between indicators selected and significant soil and plant properties for the region.

RECOMMENDATIONS

Evaluate soil health periodically(about every three years) todocument changes.

•Periodic assessments in a field shouldbe done by the same person, duringthe same season and under similarsoil moisture conditions.

•For better assessments, basesampling on variability in the fieldsuch as soil, soil moisture and yield.

•Examine the distribution of indicator values. Even if most of the indicatorsare scored 10 (healthy), the soil maystill have serious problems.

•Careful consideration should be used to identify the cause of the problem.

•Impaired properties may need immediate action and should be closely monitored.

•Keep completed soil health cards on file for future reference.

Healthy soil ⟶ Highet yield

↓

Mutch money

Soil Health Card

for

Khartuom state

Sudan

through crop rotation,multispecies cover crops andforage plantings

3.Keep living roots growing throughoutthe year to provide food for soil

microbes and reap the benefits of their presence

4.Keep the soil covered as much aspossible to conserve soil moisture,reduce soil temperature, prevent soilerosion and suppress weed growth

5.Consider adding livestock, in amanaged grazing system, to a rowcrop system in order to increase thecycling of plant nutrients

6.Talk with farmers using conservationtillage or managed grazing systems asthey can give you some ideas abouthow they are changing the health oftheir row crop or grazing lands.

ABOUT THIS CARD

The soil health card was designed and adapted for local use. It was developed by and for producers to identify where improvements could be made and to evaluate the effect of changes in management on soil health. Assessments are about quality and absolute measures.

Note the before and after conditions in the field to record long-term improvements in soil health.

In addition to farmers, the card can also be used by soil conservationists, educators, students and garden clubs.

WHAT IS SOIL HEALTH?

The terms “soil quality” and “soil health” are used interchangeably. However, soil health refers to the function of the soil as a living ecosystem to support plants and animals. Humans also benefit from improved soil function.

Soil health is very important to all people. Healthy soil absorbs and holds more water, and has better physical, chemical, and biological properties. If we have good soil health, we will have productive land, good air and water quality as a result a healthy environment.

HOW TO IMPROVE SOIL HEALTH

Management greatly affects soil health. Farmers throughout Georgia are increasing the amount of soil organic matter in their land and improving the soil’s health and function by following these basic principles of soil health:

1.Minimize disturbance due to tillageand overgrazing

2.Diversify the soil microbes thatsupport plant growth by increasingplant diversity

through crop rotation,multispecies cover crops andforage plantings

3.Keep living roots growing throughoutthe year to provide food for soil

microbes and reap the benefits of their presence

4.Keep the soil covered as much aspossible to conserve soil moisture,reduce soil temperature, prevent soilerosion and suppress weed growth

Figure 46. Introduction of Khartoum Soil Health Card

Table 24. Field Assessment of indicators **FIELD ASSESSMENT OF SOIL QUALITY INDICATOR**

Date……….. Evaluation by:…… ………..Locality… …………….Farm….. …………..Field site…………… Kind \source of irrigation………. moister of soil (check one) good medium poor (dry)….													
Indicators	**Observation**	**Preferred**										**Indicator value**	
		1	2	3	4	5	6	7	8	9	10	**Low**	**Medium**
1. Crop Growth												Uneven stand; stunted crop growth; discoloring common	Some uneven stan growth; slight discolo
2. Texture												Soil surface is hard,clumps and notbreak apart, very powdery	Soil crumbles in hand Aggregates
3. Available water Capacity (AWC)												Plant stress immediately following rain or irrigation, soil has limited capacity to hold water, soil requires frequent irrigation	Crops are not first to in area from dry spell requires average irrig
4. Compaction/ Crusting												Cannot push probe or wire flag into soil; crusting is prevalent	Can push probe or w soil with force; s crusting
5. Soil Erosion												Excessive soil movement by water and or wind	Some visible soil mo water and or wind
6. L and leveling												The soil slope > 1.0%	The soil slope 1.0 -0
7. Infiltration and WHC												Excessive runoff or ponding; Very low water holding capacity	Some runoff or pon water holding capacit
8. Sodicity\ Salinity												Visible salt/alkali soil surface seals after rain or irrigation, fluffy when dry, uneven crop stand	Only some spots with sealed surface an growth, signs of leaf
9. Soil fertility												More than two elements not within ARC recommendations	Two elements not w recommendations
10. Soil reaction												pH 1.0 lower than needed	pH 0.5 lower than nee
11. Organic matter												Less than1% on the top depth 5 cm(gravity irrigation)	1-2 in surface of soil
12. Crop residue												0-50 percent of soil surface is covered with crop residue	50-70 percent of soil covered with crop res
13. Calcium Carbonate												$CaCO_3$ more than 12% in the soil	$CaCO_3$ 5-12% in the
Other													

Table 25. Soil Test Report, Laboratory Results and Recommendations

SOIL TEST REPORT

Locality…………………………………………………………………..	Farmer name…………………………………….mobile……………………
Number of Samples………….	Name and location of the farm…………………………………..
Date Received…………………………………………………	Date of sampling………………………………………………
Date Reported…………………………………………………….	Observation…………………………………………………….

Remark:………..

SOIL TEST RESULTS										
Sample No	Bulk Density	NO3-N Nitrogen(kg\f)	Organic Matter %	Phosphorus (Kg\f)	Potassium (k\g)	pH	Exchangeable Sodium %	Calcium Carbonate%	Texture	Infiltration Rate
INTERPRETATIONS										

NUTRIENT LEVELS

NUTRIENT LEVELS	**LOW**	**MEDIUM**	**HIGH**
Nitrogen (NO3 – N)			
Phosphorus (P)			
Potassium (K)			

SOLUBLE SALTS	**SATISFACTORY**	**QUESTIONABLE**	**POOR**
Salts (ECe)			
Exch. Sodium			
Calcium Carbonate			

Plant Nutrient Recommendations: …………………………………………………………………………………………….

Name...**job**...**Singntuer**................................**Date**................

GUIDELINE STEPS ON HOW TO TAKE SOIL SAMPLE

General guidelines

- The limited soil samples collected will be used for the assessment of soilqualities so as to enhance manag productivity and for soil conservation.
- If you have a soil map or very familiar with the different types of soil in your farm; soil sampling should consider th
- Small or large farms should be treated considering the farming fields

Equipment required:

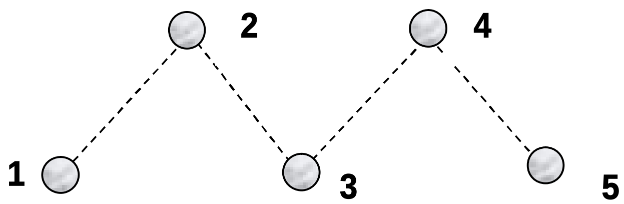
1. Spade or shovel
2. Empty sac (50 kg sugar sac)
3. Plastic bags (good quality-light colours)
4. Markers + ball pen + blank A4 papers
5. Note book

Field Methods:

a) Following the sampling digram as shown below; locate 3-5 site for soil sampling on each field depending the si dig 3 small pits (30 cm depth) at each site (5 -10 m apart) and take one kilogram soil from and put them on the sa take one kilogram soil. This amount should be separated into 2 halves (1/2 kg for each sample). Repeat this for th

b) Half Kg soil from each site should be placed in double plastic bag. On the outer plastic you should write the na depth and the date of sampling. These bags should be tied firmly and kept in a dry place tobe depatched to labora

c) The other half of the sample should be kept in the farm in a save place for 3 years as a reference sample.



Important Note:

Knowledge of soil types and their distribution and uses is a fundamental and necessary step performed always before any use of the land. Th by such activity is used to identit the soil at the farm and is considered for planning and determine which crops that are being grown. Soil s case to depths down to 1.5 meters or m and take place only once . As for the soil the soil tests, which we are here for health card are taken reg assess changes due to management practices

Figure 47. Guideline steps on how to use the card

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. The study designed an adapted health card for Khartoum State to assess soil quality based on soil indicators selected from previous agricultural research results. The application procedures will enable extension advisors to work with local producers to improve management practices, conserve resources and enhance productivity.

2. Soil quality assessments are conducted by evaluating *indicators*. Indicators can be physical, chemical, and biological properties, processes, or characteristics of soils. They can also be morphological or visual features of plants. Indicators are measured to monitor management induced changes in the soil.

3. Soil quality assessment is a useful procedures to evaluate and improve the soil resource as it provides an integrated method for assessing multiple aspects of the soil and their connections. By linking biological, physical, and chemical properties of soil, all of the components and interactions of a soil system are viewed together. This integrated approach leads to more comprehensive solutions as compared to assessing each soil property independently.

4. Soil quality management is a useful and effective approach to resource conservation and best management strategies. Some producers are familiar with many soil building practices and many producers already use the approach of integrated soil management when evaluating the effects of their practices on soil. The simple procedures of health card will promote faster learning of the approaches outlined in this research. Joint soil quality assessment between extensionest and producer will facilitate the blending of producers knowledge and scientific information from ARC, thus strengthening the information base, the ability to formulate workable solutions.

5. The designing and application of health card for assessing soil quality have inevitably brought the field efforts of all the stakeholders together. Research scientists, producers and extension advisors experiences should be pulled together to build up soil health cards.

6.2 Recommendations

1. Supporting the application of soil health card procedures to assess soil quality management should be encouraged to help producers avoid soil degradation and apply proper management practices to conserve their resources.

2. The establishment of a federal administration or center for soil quality under the umbrella of the Federal Ministry of Agriculture is highly essential to promote the concept of soil quality and its assessment through the procedures of the health cards at different parts of the country.
3. Agricultural research efforts in Khartoum State should continue to identify soil physical, chemical and biological limitations and their effect on crop performance at different farming systems around the state and advice on the proper management practices

4. The ARC regional facilities and the local agriculture colleges and institutions at different states of the country should work together to adapt and develop local health cards for the assessment of soil quality and advice on the proper management practices for different local farming systems.

5. Monitoring and evaluations of new practices or information about long-term trends will not be available immediately. The first set of applying new management practices provides baseline values that are specific to that farming system. Subsequent monitoring and evaluations later in the season and in following years will be necessary to reach definite conclusions about the trends and levels of soil quality.

6. Although it always advisable to use minimum data sets and indicators for evaluating soil quality but within each state more than one health card could be designed and used in case of contrasting land systems with different environmental resources are available with one state.

7. Soil quality indicators should be selected according their relationship to specific soil properties and must have the following characteristics:
    - easy to measure.
    - able to measure changes in soil functions.
    - assessed in a reasonable amount of time.
    - accessible to many users and applicable to field conditions.
    - sensitive to variations in climate and management.
    - representative of physical, biological or chemical properties of soil.
    - assessed by qualitative and/or quantitative methods.

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RECOMMENDATIONS

Evaluate soil health periodically(about every three years) todocument changes.

•Periodic assessments in a field shouldbe done by the same person, duringthe same season and under similarsoil moisture conditions.

•For better assessments, basesampling on variability in the fieldsuch as soil, soil moisture and yield.

•Examine the distribution of indicator values. Even if most of the indicatorsare scored 10 (healthy), the soil maystill have serious problems.

•Careful consideration should be used to identify the cause of the problem.

•Impaired properties may need immediate action and should be closely monitored.

•Keep completed soil health cards on file for future reference.

Healthy soil → Highet yield

↓

Mutch money

Soil Health Card for Khartuom state Sudan

through crop rotation,multispecies cover crops andforage plantings
3.Keep living roots growing throughoutthe year to provide food for soil
microbes and reap the benefits of their presence
4.Keep the soil covered as much aspossible to conserve soil moisture,reduce soil temperature, prevent soilerosion and suppress weed growth
5.Consider adding livestock, in amanaged grazing system, to a rowcrop system in order to increase thecycling of plant nutrients
6.Talk with farmers using conservationtillage or managed grazing systems asthey can give you some ideas abouthow they are changing the health oftheir row crop or grazing lands.

ABOUT THIS CARD

The soil health card was designed and adapted for local use. It was developed by and for producers to identify where improvements could be made and to evaluate the effect of changes in management on soil health. Assessments are about quality and absolute measures.
Note the before and after conditions in the field to record long-term improvements in soil health.
In addition to farmers, the card can also be used by soil conservationists, educators, students and garden clubs.

WHAT IS SOIL HEALTH?

The terms "soil quality" and "soil health" are used interchangeably. However, soil health refers to the function of the soil as a living ecosystem to support plants and animals. Humans also benefit from improved soil function.
Soil health is very important to all people. Healthy soil absorbs and holds more water, and has better physical, chemical, and biological properties. If we have good soil health, we will have productive land, good air and water quality as a result a healthy environment.

HOW TO IMPROVE SOIL HEALTH

Management greatly affects soil health. Farmers throughout Georgia are increasing the amount of soil organic matter in their land and improving the soil's health and function by following these basic principles of soil health:
1.Minimize disturbance due to tillageand overgrazing
2.Diversify the soil microbes thatsupport plant growth by increasingplant diversity
through crop rotation,multispecies cover crops andforage plantings
3.Keep living roots growing throughoutthe year to provide food for soil
microbes and reap the benefits of their presence
4.Keep the soil covered as much aspossible to conserve soil moisture,reduce soil temperature, prevent soilerosion and suppress weed growth

GUIDELINE STEPS ON HOW TO TAKE SOIL SAMPLES

General guidelines

- The limited soil samples collected will be used for the assessment of soilqualities so as to enhance management prac productivity and for soil conservation.
- If you have a soil map or your very familiar with the different types of soil in your farm; soil sampling should consi
- Small or large farms should be treated considering the farming fields

Equipment required:

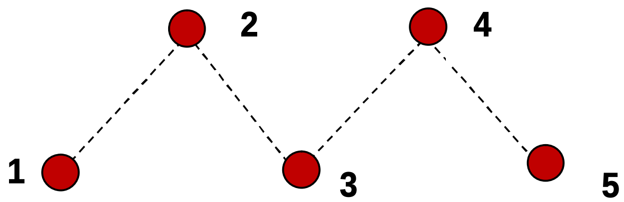
6. Spade or shovel
7. Empty sac (50 kg sugar sac)
8. Plastic bags (good quality-light colours)
9. Markers + ball pen + blank A4 papers
10. Note book

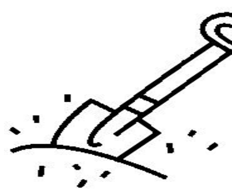
Field Methods:

d) Following the sampling digram as shown below; locate 3-5 site for soil sampling on each field depending the siz dig 3 small pits (30 cm depth) at each site (5 -10 m apart) and take one kilogram soil from and put them on the sa take one kilogram soil. This amount should be separated into 2 halves (1/2 kg for each sample). Repeat this for th

e) Half Kg soil from each site should be placed in double plastic bag. On the outer plastic you should write the name depth and the date of sampling. These bags should be tied firmly and kept in a dry place tobe depatched to labora

f) The other half of the sample should kept in the farm in a save place for 3 years as a reference sample.





Important Note:

Knowledge of soil types and their distribution and uses is a fundamental and necessary step performed always before any use report issued by such activity is used to identit the soil at the farm and is considered for planning and determine which to crop samples were taken in this case depths to depths down to 1.5 meters or m and take place only once . As for the soil the soil health card are taken regularly every three years to assess changes due to management practices

Date……….. Evaluation by:…… ………..Locality… …………….Farm….. …………..Field site…………… Kind \sourc moister of soil (check one) good medium poor (dry)….													
Indicators	Observation	Preferred										Indicator value	
		1	2	3	4	5	6	7	8	9	10	Low	Medium
14. Crop Growth												Uneven stand; stunted crop growth; discoloring common	Some uneven stand; st growth; slight discoloring
15. Texture												Soil surface is hard, clumps and does not break apart, very powdery	Soil crumbles in hand, few Aggregates
16. Available water Capacity (AWC)												Plant stress immediately following rain or irrigation, soil has limited capacity to hold water, soil requires frequent irrigation	Crops are not first to suffer in area from dry spell, soil requires average irrigation
17. Compaction/ Crusting												Cannot push probe or wire flag into soil; crusting is prevalent	Can push probe or wire fl soil with force; some crusting
18. Soil Erosion												Excessive soil movement by water and or wind	Some visible soil moveme water and or wind
19. L and leveling												The soil leveling more or less than 3 cm	The soil level 1.5 2.5
20. Water Infiltration and Water Holding Capacity (WHC)												Excessive runoff or ponding; Very low water holding capacity	Some runoff or ponding; water holding capacity
21. Sodicity\ Salinity												Visible salt/alkali soil surface seals after rain or irrigation, fluffy when dry, uneven crop stand	Only some spots with sealed surface and St growth, signs of leaf burn salts
22. Soil fertility												More than two elements not within ARC recommendations	Two elements not within recommendations
23. Soil reaction												pH 1.0 lower than needed	pH 0.5 lower than needed
24. Organic matter												Less than1% on the top depth 5 cm(gravity irrigation)	1-2 in surface of soil 5cm
25. Crop residue												0-30 percent of soil surface is covered with crop residue	50-70 percent of soil surfa covered with crop residue
26. Calcium Carbonate												$Caco_3$ more than 12% in the soil	$Caco_3$ 5-12% in the oil
Other													

SOIL TEST REPORT

Locality………………………………………………………………..	**Farmer name…………………………………mob**
Number of Samples…………	Name and location of the farm……………………
Date Received…………………………………………………	Date of sampling……………………………………
Date Reported………………………………………………………	Observation………………………………………

Remark:………………………………………………………………………………………………

SOIL TEST RESULTS									
Sample No	Bulk Density	NO3-N Nitrogen(kg\f)	Organic Matter %	Phosphorus (Kg\f)	Potassium (k\g)	pH	Exchangeable Sodium %	Calcium Carbonate%	T
INTERPRETATIONS……………………………………………………………………………………									

NUTRIENT LEVELS

NUTRIENT LEVELS	LOW	MEDIUM	HIGH
Nitrogen (NO3 – N)			
Phosphorus (P)			
Potassium (K)			

SOLUBLE SALTS	SATISFACTORY	QUESTIONABLE	POOR
Salts (ECe)			
Exch. Sodium			
Calcium Carbonate			

Plant Nutrient Recommendations: ……………………………………………………………………
………
Name……………………………………………………………**job**…………………………………………**Singntuer**…………………………