Influence of Hydraulic Behavior of Gash Delta Soils on Water Management

By

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Influence of Hydraulic Behavior of Gash Delta Soils on Water Management

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Dedication

To

My family, My Friends,

My colleagues,

To My Brothers the Farmers,

May God bless you All.

ACKNOWLEDGMENT

Deep thanks and appreciation to my advisor Prof. Ali Adeeb and recitation are extended to Prof. M. Kheir, thanks extended to Kassala Agriculture Research Station staff. Mr. Salah Bilal Elkagam, I am highly indebted to Mr. Abdullah Ali Sharif, Abdulla El Hassan, Hashim Tahir; Mohamed shanan for providing data which helped me to accomplish this work. Special thanks are due to my old sons, Ali, Mohamed, Mugahid and my wife for their invaluable support, assistance, encouragement and patience. The Sudan Government has provided the financial support. Finally thanks are extended to my friend Abdu Ahmed Ibrahim for typing this work.

ABSTRACT

The study was conducted in Gash Delta area which is located in north of Kassala State. The total area of the Delta is 750000 feddan, of which 420000 feddan could be irrigated by flooding. The irrigation system covers 240000 feddan, around 80000-100000 feddan is annually planned for irrigation. The current irrigation system resulted in water loss as the water flows to the masga for three weeks without consideration for soil properties or crop water requirements. The wetting front extends down to more than 3.0 m. The main objective of the research is to study the influence of the hydraulic behavior of the Gash Delta soils on the irrigation management and the characteristics that enable crops to give good production with only one irrigation during the flood season.

Field measurements had been done for infiltration rates, hydraulic conductivity and wetting front at four different flooding sites using Double Ring Infiltrometer. Two profiles had been dug for determination of layering of soils. Previous soil properties data have been collected, analyzed and compared with the study results. The study found that soil texture is the determining factor of the moisture content at the root zone and it causes capillary rise through which water flows back from deeper layers into the root zone. The study also found that 7 days flooding is enough for meeting the sorghum crop water requirements for course textured soils and 12 days in fine textured soils. Due to the dynamics of the soil deposition of Gash Delta, the result show that the infiltration rates differ from site to site and with the different locations at the same site. The infiltration capacity ranged between 3.0 cm hr^{-1} in the North to 18.0 cm hr^{-1} in the South. The study recommended that soil properties must be considered in controlling the irrigation water.

الملخص

اجريت هذه الدراسه في منطقة مشروع دلتا القاش الزراعي شمال ولاية كسلا . تبلغ مساحة الدلتا الكليه 750 الف فدان والمساحه التي يمكن ريها420 الف فدان والمساحه التي تحت شبكة الري 240 الف فدان يروي منها في احسن الاحوال 80 الي100 الف فدان سنويا .
نظام الري الحالي بالدلتا ينتج عنه فقدان للمياه لان المياه تغمر المسقي لمدة 3 اسابيع دون مراعاه لخواص التربه او الاحتياجات المائيه للمحاصيل. علما بان الجبهه المبلله تمتد لاسفل لاكثر من ثلاث امتار نتيجه لهذا الغمر.

الهدف الاساسي لهذا البحث هو دراسه تاثير السلوك الهيدرولوجي لتربه دلتا القاش علي ادارة مياه الري والخواص التي تجعل النبات قادر علي اعطاء انتاج بريه واحده خلال موسم الفيضان.
تم اجراء قياسات حقليه لنسبة الرشح ودرجة موصلية التربه للماء والجبهه المبلله في 4 مواقع مختلفه باستخدام المرشح ثنائي الحلقات. كما تم عمل قطاعين بروفايل للتربه لتحديد طبقات التربه .تم تجميع معلومات وبيانات سابقه لخواص التربه و تم تحليلها و مقارنتها بنتائج الدراسه.

توصلت الدراسه الي ان قوام التربه هو العامل المحدد لحجم الماء في منطقة الجذور وهو المسبب للخاصيه الشعريه و التي من خلالها تصعد المياه من الطبقات السفلي الي منطقة الجذور.كما توصلت لحقيقة ان 7 ايام فيضان كافيه لمقابلةالاحتياج المائي لمحصول الذره في الاراضي الخشنة القوام و12 يوم في الاراضي الناعمه القوام . كما توصلت الي انه نتيجه لترسب التربه الديناميكي في دلتا القاش فان ذلك ادي لان تختلف نسبة الرشح من موقع لاخر وبين نقاط الموقع نفسه وان نسبة الرشح تتراوح بين 3 سم\الساعه في شمال الدلتا و 18 سم\الساعه في جنوب الدلتا.
اوصت الدراسه انه يجب ان توضع خواص التربه في الحسبان عند التحكم او ادارة مياه الري .

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CHAPTER ONE

INTRODUCTION

1.1 Background:

This study is a follow up of a short-term assignment carried out previously by Non-Governmental, International Organization, from Kingdom of The Netherlands(1994),for assessing Gash Delta project in soil-water plant relationship of the Gash Delta lands, and compiling a land suitability map. It was concluded that only limited information is available on this subject and on the physical characteristics of the Gash Delta soils. These surveys will lead to a better understanding of the soils.

The agricultural production in The Gash Delta is completely dependent on river Gash flood water, as the amounts is poor, temporal and spatial unevenly distribution, throughout a short period of the year. The Delta is used for growing different crops, of which sorghum is the most important. The local variety (Aklamoi) is mostly used, which provides grain and also stalks for fodder, building and energy purposes. The allotment of arable land for use is done annually by means of lottery "qura'a". In this way, not always the same people benefit from the best land. The main negative aspect of this type of allotment is that very little care is taken of the land because most likely the farmer cultivates a different piece of land every year. Thus, many fields are heavily infested with weeds and mesquite trees, reducing the available soil moisture for crops. However this weed vegetation improves the structure of the soil and thus the infiltration capacity of the soil (Dutch reports.1994).

The area is heavily grazed by goats, sheeps, cows and camels, which are only herded on fallow land. This herding system can have negative effects on infiltration capacities, causing compaction of top soil by trampling and removing vegetation that improves the structure of the soil. Because of climate limitations for cultivation of crops under rainfed conditions, irrigation is necessary. For instance, sorghum requires approximately 755 mm water (Doverlon and Brutt

(1977) Comparing the rainfall amounts and reference evapotranspiration rates (178 mm/month in winter to 304 mm/month in summer (Euro Consult, 1988) it is clear that a severe drought stress will occur unless irrigation is applied.

The Delta area is about 420000 feddan (1 feddan = 0.42 hectare) which can be flooded by means of irrigation. The rest of the Delta, where the Gash dies, is not irrigated and receives water from local and rainfall, except in years of high floods. The original plan suggested by IFAD is to irrigate 120,000 fed annually, but actually only 80,000-100,000 fed are irrigated. Spate irrigation is practiced in the Delta through a network of main and tributary canals connected to the Gash River, which flows only during the summer months (May-October). The standard practice is to apply water for three weeks, after which other fields are attended to; at least as long as the Gash is bearing water. Hadaliya area (Wagar canal) is the last area to receive water.

1.2 Location and Extent:

The Gash Delta is located between latitudes 15° 30′ and 16° 30′ N and longitudes 35° 56' and 36° 30' E (Figure(1.1)). It's boundaries on the west and north is not sharply demarcated. Generally it estimated that the total area of the Delta is 750000 feddan of which 420000 feddan could be irrigated by flooding. The irrigation system was constructed for about 240.000 feddan. Around 80000-100000 feddan annually planned for irrigation, because of insufficient watering system, or uncompleted rehabilitation of the irrigation system.

The Gash Delta has an average slope of about 0.1% and lies approximately at 500 m above sea level (Figure 1.2).

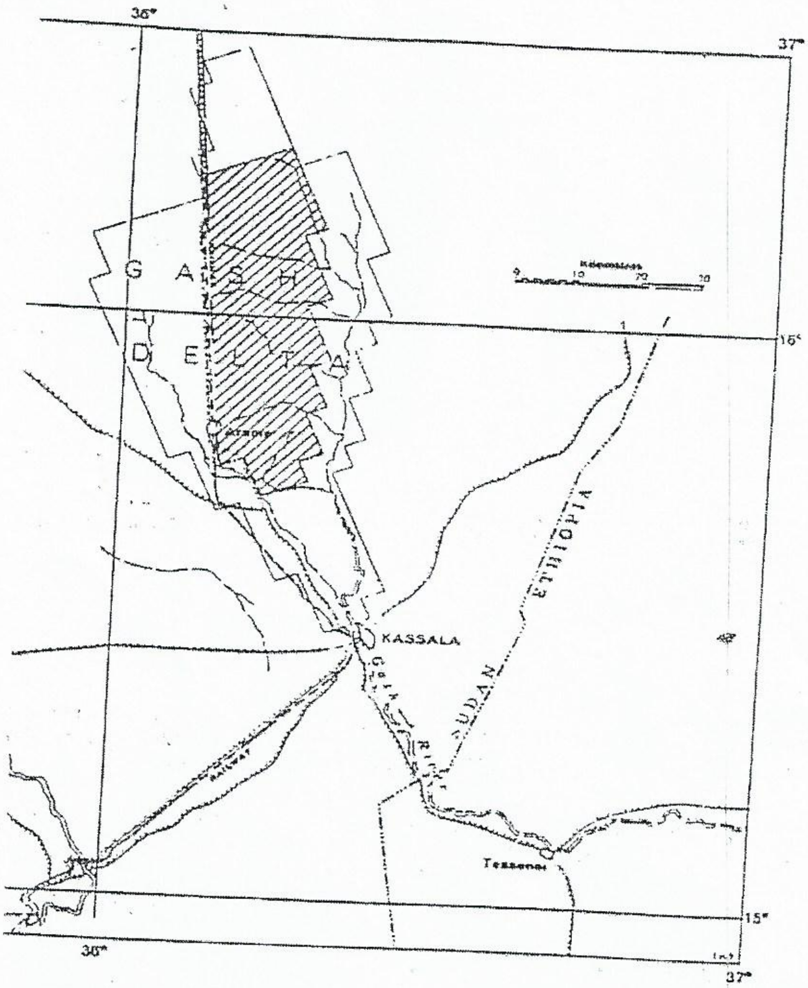


Figure (1.1): Location of Gash Delta Scheme

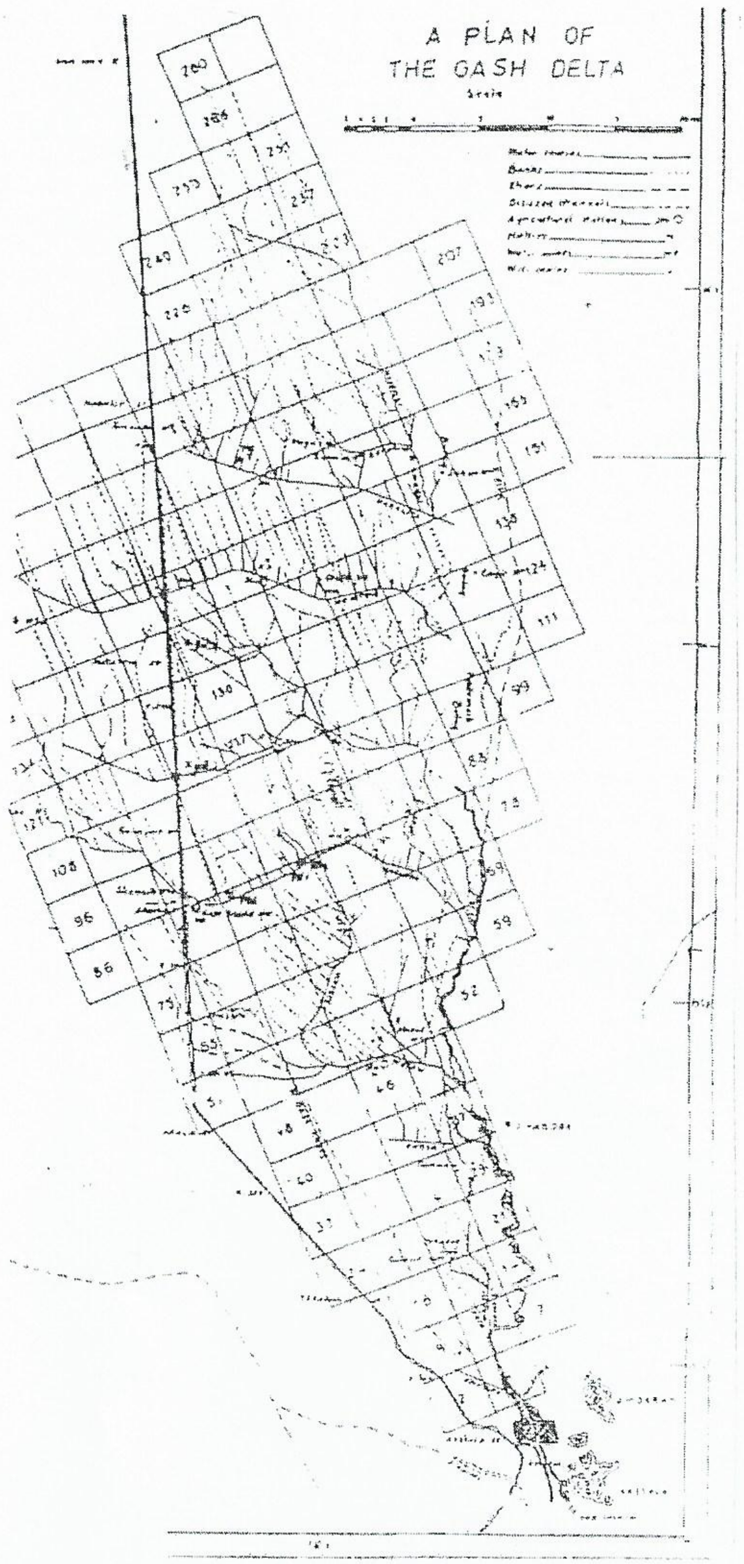


Figure (1.2): Detailed Map of Gash Delta (Irrigation Network)

1.3 Climate:

The Gash Delta lies within the arid zone of the Sudan; it is hot throughout the year with maximum temperatures ranging from 42 °C in May to 34 °C in January, minimum temperature ranges from 25 °C in May to 16 °C in January. The local annual rainfall ranges from 260 mm in the south to less than 100 mm in the north. It is highly seasonal, occurring between July and October, and is extremely variable in amount, intensity and spatial and temporal distribution. The effectiveness of the rainfall (the fraction of rainfall, that is effectively intercepted by the vegetation or stored in the root zone and used by the plant–soil system for (evapotranspiration) is severely limited by rainfall and by high evapotranspiration rates__2000 mm per year. (Adam (2000), with high spatial and temporal variability, in general the rainy seasons extends for 60 days which presents a harsh environment for the main staples of sorghum and millet. Droughts are frequent, prolonged and present serious restrictions on agriculture, which consequently relies on irrigation.

1.4 Water Supply:

The principal water supplier is the Gash River which flows from the Ethiopian highlands, it is ephemeral, meanders because its grade is low, responds rapidly to heavy and storm rainfall in the catchment area and is characterized by intense flood flows. The mean annual discharge of the Gash River at the border with Eritrea has been estimated at around 1000 million m^3, some 350 million m^3 percolate to recharge aquifers upstream of Kassala town. Downstream Kassala town and for some 100 km north Kassala town. Up to 260 million m^3, are diverted for spate irrigation of the Gash Agricultural Scheme (Swan. C. H. (1952). The balance spreads over the Gash die area, where it provides moisture for natural forests, pasture, seasonal wetlands, and crop production and recharges the aquifers which support stock water points extending over an effective period of 60-70 days from July to September with high sand and silt loads.

Recharge comes directly from infiltration from the Gash River during floods and from percolation of overland flow from the Gash scheme (Swan. H. (1952)... The depths of the upper (shallow) aquifers in the Gash Basin range between 6 to 30 m; they are underlined by thick sediments. Along the river in Kassala area and on the flood plain, the aquifers are exploited by pumping from shallow wells for horticulture, and are the principal source of water for human consumption. The shallow aquifer in the Gash Die is also a major source of water for livestock.

1.5 Soils:

The soil north Delta is richer in stable clays with less wind and water erosion as the flow of water is not strong but gentle, because of the minute slope of the area. Buildup of the soil structure (profiles) in the delta is mainly a result of sedimentation of the Gash river sediment load.

All Gash Delta soils are of alluvial origin. They are recent; hence they have not yet developed differentiation in diagnostic horizons, except some-what older alluvial soils in the northwestern area. In general, silty soils dominate in the south and clayey soils in the northwest areas. On basis of this, the Gash Delta soils are divided into two broad groups (Dutch reports1994)

The first group: locally known as "badob" occurs on older clayey alluvium. They are dark, low in organic matter, but show a distinct cracking pattern when dry; these soils include the Hadaliya Series north.

The second group: locally known as "lebad" have developed in recent alluvium. This group includes Aroma, Degain, Mekali, Tendilai and Wagar Soil Series. They are very recent, lack profile development, show distinct textural stratification and no diagnostic horizons other than a weak (A) horizon. These soils have high silt content, are moderately permeable and have a favorable capillary rise. Plant available moisture storage capacity is high.

1.6 Objectives:

The Objectives of this study:

1. To study the hydraulic behavior of Gash Delta Soils.
2. To study the influence of the hydraulic behavior of Gash Delta Soils on the (Water) irrigation management.
3. To review available data on soil moisture relationships
4. To explain why the second crop grows in healthy condition, stays ever green and gives good yield without any watering again.

CHAPTER TWO

LITERATURE REVIEW

2:1 Introduction:-

According to the available literature, Richards (1951) was the first to report on the Gash irrigation system where he concluded that the Gash Delta soil frequently overlies imbedded layers illustrating its deposition by successive floods or spates. On the other hand he reported that the canalization system of 1925 provided a large number of small misgas but the tendency later was to put in fewer and bigger misgas. It was thought that better watering was attained in that way. He also concluded that the moisture content in the soil at 1.8m was raised from 4% on dry weight basis before irrigation to about 20% to 30% on dry weight basis after flooding. Richards (1951) also stated that the rule by which the required discharges are delivered to the misgas was based on 1 m^3/sec for thirty days to irrigate 500 feds and this is obtained by trial and error. On the other hand, Swan (1956) , reported that a modified irrigation method was applied for lebad soil, i.e. a discharge of 2 m^3/sec for 25 days to irrigate 500 feds instead of 1.0 m^3/sec for 30 days mentioned by Richards. The latter modification was based on the high infiltration rate of the lebad soil.

2.2 Soil Texture and Bulk Density:

Bulk density is the ratio of the mass to the bulk or macroscopic volume plus pore spaces in a sample (Singh, 1980). Air and water space vary reciprocally with the moisture content of the soil and are indirectly dependent on texture and structure Table (2.1).

The soil texture and bulk density varied with the same misga both horizontally and with depth. These variations are attributed to the soil formation by different spates as reported by Richards (1951).

Table (2.1): Soil Bulk Density (BD) (gm/cm^3) and Texture (ST) of the Six Flooding Periods.

Flooding periods	B.D at surface (10 cm)	B.D at subsoil (180cm)	S.T Surface (10 cm)	S. Tat subsoil (180 cm)
2 days	1.2	1.3	Loamy sandy	Sandy loamy
7days	1.0	1.3	Clay	Sandy loam
10 days	1.0	1.3	Clay	Sandy loam
15 days	1.2	1.1	Silt	Silt
20 days	1.2	1.1	Silt	Silt
30 days	1.3	1.2	Sandy loam	Sandy loam

In 1968 the Sudan soil Administration carried out an intensive study that covered a large area of the Gash Scheme. It concluded that 80% of the Gash Delta soils are lebad. It reported that about 14% is class (1), 78%is class (3) and 7% is class (4) soils. They concluded that the infiltration rate ranges between 2.5 cm/hr to 6 cm/hr. An intensive study was carried out by Euro Consult (1988), where the sorghum water requirement was calculated using Penman formula to be between 650 to 850 mm according to the sowing date (Appendix 1). The crop requires 850 mm when sown in July and 650 mm when sown in October. Out of the total rainfall of 150-250 mm/year in the Delta, only 100 mm were considered by Euro Consult (1987) to be effectively used by the plant. The study divided the flooded misga into the following categories;

a. **Well watered land**: The water infiltrated is supposed to be sufficient to grow cotton after 20 days of watering for lebad soil and longer period for badob.

b. **Adequately watered land:** Water infiltrated is supposed to be enough to grow sorghum after 15 days for lebad and longer period for badob.

c. Insufficiently watered land: The infiltration opportunity time is considered to be too short to grow any crop and the water infiltrated in this area is considered as loss.

The Euro Consult (1987) study suggested an improved system to increase the cropped area, to increase yield by uniform application of water and to provide opportunity for permanent settlement of farmers in the project area. For better water distribution a unit of small area was to be subdivided into basins of 20 fed or 5 fed. Furthermore, to reduce the silt content in the irrigation water, a desisting reservoir was recommended. Based on the above irrigation system the Euro Consult (1987) rehabilitation system aimed to irrigate 110,000 fed annually using a volume of 44 m^3/sec, and a total canal intake capacity of 122 m^3/sec. It is worth mentioning that the river discharge can reach as high as 2800 m^3/sec and the average flood volume was 600 m^3 after Kassala city.

Other survey reports available of around Kassala area do not contribute much to the Gash Delta soil data base. Lately in the nineties, two surveys were carried through the assistance program of the Kingdom of Netherland to the Sudan Government by a nongovernmental International organization from the same country (1994) to the Gash Delta Project. The first study was by Mr. J.A. Dijkshoorn, in (1994) for Soil -Water- Plant Relationship in Gash Delta. The second survey was planned, collected and processed by Mr. Bart Herman's, in August/December 1994.Both studies carried out their experiments on the modified Euro Consults (1987) basins in Tendilai block to gain experience with the construction and irrigation of the improved irrigation system (small basin irrigation). Four basins of 10 fed and two basins of 20 fed were constructed .The irrigation water was supplied through a small channel of 0.2 m^3/sec capacity. Six days was allowed for the 10 fed basin to be irrigated with 270 m^3. The recommendations from the 80 fed pilot areas were:

a. To extend the pilot area with one or two larger basins of 80 and 150 feds.

b. To continue the experiments with the traditional system and dividing misga by inter- misga banks. In this way the design of the improved irrigation system can be tested and if necessary adopted before applying it in major rehabilitation projects.

c. To reduce land leveling, the design and layout of the rehabilitated land should follow the present contour lines as much as possible.

Generally the late studies carried out by the Dutch firms had recommended strengthening the data base on soil-water and cropping relationships in the coming years as follows:

- All data to be collected should fit in a yearly pre-defined experimental program.
- To make separate files for each experiment.
- To have topographical maps of irrigation and field layout at a scale of 1:75000 and 1:50000 or even larger for various planning purposes and to combine their map with the soil map or the land class map at the same scale.
- Flooding the fields evenly requires leveling of the surface.
- Use water pipe inlets for applying water on the fields.
- Continue monitoring the soil moisture content until harvesting.
- Calculate the available soil moisture content using the actually determined bulk densities not using the average particle density because of its variations.

2.2 Irrigation:

Since rainfall in the Gash Delta is irregular and erratic, crop production completely depends on irrigation from the Gash River. When it rains regularly, irrigation is possible for several weeks but if there are dry periods for sometime the water in the river can be too low for irrigation. Irrigation will start again when rainfall starts in the catchment area.

As a standard practice water is applied to the field (misga) for three weeks (first irrigation), where after the inlet is closed and other fields are attended, (second irrigation). Since fields, which are numbered according to the canal and the field number counted from the main intake can differ in acreage, topography, soil texture, area, etc; it is evident that the soil moistening of the misga will be irregular. This forces the user of the system to supply overdoses of water to guarantee that the whole misga is moistened down to 1.5 m, but as a consequence another part of the misga would be wetted up to more than 3 m. Some records mentioned even a moistening depth of 5 m (Doverlon and Brutt 1977), which means 50% loss of water. It has, however, one advantage; salts present are washed out of the root zone. Although it is reported that irrigation water is of good quality, no records on the chemical composition of the flood water was obtained.

The nature of the river, carrying only water in large quantities for a short period of the year (braided river), has its consequences for the course on it. The main river channel can change from one year to another, and is difficult to maintain to its original course. This had and has still its effect on the sedimentation regime of the Gash River.

2.3 Silt Load of the Irrigation Water:

The first flow of water in the Gash River carries a high silt load, together with a lot of "rubbish" picked up on its way. The practice is to let pass the first water for this reason. The highest measured silt loads for the Gash River, misga and lateral were respectively 5.0, 4.4, and 5.2 percent in the first days of irrigation. During the actual irrigation period these values generally are in the range between 2 and 4 percent by weight. (Dutch reports 1994). This silt is partially deposited in canals, but mainly in the misgas. The thickest layer close to the misga inlet and a diminishing layer further away. It is noticed that sometimes silt layers of as thick as 35 cm are formed near the inlet and 2.5 cm further away towards the end of the misgas (Gash scheme reports).Upon drying, the silt cracks by losing 20% moisture and forms layered surface crust, without any cultivation a thickness of over 2 cm causes problems of difficult planting. Therefore planting/sowing are usually done under the silt layer, in the original soil. For this reason the misgas are furrowed by tractor prior to planting. In such way up to 15-20 cm silt layer can be removed. When the silt layer dries out, which happens rather quickly, it has a bulk density of about 1.7 gm/cm^3 and generally no medium and coarse pores (Dutch reports,1994).

It was observed that in one case the dry silt layer, acted as mulch covering the soil surface and disconnecting the underlying soil from the atmosphere. In such a way it prevents the evaporation of soil moisture via large cracks from the subsoil.

It is expected that a part of the fine silt enters into the larger pores of the soil. This can result in sealing-off of the soil structure elements and filling up of the pores in somewhat heavier soil. This might reduce the basic infiltration rate and lead to some what compacted layers. In spite of this the permeability classes is defined good even in saturated subsoil (Table (2.2)

2.4 Soil Fertility and Water Requirement:

The importance of the effects of fertility on water requirement of plant has been a controversial topic for many years. Brigg and shantz (1913) made this statement "*Almost without exception the experiments herein cited show a reduction in the water requirement accompanying the use of fertilizer. In highly productive soils this reduction amounts to only a small percentage. In poor soils this water requirement may be reduced on–half or even two third by the addition of fertilizers. Often the high water requirement is due to a deficiency of a single plant-food element. As the supply of such an element approaches exhaustion, the rate of growth as measured by the assimilation of carbon dioxide is greatly reduced but no corresponding change occurs in the transpiration. The result is inevitably a high water requirement*".

Table (2.2): **hydraulic conductivity classes for saturated sub soils, and the Corresponding ranges :-**

Class	**Hydraulic conductivity**	
	inches/hour	**cm./hour**
Very slow	<0.05	<0.125
Slow	0.05-0.2	0.125-0.5
Moderately slow	0.2-0.8	0.5-2.0
Moderate	0.8-2.5	2.0-6.25
Moderately high	2.5-5.0	3.25-12.5
Rapid	5.0-10.0	12.5-25.0
Very rapid	>10.0	>25.0

Source: **(O' Neal, 1952)**

Viets (1962) said that: ((Whether fertilizers increase consumptive use not at all or only slightly, all evidences indicate that water use efficiency or dry matter produced per unit of water used, can be greatly increased if fertilizer increases yield. So fertilization for the adequate nutrition of all crops plays a major role in the efficient use and conservation of water resources. Fertilizers may also increase root development within the soil so that soil water is used to higher tensions and at greater depths. This effete is important in dry land agriculture and even in farming in humid areas during periods of drought.

Hence, it is quite clear that adequate fertility helps crops use water more efficiently and more of the crop is produced per mm of water. The improving of crop to tolerance to low-rainfall conditions can be explained by:

1. Root exploration of the soil is increased. Adequate fertility favors expanded root growth and proliferation. When roots explore the soil a m deeper, another mm or two of water will be obtained.

2. Adequate fertility decreases water requirements. Transpiration is reduced. Potassium had been shown to aid in closing stomata, thus reducing water loss.
3. Foliage canopy is increased and the soil is covered more quickly. These causes less evaporation directly from the soil to the air and most of the water is used by the plant.
4. The amount of plant and root residues is increased. With any given tillage practice, a higher amount of residues will break the impact of the rainfall drops, slow water movement ad increase water infiltration. The erosive effects of mater and wind are also reduced by these residues.

2.5 Soil Moisture Level and Nutrient Absorption:

Water is the key in all mechanism of nutrients uptake (interception Mass flow and diffusion). The plant absorbs nutrients adjacent to the roots and a concentration gradient is established. Nutrients then diffuse slowly from areas of higher concentration to areas of lower concentration but at distances no greater than 0.4 to 0.8 cm(Kozlowski.T.T.91973). As this occurs through the water films, the rate of diffusion depends on the water content of the soil. , the elements can with thicker water films or with a higher nutrient content in the soil; the elements can diffuse more readily.

Considerable work has been done to establish the relationship between soil moisture levels and nutrient absorption by the plants (Dutch reports 1994). Nutrient absorption is affected directly by level of soil moisture content as well as indirectly by the effect of water on the metabolic activity of the plant, soil aeration, and the salt concentration of the soil solution.

Reduction in water-absorbing efficiency of root is associated with several plant diseases including root rots, viruses, and rusts, destruction of the root system often accurse before aboveground symptoms are evident. The effects of root infections on water uptake of host plants often are Similar to those traceable to mechanical injury to roots (Subramanian and Sara, 1959). Although water akes by roots vary considerably, depending on a number of factors, these data icate the comparative uptake among crops. These factors include:-

1. variety or hybrid
2. moisture availability
3. temperature
4. soil type
5. nutrients levels and their balance in the soil
6. final plant population
7. tillage practices
8. pest control

Cumulative Infiltration Rate and Hydraulic Conductivity:

The rate of movement of water through soil is of considerable importance in y aspects of agricultural and urban life. The entry of water into soil, the ement of water to plant roots, the flow of water to drains and wells, and the oration of water from the surface of soil are but a few of the obvious itions in which the rate of movement plays an important role. An important property involved in the behavior of soil water flow systems is the ability of oil to transmit water, qualitatively, the conductivity of saturated soil has long ı determined. The data are of use in analysis of any saturated soil-water-flow em. These include drainage of soil for agriculture as well as engineering oses. Drainage of high ways, airports, and construction sites and seepage w dams are among the latter. The data also provide indirect information about tructure and structural stability of soils.

In most normal soils infiltration rate usually starts high as mentioned before falls progressively with time as the pores spaces gradually fill with water and radient of moisture within the profile becomes less steep until it declines to a determined by the hydraulic conductivity of the soil(Figure 4,5,6,7,). ying this concept to the alluvisols (Gash delta soil) which are normal in ration compared to vertisols (Gezira clay), the initial intake at the start of the infiltration is very high (higher than the most permeable sandy soil reported in the text books) because of the cracks in the clay soils. The cumulative infiltration is the accumulated water at a certain depth during a given time period, however, infiltration is a complex process and can be described by the famous infiltration equations like, Horton's equation, Phillips' equation and Green and ampt method. There are various factors affecting the measurement of hydraulic conductivity, viz, entrapped air, biological activity, swelling and slaking will interact to produce a resultant variation in the conductivity with time. Allison (1947) has studied these effects

The conductivity will be also affected by temperature of the water, cracks and worm holes in core samples. These structural phenomena are present in the field and affect the flow in different ways, depending on condition of flow.

2.6 Crop Water Requirement:

Crop water requirement (CWR) is normally calculated from the equation;

$$CWR = ETc = Kc \times ETo$$

Where;

Kc is the crop coefficient that depends on the soil and genotypic characters.

ET_0 is the reference evapotranspiration which defined as the rate of evapotranspiration of an extended surface of an 8 to 15 cm tall green grass cover, actively growing , completely shading the ground and not short of water. **Adam, (2000)**. The Dutch studies 1994&FAO. 1979 stated that through calculations using Penman -Monteth for the experimental sites in different locations in Gash delta, and here by concentration on Tendilai area and compared with Aroma annul and average, ET_0 (Table 2.3). Tendelai annual ET_0 is similar to Aroma annual and higher than Aroma average (July-September) this due to low rainfall, high temperature, low relative humidity and high wind speed, also it states that Aroma average was similar to that of Kassala with the exception that it was slightly higher during the rainy season because Kassala has a higher than that of

e (2.3): Reference evapotranspiration measured in Tendilai/ Aroma . Dijkshoon 1994)

	July	August	Sept.	Oct.	Nov.	Dec.	Jan.
i	13.3	13.5	9.4	7.9	7	5.3	6.5
	13.2	13.1	9.3	8	7.2	5.6	6.8

a, Consequently Kassala has a higher relative humidity and could cover that s the temperature and raises the vapor pressure(Dutch reports 1994). The CWR for sorghum, calculated for Tendilai (mid-July sowing date) was m, while the average CWR calculated for Kassala was 830 mm, the high ai CWR was due to the exceptionally dry months July and August and the ely dry September. They stated that CWR values depends on the sowing ecause of the onset of winter with reduced temperatures and winds. The owing dates provides more favorable climatic conditions for Sorghum emperature) that the late sowing dates, also it provides more chances to se of rainfall whenever available.

Inder years of low rainfall the early sown crops are more subjected to ress, due to their high water requirements, especially if the soil has a low olding capacity. The late sown crops have lower water requirements, so less subjected to water stress, but the vegetative stage of the crop is d by the early winter and the crop height is shorter than the early sown generally have a lower yield.

Series/ Profiles Description:

irst above mentioned study was the only source to which the physical istics of the Gash Delta soils could be related. Full information, however, otained from the FAO report (1977). In the above referred study eleven s were identified and mapped. A short review of all the soil series is d in the following:-

2.7.5 Aroma Complex:

Similar to Aroma silty clay, but has complex surface textures that wer separated. It includes silt loam and silty clay loam surface structures. It o in the middle section of the Gash Delta area.

2.7.6 Tendelai Silty Clay Loam:

This soil has a very dark greyish brown clay loam surface with bl structure. The subsoil has mainly silt loam or silty clay loam texture, brov dark brown colour and a massive structure. At greater depths texture cha abruptly, soil permeability is moderate. The soil is nonsaline non sodic. So is slightly alkaline p^H 7.5 to moderately alkaline with depth (max 8.3).

2.7.7 Degain Silt Loam:

The topsoil of this series is a dark brown silt loam with massive or pl structures. The subsoil is a typical yellowish brown or dark brown silt loa silty clay loam with platy structures. At lower depths the soil might have s of sandy loam. Permeability is moderately slow. Fertility is good. The so nonsaline non sodic, surface tilt is good. Soil p^H is slightly to modera alkaline (max 8.2) in the topsoil and moderately alkaline (max 8.4) in subsoil.

2.7.8 Degain Silt Loam (wind hummocky):

This soil differs from the Degain silt loam in that it has a recent deposi wind drifted materials in patterns of hummocks and low- dunes. The he varies from 30 to 100 cm and consists mainly of sandy loam and fine sa loam with patches of loamy fine sand and fine sand. Proper irrigation is v difficult because of the hummocks leveling of the dunes/hummocks necessary for proper irrigation. Even then, some parcels might be too high proper water distribution. Protection of this land by soil conservation meth is needed.

2.7.9 Mekali Silty Clay Loam:

This soil has a dark brown silty clay loam topsoil with a platey structure, the subsoil is dark brown blocky or platey clay, while below one meter the texture is usually silty clay. Permeability is moderately slow. Good seedbeds are easy to prepare. Overall fertility is good. The soil is non saline non sodic. The soil p^H is mildly to moderately alkaline (max 8.2).

2.7.10 Mekali Silty Clay Loam Wind hummocky:

Similar to Mekali silty clay loam, but differs in that recent deposits of wind drifted soil material covers the surface. The latter is similar to the wind hummocks of the Degain silt loam.

2.7.11 Undifferentiated Alluvial Soils, Sandy:

This unit stands for a miscellaneous land type and consists of several alluvial soils so intermixed that they could not be separated they cover all textures, and are stratified and subject to frequent flooding. Permeability is rapid and available water holding capacity is low, fertility is usually low. Soils are subjected to wind erosion and need to be protected by proper conservation practices. J.A. Dijkshoorn (1994) mentioned six land classes in his study which are;

1. Tendilai-Degain Complex (35000 fed) moderately permeable soils.
2. Mekali-Aroma Complex (143000 fed.) moderately to slowly permeable soil.
3. Wagar clay (7000 fed.) slowly permeable soils.
4. Hadaliya Complex (48000 fed) very slowly permeable soils.
5. Wind-hummocky Complex (3000 fed) as complexes 1 and 2, but Covered by special deposits).
6. Undifferentiated (17000 fed.) rapidly permeable soils.

The subsoil composition of the above complexes mentioned by Dijkshoorn (1994) is somewhat different from what is suggested by the mechanical analysis results of land class 1, 2 and 4 presented by Bart (1995) in his report because of:

1. From the analysis results, the soil of land classes 1 and 2 mainly consist of silt, silt loam and loamy sand, with rarely silty clay loam deposits.
2. The spatial heterogeneity of the soil profiles is high.
3. The braided river system originates from sedimentation
4. Gash River is not water flowing during most of the year and the evapotranspiration rates are high and that affect the ground water table thus the results differ.
5. Types of soils may have similar physical properties but they have differences in drainage rates.
6. The source areas of the Gash River generate a sediment load of high quantities of montomorillonites.

Table (2.4) shows the hydraulic conductivity for some soil series.

2.8 Land Use:

In the past, cotton was the main cash crop cultivated in the Gash Delta. Because of a number of problems associated with the growth of the crop, weeds infestation, plant diseases, smuggling across the border, labor shortage, marketing, and other reasons, crop was gradually replaced by castor beans since 1970.Yields of castor beans declined rapidly to 8kg/fed in 1977/79 (Euro consult, 1988).

Sorghum was the only food crop in the Delta. Particularly the local type Aklomoi is favored by the majority of the Gash Delta farmers. As 75% of the tenants belong to the semi nomadic Hadndowa Tribes, sorghum straw is highly valued for cattle feed in the months February till August, during which pasture is scare. Moreover, sorghum can be ratooned to produce extra cop of animal feed. In cases where sufficient soil moisture is still available, sorghum will form tillers and starts to regrow. After harvest, the farmers are allowed to have their cattle

Table (2.4): Hydraulic conductivity in Gash delta soil (Dijkshoon, 1994)

Soil name/Series	Texture class USDA		indicative K_0- value cm/day		Remarks
	surface	subsoil	surface	subsoil	
Hadeliya	sic	c	1.3	0.2	cracking soil(badob)
Hadeliya gilgay	c	c	0.2	0.2	Initial infiltration high, later extremely slow.
Wager	c	sic	0.2	1.3-6.5	initial infiltration rate
Aroma	sic	sic	1.3-3.6		different subsoil
Dagain	sil/sicl	sil/sicl	12.0	1.5-6.5	infiltration rates about the same
Mekali	sicl	c	1.5	3.5	infiltration rates about the same
Tendelai	sicl	sil/sicl	1.5	1.5-6.5	infiltration rates about the same
Undifferentiated soil	sil/sicl	s/ls	1.5-6.5	26-50	sandy subsoil

grazing on the fallow land. Moreover, the same piece of land can be used to plant another crop (water melon). This crop can continue till harvest without irrigation due the presence of sufficient soil moisture. This indicates capillary rise in lebad soils.

According to the current crop rotation on average, the same land is irrigated once every 2 years, but in practice it can be even more than that. The rotational land use most likely originates from the period cotton was the cash crop. Reason cited includes sanitarian reasons (controlling insects and weed control), ertainly about the quantity of flood water received every year in Gash River the needs of the nomadic population.

)ther group of farmers which have settled in urban centers like Aroma and ʒar, might possess cattle. They prefer to cultivate the same parcel of land 'y year or couple of years (rotation), although they are also subsistence ıers, they grow a limited number of cash crops like water melon, sun–flower, ı, karkadeh, cowpea, … etc.

.ately (2000-2004) under Gash Sustainable Livelihood Regeneration Project LRP) it was planned through several components for rehabilitation to change ›ystem of the lottery to permanent use of the fields by the same farmer or his ly (ownership or long term lease). Fixing tenancies such that a farmer would llocated a specific and stable piece of land in each of the three (in future) or annual watering rotations (now) is an advance form of dry land allocation, to fy better care of land and encourage different investments on land. This les the farmers to pay much more attention to their lands. Investments made ıeir fields e.g. leveling, bush clearing, mesquite eradication, weeding etc, :her with proper irrigation, well trained farmers, efficient water users :iations, will lead to more sustainable system and higher yield. This will ge the present land use; apart from sorghum, marketable crops will be grown.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Site of Experiments:-

The experimental work was conducted in (4) sites, namely;-

1. Tendilai Block
2. Degain Block
3. Mekali Block
4. Kassala Block

Most of the work was conducted in Kassala/Degain Blocks because they lie at ıe important area of Gash Scheme and assumed to represent it.

The climate is within the arid zone it is hot throughout the year with aximum temperatures ranging from 42 °C to 34 °C, minimum temperature nges from 25 °C to 16 °C. The local rainfall ranges from 260 mm to less than 0 mm /year. It is highly seasonal, , and extremely variable in amount, intensity d spatial and temporal distribution, in general the rainy seasons extends for 60 ys which presents a harsh environment for the main staples of sorghum and llet, and represent serious restrictions on agriculture, which consequently relies irrigation.

Climatic characterization and average data for Kassala area are given in ble 3.1). The average values cover only the period 1971-2000. Data covering re recent years were available at the Kassala Meteorological Station, but not ıplete.

3:2 Experiments:-

re are several tools and methods to determine the coefficients k, a, and C; ever the double ring infiltrometer is suitable for flat surfaces. Walker and зerboe (1987) describe the device which is composed of two concentric

Table (3.1): Climatolgical Normals Kassala town (1971 - 2000)

Sudan-Meterological Authority

Kassala LAT 15 28 N Long :36 24 E ALT 500 m

Element/Months	Jan.	Feb.	March.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Station level press	953.9	953.0	951.2	949.8	950.4	951.6	953	953.1	952.6	952	952.8	953.9	952.3
Temperatures C:													
Mean Daily maximum	33.5	35.2	38.2	41	41.4	39.8	36.3	35.2	36.9	38.7	37.1	34.5	37.3
highest daily temperature	41.2	43.5	45.2	45.6	47	44.8	42.4	41.6	42.3	42	40.7	40.2	47
mean daily minimum	16.8	17.5	20.2	23.7	26.2	26	24.1	23.7	24.3	24.7	21.9	18.4	22.3
lowest daily temperature	7.5	5	10.3	15	17.9	19.5	18.4	17.2	18.3	15.8	11.5	6.4	5
mean dry temperature (max-min(/2	25.1	26.3	29.2	32.3	33.8	32.9	30.2	29.5	30.6	31.7	29.5	26.4	29.8
sunshine duration (hrs)	9.3	9.1	8.9	8.9	6.7	7	6.6	6.6	8.4	8.8	8.9	9.2	8.2
mean relative humidity	46	40	32	27	31	39	54	60	53	42	41	46	43
Total rain<all(mms)	0.6	0.6	0	2	11.3	24.7	74.9	81.2	43.6	9.5	o.2	0	247.4
maximum daily rain fall (mm)	0.3	0	0.3	0.6	50.5	104.5	86.5	90	59.2	52	5.6	0	104.3
evaporation (piche)mm	9.4	11.3	13.9	15.7	14.9	13.5	10.o	8.2	8.6	11.3	11.o	9.6	11.5
mean wind speed (m.p.h)	5	5	6	5	5	7	8	8	6	5	5	6	

cylinders driven into the soil and filled with water. The fall of the water level in the inner cylinder is recorded against time. The test continues until the rate of fall of water level becomes constant; this is the value of C. The data is then plotted to obtain the coefficients k and a. The value of C is also used as an estimate of the vertical hydraulic conductivity, K.

3.3 Materials:

- Soil sample ring kit.
- Double ring infiltrometer.
- Edelman Auger.
- Plastic bags.
- Plastic test flask (100 ml)
- Oven.
- Stop watch.
- Measuring rod.

3.5 Profile Description:

Two profiles pits were dug at Kassala and Degain Blocks misgas to a depth of 2.5 m, which is considered the average maximum rooting depth of sorghum, being the main crop. According to land classes mentioned by Dijkshoorn (1994) the two profile pits were dug at land class 1 and land class 2, also some auger holes were made near profile pits to have an idea of the spatial profile heterogeneity of the soils and spatial, temporal heterogeneity of soil moisture distribution and the results were recorded

3.6 Gathered Data

More than eleven studies and reports written about Gash Delta Soils were revised and compared their results with the results of the study and discussed.

3.7 Infiltration Measurements:

nfiltration of water to the soil is a surface phenomenon describing the water entry nto the soil through the surface. The driving forces are the matric and the gravity potentials. At the beginning of any infiltration test, the rate of entry of water into he soil is high due to the high matric potential as a result of the low moisture content of the soil. After a long time of the process, only the gravity head becomes he driving force; therefore, the rate of infiltration becomes constant. There are several equations describing the infiltration behavior of porous materials; however, he modified Kostiakov-Lewis equation shown here is used in irrigation as it is simple and can easily be derived from a test.

$$Z = k\, t^{a} + C\, t$$

$$dZ/dt = I = k\, a\, t^{a-1} + C$$

Where Z is the cumulative infiltrated depth (m), t is time (min), C is the final nfiltration rate (cm/min),dZ/dt (I) is the infiltration rate (cm/min) and K and are empirically determined coefficients.

There are several tools and methods to determine the coefficients k, a and C; however the double ring infiltrometer is suitable for flat surfaces. Walker and Skogerboe (1987) describe the device which is composed of two concentric cylinders driven into the soil and filled with water. The fall of the water level in the nner cylinder is recorded against time. The test continues until the rate of fall of water level becomes constant; this is the value of C. The data is then plotted to obtain the coefficients k and a. The value of C is also used as an estimate of the vertical hydraulic conductivity, K.(Walker W. R. and Skogerboe G. V. 1987).

A double ring infiltrometer as mentioned above was used to measure the nfiltration rate for the traditional flooding system.(4)tests were conducted at different sites, and then proceed to the other steps., The Long term infiltration rates were taken as the Hydraulic conductivity. The wetting front was measured a week after flooding and the results were recorded.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Deposit Process in Gash Delta:-

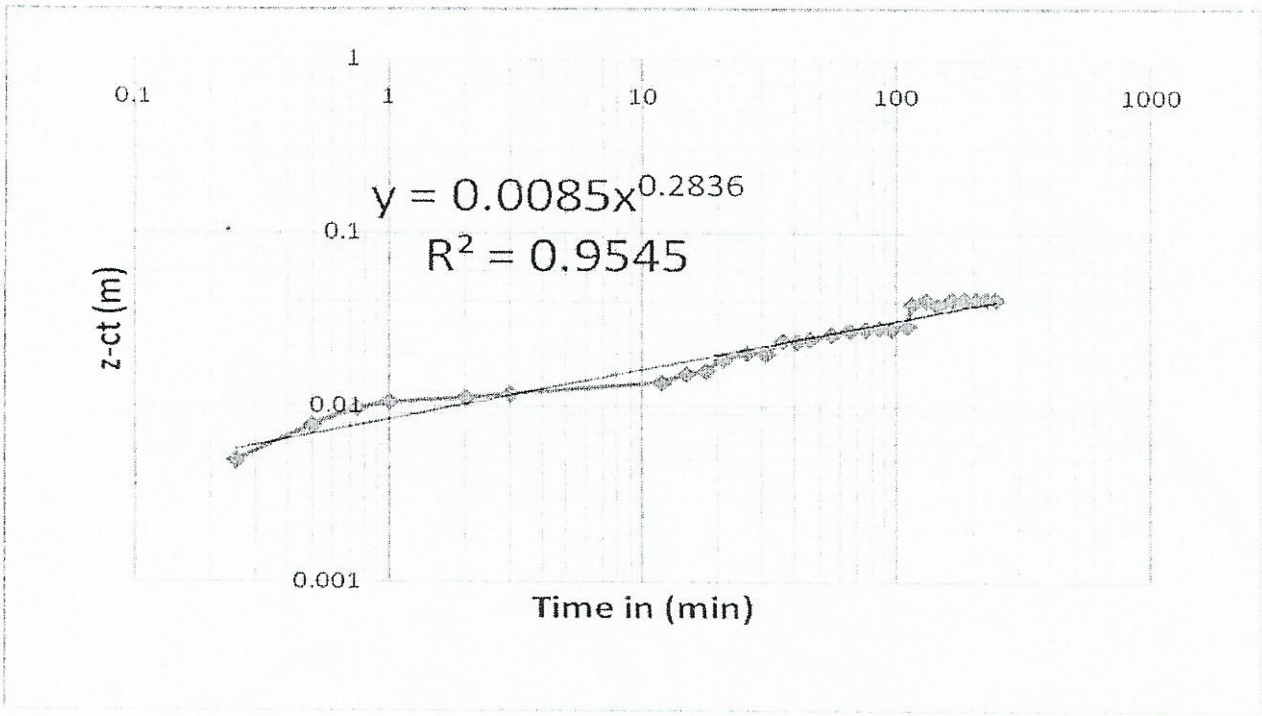
Coarse materials were deposited by high flood speed and fine materials were deposited by low flood speed (Dutch reports 1994). When the misga was flooded, courser material in the misga is deposited at the head while the fine materials were deposited in the tail of the misga.

The significance of the soil texture is that it affects the soil water holding capacity where it is high in fine textural soils and low in course textured soil. The soil texture also affects the infiltration rate which is higher in course textured soil than in fine textured soil. The presence therefore of a clay layer within a layered soil profile will impede its saturation flow(Profile Description results).

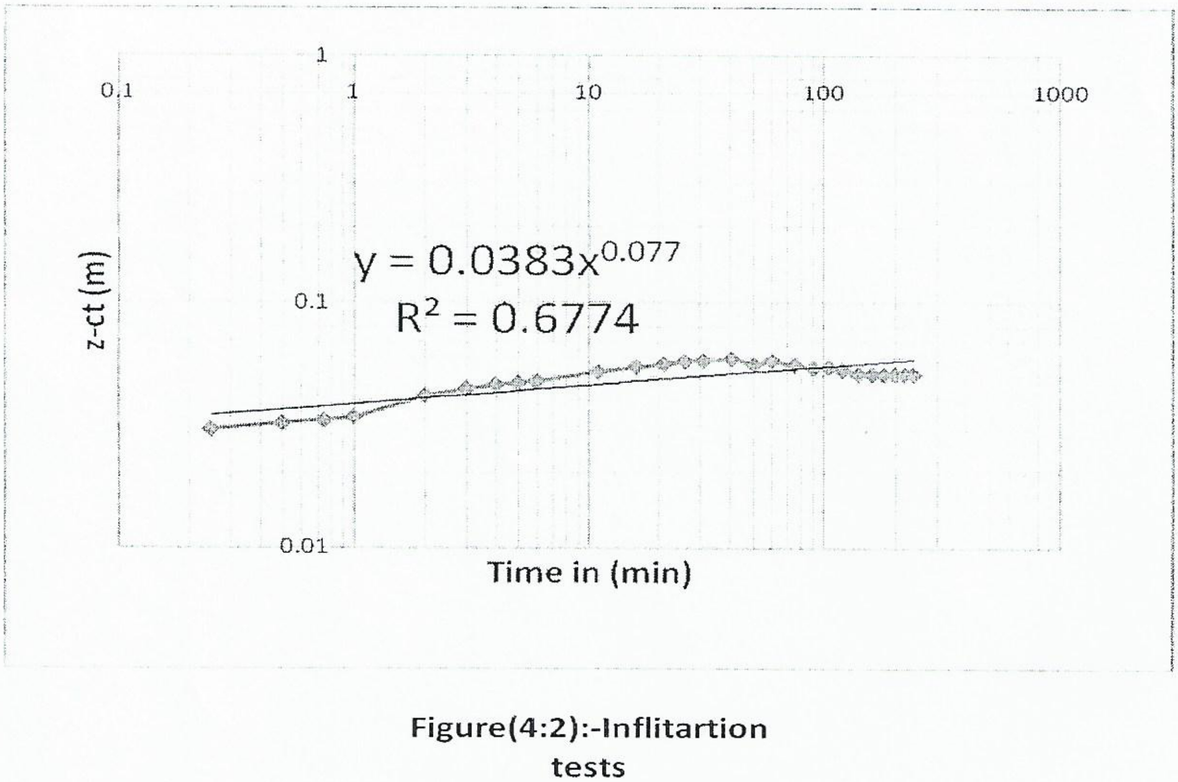
These findings are compared with those reported by Abdelmoniem (1982) who showed that the Gash soil are characterized by having vertical layering and vertical textural differences typical of alluvial deposits and found no significant differences. Also their horizontal distribution is so intricate and complex that mapping of each individual soil type would require a highly detailed level of survey.

4.2 Infiltration Rate and Wetting Front:

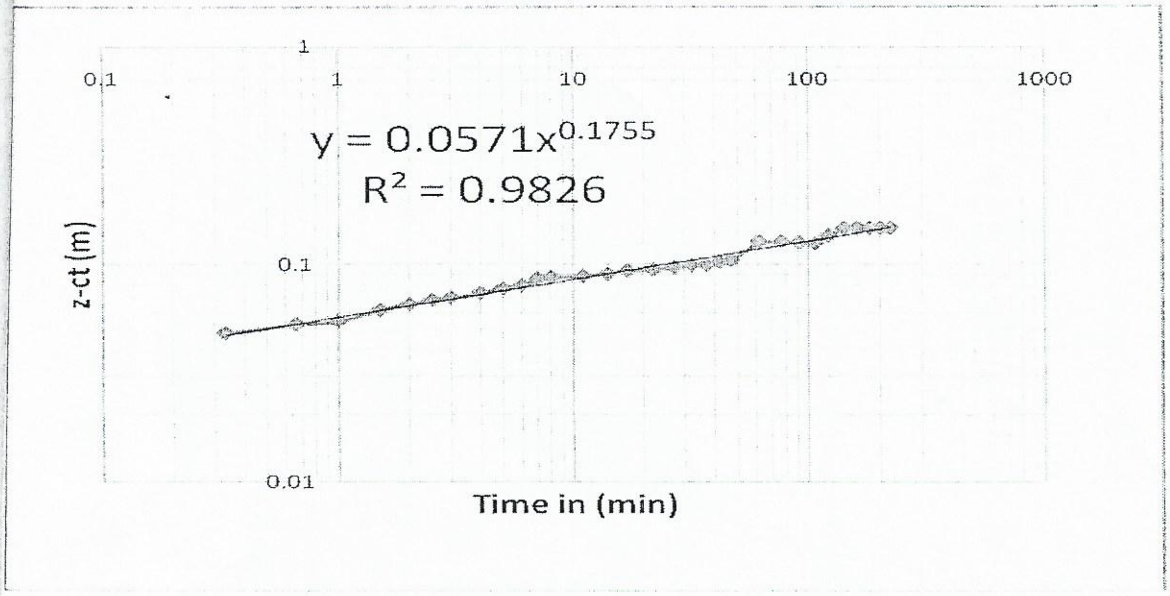
Figures (4.1, 4.2, 4.3, and 4.4) show the infiltration rate of the double rings method. Along period for measurements is required (4 to 3.5hours) because in the misga infiltration takes place for 30 days and the silt laden water will deposit its silt which closes the pores. The highest infiltration rate measured by the double rings was recorded for the location of the short flooding period (2-5) days. The lowest infiltration rate was recorded for the location of long flooding period (7-20) days. The difference in the infiltration rates between the locations was due to the soil surface texture, where it is a sandy loam in short flooding period and a clay loam in long flooding period.



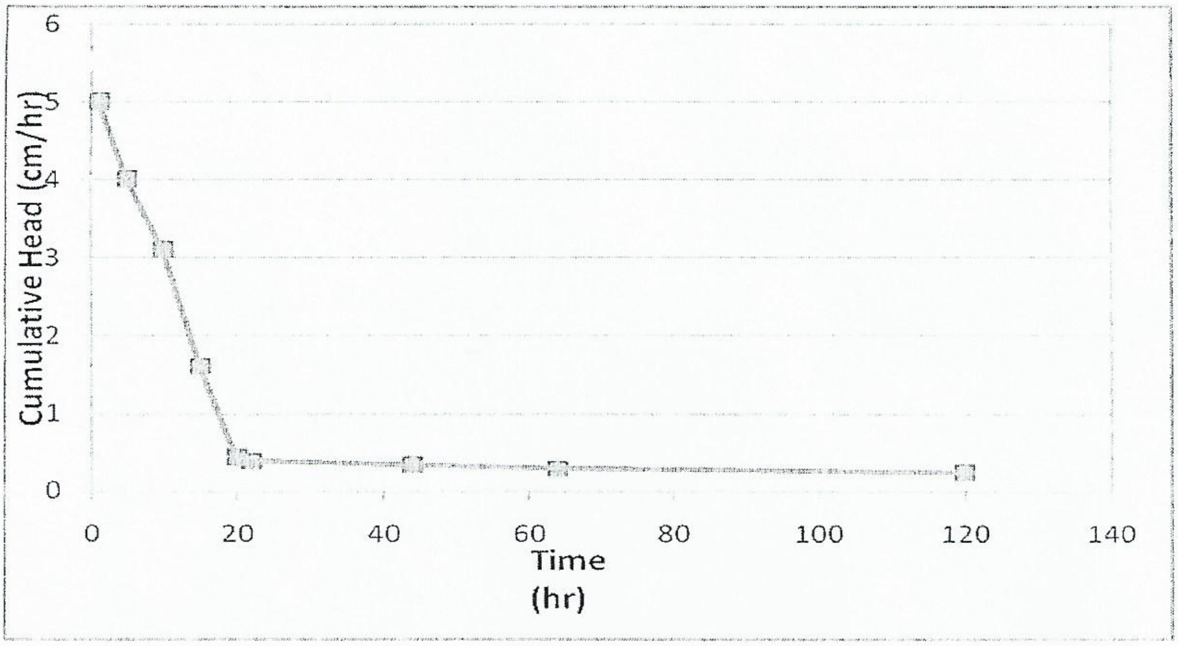
Figure(4:1):-Inflitartion tests
Test(1) Kassala Block
(Rabacasa Area) c=0.00045



Figure(4:2):-Inflitartion tests
Test(2) Tendilai Area
c=0.0003



Figure(4:3):-
Inflitartion tests
Test (3)Degain Area
C=0.0005



Figure(4:4):-Cumulative Infiltartion Rate in Tukroof Area

August	415.4	0.85	353	0.3*	62.3				
September	276	1.05	298.8	0.85	234.6	0.3*	41.4		
October	235.6	1	235.6	1.05	274.4	0.85	200.3	0.3*	35.3
November	207	0.65	67.2*	1	207	1.05	217.4	0.85	170
December	160.5	-	-	0.65*	52.2	1	160.5	1.05	168.5
January	201.5	-	-	-	-	0.65*	65.5	1	201.5
February	201.5	-	-	-	-	-		0.65	72.7
Tendelai annual CWR	11.85	-	995.6		830.5		685.1		648
Kassala average CWR	-	-	832.3		792.7		723.4		663.6

(Source Euro consult 1988)

ure of the water, cracks and worm holes in core samples. These structural ɜna are present in the field and affect the flow in different ways, depending tion of flow (Table 4.1).

ɜntion of Water by Soil:

the fact that water will continue to enter the soil, it cannot be concluded pore space is not filled and that it is possible to store more water in the en a certain maximum amount of water is stored, the remainder will drain his had led to the concept of field capacity which presents the amount of 'hich a soil will hold against gravitational forces; also it presents the um state between the upward movement as result of capillary rise and rd movement because of the gravitational pull in the absence of strong movement due to evaporation.from the surface. This explains what usually during the second irrigation period which starts from September for short f we compared with the first. At this time the evaporation is almost zero ET_0 (evapotranspiration) is almost not more than 4 mm/day- The fine soil has a fantastic capillary rise phenomenon. This led the grass and reen and healthy.

difference between the upper limit of water available to plant growth, and ɜr limit of available water the plant can use, represents the available water ɔlant, in other words, the difference between field capacity and permanent point ranges between 140 and 350 mm as an average in different flooding due to the finding that the field capacity range between 200 and 450 mm ɔnding to a bulk density at 1.5 to 1.25 gm/cm^3 and the permanent wilting 'ange between 60 to 100 mm using the same bulk density values. This s the finding by Richards (1951) that the water raised between 20 and 30% ınd after flooding; the findings are also similar to Hopmans (1993) at 270 O (1979) reported the available soil moisture to range between 60 to 200 ıending on soil texture, 60 mm for coarse textured soils and 200 mm for the ɜxtured soil. This indicates that the Gash soils are of high water holding

le (4.1): The surface infiltration rates calculated (Dutch reports 1994)

Test no.	Location	Texture topsoil	Infiltration rates (m. day $^{-1}$)
1	Tendilai	Sandy loam	4.4
2	Tendilai	Sandy loam	3.6
3	Tendilai	Silt loam	1.3
4	Degain	Sandy loam	3.9
5	Aroma	Silt	1.7
6	Degain	Siltloam	1.8
7	Mekali	Siltloam	2.6
8	Mekali	silt loam	2.3
9	Mekali	silt loam	1.3
10	Mekali	silt loam	0.7

capacity about double that of the heavy textured soil. However the findings are also similar to those reported by Euro Consult. (1987), who estimated the field capacity to be 350 to 450 mm and initial moisture before flooding at between 50 and 100 mm.

4.4 General Discussion:-

The difference between the hydrostatic pressure in the tube on a level with the surface and the hydrostatic pressure immediately below the interface is commonly known as suction (lowering pressure) also the water is more tightly held in narrow pores than in wide one because the lowering of the hydrostatic pressure increases with a decrease in diameter of the pores and this gives a new evidence for why the plants stays green in Gash Delta Soils during November–March although there is no irrigation. The retention of water between soils particles can be thought of as a capillary phenomenon in which the soil particles are usually assumed to exhibit a contact angle equal zero. In addition to what had been mentioned above, Gash soils