بسم الله الرحمن الرحيم

Sudan University of Sciences and Technology

College of Graduate Studies

A Comparative Study for the Supplied Intended and Actual Irrigation Water Requirements of Sennar Sugar Scheme

دراسة مقارنة بين الامداد المائى , وطلبيات المياه واحتياج مياه الرى الفعليه لمشروع سكر سنار

A thesis Submitted in partial Fulfillment of the Requirement for the Degree of M.Sc. in Agricultural Engineering

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THE DEDICATION

I dedicate this research

To my parents who supported me though out my

Life and gave me full confidence

To my wife,

my brothers

And my friends,

To everybody who helped me.

Acknowledgment

First of all thanks to Allah for everything

Deep thanks and respect are conveyed to Doctor:

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For his guidance and support

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For his guidance and valuable help

Thanks are conveyed to the teachers and workers of agriculture engineering department in Sudan University

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مستخلص الدراسة

أجريت هذه الدراسة فى عام 2014_2015 بمشروع سكر سنار بهدف دراسة اداء منظومة الرى بمزرعة سكر سنار وذلك من خلال حساب ومقارنة كميات المياه المرفوعة بواسطة محطة الرفع وكميات المياه المطلوبة بواسطة ادارة الحقل و الاحتياجات المائية الفعليه المحسوبة.

تم الحصول على المعلومات المناخيه المتعلقة بالمنطقة من محطة ارصاد المشروع وتم استخدام معامل المحصول من البيانات الواردة من ادارة الحقل بالمشروع.

بالنسبة للمطر الفعال تم حسابه من خلال طريقة حساب المطر الفعال لبرنامج CropWat

تمت مقارنة كميات المياه المرفوعة وكميات المياه المطلوبة مع الاحتياج الفعلى المحسوب.

تبين من التحليل الاحصائى ان هنالك فروق معنوية عاليه بين كميات المياه المرفوعة بواسطة محطة الضخ والاحتياج الفعلى المحسوب مما يشير الى ضرورة مراجعة برنامج تشغيل محطة الضخ.

كما تبين من الدراسة ان هنالك فروق معنوية بين كميات المياه المطلوبة بواسطة ادارة الحقل والاحتياج الفعلى للمحصول الشئ الذى يحتم ضرورة مراجعة برنامج طلبيات المياه.

توصى الدراسة الى امكانية اعادة استخدام الفاقد الكبير فى المياه فى انتاج محاصيل اخرى .

ABSTRACT

The field work of this study was conducted at sennar sugar scheme 2014_2015.The main objective was to study the performance of the irrigation network of sennar sugar scheme ,through the determination and comparison of the irrigation water supplies ,irrigation water intended and the actual irrigation water requirements. Meteorological data was obtained from the scheme meteorological station .Crop coefficient data was taken as given by the field authorities .Effective rain was determine according the cropwat program method .

Statistical analysis revealed high significant difference between the supplied irrigation water and the actual crop irrigation water requirements this fact necessitates the reversion of the pumping station program .

A significant difference was also found between the intended irrigation water and the actual irrigation water requirements .This indicates that the irrigation water intending program has to be revised.

The study reflects that the huge amount of irrigation water losses can be reused for production of other crops.

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ABBERVIATIONS

γ psychometric constant (kPa $^oC^{-1}$)

Δ Slope vapor pressure curve (kPa $^oC^{-1}$),

e_a Actual vapour pressure (kPa),

e_s Saturation vapour pressure (kPa),

$e_s - e_a$ Saturation vapour pressure deficit (kPa),

ET_c crop water requirements

ET_o The reference evapotranspiration

ETri Average initial period reference evapotranspiration (mm day^{-1})

FAO Food Agricultural Organization

G Ground heat flux density (MJ m^{-2} day^{-1}),

IF Normal interval between irrigations or significant rainfall (days)

Ig Gross irrigation

II Irrigation interval

In Net irrigation

K_c Crop coefficient

$K_{c\ mid}$ Crop coefficient in the mid stage.

Kcin Initial stage crop coefficient

Req requirement

R_n Net radiation at the crop surface (MJ m^{-2} day^{-1}),

S.S.C Sudanese Sugar Company

SPSS Statistical Package for Social Sciences

U_2 Wind speed at 2 m height (ms^{-1}),

USDA United States Department of Agric

WHO The world health organization.

CHAPTER ONE

1.1 Introduction

An adequate water supply is important for plant growth. When rainfall is not sufficient, the plants must receive additional water from irrigation. Various methods can be used to supply irrigation water to the plants. Each method has its advantages and disadvantages. These should be taken into account when choosing the method which is best suited to the local circumstance. The irrigation network of the scheme is open cannal surface irrigation which known to have low efficiency. Hydroflume was introduced to raise the irrigation efficiency but it encountered many problems that led to its abandonment .

1.2 Problem:

In sugar production schemes its noticed that these are a lot of water losses to the drains that flow back to the river .

Irrigation water is lifted from the sources by pumps powered from electrical supply its well known the cost of energy is one of the highest input cost this study is directed to estimation of the overall irrigation efficiency of the sennar sugar schemes.

1.3 Objectives:

Main objective is to study the performance of the irrigation net work of Sennar Sugar Scheme through the determination of the following sub-objective:

1/to find the amounts of water lifted from the river by the scheme pump station.

2/ to find the intended amounts of water ordered by the field staff.

3/Determination of the actual crop water requirements.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Back ground:

Sudan is the largest country in Africa and has a special geopolitical location binding The Arab world to Africa South of the Sahara . It has an area of 2.5 million km^2 extending between 4 ° and 22 ° latitudes north and 22 ° to 38 ° longitudes East. Its north - south extent is about 2000 km , while its maximum east-west extent its about 1500 km. it is bordered by the Red Sea and its shares common borders with nine countries: Eritrea and Ethiopia in the east, and the republic of Southern Sudan in the south, The Central Africa Republic, Chad and the Libyan Jamahiriya in the west , and Egypt In the north . Boron (2005).

2.2 Sugar cane production schemes of Sudanese Sugar Company(S.S.C).

Sugar cane is a tropical crop which can be grown successfully under a wide range of environmental conditions. Most of the enormous industries for cane sugar production were distributed in subtropical areas between latitudes 15 ° and 30 ° (Black –Burn, 1984, Tanico 1986) .

Sugarcane performs well under Sudan conditions because of the suitable soil type ,water supply, light intensities and long duration for milling .The availability of qualified personnel with the technical know-how is a great achievement towards the promotions of sugarcane production After the end of the second world war, the production of sugars was not sufficient to meet the world demand , so the local prices shot up very high . To meet the local consumption , Sudan began with the establishment of the Gunied sugar factory on the eas t bank of the Blue Nile some 120 kilometers southeast of Khartoum in1962 on an area of about 42000 Faddens.The factory was designed to crush 4,000 tons of cane per day with an annual production of 60,000 tons of refined sugar. It was the only growing sugar scheme in Sudan and it was adopted from a cotton irrigation scheme. A second sugar factory, New Halfa located near the Atbara river 350 kilometers east of Khartoum began production in 1965 in an area of about 16385 ha. The factory was designed to cruch 5,000 tons of cane per day to produce 75,000 tons of refined sugar. The third factory ,sennar, began production in1976in an area about 34000 feddan and was designed to crush 6,500 tons of cane per day and have an annual production capacity of 110,000 tons of refined sugar. . The factory is located in the southern Gezira Scheme about 240 kilometers southeast of Khartoum. .Assalaya sugar factory, located on the east side of the White Nile about 240 kilometers south of Khartoum near the town of Rabak, began producing in 1979 in an area of about 15126ha. As the fourth sugar factory in Sudan. It was built with a capacity to crush 6,500 tons of cane per day and produce 110,000 tons of sugar annually. The last of the sugar factories built was Kenana which began production in 1980 with a crushing capacity of 17,000 tons of cane per day and production capacity of 300,000 tons of refined sugar per year. The factory is located 250 kilometers south of Khartoum. It was expanded in 2001 to crush 26,000 tons of cane per day and have production capacity of 450,000 tons of sugar per year. The total cane crushing capacity of all factories is 48,000 tons and the sugar production capacity is 805,000 tons(Table 2.1). Sugar production reached a high of 754,915 tons in 2003 and averaged 656,395 tons during 2008-2009.

Kenana produced 45 percent of the total sugar, and the other (Galaleldin,2011) .

factories produced the remaining 55 percent. A new sugar company, the White Nile, is being constructed about 250 kilometers south of Khartoum with investment and technical assistance from Kenana. It is scheduled for completion in 2012 and will expand national sugar production by 350,000 tons when fully operating (Table 2.1). (Galaleldin,2011).

Table(2.1) Existing and under development sugar production schemes in Sudan

factory		Cane crushing	Sugar production	Average annual sugar
		Capacity	capacity	Production 2008-2009
factory	Year production	Per day	Per year	Per year
	Started/expanded	(Tons)	(tons)	(tons)
Gunied	1962	4,000	60,000	87,615
New Halfa	1966	5,000	75,000	84,151
Sennar	1976	6,500	110,000	87,116
Assalay	1980	6,500	110,000	97,511
Total				356,395
Kenana	1980	17,000	300,000	300,000
Expanded	2001	26,000	450,000	
Total		48,000	805,000	65+,395
Under development				
White Nile	Expected 2012	-	350,000	-
Blue Nile	Considered	-	250,000	-

(Galaleldin , 2011)

2.3 Introduction

An adequate water supply is important for plant growth. When rainfall is not sufficient, the plants must receive additional water from irrigation. Various methods can be used to supply irrigation water to the plants. Each method has its advantages and disadvantages. These should be taken into account when choosing the method which is best suited to the local circumstance.

A simple irrigation method is to bring water from the source of supply.

This can be a very time-consuming method and involves very heavy work. However, it can be used successfully to irrigate very small plots of land, such as vegetable gardens, that are close to the water source.

More sophisticated methods of water application are used when larger areas require irrigation. There are

three commonly used methods: surface irrigation, sprinkler irrigation and drip irrigation;

1. Surface irrigation: basin irrigation
2. furrow irrigation
3. border irrigation
4. Sprinkler irrigation
5. Drip irrigation

2.4.1Surface Irrigation

Surface irrigation is the application of water by gravity flow to the surface of the field. Either the entire

field is flooded (basin irrigation) or the water is fed into small channels (furrows) or strips of land(borders) . **(Prins. K , Ka. M, and Heibloem M.,2001)**.

2.4.2 Furrow Irrigation

Furrows are small channels, which carry water down the land slope between the crop rows. Water

infiltrates into the soil as it moves along the slope. The crop is usually grown on the ridges between the

furrows

2.4.3 Border Irrigation

Borders are long, sloping strips of land separated by bunds. They are sometimes called border strips.

Irrigation water can be fed to the border in several ways: opening up the channel bank, using small

outlets or gates or by means of siphons or spiles. A sheet of water flows down the slope of the border,

2.4.4 Sprinkler Irrigation

Sprinkler irrigation is similar to natural rainfall. Water is pumped through a pipe system and then sprayed onto the crops through rotating sprinkler heads.

2.4.5 Drip Irrigation

With drip irrigation, water is conveyed under pressure through a pipe system to the fields, where it drips

slowly onto the soil through emitters or drippers which are located close to the plants. Only the
immediate root zone of each plant is wetted. Therefore this can be a very efficient method of irrigation **(Prins. K , Ka. M, and Heibloem M.,2001)**.

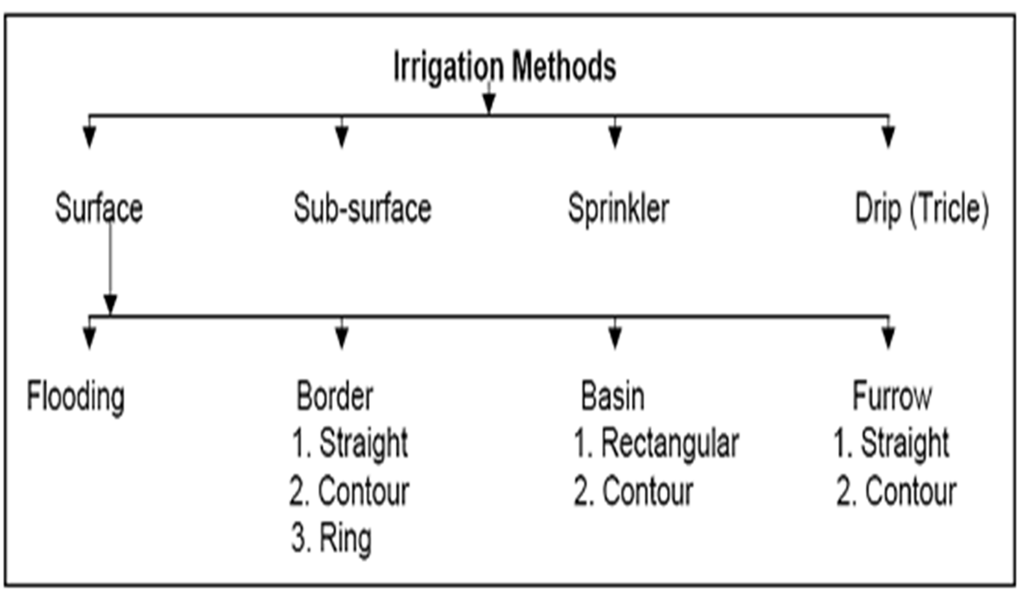
2.5 Irrigation is the artificial application of water for the cultivation of crops, trees, grasses.

Irrigation, the addition of water to lands via artificial means, is essential to profit-able crop production in arid climates. Irrigation is also practiced in humid and sub-humid climates to protect crops during periods of drought. Irrigation is practiced in all environments to maximize production and, therefore, profit by applying water when the plant needs it... (**USDA**, 1997).

2.6 Irrigation methods:

Various types of irrigation techniques differ in how the water obtained from the source is distributed within the field. In general, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little.

Table. (2.2) The various irrigation techniques Hoogeveen, P. Döll, J-M. Faurès, S. Feick, and K. Frenken (2006).



(**Arid poop, 2012**)

2.7 surface Irrigation:

In surface irrigation systems, water moves over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil. Surface irrigation can be subdivided into furrow, border strip or basin irrigation. It is often called flood irrigation when the irrigation results in flooding or near flooding of the cultivated land. It may also be applied as a small discharge to each plant or adjacent to it. Drip irrigation, spray or micro-sprinkler irrigation and bubbler irrigation belong to this category of irrigation methods

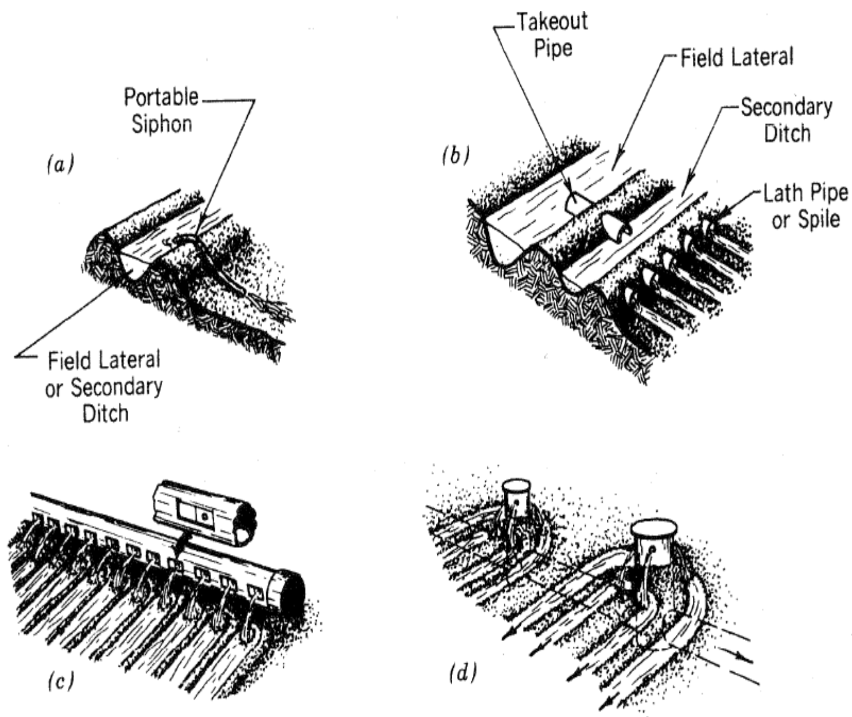


Figure (2.1) Surface irrigation diagram

2.7.1 Sub-irrigation:

Sub-irrigation also sometimes called seepage irrigation has been used for many years in field crops in areas with high water tables. It is a method of artificially raising the water table to allow the soil to be moistened from below the plants' root zone. Often those systems are located on permanent grasslands in lowlands or river valleys and combined with drainage infrastructure. A system of pumping stations, canals, weirs and gates allows it to increase or decrease the water level in a network of ditches and thereby control the water table. Sub-irrigation is also used in commercial greenhouse production, usually for potted plants. Water is delivered from below, absorbed upwards, and the excess collected for recycling. (**Arid poop, 2012**).

2.8 Centrifugal pumps:

A centrifugal pump consists of a set of rotating vanes, called impellers, enclosed within a stationary housing called casing water is forced into the center (eye) of the impeller by atmospheric or pressure and set into rotation by impeller vanes. The resulting centrifugal force accelerates the fluid outward between the vanes until it is thrown from the periphery of the impeller into the casing. The casing collects the liquid, converts a portion of its velocity energy into pressure energy and direct the fluid to the pump outlet .

Centrifugal pumps are either single or multistage depending on the number of impeller. Single-stage pumps have only one impeller, while multistaged pumps have several impellers connected in series(i.e. , the outflow of the first impeller is directed into the eye of the second, the outflow of the second impeller into the third, etc) . Centrifugal pumps are classified as either horizontal or vertical according the orientation of their axis of rotation. Horizontal pumps are sub-classified according to the location of the suction nozzle (inlet) as end-suction, side suction ,bottom-suction ,or top-suction .In addition , pumps are also classified by casing and impeller type **(James,1988)**

2.9 Cultivation of sugar cane in Sennar

2.9.1 Method of cultivation:

2.9.a Soil preparation operations:

Deep plowing using heavy disc to a depth between 50–80cm in medium or light soils ,followed by harrowing using disc harrow. shown in figure(2.2).

Figure(2.2) Deep plowing

Land leveling is done by laser leveler, followed by ridging for manual planting. shown in figure(2.3)

Figure(2.3a) laser leveller

Figure(2.3b) laser leveller.

2.9.b Ridger

Ridge spacing 55cm. shown in figure(2.4)

The ridge length ranges between 250 to 800m

Figure(2.4)

2.9.c Sugar cane planting dates

Sugar cane planting starts in May and continues through June to July .This resembles Summer Planting Winter planting start in October and proceeds to December Planting is either manual or mechanical. In manual planting a cane plant is chopped into two to three nodes cuttings . Cuttings are laid in furrows between ridges with an overlap. Cuttings are buried manual using hand hoes

In mechanical planting the planting machine is designed to carried out four operations:

a) Open the furrow
b) Laying cuttings within the furrow
c) Burying or covering planted cuttings
d) Applying the granule fertilizer

This operation has been modified so that the machine opens the furrows and lays the cuttings within the furrow

Arranging the cuttings in an overlap and covering the cuttings is carried out manually . shown in figure(2.5)

Figure(2.5) mechanical planting

2.9.d Sugar cane varieties:

1 / **c**o. 6806 This verity represents about 95% of the total cultivated area

2 / **c**o.527 this verity represents about 3 %

3 / Br.8116 this verity represents about 1%

4 / CD. 881 762 and FR.9821 and FR. 9641 all represent 1 %

2.9.e First light watering

The first light watering comes immediately after the fertilizer distributer. Then irrigation continues with an irrigation interval of 7to10 days in summer and 12 to 14 days in winter

Weeding is done by chisel cultivator three months from planting as shown in figure(2.6).

Figure(2.6) chisel caltivator use for weeding

Split ridging is done by a ridger where by the old ridge is turned into furrow and the planted furrow is turned into planted ridge. The cultivation and split ridging process can be done by a single combined implement that combines a cultivator and ridger a Irrigation continues to just before harvest s shown in figure(2.7).

Figure(2.7) combined cultivator and ridger

2.9.f Cane harvest

Sugar cane crop is left to dry for about 25–30 days without irrigation in summer .

In winter drying takes about 30–35 days

There are two methods of harvest

1) Manual
2) Mechanical

2.10 Estimation of crop water requirements

Irrigation systems are designed, constructed and operated to meet the deficit in crop water requirements due to shortages in precipitation or soil-moisture storage capacities. Nevertheless, little efforts are sometimes exerted in estimating crop water requirements for the purpose of design and management of irrigation systems. The portion of system capital costs allocated for improved water requirement estimates is very minor, compared to that spent on equipment specifications and other hydraulic aspects.

The crops water requirement is the driving force of the entire system. Improper crop water estimates may offset the economic profitability of the system and lead to complete economic failure. The reasons why crop water requirement estimates was given secondary priority are lack of personnel training and the complexity of the methods used in crop water requirement estimation. This confusion is gradually being rectified by the leading work performed by specialized committees or consultants for the American Society of Agricultural Engineers (**Ahmed,2005**)

Proper estimation of crop water requirements (crop water demand) is a pre-requisite for proper irrigation water management. Irrigation management is concerned mainly with the optimization of water supply and demand. The end goal is to sustain an optimum water supply avoiding both excess and deficit conditions. This is achieved by fair compensation of the depleted portion of soil moisture, predetermined depletion, after the excess soil water has been drained. Crop water requirements and soil storage characteristic have to be known as priority to achieve proper water management. Effective precipitation is a very important factor in determining the crop water needs. Crop water demand is a function of climatic factors, crop type, its growth stage, soil characteristics and their interaction. The climatic factors are the essential inputs in estimating reference Evapotranspiration (ET_o) (Ahmed,2005)

2.11 Determination of reference evapotranspiration (ET_o)

Reference evapotranspiration can either be measured through actual measurement methods or calculation methods.

Actual measurement methods: include soil water depletion, lysimeters and soil-water balance (Allen *et al.*, 1991; Carrijo and Cuenca, 1992; Grebet and Cuenica, 1991; Waiter *et al.*, 1991). Actual measurement method are more accurate but more expensive and require well trained personnel.

Calculation methods: early approaches were laborious and site specific but newly developed methods are of general and wider use. Their level of accuracy depends on the accuracy of climatic data involved. The calculation methods are extensively used for irrigation planning, scheduling and system operation (Bailey and Spackman, 1996; Carazza *et al.*, 1996; De Jager an Kennedy, 1996; Hess, 1996; Hill and Allen, 1996). These methods can be classified into:

——— Temperature methods (Blaney-Criddle equation 1950 and Thornth wait equation, 1948).

——— Radiation method: (Jensen-Haise equation, 1963 and Mak kink equation, 1957). -Pan evaporation (Allen *et al.*, 1998 and Christiansen, 1968). They include class A pan, sunken pan, Piche tube and evaporometers.

——— Combination method (Penman equation, 1948 and Penman-Montieth, 1998).

Calculation methods are based on the concept of reference crop (Doorenbos and Pruitt, 1977). A number of theoretical and practical attempts have been made to improve the estimation performance of these methods for different locations and data availability(Batchelor, 1984; Beven, 1979; Coleman and De Coursey, 1976; Doorenbos and Pruitt, 1977; Jensen *et al.,* 1990 and Perrier, 1985). Still, many of these attempts have manifested some weaknesses under global application, due to:-

a- grass variety and its morphological characteristics have not been standardized for different climatic conditions, causing a great difficulty in relating calculated (ETo) to a reference crop.

b- grass management such as (alfalfa) varies with location (Allen *et al.*, 1994a).

c- problems associated with lysimeters and microclimatological measurement as they affect (ETo) values (Abu Khalid *et al.*, 1982 and Allen *et al.,* 1991).

The FAO adopted Penman combination equation (Doorenbos and Pruitt, 1977), although considered as the most comprehensive equation, it is still found to overestimate (ETo) for many reasons pertaining to the conceptual procedures used to compute the parameters within the equation and party for data reliability and processing.

Other equations such as the FAO-Radiation, FAO Blaney-Criddle and FAO-Pan evaporation equations have exhibited variable adherence to a

reference ETo. Nevertheless the deviation of these equations from the grass reference is not as wide as that of the FAO –Penman.

Methodologies used to improve the estimation of crop water requirement were revised by FAO, in collaboration with the International Commission on Irrigation and Drainage (ICID). Consequently, a decision was taken to change the concept of reference evapotranspiration and revise the calculation procedures, in an expert consultation held in Rome (1990). A hypothetical reference canopy, as described by Penman-Montieth equation has been substituted for a living reference crop (Smith *et al.*, 1991). Grass reference evapotranspiration (ETo) is defined as: The rate of evapotranspiration from a hypothetical reference crop with an assumed crop height of 0.12 m of a fixed surface resistance of 70s/m and an albido of 0.23 m. It closely resembles the evapotranspiration from an extensive surface of green grass of uniform height, actively growing, completely shading the ground, with adequate water supply and free from diseases.

The FAO Penman-Montieth equation (1994) of estimating ETo is as follows:-

$$ETo = \frac{0.408\,\Delta\,(Rn - G) + \gamma\,\frac{900}{T+273}\,U_2\,(e_s - e_a)}{\Delta + [\gamma\,(1 + 0.34\,U_2)]} \qquad (2.1)$$

Where:

ET_o = Reference evapotranspiration (mm day^{-1}),

R_n = Net radiation at the crop surface (MJ m^{-2} day^{-1}),

G = Ground heat flux density (MJ m^{-2} day^{-1}),

U_2 = Wind speed at 2 m height (ms^{-1}),

e_s = Saturation vapour pressure (kPa),

e_a = Actual vapour pressure (kPa),

$e_s - e_a$ = Saturation vapour pressure deficit (kPa),

Δ = Slope vapor pressure curve (kPa $^oC^{-1}$),

γ = psychometric constant (kPa $^oC^{-1}$)

2.12 Determination of crop water requirements (ET_c)

Reference evapotranspiration is estimated for a standard crop grown in vast fields under standard field conditions, securing optimum agronomic and soil water conditions. These conditions can rarely be maintained for field crops. This is why crop evapotranspiration (ETc) is distinctly different from ETo, as ground cover, canopy properties and aerodynamic resistances of field crops are different from those of the standard reference crop. The effects of the characteristics that distinguish field crops from standard (reference) crop are integrated into the crop coefficient (Kc). Consequently, crop evapotranspiration is calculated using crop coefficient approach as follows: -

$$ET_c = ET_o * K_c \qquad (2.2)$$

Where:

ET_c: Crop evapotranspiration (mm day^{-1})

ET_o: Reference crop evapotranspiration (mm day^{-1})

K_c : Crop coefficient

The crop coefficient (Kc) is basically the ratio of the (ETc) to the (ETo) (Elliott *et al.*, 1988). Factors for determining the crop coefficient are: - Crop type, climate, soil evaporation and crop growth stages (Elliott *et al.*, 1988; Grattan *et al.*, 1998; Martin and Gilley, 1993 and Snyder *et al.*, 1989 a and 1989b). The procedure suggested by Doorenbos and Pruitt (1977) for the determination of crop coefficient (Kc) for various crop stages is based on selecting (Kc) for mid and late stages from established tables. For initial crop growth stage it uses a curve relating the evapotranspiration of the initial growth stage and average recurrent interval of irrigation or significant rainfall. This procedure for estimating initial (Kc) was considered by many researchers as laborious, cumbersome and tedious (Elkayal, 1983 and Rayan and Cuenca, 1984). Regression equations have been developed to allow for convenient computation and calculation of initial (Kc) (Elkayel, 1983 and Rayan and Cuenica, 1984) follows:-

a- Kcin = (1.286 – 0.27 LnIf) exp [(- 0.01 – 042 LnIf) ETri]

(for If < 4 days) (2.3a)

b- Kcin = 2 (If) – 0.49 exp [(-0.02 – 0.04 LnIf) ETri]

(for If ≥ 4 days) (2.3b)

Where:

IF = Normal interval between irrigations or significant rainfall (days)

Kcin = Initial stage crop coefficient

ETri = Average initial period reference evapotranspiration (mm day^{-1})

Such regression equations are limited by an irrigation interval of four days only. However, for drip and sprinkler irrigation systems four days interval is considered very large while in surface irrigation a wide range of intervals is used such as seven or even fourteen days. Unfortunately

the developed regression equations treat the seven, ten and fourteen day's interval as the same. This case needs to be corrected if proper irrigation scheduling is targeted. (**Ahmed,2005**).

2.13 FAO Method for Determination of Crop Coefficient (K_c)

The growing period of the crop is divided into four general growth stages namely the initial, development, mid-season and late season stage. Kc values are determined for each of these stages referred to as Kcin, Kc dev., Kcmid and Kc end respectively.

The values for (kcin) provided in FAO paper 56 are only approximations to be used in planning studies. Only one value for Kcin is given for several crop group types and is considered to be representative of the whole group. For a typical irrigation water management more accurate estimates of Kcin can be obtained by considering: -

——— Time interval between wetting events:

Evapotranspiration during the initial stage for annual crops is predominately in the form of evaporation. Therefore, accurate estimates

for Kcin should consider the frequency with which the soil surface is wetted during the initial period. When the evaporation from soil surface is considerable Kcin will be large. Where the soil surface is dry, evaporation is restricted and the Kcin will be small.

——— Evaporative power of the atmosphere:

The value of (Kcin) is affected by the evaporating power of the atmosphere (i.e ET_o). The higher the evaporative power of the atmosphere; the quicker the soil will dry between water applications and the smaller the time averaged Kc will be for any particular period.

——— Magnitude of the wetting event:-

As the amount of water available in the topsoil for evaporation ,and hence the time for the soil surface to dry, is a function of the magnitude of the wetting event, Kcin will be smaller for light wetting events than for larger wettings. (**Ahmed,2005**).

2.13 FAO method for determination of Kcmid:-

Values for Kcmid are listed in Tables in FAO paper (56). The values for Kcmid as well as Kc end in these tables represent those for a sub-humid climate with an average day light, minimum relative humidity (RH min) of 45% and with calm to moderate wind speeds averaging 2 m/s. For more humid or arid conditions, or for more or less windy conditions, the Kc coefficient for the mid-season and end of late season stages should be modified. The values in these tables are values for non-stressed crops cultivated under excellent agronomic and water management conditions and achieving maximum crop yield (standard conditions). When stand density, height or leaf area are less than attained under such conditions the values for Kcmid, and for most crops, for Kc end need to be modified

Kcmid from these tables is adjusted as follows:-

$$Kcmid = Kcmid\ (Tab) + [0.04\ (u_2 - 2) - 0.004\ (RH_{min} - 45)] \left(\frac{h}{3}\right)^{0.3} \quad (2.4)$$

(**Ahmed,2005**).

2.15 Crop coefficient for the end or the late season stage (Kc end):-

Typical values for the crop coefficient at the end of the late season growth stage (Kc end) are giver in FAO Kc tables for various agricultural crops. The value given in these tables reflect both crop and water management practices adopted for those crops.

The Kc end values provided in FAO tables are typical values expected for average Kc end under the standard climatic conditions. More arid climates and conditions of greater wind speed will have higher values of Kc end. More humid climates and conditions of lower wind speed will have lower values of Kc end. Specific adjustments for climate changes are made as follows: -

$$Kc\ end = Kc\ end\ (tab) + [0.04(u_2 - 2) - 0.004\ (RH_{min} - 45)] \left(\frac{h}{3}\right)^{0.3} \quad (2.5)$$

2.16 Construction of the Kc curve:-

For the construction of Kc curve for annual crops only three point values are required to describe and to construct the Kc curve. The curve is constructed using the following three steps:-

- The crop growing period is divided into four general growth stages that describe crop phenology or development (initial, crop development, mid-season and late season stage).

- The length of the growing stage are determined, the three values of Kc that correspond to Kcin, Kcmid and Kc end are identified from FAO tables.

- Adjust the Kc values to the frequency of wetting and/or climatic conditions of the growth stages as outlined earlier.

- Construct a curve by connecting the straight line segments through each of the four growth stages. Horizontal lines are drawn through Kcin in the initial stage and through Kcmid in the mid-season stage. Diagonal lines are drawn from Kcin to Kcmid within the course of the crop development stage and from Kcmid to Kc end within the course of the late season stage. (**Ahmed,2005**).

Concerning maximum Kc Hess (1996) reported values of 1.1 or 1.2 depending on crop type. It is well known that values higher than 1.2 are sometimes used. It should be pointed out that these values were probably obtained from field experiments performed under advective conditions (very small plots) and that they are not valid for fields larger than one hectare. The crop coefficient (Kc) being a ratio of the crop ET_c to the reference ET_o, represents an integration of the effects of four primary characteristics that distinguish the crop from reference grass. These characteristics are:-

Crop height: The crop height influences the aerodynamic resistance term, (Ra), of the FAO Penman-Montieth equation and the turbulent transfer of vapour from the crop into the atmosphere. The (Ra) term appears twice in the full form of the FAO Penman-Montieth equation.

Albedo (reflectance) of the crop-soil surface: The albedo is affected by the fraction of the ground covered by vegetation and by the soil surface wetness. The albedo of the crop-soil surface influences the net radiation of the surface, Rn, which is the primary source of the energy exchange for the evaporation process.

Canopy resistance: The resistance of the crop to vapour transfer is affected by leaf area (number of stomata), leaf age and condition and the degree of stomatal control. The canopy resistance influences the surface resistance (rs).

Evaporation from especially exposed soil: The soil surface wetness and the fraction of ground covered by vegetation influence the surface resistance (rs). Following soil wetting, the vapour transfer rate from the soil is high, especially for crops having incomplete ground cover. The combined surface resistance of the canopy and of the soil determines the (bulk) surface resistance (rs). The surface resistance term in the Penman-Montieth equation represents the resistance to vapour flow from within plant leaves and from beneath the soil surface.

The (Kc) in the equation $ET_c = Kc * ET_o$ predicts ET_c under standard conditions. This represents the upper envelope of the crop evapotranspiration and represents the conditions where no limitations are placed on the crop growth or evapotranspiration due to water shortage, crop density, disease, weed, insect and salinity pressures.

The calculation procedure for crop evapotranspiration, (ET_c) involves the following steps:-

Identifying the crop growth stages, determining their lengths and selecting the corresponding Kc coefficients.

Adjusting the selected Kc coefficients for frequency of wetting or climatic condition during the stage.

Constructing the crop coefficient curve (allowing one to determine ETc as the product of ET_o and Kc).

2.17 Determination of effective rainfall:-

According to cropwat, FAO Irrigation and Drainage Paper (46) (1992) and El-Ramlawi (1999) four different methods are used to determine the effective rainfall. The different options are:-

Fixed percentage of rainfall: effective rainfall is calculated according to:

$$P_{eff} = a . P_{tot}$$

Where (a) is a fixed percentage to be given by the user to account for losses from runoff and deep percolation. Normally the losses are around 10%to 30%, thus a = 0.7 – 0.9. A value of 0.75 was given by Adam (19) for conditions of central clay plains of the Sudan.

Dependable rain: based on an analysis carried out for different arid and sub-humid climates an empirical formula was developed in FAO/AGLW to estimate dependable rainfall, the combined effect of dependable rainfall (80% probability exceedance) and estimated losses due to runoff and percolation this formula may be used for design purposes where 80% probability of exceedance is required calculation according to:-

$$P_{eff} = 0.6\ P_{tot} - 10 \qquad \text{for } P_{tot} \leq 70 \text{ mm}$$

$$P_{eff} = 0.8\ P_{tot} - 24 \qquad \text{for } P_{tot} > 70 \text{ mm}$$

a) Empirical formula:- The parameters may be determined from an analysis of local climate records. An analysis of local climate records may allow an estimate of effective rainfall. The relationship can, in most cases, be simplified by the following equations:-

$$P_{eff} = a\ P_{tot} + b \qquad \text{for } P_{tot} < Z \text{ mm}$$

$$P_{eff} = c\ P_{tot} + d \qquad \text{for } P_{tot} > Z \text{ mm}$$

a, b, c and d are correlation coefficients.

b) USDA Soil Conservation Service Method:

Where effective rainfall can be calculated according to:

$$P_{eff} = P_{tot}\ (125 - 0.2\ P_{tot}) / 125 \qquad \text{for } P_{tot} < 250 \text{ mm}$$

$$P_{eff} = 125 + 0.1\ P_{tot} \qquad \text{for } P_{tot} > 250 \text{ mm}$$

(Ahmed, 2005)

CHAPTER THREE

MATERIALS AND METHODS

3.1 The study site:

The field work of this study was conducted at Sennar Sugar Scheme (2014) which is located in Sennar State about 300 kilometers south of Khartoum and 12 km west of Wad Alhdad City .The dada used in this study belongs to seasons 2011-2012-2013.

The project is irrigated from a pump station at Iraidiba on the western bank of the Blue Nile It lies about 56 kilometers south of the plant site. The pump station has four pumps two of them have a pumping capacity of 6.1 cubic meters / second and other two have a pumping pumping capacity of 6.8 cubic meters / second. **(Field Managing Office,2014)**.

3.2 Determination of crop water requirements:

Determination of reference evapotranspiration was carried out from sennar meteorological data which was fed into cropwat program to compute reference evapotranspiration table (3.1) .

Table(3.1) Calculation of reference evapotranspiration (ET_o)

Country: Sudan | Station: SENNAR

Altitude: 418 m. | Latitude: 13.33 °N | Longitude: 33.37 °E

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	6.0	35.0	64	164	10.6	21.8	5.10
February	8.2	36.6	50	164	10.9	24.0	5.91
March	9.3	39.3	47	164	11.0	25.8	6.71
April	13.2	41.6	43	138	11.3	26.9	6.98
May	16.0	41.0	48	164	11.3	26.7	7.26
June	18.2	38.8	61	104	10.5	25.1	6.01
July	17.7	35.0	74	104	8.1	21.6	4.94
August	17.1	33.2	86	164	7.8	21.3	4.60
September	17.1	35.0	76	138	9.5	23.6	5.24
October	13.8	38.2	74	78	10.2	23.3	5.08
November	12.1	37.7	61	164	10.6	22.1	5.63
December	7.7	35.5	68	164	10.5	21.1	5.01

Table (3.2) K_c data as given by sennar farm records and cropwat data base

k_c from sennar transplant	k_c cropwat	k_c ratoon
0.6	0.6	0.6
0.7	0.6	0.6
0.9	1.1	0.8
1.1	1.32	1.1
1.25	1.32	1.25
1.3	1.32	1.2
1.25	1.32	1
1.2	1.32	1
1.1	1.32	1
1.1	1.25	1
1.1	1.09	1
1.1	0.94	0.9
1.1	0.85	0.9
1	0	0
0.9	0	0

Table (3.3) Average monthly rainfall as taken from Cropwat data base, Sennar meteorological station and Sennar cane farm rain data

Month	Crop watt rain data	Sennar meteorological station rain data	Sennar cane farm rain data
January	0	0	0
February	0	0	0
March	0	0	0
April	4	0	0
May	30	20.5	6
June	55	66.1	22
July	135	99.2	112
August	160	135.9	157
September	65	84.5	58
October	20	13.7	18
November	1	0.2	0
December	0	0	0
Total	470	410.1	373

Table (3.4)Calculation of cane crop evapotranspiration(ET_c)

Equation(3.1)was used to calculate (ET_c) $ET_c = ET_o * K_c$

Month	ETo	Kc	ETc
	mm/day		
May	7.26	0.6	4.4
May	7.26	0.6	4.4
May	7.26	0.6	4.4
June	6.01	0.7	4.21
June	6.01	0.7	4.21
June	6.01	0.7	4.21
July	4.94	0.9	4.45
July	4.94	0.9	4.45
July	4.94	0.9	4.45
August	4.6	1.1	5.06
August	4.6	1.1	5.06
August	4.6	1.1	5.06
September	5.24	1.25	6.55
September	5.24	1.25	6.55
September	5.24	1.25	6.55
October	5.08	1.3	6.6
October	5.08	1.3	6.6
October	5.08	1.3	6.6
November	5.63	1.25	7.04
November	5.63	1.25	7.04
November	5.63	1.25	7.04
December	5.01	1.2	6.02
December	5.01	1.2	6.02
December	5.01	1.2	6.02
January	5.1	1.1	5.61
January	5.1	1.1	5.61
January	5.1	1.1	5.61
February	5.91	1.1	6.5
February	5.91	1.1	6.5
February	5.91	1.1	6.5
March	6.71	1.1	7.4
March	6.71	1.1	7.4
March	6.71	1.1	7.4
April	6.98	1.1	7.7
April	6.98	1.1	7.7
April	6.98	1.1	7.7
May	7.26	1	7.26
May	7.26	1	7.26
May	7.26	1	7.26

Table(3.5)Net irrigation requirements in mm per day

Equation(3.2) $In = ET_c - \text{effect rain}$

Month	ETo	KC	ETc	Effect rain	Effect rain	In
	mm/day			per Month	per day	
May	7.26	0.6	4.4	28.6	0.95	3.45
May	7.26	0.6	4.4	28.6	0.95	3.45
May	7.26	0.6	4.4	28.6	0.95	3.45
June	6.01	0.7	4.21	50.2	1.67	2.54
June	6.01	0.7	4.21	50.2	1.67	2.54
June	6.01	0.7	4.21	50.2	1.67	2.54
July	4.94	0.9	4.45	105.8	3.53	0.92
July	4.94	0.9	4.45	105.8	3.53	0.92
July	4.94	0.9	4.45	105.8	3.53	0.92
August	4.6	1.1	5.06	119	3.97	1.09
August	4.6	1.1	5.06	119	3.97	1.09
August	4.6	1.1	5.06	119	3.97	1.09
September	5.24	1.25	6.55	58.2	1.94	4.61
September	5.24	1.25	6.55	58.2	1.94	4.61
September	5.24	1.25	6.55	58.2	1.94	4.61
October	5.08	1.3	6.6	19.4	0.65	5.95
October	5.08	1.3	6.6	19.4	0.65	5.95
October	5.08	1.3	6.6	19.4	0.65	5.95
November	5.63	1.25	7.04	1	0.033	7.01
November	5.63	1.25	7.04	1	0.033	7.01
November	5.63	1.25	7.04	1	0.033	7.01
December	5.01	1.2	6.02	0	0	6.02
December	5.01	1.2	6.02	0	0	6.02
December	5.01	1.2	6.02	0	0	6.02
January	5.1	1.1	5.61	0	0	5.61
January	5.1	1.1	5.61	0	0	5.61
January	5.1	1.1	5.61	0	0	5.61
February	5.91	1.1	6.5	0	0	6.5
February	5.91	1.1	6.5	0	0	6.5
February	5.91	1.1	6.5	0	0	6.5
March	6.71	1.1	7.4	0	0	7.4
March	6.71	1.1	7.4	0	0	7.4
March	6.71	1.1	7.4	0	0	7.4
April	6.98	1.1	7.7	4	0.13	7.57
April	6.98	1.1	7.7	4	0.13	7.57
April	6.98	1.1	7.7	4	0.13	7.57
May	7.26	1	7.26	28.6	0.95	6.31
May	7.26	1	7.26	28.6	0.95	6.31
May	7.26	1	7.26	28.6	0.95	6.31

Table (3.6) Gross irrigation requirements in mm per day

60 per cent irrigation efficiency was taken as upper level for surface irrigation efficiency equation(3.3)

$$Ig = In*100/60$$

Month	In	Efficiency60%	Ig
May	3.45	60%	5.75
May	3.45	60%	5.75
May	3.45	60%	5.75
June	2.54	60%	4.23
June	2.54	60%	4.23
June	2.54	60%	4.23
July	0.92	60%	1.53
July	0.92	60%	1.53
July	0.92	60%	1.53
August	1.09	60%	1.82
August	1.09	60%	1.82
August	1.09	60%	1.82
September	4.61	60%	7.7
September	4.61	60%	7.7
September	4.61	60%	7.7
October	5.95	60%	9.92
October	5.95	60%	9.92
October	5.95	60%	9.92
November	7.01	60%	11.7
November	7.01	60%	11.7
November	7.01	60%	11.7
December	6.02	60%	10.03
December	6.02	60%	10.03
December	6.02	60%	10.03
January	5.61	60%	9.35
January	5.61	60%	9.35
January	5.61	60%	9.35
February	6.5	60%	10.8
February	6.5	60%	10.8
February	6.5	60%	10.8
March	7.4	60%	12.3
March	7.4	60%	12.3
March	7.4	60%	12.3
April	7.57	60%	12.62
April	7.57	60%	12.62
April	7.57	60%	12.62
May	6.31	60%	10.52
May	6.31	60%	10.52
May	6.31	60%	10.52

Table(3.7) Gross irrigation requirements in mm per watering equation(3.4) Gross irrigation requirements in mm per watering =Ig*I.I I.I= irrigation interval

Month	Ig	Ig/watering
May	5.75	57.5
May	5.75	57.5
May	5.75	57.5
June	4.23	42.3
June	4.23	42.3
June	4.23	42.3
July	1.53	15.3
July	1.53	15.3
July	1.53	15.3
August	1.82	18.2
August	1.82	18.2
August	1.82	18.2
September	7.7	77
September	7.7	77
September	7.7	77
October	9.92	99.2
October	9.92	99.2
October	9.92	99.2
November	11.7	117
November	11.7	117
November	11.7	117
December	10.03	100.3
December	10.03	100.3
December	10.03	100.3
January	9.35	93.5
January	9.35	93.5
January	9.35	93.5
February	10.8	108
February	10.8	108
February	10.8	108
March	12.3	123
March	12.3	123
March	12.3	123
April	12.62	126.2
April	12.62	126.2
April	12.62	126.2
May	10.52	105.2
May	10.52	105.2
May	10.52	105.2

Table(3.8) Gross irrigation requirements in m^3 per Fadden per watering equation (3.5) Gross irrigation requirements in m^3 per Fadden per watering = Ig/watering*4200/1000 or = Ig/watering * 4.2

Month	Ig/watering	Ig.Reg. m.fd
May	57.5	241.5
May	57.5	241.5
May	57.5	241.5
June	42.3	177.66
June	42.3	177.66
June	42.3	177.66
July	15.3	64.26
July	15.3	64.26
July	15.3	64.26
August	18.2	76.44
August	18.2	76.44
August	18.2	76.44
September	77	323.4
September	77	323.4
September	77	323.4
October	99.2	416.64
October	99.2	416.64
October	99.2	416.64
November	117	491.4
November	117	491.4
November	117	491.4
December	100.3	421.26
December	100.3	421.26
December	100.3	421.26
January	93.5	392.7
January	93.5	392.7
January	93.5	392.7
February	108	453.6
February	108	453.6
February	108	453.6
March	123	516.6
March	123	516.6
March	123	516.6
April	126.2	530.04
April	126.2	530.04
April	126.2	530.04
May	105.2	441.84
May	105.2	441.84
May	105.2	441.84

Table (3.9) Gross irrigation requirements in m^3 for area planted on first May equation (3.6) Gross irrigation requirements in m^3 for area planted on first May = Ig.Reg m^3.fd * Area planted

Month	Ig.Reg. m^3.fd	Area planted first of may	Ig.Reg.Req.m.fd
May	241.5	1042	251643
May	241.5	1042	251643
May	241.5	1042	251643
June	177.66	1042	185121.72
June	177.66	1042	185121.72
June	177.66	1042	185121.72
July	64.26	1042	66958.92
July	64.26	1042	66958.92
July	64.26	1042	66958.92
August	76.44	1042	79650.48
August	76.44	1042	79650.48
August	76.44	1042	79650.48
September	323.4	1042	336982.8
September	323.4	1042	336982.8
September	323.4	1042	336982.8
October	416.64	1042	434138.88
October	416.64	1042	434138.88
October	416.64	1042	434138.88
November	491.4	1042	512038.8
November	491.4	1042	512038.8
November	491.4	1042	512038.8
December	421.26	1042	438952.92
December	421.26	1042	438952.92
December	421.26	1042	438952.92
January	392.7	1042	409193.4
January	392.7	1042	409193.4
January	392.7	1042	409193.4
February	453.6	1042	472651.2
February	453.6	1042	472651.2
February	453.6	1042	472651.2
March	516.6	1042	538297.2
March	516.6	1042	538297.2
March	516.6	1042	538297.2
April	530.04	1042	552301.68
April	530.04	1042	552301.68
April	530.04	1042	552301.68
May	441.84	1042	460397.28
May	441.84	1042	460397.28
May	441.84	1042	460397.28

Table (3.10) Total intended water and total applied water as supplied by Sennar scheme for seasons (2011_2012_2013)

Month	Total intended water	Total applied water
May	33900	34186
June	29528	35235
July	15168	20102
August	11497	11497
September	21200	22608
October	24986	34609
November	22519	25321
December	26317	30133
January	20960	22651
February	23450	24984
March	26111	34775
April	22194	30454
May	33152	42010
June	24609	33368
July	25825	23783
August	10111	8061
September	28388	30032
October	27477	34566
November	24414	35455
December	22330	26132
January	21000	227240
February	22000	233680
March	30000	267260
April	26000	278070
May	31000	313720
June	34500	197110
July	33590	267157
August	0	0
September	27459	261690
October	34590	363455
November	40678	382901
December	31946	300950

3.3 Introduction to Cropwat:

The main purpose of CROPWAT is to calculate crop water requirements and irrigation schedules based on data provided by the user. These data can be directly entered into CROPWAT or imported from other applications.
For the calculation of crop water requirements (CWR), CROPWAT needs data on evapotranspiration (ETo). CROPWAT allows the user to either enter measured ETo values, o r to input data on temperature, humidity, wind speed and sunshine, which allows CROPWAT to calculate ETo using the Penman-Monteith formulae. CROPWAT fully supports the .PEN and . CLI files from t he CLIMWAT database.
Rainfall data are also needed, and are used by CROPWAT to compute effective rainfall data as input for the CWR and schedule.10ing calculations. Finally, crop data (dry crop or rice) are needed for the CWR calculations, and soil data if the user also wants to calculate irrigation schedules (dry Whereas CROPWAT normally calculates CWR and schedules for 1 crop , it can also calculate a scheme supply which is basically the combined crop water requirements of multiple crops, each with its individual planting date (a so-called cropping pattern).

Both for data input and for the calculations CROPWAT offers a wide variety of options that can be set interactively by the user during programme execution by clicking on the Options button on the toolbar, or through the Settings>Options menu

3.4 Program structure:

The CROPWAT program is organised in 8 different modules, of which 5 are data input modules and 3 are calculation modules. These modules can be accessed through the CROPWAT main menu but more conveniently through the Modules bar that is permanently visible at the left hand side of the main window. This allows the u ser to easily combine different climatic, crop and soil data for calculation of crop water requirements ,irrigation schedules and scheme supplies.
The data input modules of CROPWAT are:

1. Climate/ETo: for the input of measured ETo data *or* of climatic data that allow calculation of ETo Penman-Monteith;
2. Rain: for the input of rainfall data and calculation of effective rainfall;
3. Crop (dry crop or rice): for the input of crop data and planting date;
4. Soil: for the input of soil data for (only needed for irrigation scheduling);
5. Crop pattern: for the input of a cropping pattern for scheme supply calculations

Note that in fact Climate /Eto and Rain modules are not only for data input but also calculate data, namely Radiation /ET0 and Effective rainfall respectively.

The calculation modules of CROPWAT are:

6. CWR - for calculation of Crop Water Requirements
7. Schedules (dry crop or rice) - for the calculation of irrigation schedules
8. Scheme - for the calculation of scheme supply based on a specific croppin

3.5 Determination of conveyance percent losses

$$\text{Conveyance percent losses} = \frac{\text{supplied} - \text{actual compute}}{\text{Supplied}} * 100 \quad (3.1)$$

Table (4.4)

3.6 Determination of percent losses of intended irrigation water

$$\text{Intended losses \%} = \frac{\text{intended efficiency} - \text{actual compute}}{\text{Intended}} * 100 \quad (3.2)$$

Table (4.5)

CHAPTER FOUR

RESULTSAND DISCUSSION

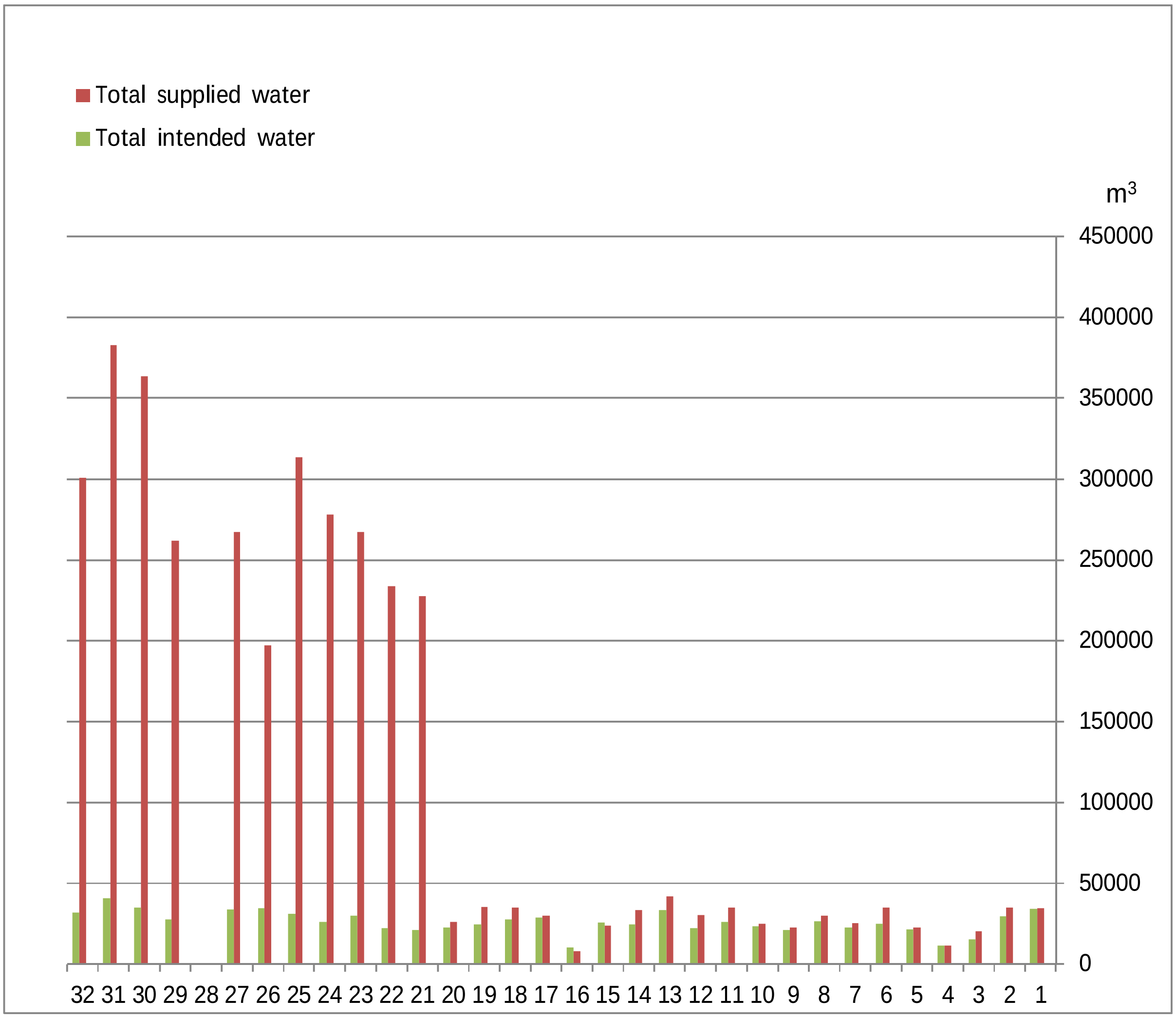


Fig.(4.1) shows the total amounts of supplied irrigation water for the three seasons versus the intended irrigation water .

Figure (4.1) shows that the total supplied amounts exceed by far the total intended amounts.

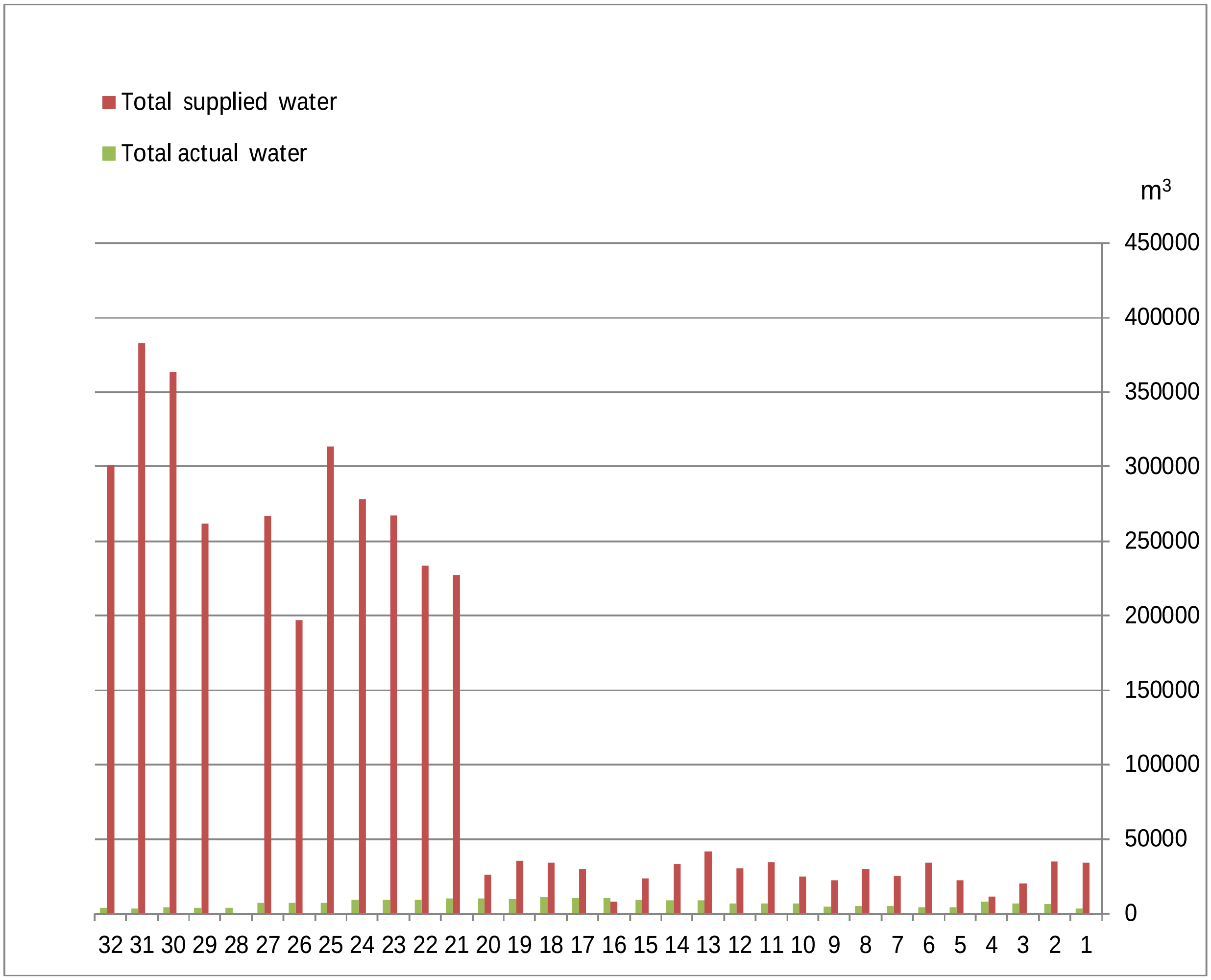


Fig.(4.2) shows the total supplied water for three seasons 2011-2013 versus the total actual computed irrigation requirements for the same period.

The figure shows that (4.2) great differences between the two supplied and actual computed quantities.

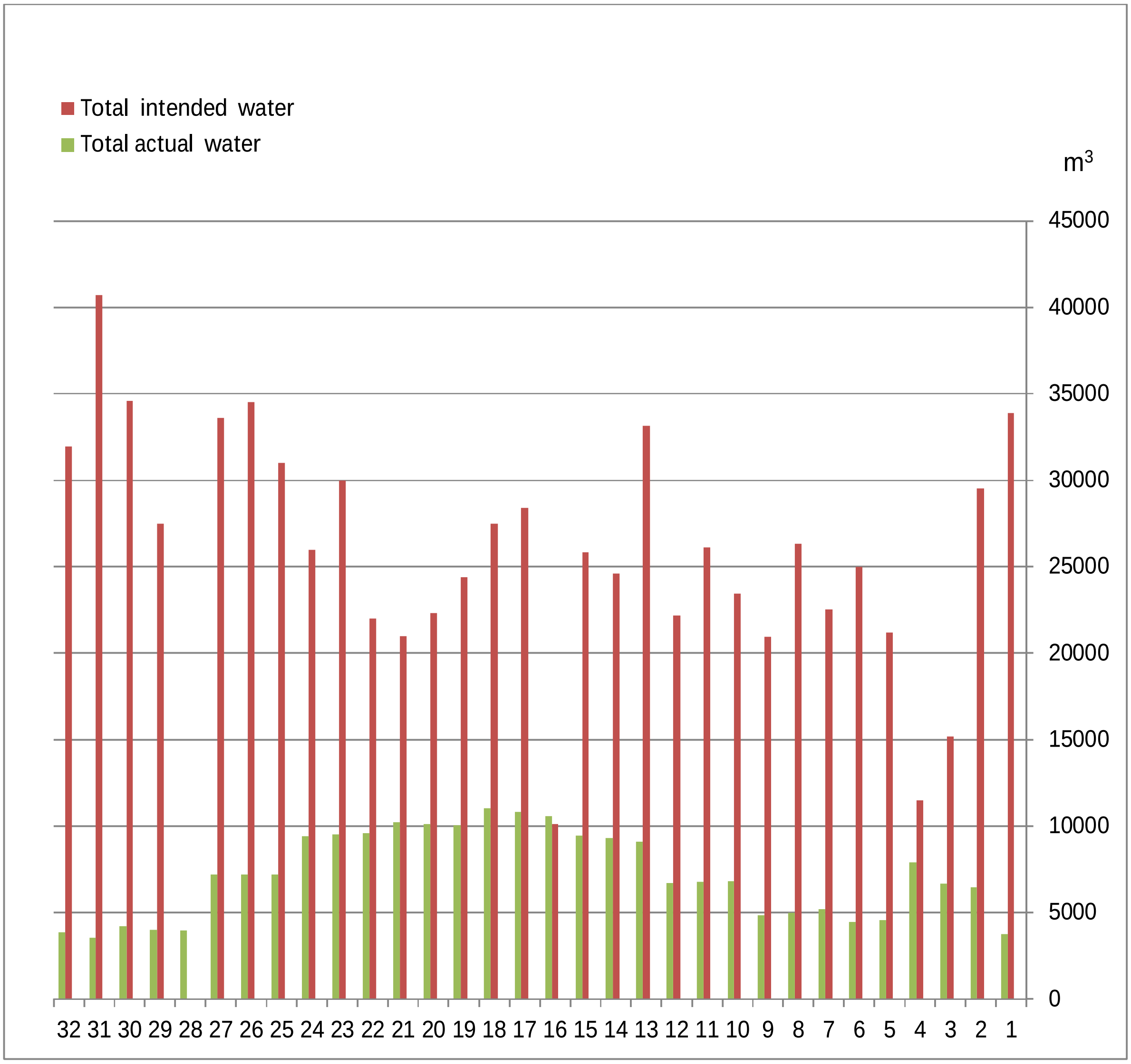


Fig.(4.3) shows the total intended irrigation water versus the total actual computed irrigation water .

The figure shows that (4.3) clearly over estimation of the intended amounts .

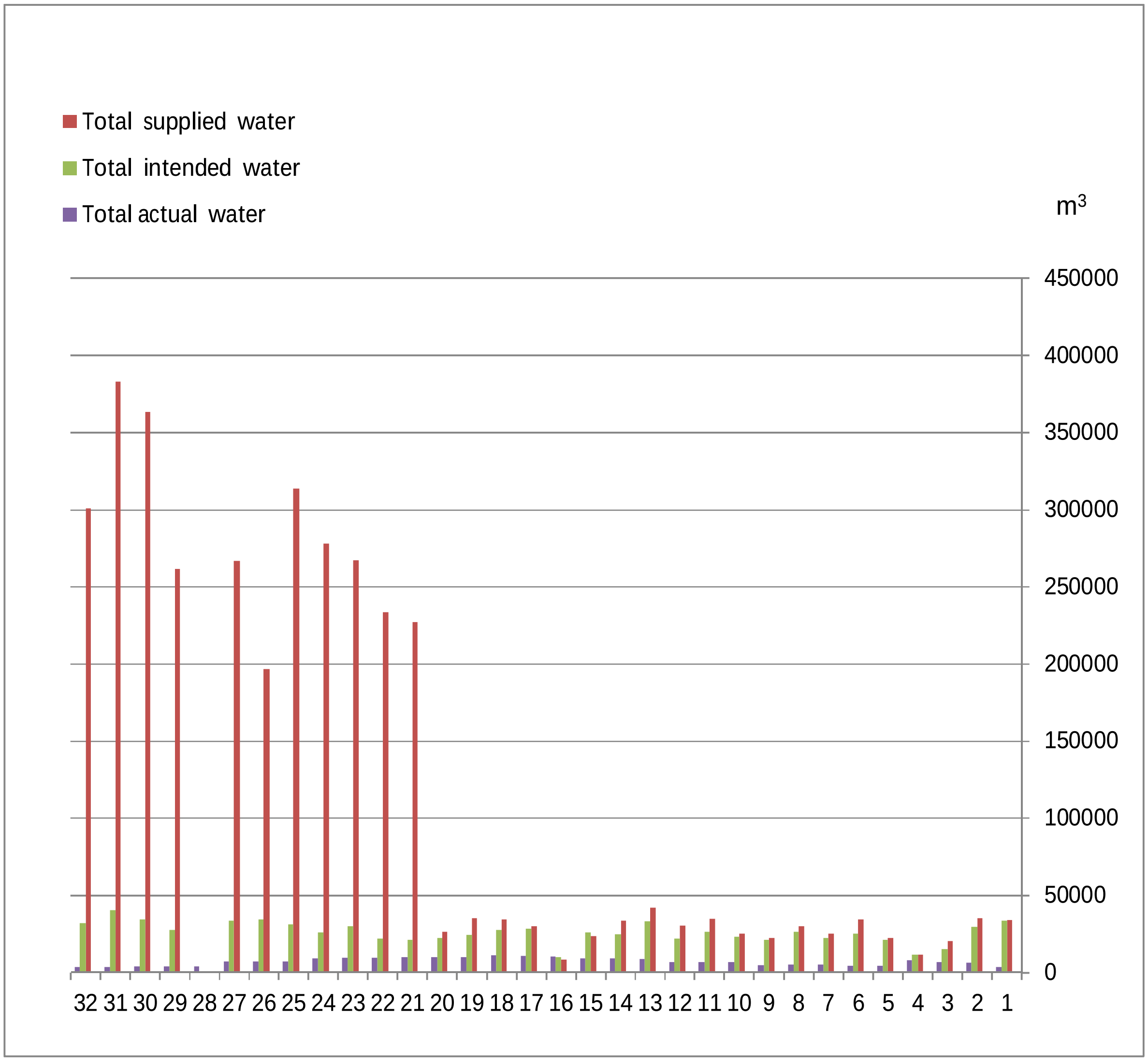


Fig (4.4) Illustrates the comparison between the total supplied , total intended and total actual computed irrigation requirements.

The over supplies and over intends are very clear in the above figure.

Table(4.1)

Total Supplied water = V_2
Total actual water = V_3

Paired Samples Test

	Paired Differences					t	Df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1 VAR00002 - VAR00003	106982.97704	127603.32093	22557.29338	60977.07387	152988.88021	4.743	31	.000

Table (4.1) Statistical analysis using pair t- test showed high significant difference between total Supplied irrigation water and total actual computed irrigation water.

Table (4.2)

Total Supplied water = V_2
Total Intended water = V_1

Paired Samples Test

	Paired Differences					t	Df
				95% Confidence Interval of the Difference			
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper		
Pair 1 VAR00001 - VAR00002	-88946.75000	122882.55367	21722.77175	-133250.63507	-44642.86493	-4.095	31

Table (4.2) Statistical analysis using pair t- test showed high significant difference between total supp

and total intended irrigation water.

Table (4.3)

Total Intended water $=V_1$

Total actual water $= V_3$

Paired Samples Test

	Paired Differences					t	Df
				95% Confidence Interval of the Difference			
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper		
Pair 1 VAR00001 - VAR00003	18036.22704	8719.21989	1541.35488	14892.61304	21179.84104	11.702	31

Table (4.3) Statistical analysis using pair t- test high showed significant difference between total Inte

and total actual computed irrigation water**.**

Table (4.4)

Determination of conveyance percent

difference supplied	Percent
30440	89.0%
28768	81.6%
13409	66.7%
3589	31.2%
18039	79.8%
30148	87.1%
20127	79.5%
25122	83.4%
17821	78.7%
18155	72.7%
27997	80.5%
23727	77.9%
32911	78.3%
24083	72.2%
14315	60.2%
-2520	-31.3%
19222	64.0%
23532	68.1%
25387	71.6%
16010	61.3%
217012	95.5%
224067	95.9%
257730	96.4%
268645	96.6%
306509	97.7%
189887	96.3%
259938	97.3%
00000	000%
257662	98.5%
359227	98.8%
379351	99.1%
297116	98.7%

Average supplied losses percent = 80.8

Table (4.5)

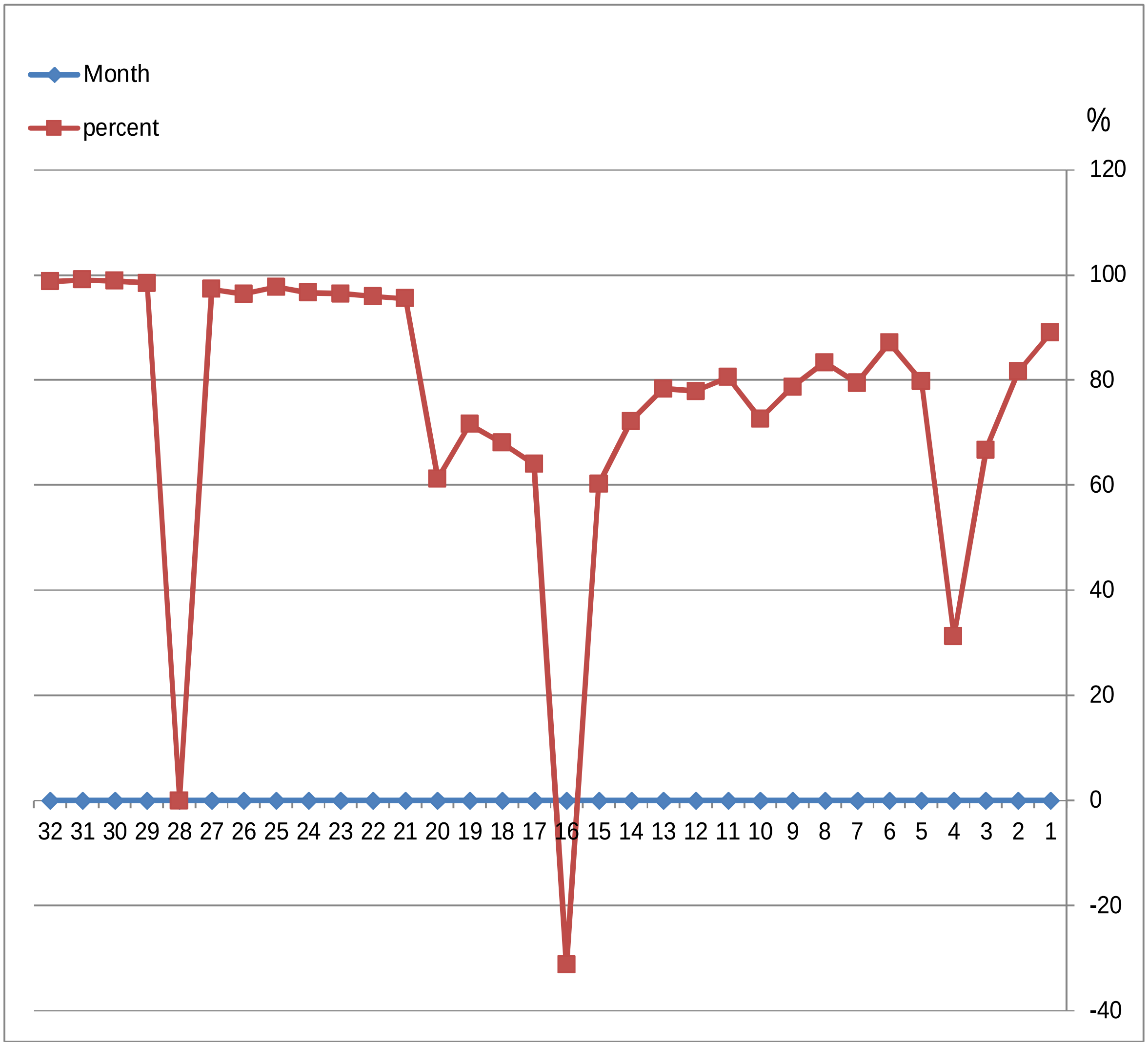
Determination of percent losses of intended irrigation water

difference intended	Percent
30154	88.9%
23061	78.1%
8475	55.9%
3589	31.2%
16631	78.4%
20525	82.1%
17325	76.9%
21306	81.0%
16130	77.0%
16621	70.9%
19333	74.0%
15467	69.7%
24053	72.6%
15324	62.3%
16357	63.3%
-470	-4.6%
17578	61.9%
16443	59.8%
14346	58.8%
12208	54.7%
10772	51.3%
12387	56.3%
20470	68.2%
16575	63.7%
23789	76.7%
27277	79.1%
26371	78.5%
00000	000%
23431	85.3%
30362	87.8%
37128	91.3%
28112	88.0%

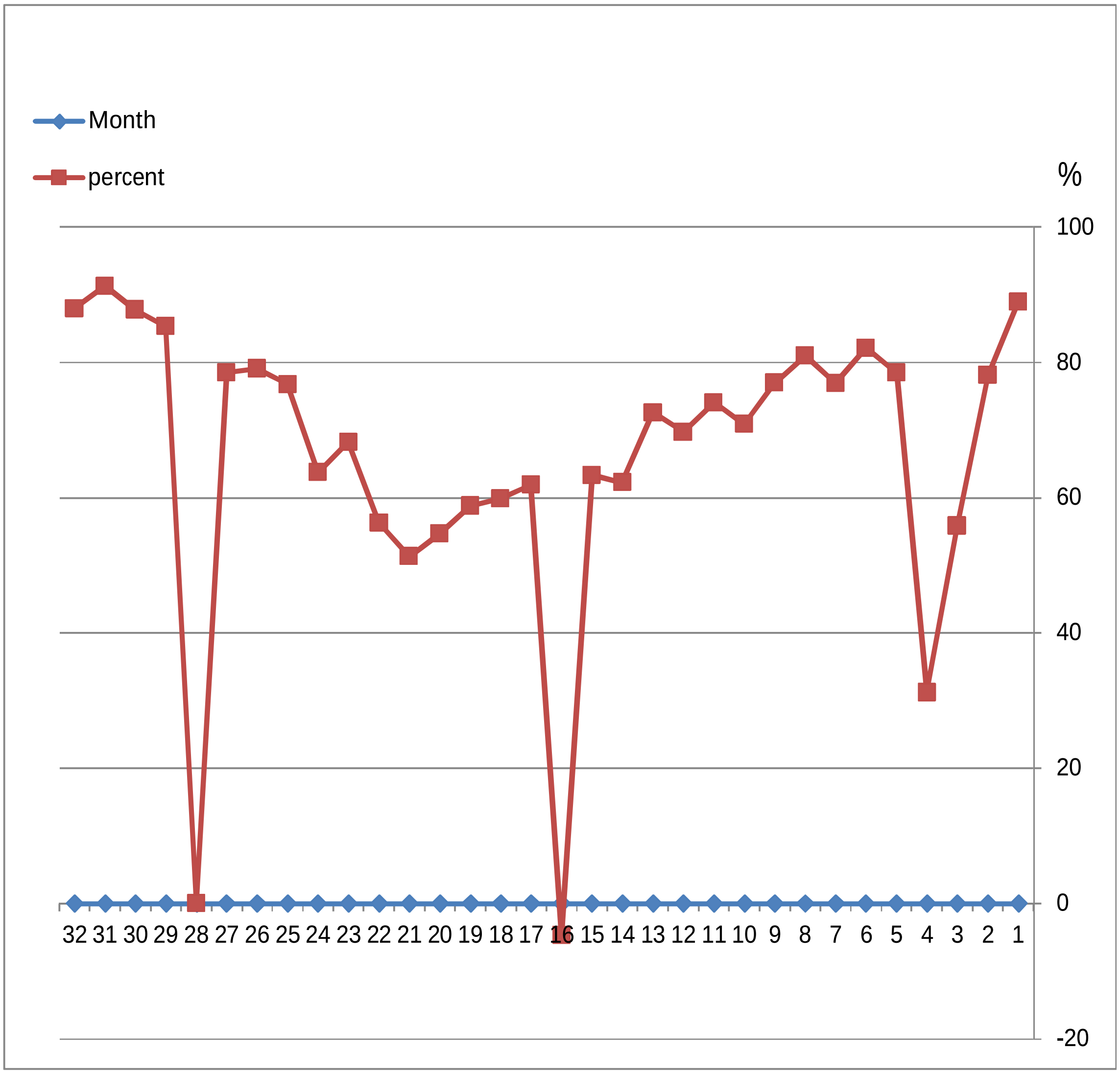
Average intended losses percent = 70.6

This study proved that the total supplied irrigation water exceeds by far the total actual irrigation requirements with average total loss that may exceed 80% table (4.5).

This fact implies that the practiced supplies and demands incur unnecessary high cost which will reflect on the cost of the production .



Fig(4.5) Shows the annual monthly percent losses in total supplied irrigation water.



Fig(4.6) Shows the annual monthly percent losses in total intended irrigation water .

The three drops in graph coincide with August where rainfall satisfies the crop water requirements with nearly no intended or supplied irrigation water .

CHAPTER FIVE

CONCLUION AND RECOMMENDATIONS

Conclusion:

The water intended for the scheme is over estimated .

The cane planting program of the scheme which starts on May and resumes on October dictates the overlap of seasons which makes the water orders a complicated process.

Recommendations:

The study manifested that the amounts of total irrigation water losses exceed 80%.

This fact necessitate the reversion the water supply program of the scheme .

The huge surplus water deflected to the drainage system can be reused to produce other crops.

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Appendix

Comparison between total intended, applied and actual computed irrigation water requirements in thousand cubic meter

Month	Total supplied water	Total intended water	Total actual computed water
May	34186	33900	3746
June	35235	29528	6467
July	20102	15168	6693
August	11497	11497	7908
September	22608	21200	4569
October	34609	24986	4461
November	25321	22519	5194
December	30133	26317	5011
January	22651	20960	4830
February	24984	23450	6829
March	34775	26111	6778
April	30454	22194	6727
May	42010	33152	9099
June	33368	24609	9285
July	23783	25825	9468
August	8061	10111	10581
September	30032	28388	10810
October	34566	27477	11034
November	35455	24414	10068
December	26132	22330	10122
January	227240	21000	10228
February	233680	22000	9613
March	267260	30000	9530
April	278070	26000	9425
May	313720	31000	7211
June	197110	34500	7223
July	267157	33590	7219
August	0	0	3971
September	261690	27459	4028
October	363455	34590	4228
November	382901	40678	3550
December	300950	31946	3834