

بسم الله الرحمن الرحيم
Sudan University of Science and Technology

College of Graduate Studies

Selection and Development of Suitable
Mathematical Model for Evaluation and
Improvement of Furrow Irrigation

إختيار وتطوير نموذج رياضي مناسب لتقييم وتحسين

نظام الري بالسراب

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

By:

Um salama Basheer Ali Abass

Supervisor:

Dr. Abbas Elshaikh Rahama Mohamed

May 2016

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قال تعالى:

(أَوْ لَمْ يَرَوْا أَنَّا نَسُوقُ الْمَاءَ إِلَى الْأَرْضِ الْجُرْزِ فَنُخْرِجُ بِهِ زَرْعًا تَأْكُلُ مِنْهُ أَنْعَامُهُمْ وَأَنْفُسُهُمْ
أَفَلَا يَبْصُرُونَ)

صدق الله العظيم

THE DEDICATION

I dedicate this research

To... my father who support me in everything in

my

Live and make me convinced,

To... my mother who gave me her love and light my

life

To...my aunt, sisters

And ... brothers

To... my friends,

ToSomeone in the world that is making my life

better by his presence.

Acknowledgment

First of all thanks Allah for everything

Deep thanks and respect are conveyed to Doctor:

Abbas Elshaikh Rahama

For his guidance and support

Great thanks are conveyed to PROF:

Hassan Ibrahim Mohamed

- For his guidance and valuable help,,,

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

For their help and Co-operation.

*Special thanks are also conveyed to my friends and my
dear family for their support.*

Abbreviations

Symbol	Definition
A	Furrow <i>cross –sectional</i> area(cm^2)
R	Columns highs (cm)
X	Width of one part (cm)
W	Weight (g) used at vane flow meter to measured flow rate
L	Length (cm) between the weight and center of the vane flow meter.
Q	Flow rate supply to the field (litr/sec)
E_a	Application efficiency %
Z_{req}	Required infiltrated volume per unit length
L	Furrow length (m)
Q_{cb}	Cutback flow rate (m^3/min)
A_0	Wet cross –sectional Area
t_{opp}	Intake opportunity time (min)
K	Intake constant ($m^3/min/m$)
a	Intake power
f_0	Basic intake rate ($m^3/min/m$).
N	Manning's roughness coefficient
so	Field slope %
Q_{max}	Maximum inflow discharge (m^3/min)
V_{max}	Soil erosive velocity (m/min).
$\rho_2 \rho_1$	Cross-sectional geometry parameters

t_{lag}	Recession lag time (min)
$t_{0.5l}$	Advance time to one half the field length (min)
t_l	Advance time to the field end (min)
σ_z	Subsurface shape factor
Z	Accumulated intake in volume per unit length(m^3/m)
tco	Cutoff time (min)
t rec	Recession time (min)
Vs	volume in surface storage(m^3)
C	constant is less than one
VI	inflow volume(m^3)
T_i	Total irrigation time (min)
θ, K	Muskingum parameter
T0	top width
I, O	Inflow &outflow
$a_1, a_2, \delta_1, \delta_2$	Parameter

Abstract:

Water infiltration and storage under surface irrigation are evaluated, based on the initial soil water content and inflow rate as well as on the irrigation parameters and efficiencies. For that purpose a field experiment was conducted at demonstration Farm College of agricultural Studies – Sudan university of Science and Technology in clay soil. To improve the application efficiency of furrow irrigation system by using cut back technique. The experiment was conducted at field with length of 85m and width of 50 m and the spacing between furrows was 1.5 m. using parshal flume to applied three flow rate (8.16, 7.72, and 6.37 L/s) with different slopes (26%, 17%, 15%). Under field condition were evaluated and improving the water management. From the results indicated that for conventional irrigation without cut back high rate of application efficiency (53.66%) was obtained under the flow rate and slope 8.16 l/s and 12% respectively. To evaluate the field performance for conventional irrigation system using the data collected from the field entered to a computer program including Muskingum, Skogerboe and Clemmence Models the results show that the data obtained from the field compared to the three computer models give application efficiency value similar to the Muskingum models model. To improve the application efficiency using the cutback irrigation method under the same condition of conventional irrigation system by reduce the flow rate at half when reached 3/4 of the furrow length.

The flow rate and the slope which were archived high application efficiency were 12 % and flow 6.37 L/sec was higher that obtained at the 35% conventional irrigation system by cut-back.

Compare the actual field data for cut back irrigation method by entered to the a computer program including Muskingum and Skogerboe model, the results show that the field data was to be similar to Skogerboe model. In this study developed and built extension of computer program for cut back irrigation method at Muskingum model. To validate the new computer model built at the basis of storage equation compare the actual field data for cut back irrigation method to a computer program including Muskingum, Skogerboe and clement model , the new computer model give high application efficiency more the two computer model it is worth to be mentioned Skogerboe , model is closest.

Key words: furrow irrigation, cutback, application efficiency, simulation model

المخلص:

اجريت هذه الدراسة في كلية الدراسات الزراعية، جامعة السودان للعلوم والتكنولوجيا (شمبات) في تربة طينية لاغراض تحسين كفاءة الري الحقلي بالسرا بو ذلك باستخدام تقنيات الري القطعي. تم اجراء التجربة في حقل طوله 85 متر وعرضه 50 متر والمسافة بين الخطوط 1.5 متر للحصول علي خطوط بطول 85 متر. وتم استخدام البارشال فلوم لتطبيق ثلاثة تصرفات (7.72, 8.16, 6.37لتر/ ثانية)، وثلاث ميول (12%، 17%، 26%) وتم تقسيم الحقل الى 27 سراه . تمت دراسة تاثير هذه العوامل على كفاءة التشغيل في ظروف الحقل.

من خلال النتائج للري التقليدي(بدون استخدام الري القطعي) اتضح ان اعلى كفاءة اضافة (53.66%) تم الحصول عليها عند اعلى معدل تصرف(8.16 لتر) واقل قيمة للميل(12%) . لتقييم الاداء الحقلي بالخطوط ادخلت بيانات التجربة الحقلية لنظام الري التقليدي بالسراب في النموذج الحاسوبي لكل من كلمنس وسكوقريو ومسكنجام-كنج حيث اوضحت النتائج المتحصل عليها من بيانات الحقل بمقارنتها مع النماذج الثلاثة حيث اعطت بيانات التجربة كفاءة اضافة مشابهة لمخرجات نموذج مسكنجام-كنج .

ولرفع كفاءة الاضافة تم استخدام الري القطعي وذلك تحت نفس ظروف الري التقليدي وذلك بتخفيض التصرف الى النصف عند وصوله الى ثلاثة ارباع طول الخط. معدل التصرف و الميل اللذان حققا اعلى كفاءة اضافة للري التقليدي بالسراب تم استخدامهما تحت ظروف الري القطعي وتم الحصول على قيمة لكفاءة الاضافة تصل الى 83% بنسبة زيادة تصل الى حوالي 35% اعلى من قيمة كفاءة الاضافة في الري التقليدي بالسراب.

تمت مقارنة البيانات التي تم الحصول عليها من تجربة الري القطعي وذلك بادخال تلك البيانات في النموذج الحاسوبي لكل من كلمنس وسكوقريو واوضحت النتائج انها اقرب مايكون لنموذج سكوقريو .

في هذه الدراسة تم تطوير واطافة امتداد نموذج حاسوبي للري القطعي في النموذج الحاسوبي لمسكنجام-كنج .

في نموذج لكل من كلمنس وسكوقربو يتم حساب المعامل المستخدم في حساب التدفق القطعي بمعامل ثابت .

الجديد في النموذج الحالي هو استخدام معامل مرتبط بمعادلة التخزين وذلك لحساب معدل التدفق للري القطعي.

للتأكد من صحة النموذج الحاسوبي الجديد المبني على معادلة التخزين تمت مقارنة بيانات الحقل للري القطعي لكل من النموذج الحاسوبي الجديد ونموذج كل من كلمنس وسكوقربو و مسكنجام- كنج. حيث اعطي النموذج الجديد كفاءة اضافة اعلي من النموذجين . و الجدير بالذكر ان نموذج اسكوقربو هو الاقرب .

الكلمات الافتتاحية: الري بالسراب ،الري القطعي، كفاءة الاضافة ، نموذج حاسوبي

TABLE OF CONTENT

الاية	i
Dedication	ii
Acknowledgment	iii
Abbreviations	iv
Abstract	vi
الملخص	viii
Table of content	x
List of tables	xiii
List of figures	xiv
CHAPTER ONE	1
1.1 Introduction	1
1.2 Study scope	4
1.3 Problem descriptions	4
1.4 Study objectives	5
1.4.1 Main objective	5
1.4.2 Specific objectives	5
CHAPTERTWO	6
2.1 Introduction	6
2.2 Materials and method	9
2.2.1 Field preparation	9
2.2.2 Field Measurements	11
2.3Result and dissection	15
CHAPTER THREE	22

3.1 Introduction	22
3.2 The main objective	23
3.3 Materials and methods	23
3.4 Result and dissection	27
CHAPTER FOUR	33
4.1 Introduction	33
4.2 The objective	34
4.3 Materials and methods	34
4.3 Result and dissection	37
CHAPTER FIVE	52
5.1 Introduction	52
5.2 Materials and methods	53
5.3 Result and dissection	66
CHAPTER SIX	71
Conclusions	71
Recommendations	73
References	74

LIST OF TABLETS

Table		Page
2.1	Cross-Section area	15
3.1	Model input parameters of the experimental furrows used for assessment of the performance of the various simulation models.	25
3.2	Comparison of various models in terms of estimating advance time, opportunity time and application efficiency for the furrow	27
4. 1	Model input parameters of the experimental furrow used for assessment of the various simulation models	36
4.2	Comparison of various models in terms of estimating advance time, opportunity time and application efficiency for the furrow	45
5.1	Results for furrow irrigation system during experiments. The error percent for the advance time t_a , net opportunity time t_{opp} , design inflow time Q and application Efficiency E_a was recorded.	67
5.2	Comparison predicted output results and % error of the program for the two models	69
5.3	Comparison predicted output results and % error of the program for the two models	69
5.4	Comparison predicted Muskingum developed model output results and % error of the program for the Skogerboe and Clemmence models	70

LIST OF FIGURES

Figure	Page
1.2 Field layout for the experimental area	10
2.2 Laser guided land leveling equipment	11
2.3 Furrow profile meter for determining cross-sectional area	11
2.4 Vane flow meter for determining flow rate	12
2.5 Parshal flume determining flow rate	13
2.6 Advance time of continuous flow for different discharges	16
2.7 Advance time of continuous flow for different slopes	17
2.8 Rescission time of continuous flow for different discharges	18
2.9 Rescission time of continuous flow for different slopes	19
2.10 Efficiency of continuous flow for different discharges and furrow length	20
2.11 Efficiency of continuous flow for different slopes and furrow length	21
3.1 Predicted and observed advance time for different experimental furrow data with the (Skogerboe and Clemmence) models	28
3.2 Predicted and observed recession time for different experimental furrow data with the (Skogerboe and Clemmence) models	30
3.3 Observed and Predicted application efficiency	31
4.1 Advance time of continuous flow for different discharges	37
4.2 Advance time of continuous flow for different slopes	38
4.3 Rescission time of continuous flow for different discharges	39
4.4 Rescission time of continuous flow for different slopes	40

4.5	Application efficiency (Ea) Conventional irrigation and cutback irrigation	42
4.6	Furrow length , application efficiency for slope different discharges	43
4.7	Furrow length , application efficiency for discharge different slopes	44
4.8	Predicted and observed advance time for different experimental furrow data with the (Skogerboe and Clemmence) models	47
4.9	Predicted and observed recession time for different experimental furrow data with the (Skogerboe and Clemmence) models	48
4.10	Observed verse Predicted advance time for the total data of furrow with (Skogerboe and Clemmence) models	50
4.11	represents the relationship between the cut-back irrigation(Observed),Skogerboe and Clemmence models	51
5.1	Flow chart of the model	55
5.2	Observed and Predicted application efficiency	68

CHAPTER ONE

1.1 Introduction

Surface irrigation is defined as a group of application techniques where water is applied and distributed over the soil surface by gravity. It is by far the most common form of irrigation throughout the world and has been practiced in many areas virtually unchanged for thousands of years.

Surface irrigation is often referred to as flood irrigation, implying that the water distribution is uncontrolled and therefore, inherently inefficient. In reality, some of the irrigation practices grouped under this name involve a significant degree of management (for example surge and cut-back irrigation). Surface irrigation comes in three major types; level basin, furrow and border strip (*Walker and Skogerboe, 1987*).

The surface irrigation is predominantly used in the Sudan with low irrigation efficiencies. An estimate made by FAO (1993) showed that distribution losses constitute 15%, field application losses 25%, other losses 15% and the water effectively used by crops constitutes only about 45% of the total irrigation water.

Many surface irrigation systems are ineffective and inefficient. This can be caused by physical constraints (e.g., steep land slopes, shallow soils, poor water supplies, etc.), by poor design and layout, or by improper operation and management (*Walker and Skogerboe 1987*), (*Clemmens and Dedrick (1982)*; *Burt et al. 2000*). One advantage of surface irrigation over pressurized irrigation methods is that it often does not require a good, reliable water supply. It can be adapted to different rates of flow, flows that vary randomly, and flow with poor water quality (sediment, debris, etc.). Efforts in surface irrigation research and extension have focused on methods for providing better water control – control over flow rate or control over volume applied. These generally focus on how the system is operated. Of

equal importance is field design and layout. Good operation cannot make up for a poor field design.

However, when surface irrigation systems are properly designed and more modern operating procedures are used, irrigation efficiencies and uniformities can be high (Kennedy, 1994). The process of surface irrigation can be described using four phases (advance phase, storage phase, depletion phase and recession phase). As water is applied to the top end of the field it will flow or advance over the field length. The **advance phase** refers to that length of time as water is applied to the top end of the field and flows or advances over the field length. After the water reaches the end of the field it will either run-off or start to pond. The period of time between the end of the advance phase and the shut-off of the inflow is termed the wetting, ponding or **storage phase**. As the inflow ceases the water will continue to runoff and infiltrate until the entire field is drained. The **depletion phase** is that short period of time after cut-off when the length of the field is still submerged. The **recession phase** describes the time period while the water front is retreating towards the downstream end of the field. The depth of water applied to any point in the field is a function of the **opportunity time**, the length of time for which water is present on the soil surface(www.fao.org/docrep /t023 1e03.htm).

Efficient irrigation can be achieved by better design, the efficiency of surface irrigation is function of field design, infiltration characteristic of the soil, and the irrigation management practice. The complexity of the parameter interactions within each of these main influences makes it difficult for irrigators to identify optimal design or management practices under commercial conditions. (Abd el wahab, 2005) to improve water application efficiencies use appropriate flow rate, furrow lengths, and slope.

However, one of the main constraints to the improvement of application efficiencies is use cut-back irrigation system.

Furrow irrigation is conducted by creating small parallel channels along the field length in the direction of predominant slope. Water is applied to the top end of each furrow and flows down the field under the influence of gravity. Water may be supplied using gated pipe, siphon and head ditch or bank less systems. The speed of water movement is determined by many factors such as slope, surface roughness and furrow shape but most importantly by the inflow rate and soil infiltration rate. The spacing between adjacent furrows is governed by the crop species, common spacing typically range from 0.75 to 2 meters. The crop is planted on the ridge between furrows which may contain a single row of plants or several rows in the case of a bed type system. Furrows may range anywhere from less than 100 m to 2000 m long depending on the soil type, location and crop type. Shorter furrows are commonly associated with higher uniformity of application but result in increasing potential for runoff losses. Furrow irrigation is particularly suited to broad-acre row crops such as cotton, maize and sugar cane. It is also practiced in various horticultural industries such as citrus, stone fruit and tomatoes(www.fao.org/docrep /t023 1e03.htm)

The water can take a considerable period of time to reach the other end, meaning water has been infiltrating for a longer period of time at the top end of the field. This results in poor uniformity with high application at the top end with lower application at the bottom end. In most cases the performance of furrow irrigation can be improved through increasing the speed at which water moves along the field (the advance rate). This can be achieved through increasing flow rates or through the practice of surge irrigation. Increasing the advance rate not only improves the uniformity but also reduces the total volume of water required to complete the irrigation (*El-Dine and; Hosny, 2000*).

1.2 Study Scope

This research content on five chapters, chapter one contains the introduction, Chapter two contains the Determination of Application Efficiency of Furrow Irrigation System, Chapter three contains the Field Evaluation of Various Mathematical Models for conventional Furrow Irrigation Systems, Chapter four contains Improving the performance of furrow irrigation system using (cut back), Chapter five contains the model development of cut-back using volume storage equation.

1.3 Problem Description

Irrigated agriculture faces a number of difficult problems in the future. One of the major concerns is the generally poor efficiency with which water resources have been used for irrigation. A relatively safe estimate is that 40 percent or more of the water diverted for irrigation is wasted at the farm level through either deep percolation or surface runoff. These losses may not be lost when one views water use in the regional context, since return flows become part of the usable resource elsewhere. However, these losses often represent foregone opportunities for water because they delay the arrival of water at downstream diversions and because they almost universally produce poorer quality of water. One of the more evident problems in the future is the growth of alternative demands for water such as urban and industrial needs. These uses place a higher value on water resources and therefore tend to focus attention on wasteful practices. Irrigation science in the future will undoubtedly face the problem of maximizing efficiency

([www.fao.org/docrep /... / t023 1e03.htm](http://www.fao.org/docrep/.../t0231e03.htm))

Surface irrigation accounts for almost all of the irrigated land area in Sudan (both large schemes e.g. Kenana scheme and small holder farms e.g. Gezira scheme) and over 90% worldwide. Many schemes are built and operated without adequate technical input, with consequent low uniformity and

efficiency of water application. Yet, water supplies for irrigation are limited and likely to decline due to competition from environmental and urban water demands. The decrease in crop yields in these schemes is often attributed to the low performance of furrow irrigation.

Consequently, to improve crop productivity it is essential to improve furrow performance. Improvement of furrow performance can be achieved via proper design and better operation. Therefore, science-based criteria for design and management of surface systems are critically needed.

1.4 Study Objectives

1.4.1 Main objective

To improve the performance of the conventional furrow irrigation systems by using cutback method.

1.4.2 Specific objective

1. Development evaluation of furrow irrigation.
2. Improvement performance by develop cut-back model.
3. Development of cut-back design model.

CHAPTER TWO

DETERMINATION OF APPLICATION EFFICIENCY OF FURROW IRRIGATION SYSTEM

2.1 Introduction

Optimum management of water resources at the farm level is needed in view of increasing water demands, limited resources, and aquifer contamination (Kumar and Singh, 2003). When irrigation is required there are many available methods and management strategies. The selection of the method and approach depends on factors such as water availability, crop type, soil characteristics, land topography, and associated cost (Holzapfel y Arumí, 2010).

Surface irrigation systems have many advantages such as: Lower capital and operating costs, simplicity of maintenance and ability to use unskilled. Recent improvements in surface irrigation methods such as automation, cutback, and surge irrigation have furthered increase their appeal. The most frequently used surface irrigation methods in the world are contour irrigation, border irrigation, and furrow irrigation (Walker and Skogerboe, 1987). The latter is used mainly to irrigate row crops and orchards. Most recently, furrow irrigation has become important because of the high cost of energy in pressurized Irrigation methods and the incorporation of automation in its operation (Holzapfel and Arumí, 2010). Optimizing the design of furrow irrigation systems has been approached by a number of researchers. For example, Reddy and Clyma (1981, a, b) applied Kelly's cutting plane algorithm to solve the boarder and furrow irrigation optimal design problem. They found that the main constraint on furrow irrigation efficiency is that a significant amount of water is lost to runoff and deep percolation. These losses depend on the furrow length, discharge and cutoff times. Wallender and Rayej(1987) conducted a study in which they maximized profits for a

surface irrigation system using both uniform and non-uniform soils while analyzing two design variables (inflow rate and cutoff time), and deep percolation was not considered in their analysis.

Soil infiltration plays an important role in irrigation design efficiency and in the selection of irrigation method. Infiltration characteristics are highly variable. This high variability has motivated studies on the effects of spatial variability of infiltration rates on surface irrigation system performances (Nielen et al., 1973, b Bautista and Wallender, 1985, Prasher et al, 1997, Childs et al., 1993, and Greminger et al., 1985). In general, furrow irrigation is characterized by four phases: advance, storage, depletion, and recession (Walker and Skogerboe, 1987). The difference in time between the advance and recession phases is known as irrigation opportunity time. Numerical simulation techniques are common for irrigation analysis and were successfully applied to simulate steady and unsteady flow with solute transport in furrow irrigation (Burguete et al., 2009a). Surface irrigation is characterized by their operation simplicity; however, design and management are complicated (Burguete et al., 2009b). Several mathematical models have been proposed to simulate the advance front of the irrigation water (Souza, 1981). Some of those models have been implemented to simulate the advance phase in furrow irrigation. Holzapfel et al. (1984) showed that the kinematic-wave and volume-balance models closely predicted the advance and recession phases. In furrow irrigation in clayey soil, Eldeiry et al. (2004) found that furrow length and application discharge are the main management and design parameters affecting application efficiency. The environmental impact of furrow irrigation has been reported by Lehrs et al. (2000). Popova et al. (2005) found that in irrigation, a risk of nitrate leaching depends on the manner of water and fertilizer application. Lazarovitch et al. (2009) study of the moment analysis technique describes spatial and temporal subsurface wetting patterns resulting from furrow

infiltration and redistribution that contribute to improve irrigation management. In many irrigated regions of the western United States, commercial growers that irrigate by furrow irrigation systems are facing serious challenges to improve irrigation efficiency and reduce contamination of water supplies (Rice et al., 2001).

For the long term sustainability of an irrigation system, improvements in the performance of current water application and on-farm water management practices seem to be more necessary than any other practice (Sarwaret al., 2001). To increase the sustainability of irrigated agriculture, an important aspect that has been considered in several studies is to design efficient irrigation systems at the farm-level (Feyen and Zerihun, 1999; Zerihun et al., 2001; Hillel and Vlek, 2005; Khan et al., 2006; Hsiao et al., 2007). The irrigation efficiency is a crucial aspect for irrigated agriculture and a key factor due to the competition for water resources. In the case of furrow irrigation, the most important points are to adequately select furrow irrigation variables (furrow length, furrow slop, and discharge), improve irrigation scheduling, and improve water management of the furrow.

The purpose of this study was to analyze furrow irrigation variables (three inflow discharges, and three furrow slopes) and their relation to performance irrigation parameters.

The performance of an irrigation method can be evaluated by determining how well the irrigation meets the water requirements and how well the applied water is distributed throughout the field (Holzapfel et al., 1985).

To improve the efficient of water application and distribution, some designs have used the maximum non-erosive flow rate, reducing the flow when the advance front reaches the end of the furrow. The efficiency of furrow irrigation systems can often be improved by reducing the inflow rate after water has advanced to the end of the filed (Clemmens 2007).

Water applied for irrigation should: (1) meet the plant water requirements at the time of irrigation; (2) not exceed the available water-storage capacity of the soil profile; (3) avoid leaching in excess of that required to prevent soil salinization and excessive runoff; and (4) minimize erosion and deterioration of the soil structure. The performance of an irrigation method is affected by: rate of infiltration of water into the soil; inflow rate of the water; slope of the field; time of irrigation; time of recession of water from the soil surface; soil moisture prior to irrigation; spatial variability of the soil; climatic conditions; and furrow shape. The performance of irrigation parameters have been analyzed by various researchers (Holzapfel et al., 1985; Heermann et al., 1990; Burt et al., 1997; Hsiao et al., 2007). However, problems have been encountered in the effective evaluation of the performance of an irrigation method, owing to difficulties in identifying inadequacies in operation, management or design (Feyen and Zerihun, 1999).

The objective of this work is to analyze the impact the inflow rate and slope variability on irrigation management and efficiency.

2.2 Materials and Methods

2.2.1 Field preparation

The experiment was conducted at the Farm of Faculty of Agriculture, University of Sudan in Shambat latitude 15o 40'N and longitude 32°32'E. The climate is described as tropical arid.

The layout of the experiment area is show in figure 2-1. The area consists of three groups of furrows, each groups consists of nine furrows and different slops (26%, 17%, 12%). The field length (85m) and field width (50m).

A spacing of (1.5m) was maintained between the furrows in all the groups. The canal was used to deliver water to each furrow group by vane flow meter. The vane flow meter was measured three different discharges (8.16, 7.72, and 6.37) L/sec , for each group of furrows could applied and measured with parshal flumes during irrigation at any station.

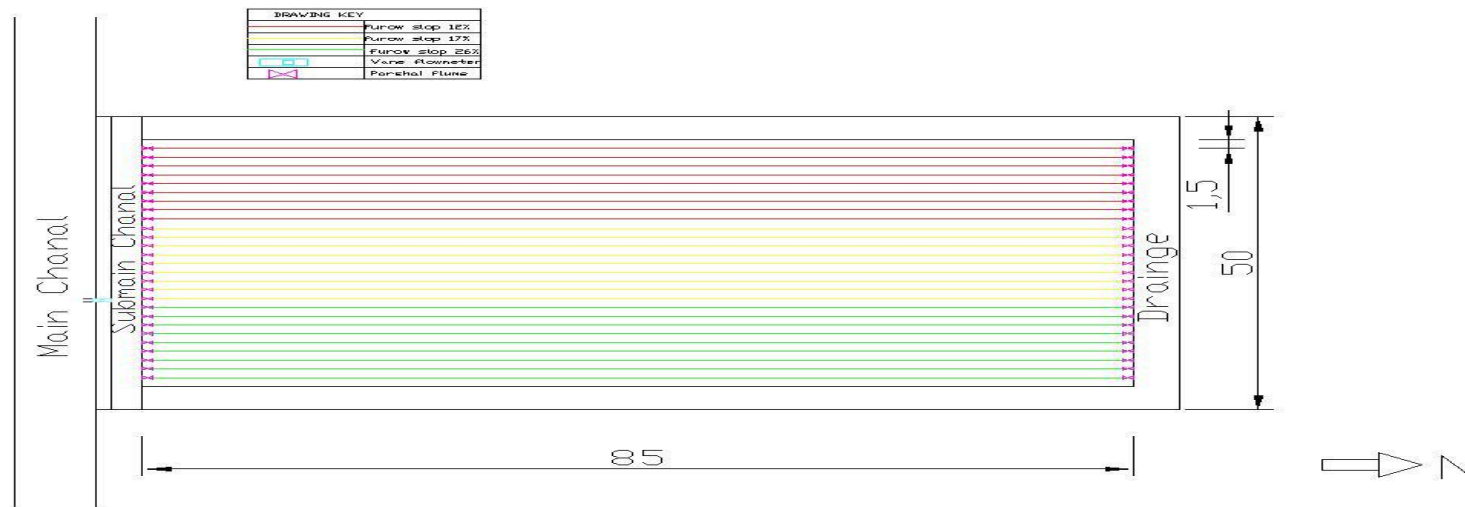


Figure 1 shows field layout for the experiment. Block A was constructed with furrow length of 85 m. A spacing of 1.5 m was maintained between the furrows in the entire Block

2.2.2 Field Measurements

2.2.2.1 Field Slope:

Laser guided land leveling equipment was used to adjust the level of land at different locations throughout the furrow lines. As show in Figure (2.2).

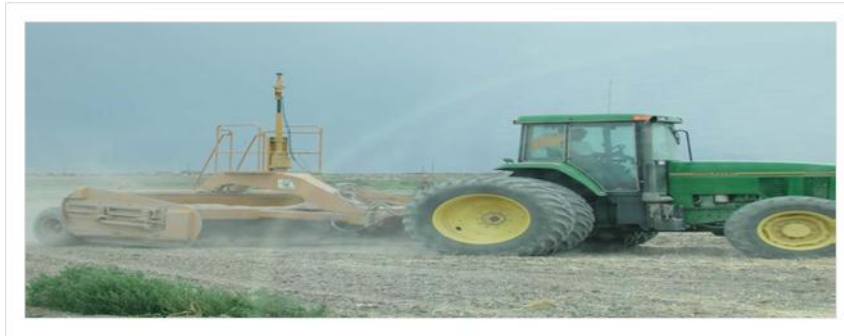


Figure 2.2 Laser guided land leveling equipment

2.2.2.2 Furrow shape geometry:

For each furrow, the cross-sectional geometry was measured at two to three stations before and after the irrigation. A profilometer for determining the cross-sections of furrows is show in **Figure (2.3)**.

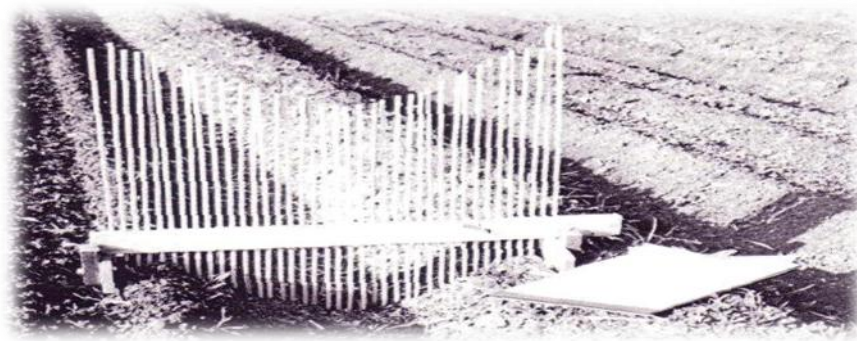


Figure 2.3 Furrow profilometer for determining cross-sectional area

The trapezoidal method was used to calculate cross section area for each station by the equation:

$$A = X \left[\left(\frac{R_f + R_L}{2} \right) + \sum R \right] \quad (2-1)$$

Where: A is Furrow area(cm^2), X is width of one part (cm), R_f is first column height (cm), R_L is last column height (cm), R is columns height (cm)

$$X = W_f / R_{No} \quad (2-2)$$

Where: W_f is furrow width (m), R_{No} is no of column

2.2.2.3 Furrow Discharge:

The vane flow meter was used to measure the discharge Figure (4.2), and computed the amount of discharge by equation:

$$Q = 0.68 \sqrt{W * L} \quad (2-3)$$

Where: Q is flow rate(litr/sec), W is weight (g), and L is length (cm).



Figure (2.4) vane flow meter for determining flow rate

Parshall flumes figure (2.5) were used to measure inflow and outflow per furrow, the dimension for construction of the 2-inch parshall flumes and the coefficient for the discharge calculations were taken from Skogerboe et al. (1969) by equations:

$$Q_{\text{free}} = c_f * (KH)^{n_f} \text{ for } S \leq S_t \quad (2-4)$$

$$Q_{\text{submergence}} = c_s * (K(h_u - h_d))^{n_f} / (-(\log s + C))^{n_s} \text{ for } S > S_t \quad (2-5)$$

Where: Q is flow rate (litr/sec), c_f, c_s is coefficient, K is unit constant ($k=3.28$ for H in m), H is head(m), n_f, n_s is flow exponent, S is submergence ratio $= \frac{h_u}{h_d}$, h_u is upstream head (m), h_d is downstream head (m), $C = 0.0044$ for Parshall flume, S_t is transition submergence (0.61)



Figure (2.5): Parshal flume when determining flow rate

2.2.2.4 Advance, recession, required and cutoff time:

At each furrow, eleven pieces of wood were set into the furrows at equal distances along the furrow length. The travel time of water advancing through each furrow was recorded at each mark. The cutoff time for each furrow was recorded along with the required and recession times for each furrow.

2.2.2.5 Application efficiency: used field data to calculate application efficiency by equation:

$$E_a = \frac{Z_{req} * L}{t_1 * Q_0} * 100 \quad (2.7)$$

Where: E_a is application efficiency, Z_{req} is the required infiltrated volume per unit length, L is furrow length (m), Q_0 is flow rate (m^3/min), t_1 is advance time (min)

2.3 Result and discussion

2.3.1 Cross –sectional area: table (2.1) shows the comparison between furrow dry and wet cross –sectional area. From the result indicates that there is no significant difference between the wet and dry area (Calculated T-test value is 0.029).

S1									
No of furrow	F1	F2	F3	F4	F5	F6	F7	F8	F9
dry cross – sectional area (m ²)	0.02 2	0.024	0.016	0.026	0.025	0.024	0.023	0.020	0.017
wet cross – sectional area(m ²)	0.01	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.02
S2									
dry cross – sectional area(m ²)	0.02 2	0.013	0.015	0.024	0.022	0.016	0.018	0.024	0.021
wet cross – sectional area (m ²)	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01
S3									
dry cross – sectional area(m ²)	0.01 9	0.018	0.015	0.022	0.013	0.021	0.016	0.021	0.020
wet cross – sectional area(m ²)	0.02	0.02	0.01	0.03	0.03	0.03	0.02	0.01	0.01

2.3.2 Advance time of continues flow for different discharges

The figures (2.6) show that the relationship between the furrow length and advance time. From the result the advance time increase when the length increase that agree with (M.Ghobadi et al, 2011)

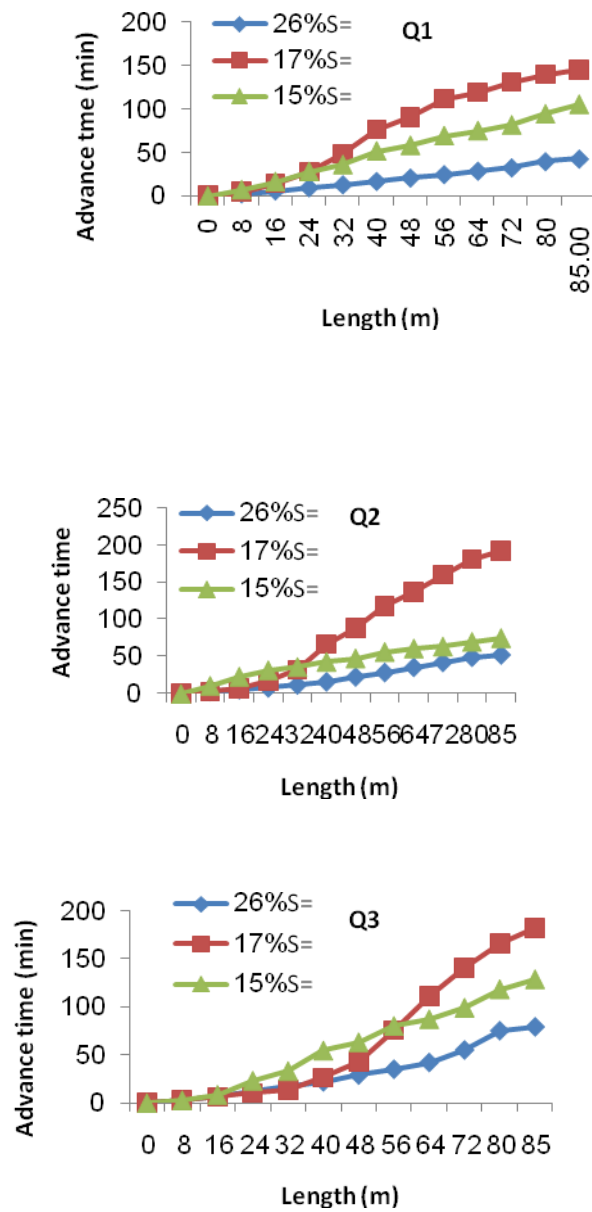


Figure (2.6) Advance time of continues flow for different discharges

2.3.3 Advance time of continues flow for different slopes

Figure (2.7) represents the relationship between the advance time and furrow length for different slopes, that agree with (M.Ghobadi et al, 2011)

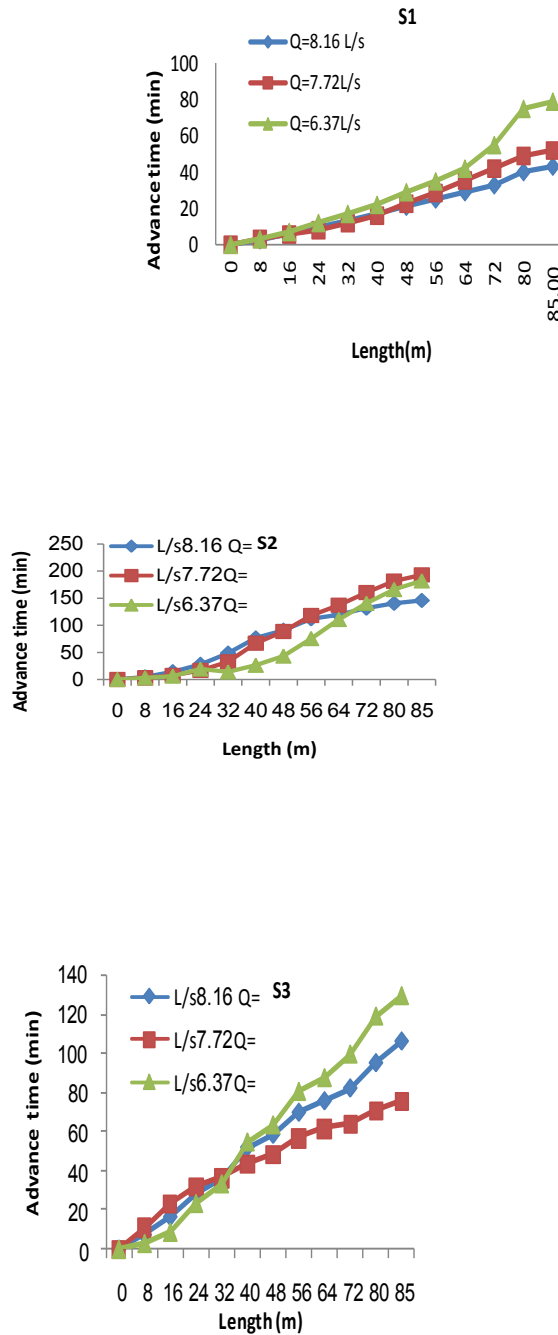


Figure 2.7 Advance time of continues flow for different slope

2.3.4 Recession time of continues flow for different discharges

Figure (2.8) represents the relationship between the recession time and furrow length for different discharges,.

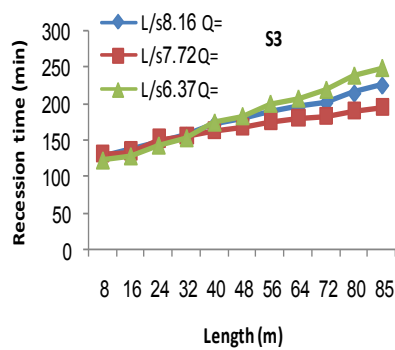
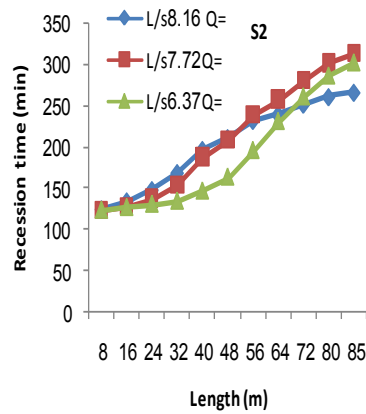
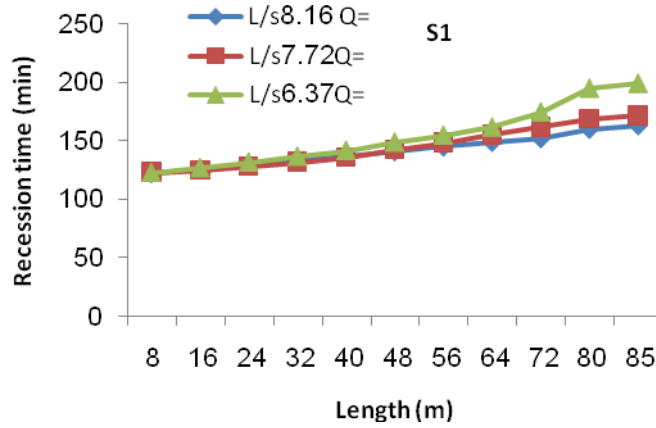


Figure 2.8 Recession time of continues flow for different discharge

2.3.5 Recession time of continues flow for different slopes

Figure (2.9) represents the relationship between the recession time and furrow length for different discharges, from the figure (2.12) the result show that the rescission time increase when the discharge increase that agree with (M.Ghobadi 2011)

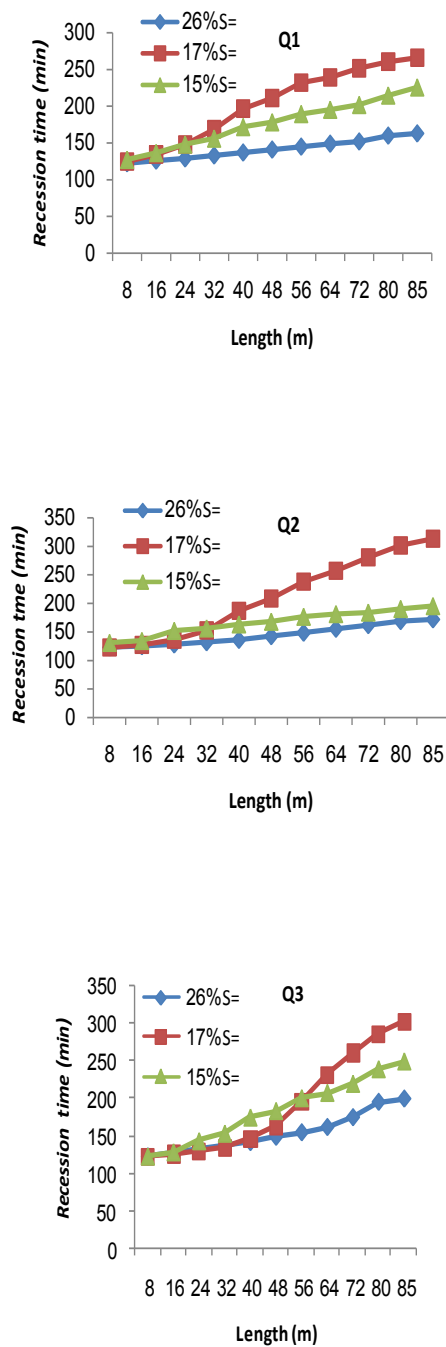


Figure 2.9 Recession time of continues flow for different slopes

2.3.6 Efficiency of continuous flow for different discharge and furrow length

Fig (2.10), (2.11) show the relationship between the furrow length and application efficiency for different discharges and slopes. High efficiencies can be achieved for small furrow length, that agree with (Ahmed2004).

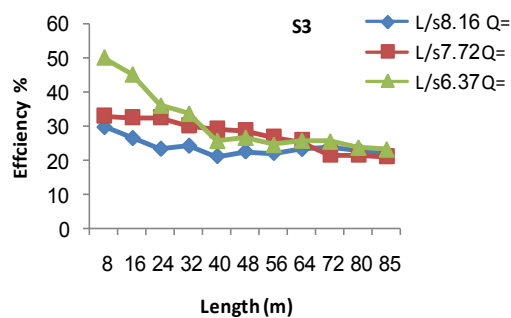
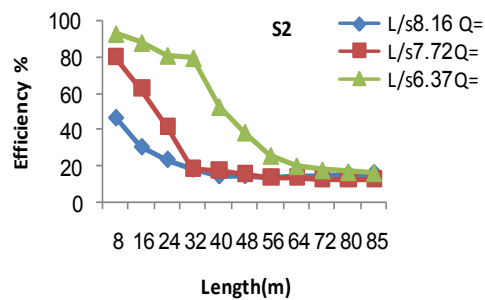
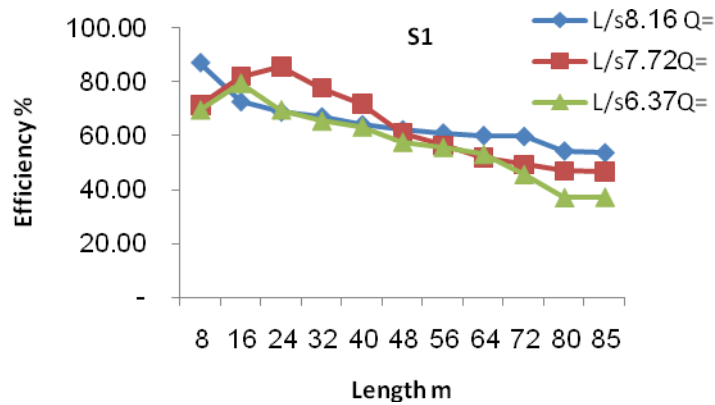


Figure (2.10): Furrow length. Application Efficiency for slope and different discharges

2.3.7 Efficiency of continues flow for different Slopes and furrow length

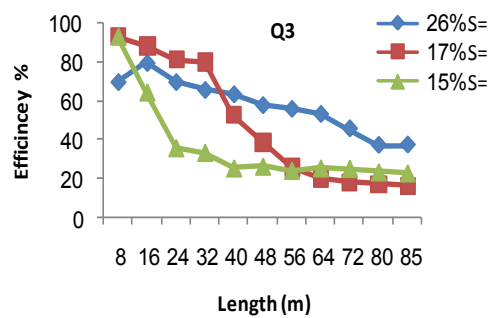
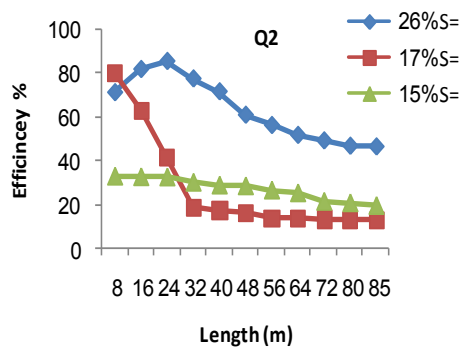
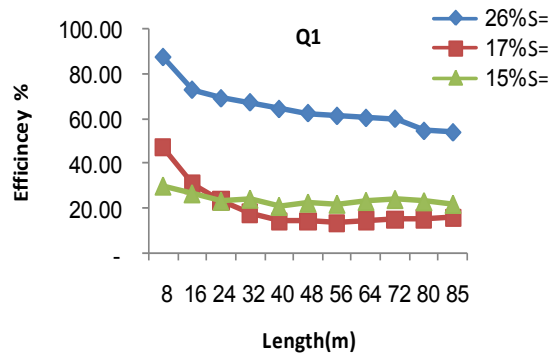


Figure (2.11): Furrow length. Application Efficiency for discharges and Different slops

Figure (2.10), (2.11) high application efficiency achieved at the end furrow in slop 12% and flow 8.16 L/s.

CHAPTER THREE

FIELD EVALUATION OF VARIOUS MATHEMATICAL MODELS FOR FURROW IRRIGATION SYSTEM

3.1 Introduction

The poor design, implementation, and management are generally responsible for insufficient irrigation, leading to the wastage of water, water logging, Salinizations and pollution of surface water and groundwater resources.

Surface-irrigation mathematical models are important for the evaluation and design purposes. Those models are classified into four main groups: (1) full hydrodynamic models; (2) zero-inertia models; (3) kinematic-wave models, and (4) volume balance models. The fully hydrodynamic model is the most complex and the most accurate. It is based on the complete Saint-Venant equations for the conservation of mass and momentum. The zero-inertia model is a slightly simplified version of the complete Saint-Venant equations that leaves out the acceleration or inertia terms in the momentum equation. The kinematic wave model uses further simplifications and uniform flow assumptions. The simplest model, i.e., one that involves the largest number of assumptions, is the volume balance model. It is based on the analytical or numerical solution of the temporally and spatially-lumped mass conservation, commonly referred to as the “volume balance” approach (Jurriens et al. 2001).

The data from the mathematical models have allowed engineers to improve systematically irrigation system design and operation which, for many years, have been mainly based on the rule of thumb, rough empirical guidelines, and approximations (Jurriens et al. 2001). Mathematical models for the design, operation, and evaluation of various surface irrigation methods have been used in user-friendly.

computer programs such as the SRFR (Strelkoff et al. 1998); SURDEV (Jurriens et al. 2001), and SIRMOD (Walker 1998). The SIRMOD software simulates the hydraulics of surface irrigation (border, basin, and furrow) at the field level. The simulation routine used in SIRMOD is based on the numerical solution of the Saint-Venant equations for the conservation of mass and momentum as described by Walker and Skogerboe (1987). The SIRMOD software includes the hydrodynamic, zero-inertia, and kinematic-wave models.

3.2 The main objective

The objective of this study was to test and compare the three mathematical models (Skogerboe, Muskingum and Clemmence) with field data. The ultimate goal was to determine the accuracy of these models for conventional furrow irrigation system.

3.3 Materials and Methods

3.3.1 Models of surface irrigation

The mathematical models are based on the equations that describe the processes governing the overland flow in surface irrigation.

3.3.1.1 Skogerboe model

Calculate the Application Efficiency, E_a , as a function of inflow discharge, Q_o . This involves the following steps:

- i. Select an initial value of Q_o equal to Q_{min} and using the procedure outlined in the section “Computation of Advance Time” and “Computation of the Cutoff Time”, calculate t_{co} .
- ii. Calculate E_a as:

$$E_a = \frac{Z_{req}L}{t_{co}Q_o} 100 \quad (3.1)$$

Z_{req} Is required depth, L length of furrow, Q_0 inflow discharge, t_{co} cutoff time.

3.3.1.2 Clemmence model

Calculate the Application Efficiency, E_a , as a function

$$E_a = \frac{Z_{req}}{I_t * R_0} 100 \quad (3.2)$$

Where I_t is total infiltration, R_0 is runoff.

3.3.1.3 Muskingum model

The Muskingum method assumes that the surface storage in the reach can be written as a linear function of inflow and out flow:

$$S = K [\theta I + (1 - \theta) O] \quad (3.3)$$

Where:

S is the surface storage (m³)

I and O are the inflow and the outflow respectively (m³/min)

K and θ are Muskingum parameters

Calculate the Application Efficiency, E_a , as a function

$$E_a = \frac{Z_{req} L}{t_L Q_0} 100 \quad (3.4)$$

Where t_L is advance time (min)

3.3.2 Model verification

3.3.2.1 Input data: Generally, the numerical models are verified by comparing the model predictions with field measured data. In this study, the results of the various models were compared with the observed data filed.

Table 3.1: Model input parameters of the experimental furrows used for assessment of the performance of the various simulation models

Parameters	R1	R2	R3
Inflow rate, q_0 (l/s)	8.16	7.72	6.37
Field length, L (m)	85	85	85
Field width m	50	50	50
Field slope, S_0 (%)	26	17	12
Manning's n	0.04	0.04	0.04
Furrow spacing (m)	1.5	1.5	1.5
Furrow section parameters			
ρ_1	1	1	1
P2	3.33	33.3	33.3
Kostiakov-Lewis parameters			
k (m ³ /min/m)	0.0043	0.0043	0.0043
a (-)	0.258	0.258	0.258
f_0 (m ³ /min/m)	0.00022	0.00022	0.00022

In this study (Skogerboe, Muskingum and Clemmence) models were run with the input data for furrow irrigation systems. The outputs of the models included the advance and recession curves and total infiltrated and runoff volumes were compared with the field data. To evaluate the suitability of the

furrow irrigation models, three criteria were chosen to analyse the degree of the goodness of fit. These criteria can be defined as follows:

(1) The coefficient of determination (R^2)

$$R^2 = \frac{[\sum_{i=1}^n (O_i - \bar{O})(P_i - \bar{P})]^2}{\sum_{i=1}^n (O_i - \bar{O})^2 \times \sum_{i=1}^n (P_i - \bar{P})^2} \quad (3.5)$$

(2) Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (O_i - P_i)^2}{n}} \quad (3.6)$$

(3) Standard error (SE)

$$SE = \sqrt{\frac{\frac{1}{n} \sum_{i=1}^n (O_i - P_i)^2}{\bar{P}}} \quad (3.7)$$

Where

N = number of observation

Q_i = value of observation measurement

P_i = value of the predicted measurement

\bar{O} = mean of the observation values

\bar{P} = the mean predicted value

3.4 Result and Dissection

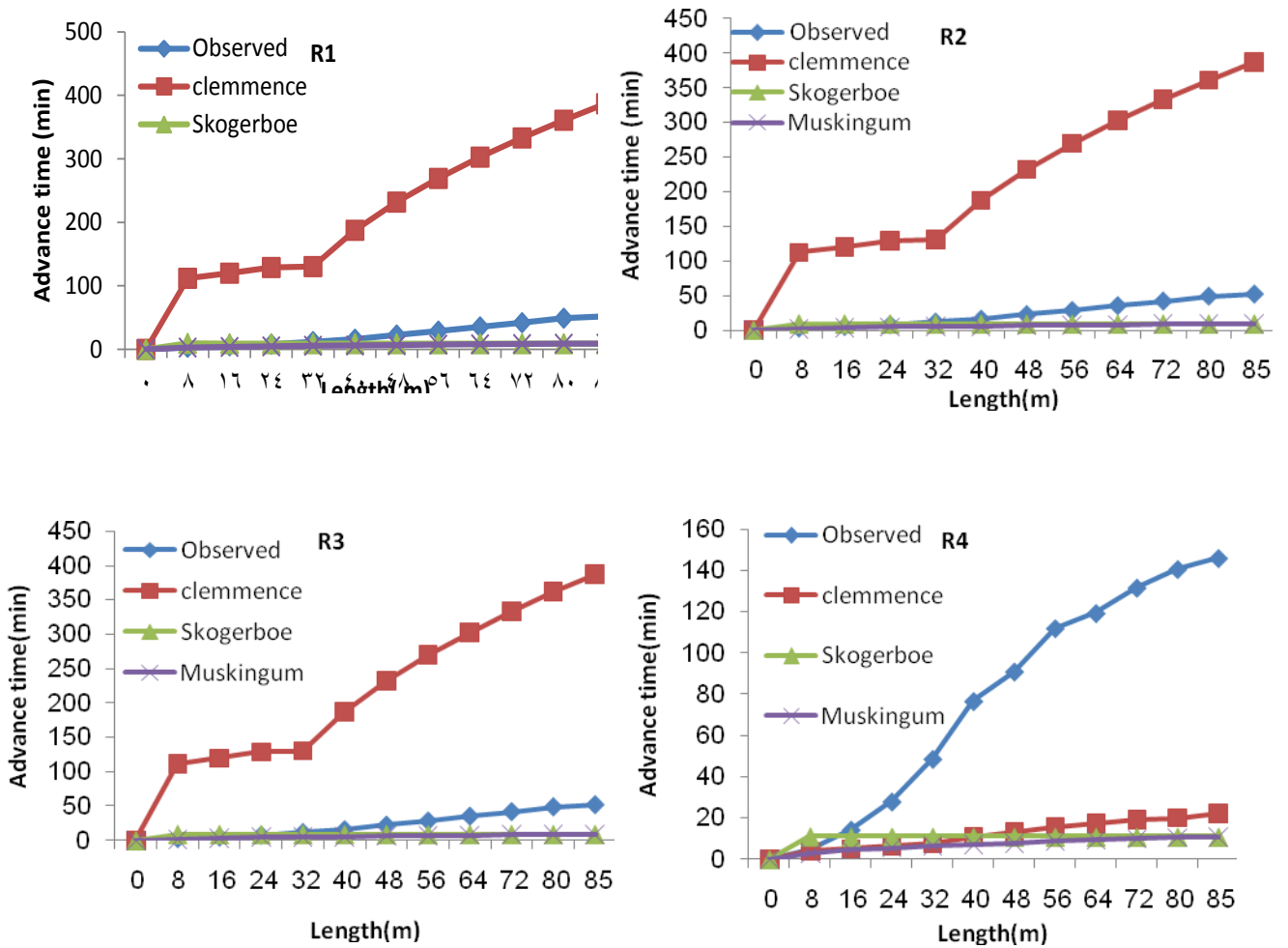
Table3.2: Comparison of various models in terms of estimating advance time, opportunity time and application efficiency for the furrow

Flow L/p	Slop%	Advance time (min)				Opportunity time(min)				Efficiency			
		Muskingum	Skogerboe	Clemmence	Observed	Muskingum	Skogerboe	Clemmence	Observed	Muskingum	Skogerboe	Clemmence	Observed
24.49	12	9.89	9.89	21.45	105.7	115.2	115.29	640	120	26.5	69.96	40.6	53.66
23.17		10.13	10.13	387.11	75.33					20.4	73.82	67.2	46.68
19.12		11.03	11.03	465.31	129					24.72	88.88	80.9	37.2
24.49	17	10.95	10.95	22.42	146	115.29	115.29	640	120	21.1	68.74	40.6	15.85
23.17		11.21	11.21	415.25	193.3					21.8	72.5	66.9	12.65
19.12		12.18	12.18	463.32	182.3					24.3	78.18	80.9	16.25
24.49	26	8.74	8.74	22.40	43.12	115.29	115.29	640	120	23.4	69.32	40.6	21.89
23.17		8.96	8.96	397.31	52.40					24.1	73.12	67.1	32.47
19.12		9.75	9.75	504.11	79.67					26.9	87.98	80.4	22.97

3.4.1 Predicted and Observed Advance Time, Recession Time and Efficiency

The results predicted by the various models were compared with the field measured data and are presented in Figure 1, 2 and 3 for the experimental furrows. The figures show the advance and recession time for the models and field data.

3.4.1.1 Predicted and observed advance time



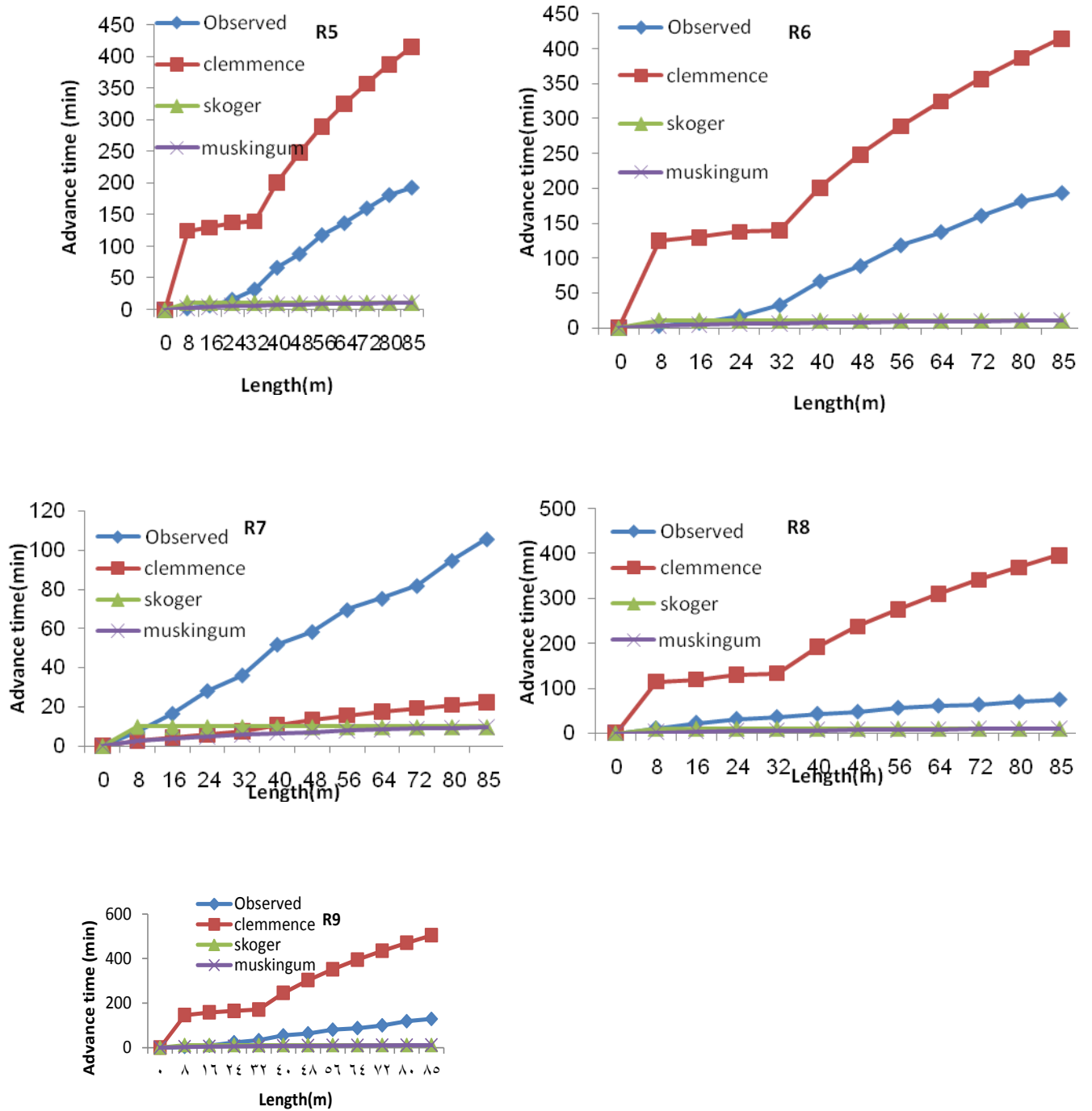


Figure 3.1: Predicted and observed advance time for different experimental furrows data with the (Skogerboe, Muskingum and Clemmence) models

Figure 3.1 indicates a good fit of the observed and predicted values of the advance times over the entire length of the furrow. An excellent agreement

exists between both the measured data and the simulated advance times in the length of furrows (Figure 3.1). In a few cases, the models slightly overestimated or underestimated the recession times.

The coefficients of determination of the three models are almost the same and equal to 0.99 and 1.00 for the prediction of advance time for the experimental furrow. Being high, the coefficient of determination shows a very good correlation between the predicted and measured values of the advance and recession times.

To predict the advance times, the values of RMSE for the Muskingum, Skogerboe and Clemmence models were 14.24, 6.25, and 14.88 min for the furrows, SE 6.18, 2.49 and 0.19 for the furrows, respectively.

3.4.1.2 Predicted and Observed Recession Time

Predicted and observed recession time for different experimental furrows data with the (Skogerboe Muskingum and Clemmence) models i.e. either by using (Hamed and Abdolmajid 2011).

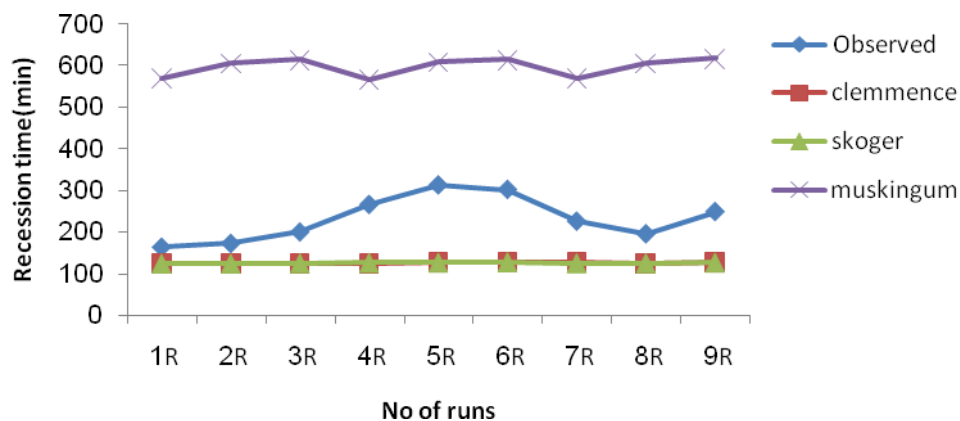


Figure 3.2: Predicted and observed recession time for different experimental furrows data with the (Skogerboe, Muskingum and Clemmence) models

The results predicted by the various models were compared with the field measured data and are presented in Figure (3.2) for the experimental furrow irrigation systems. The Clemmence model the predicted recession times were several times longer than the recession times measured (for example, predicted by Clemmence model, the recession time in the downstream end of the furrow length was equal to 570 minutes whereas its measured value was equal to 163 minutes for R1 data series). But the (Muskingum and Skogerboe) models the predicted recession times were several times smaller than the recession times measured (for example, predicted by Skogerboe model, the recession time in the downstream end of the furrow length was equal to 124 minutes whereas its measured value was equal to 163 minutes for R1 data series). For predicting the recession time, the values of RMSE for the Muskingum, Skogerboe and Clemmence models were 16.14, 6.11, and 20.81 min. for the furrows, SE 2.55, 2.54 and 1.84 for the furrows, respectively.

3.4.1.3 Efficiency of the Three Models and Observed

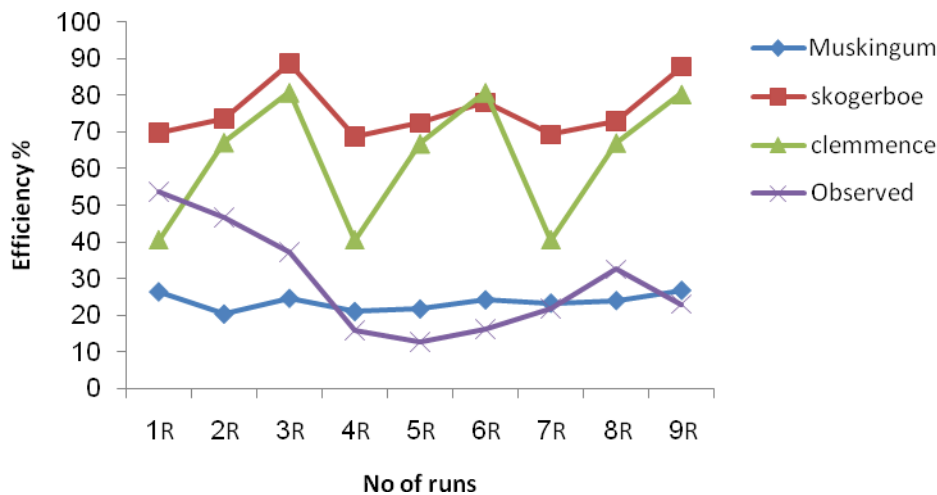


Figure 3.3: observed and predicted Efficiency

Fig (3.3): shows the Efficiency as measured in the field in comparison with that predicted by the Muskingum, Skogerboe and Clemmence Models.

The Efficiency of the Muskingum model is typical from actual while Skogerboe and Clemmence models deviate a little. For predicting the application efficiency, the coefficients of determination of the three models are almost the same and equal to 0.99 and 1.00 for the prediction of advance time for the experimental furrow, the values of RMSE for the Muskingum, Skogerboe and Clemmence models were 14.23, 23.33, and 19min for the furrows, SE 0.65, 1. 86 and 1.62 for the furrows, respectively.

CHAPTER FOUR

IMPROVING THE PERFORMANCE OF FURROW IRRIGATION SYSTEM USING (CUT-BACK)

4.1 Introduction

Cutback system it is always desirable to obtain higher water distribution efficiency. When high distribution efficiency achieved, considerable surface run – off results. For the purpose of water conservation, a compromise between these conflicting practices is highly needed (Trout, 1990; Ahmed, 2002). Cut-back is used to reduce the quantity of irrigation runoff. This method utilizes a large furrow stream to rapidly advance the length of the field and wet-up the furrow. When the water has reached the end of the field, the size of furrow stream is cut-back to one third or to one half of the original furrow flow. While cut off is a traditional practice to stop the flow when the advancing wetting front reached 75% of the furrow length(R.G. Evans, B.N. Girgin ,1995). There have been a few studies on cutback furrow irrigation systems. Due to the potentially higher application efficiency and easy implementation of cutback irrigation (Waskom 1994; Bauder and Waskom 2003; Hanson 2005) compared to other surface irrigation regimes such as surge flow; it deserves the same attention that has been given to other systems. The purpose of the present study was to develop explicit performance functions from independent irrigation variables in order to evaluate the cutback regime in furrow irrigation systems. This study is part of a larger research project aimed at optimizing the runoff of nutrient from furrows with cutback flows. Soares et al. (2000) declared that for continuous and cutting-back irrigation, the application efficiency increased with the discharge, reaching a maximum value and decreased thereafter, the runoff loss increased and the deep percolation loss decreased as the discharge increased. Mostafazadeh and Farzamia(2000)

pointed out that deep percolation ratio and runoff ratio was less in the cut-back method compared to the conventional method. Therefore, the cut-back method had higher application efficiency in heavy textured soils as compared to light textured Soils. Azevedo et al. (2003) observed in the 100m furrow length, the application efficiency decreased as the required depth increased, but in the 250 m furrow length, the application efficiency increased as the required water depth increased.

4.2 The Objective

To improve the performance of furrow irrigation system used cut-back technique.

To test and compare the two mathematical models (Skogerboe and Clemmence) with field data. The ultimate goal was to determine the accuracy of these models for furrow irrigation system.

4.3 Materials and Methods

4.3.1 Field Experiment:

4.3.1.1 Advance, Recession, Required, Cut-back and Cutoff Time:

At each furrow, eleven pieces of wood were set into the furrows at equal distances along the furrow length. The travel time of water advancing through each furrow was recorded at each mark. When the water in the furrow has reached $\frac{3}{4}$ of the way down, the amount of water is reduced (= cut back) by half Water speed in the furrow becomes more slowly. The cutoff time for each furrow was recorded along with the required and recession times for each furrow.

4.3.1.2 Cutback flow: calculated the cutback flow, the size of furrow stream is cut-back to $\frac{1}{2}$ of the original flow (Q_0) into the furrows by equation:

$$Q_{cb} = Q_0/2 \quad (4.6)$$

4.3.1.3 Application efficiency: used field data to calculate application efficiency by equation:

$$E_a = \frac{Z_{rea} * L}{t_l(Q_{cb} + Q_o)} * 100 \quad (4.7)$$

Where: E_a is application efficiency, Q_{cb} is the cutback flow rate (m^3/min), L is furrow length (m), Q_o is flow rate (m^3/min).

4.3.2 Models of Surface Irrigation

The mathematical models are based on the equations that describe the processes governing the overland flow in Cut-back of surface irrigation.

4.3.2.1 Skogerboe Model

Calculate the Application Efficiency, E_a , as a function of inflow discharge, Q_o . This involves the following steps:

i. Select an initial value of Q_o and using the procedure outlined in the section “Computation of Advance Time” and “Computation of the Cut-back inflow”, calculate

$$Q_{ch} = 1.1 * f_0 * L \quad (4.8)$$

ii. Calculate E_a as:

$$E_a = \frac{Q_{cb}L}{tL(Q_o + Q_{cb})} 100 \quad (4.9)$$

Q_{cb} is cut-back inflow rate, L length of furrow, Q_o inflow discharge, tL advance time.

4.3.2.2 Clemmence Model

A common practice is to cut back to 50% of the inflow. Dividing the cutback inflow rate by the Wetted field area gives the average infiltration rate that matches the cutback inflow rate; calculate the cut-back inflow as:

$$Q_{cb} = Q_o/2 \quad (4.10)$$

Calculate the Application Efficiency, E_a , as a function

$$E_a = \frac{Z_{req}}{I_t * R_0} 100 \quad (4.11)$$

Where I_t is total infiltration, R_0 is runoff.

4.3.3 Data analysis:

The criteria were chosen to analyses data using T. test

4.3.4 Model Verification

4.3.4.1 Input Data: Generally, the numerical models are verified by comparing the model predictions with field measured data. In this study, the results of the various models were compared with the observed data filed.

Table 1.4: Model input parameters of the experimental furrows used for assessment of the performance of the field

Parameters	R1	R2	R3
Inflow rate, q_o (l/s)	8.16	7.72	6.37
Field length, L (m)	85	85	85
Field width m	50	50	50
Field slope, S_o (%)	26	17	12
Manning's n	0.04	0.04	0.04
Furrow spacing (m)	1.5	1.5	1.5
Furrow section parameters			
ρ_1	1	1	1
P2	3.33	33.3	33.3
Kostiakov-Lewis parameters			
k (m ₃ /min/m)	0.0043	0.0043	0.0043
a (-)	0.258	0.258	0.258
f_o (m ₃ /min/m)	0.00022	0.00022	0.00022

4.4 Result and Dissection

4.4.1 Advance Time of Continues Flow for Different Discharge:

The figure (4.1) show that the effect of different flow to constant slope against advance time. From the figure the results show the advance time is increase at small discharge.

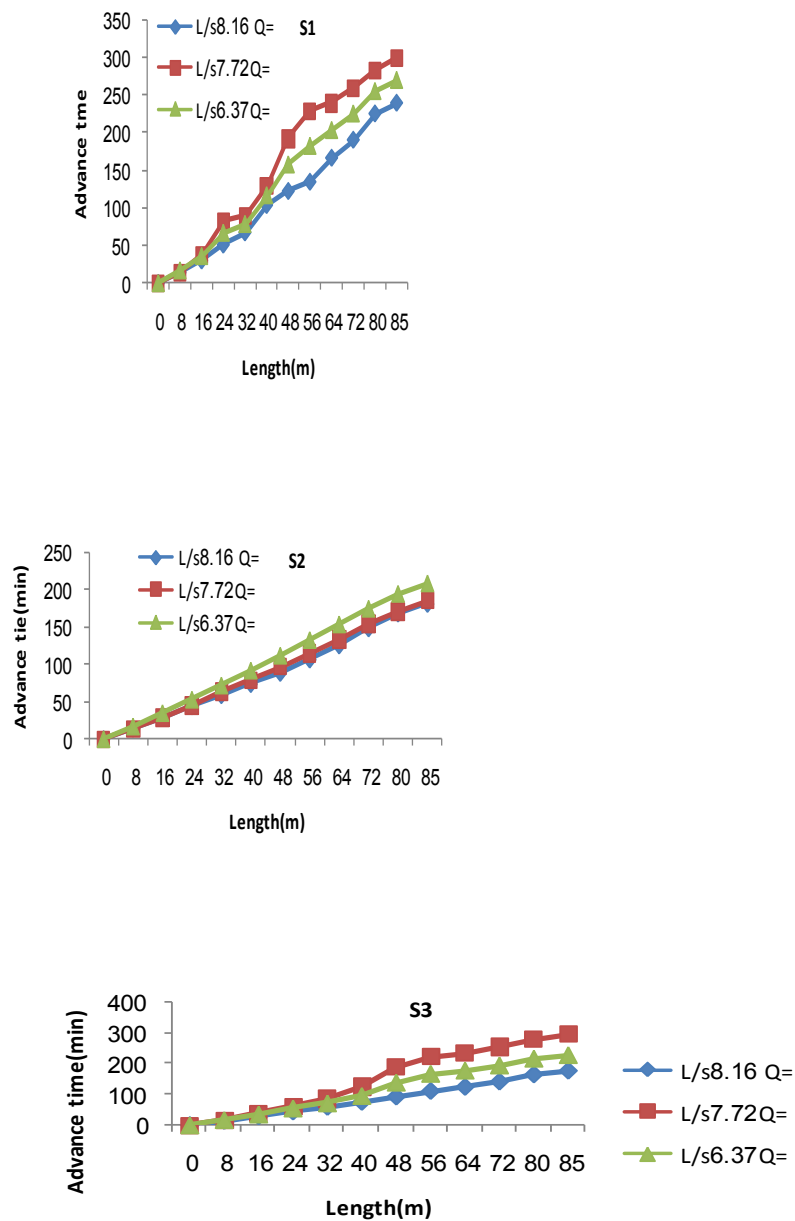


Figure (4.1) Advance time of continues flow for different discharge

4.4.2 Advance Time of Continues Flow for Different Slopes:

The figure (4.2) show that the effect of different slope to constant flow against advance time. From the figure the results show the advance time is increase at large slope.

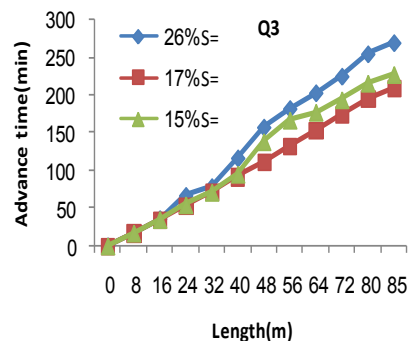
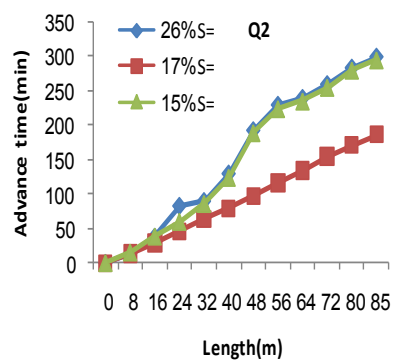
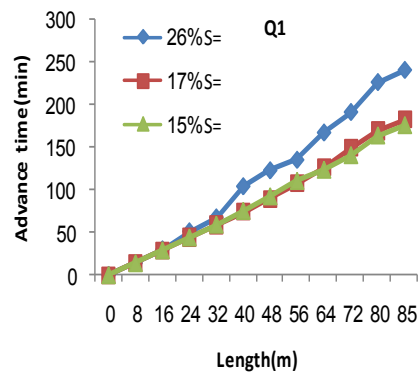


Figure (4.2) Advance time of continues flow for different slope

4.4.3 Recession Time of Continues Flow for Different Discharges:

The figure (4.3) show that the effect of different flow to constant slope against recession time. From the figure the results show the recession time is increase at small discharge.

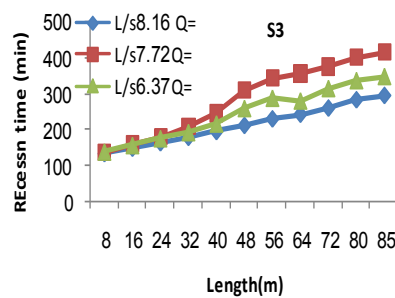
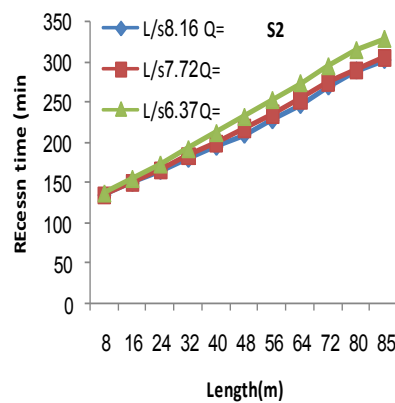
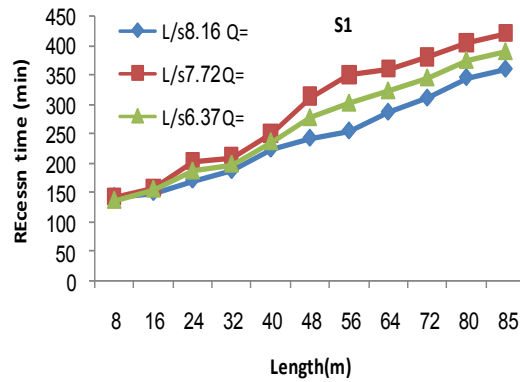


Figure (4 .3) Recession time of continues flow for different discharges

4.4.4 Recession Time of Continues Flow for Different lopes

The figure (4.4) show that the effect of different flow to constant slope against recession time. From the figure the results show the recession time is increase at large slope

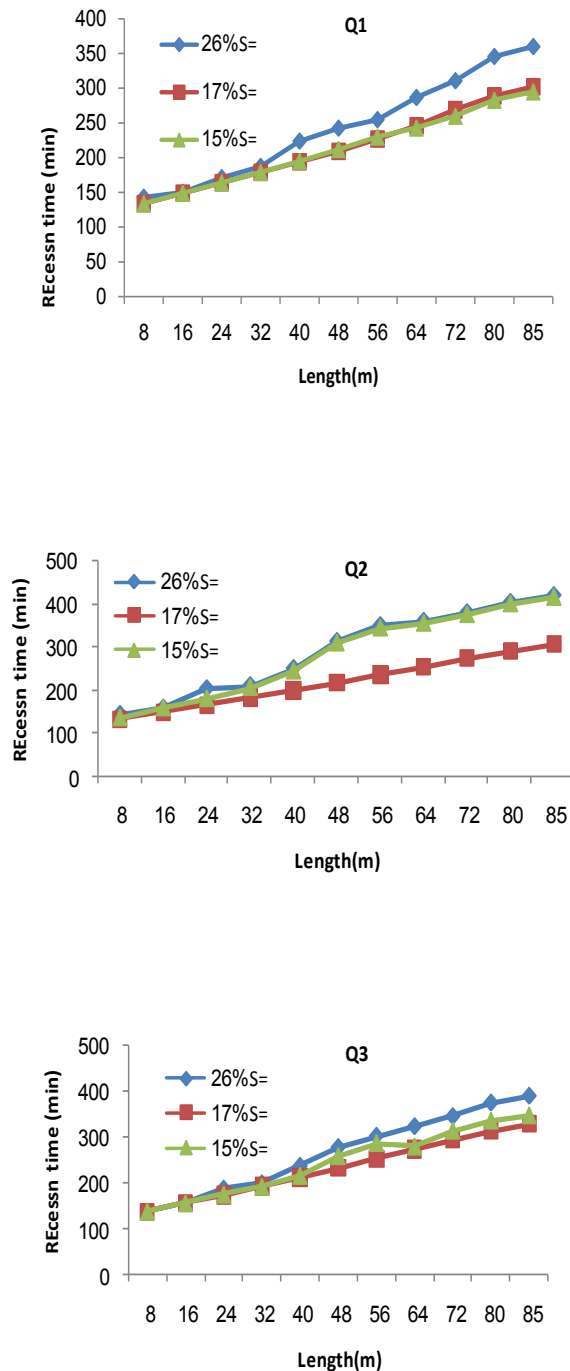
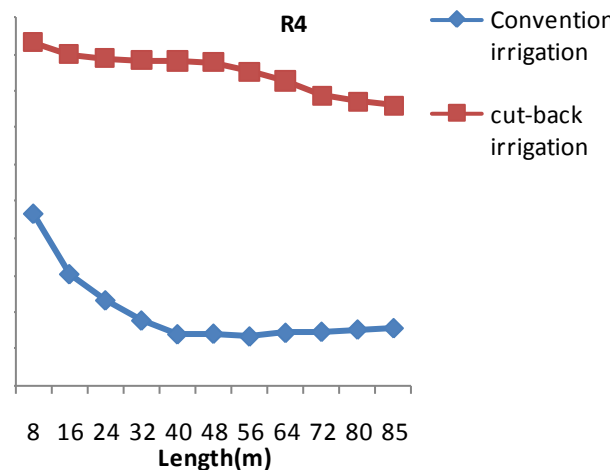
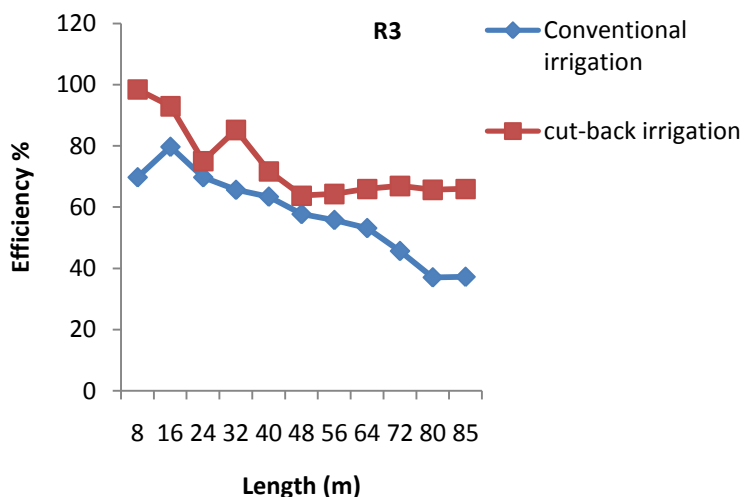
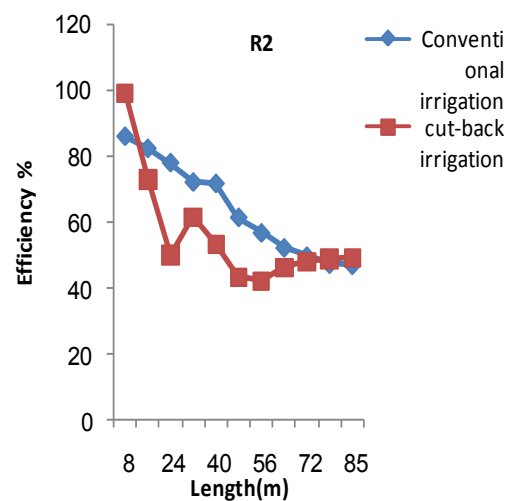
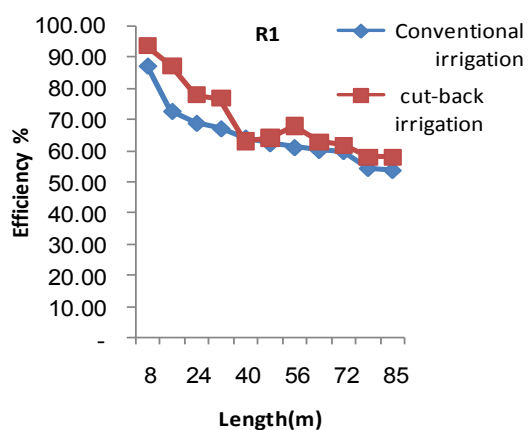


Figure (4.4) Recession time of continues flow for different slopes

4.4.5 Efficiency and Types of Irrigation

Fig (4-5) show the Comparison analysis between cut-back irrigation and conventional irrigation regarding the inflow, the length of and slop for irrigation efficiencies, the cut-back irrigation achieved high efficiency comparison with conventional irrigation. (Ahmed2003).



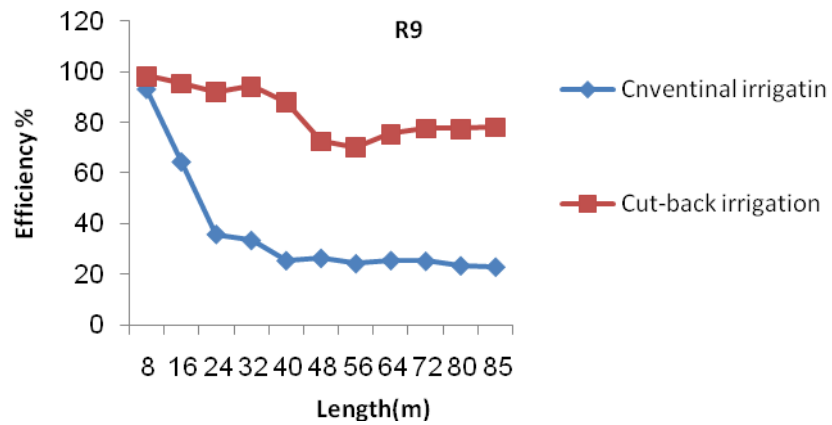
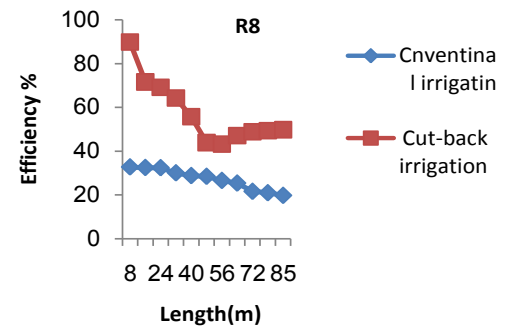
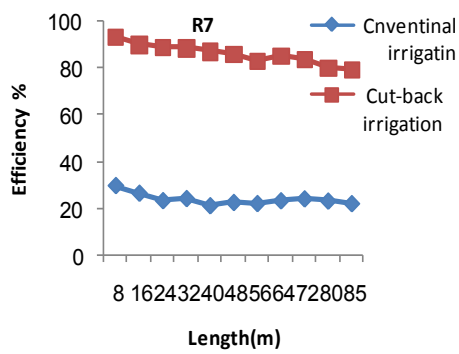
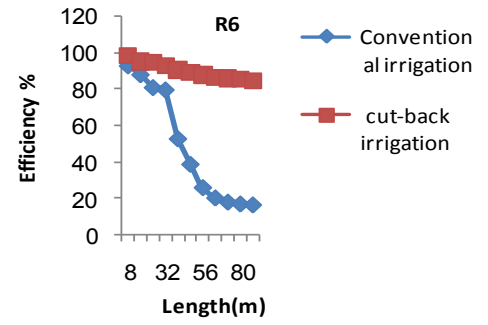
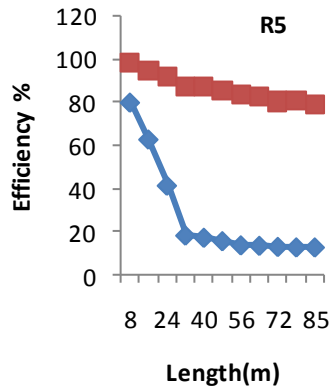


Fig (4.5) Application efficiency (E_a) Conventional irrigation and cutback irrigation

4.4.6 Application Efficiency Furrow Length for Different Discharges

Figure (4.6) represent the relationship between the furrow length and application efficiency for different discharges (Mohammed 1982). (Ahmed2004).

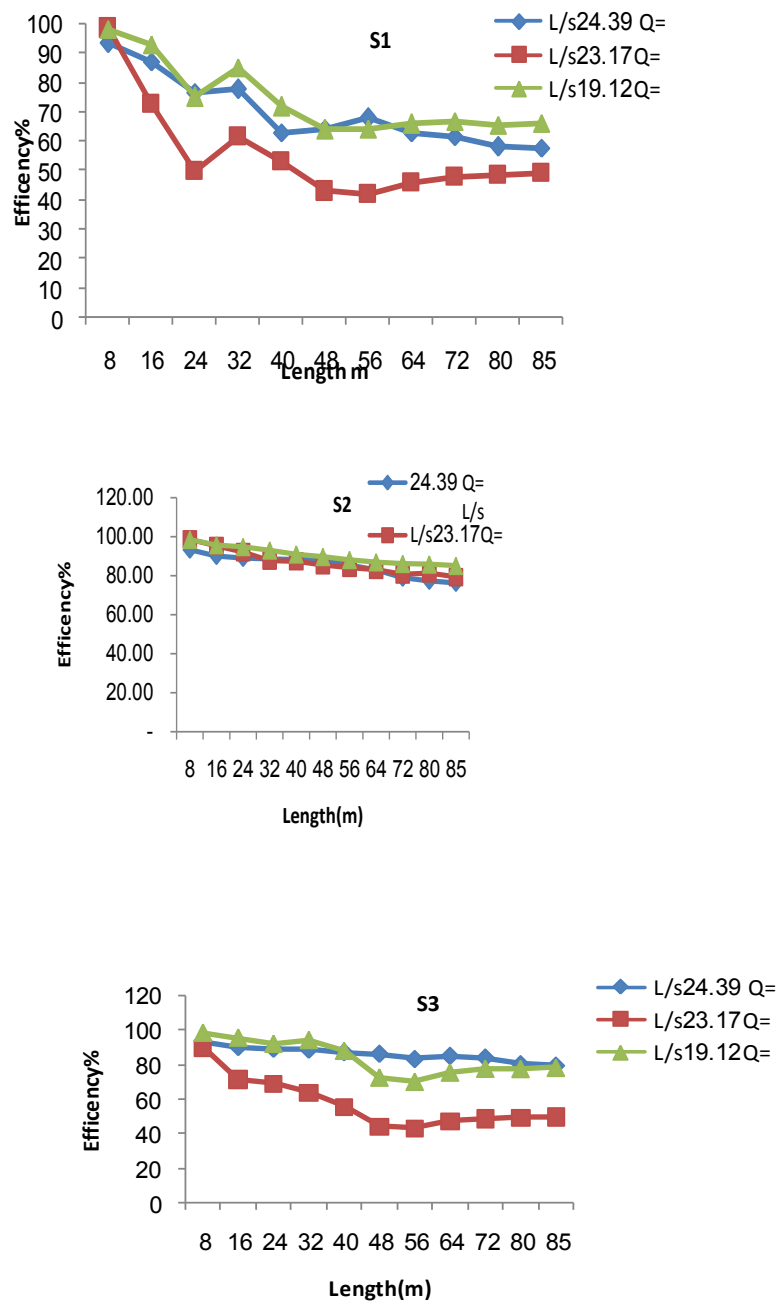


Figure (4.6): Furrow length. Application Efficiency for different discharges

4.4.7 Application Efficiency Furrow Length for Different Slopes

Figure (4.7) represent the relationship between the furrow length and application efficiency for different slopes (Mohammed 1982). (Ahmed2004).

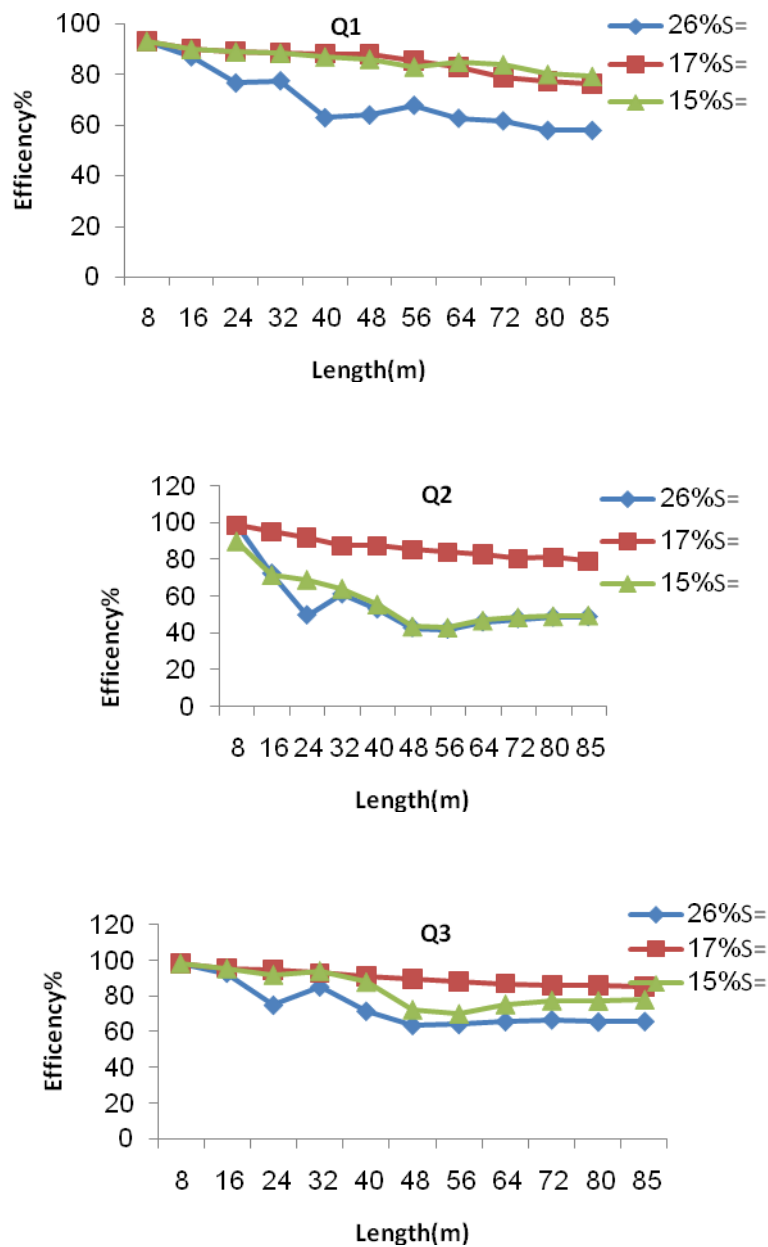


Figure (4.7): Furrow length. Application Efficiency for different slopes

The values attained from field experiments and calculated from two models can be summarized as in the table below:

Table 4.2: Comparison of various models in terms of estimating advance time, opportunity time and application efficiency for the furrow

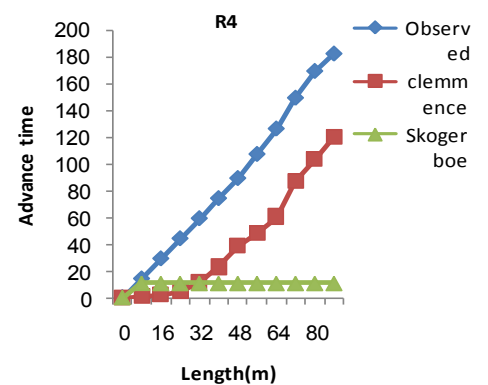
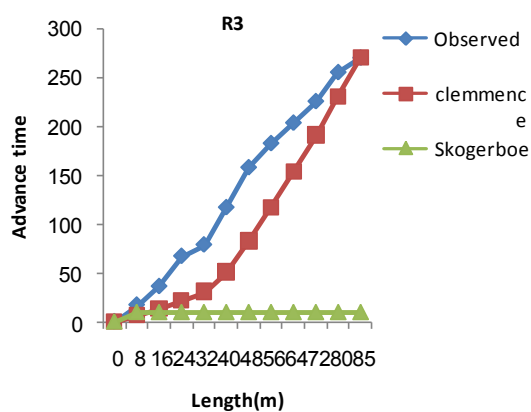
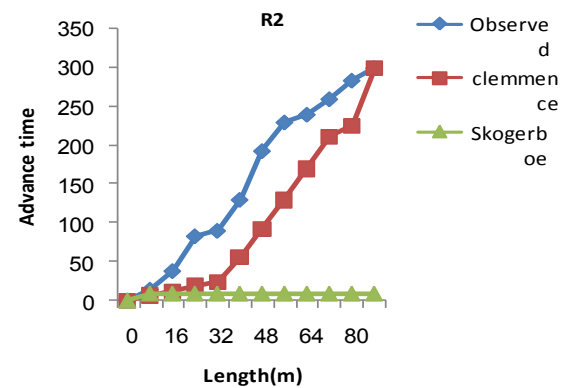
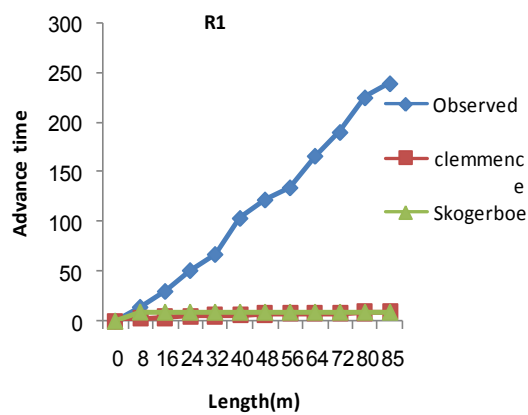
Flow L/p	Slop%	Cut- back flow L/p			Advance time (min)			Opportunity time(min)			Efficiency %		
		actual	Clemmence	Skogerboe	Skogerboe	Clemmence	actual	Skogerboe	Clemmence	actual	Skogerboe	Clemmence	actual
24.49	12	4.1	12.25	0.35	9.89	120	182	115.29	124	120	31.43	42.4	76.27
23.17		3.9	11.95		10.13	127	185				30.67	45.5	79.33
19.12		3.2	9.56		11.03	125	209				31.43	57.4	83.08
24.49	17	4.1	12.25	0.35	10.95	147	175	115.29	124	120	21.86	36.4	79.32
23.17		3.9	11.95		11.21	295	295				21.43	24.1	49.75
19.12		3.2	9.56		10.9	11	227				21.86	89.4	78.33
24.49	26	4.1	12.25	0.35	8.74	8.8	240	115.29	124	120	48.90	37.3	57.84
23.17		3.9	11.95		8.96	300	300				47.73	23.2	48.92
19.12		3.2	9.56		9.75	269	269				43.83	30.4	65.95

Statistic the advance time (Calculated T-test values are 0.96 and 0.95 for Skogerboe and Clemmence models respectively), Cut- back flow rate (Calculated T-test values are 0.89 and 0.67 for Skogerboe and Clemmence models respectively), The opportunity time (Calculated T-test values are 0.039 and 0.032 for Skogerboe and Clemmence models respectively),

4.5 Predicted and Observed Advance Time Recession Time and Efficiency

The results predicted by the various models were compared with the field measured data and are presented in Figure (4.12),(4.13),(4.14)and (4.15) for furrows the experiment (HamedandAbdolmajid2011).

4.5.1 Predicted and Observed Advance Time



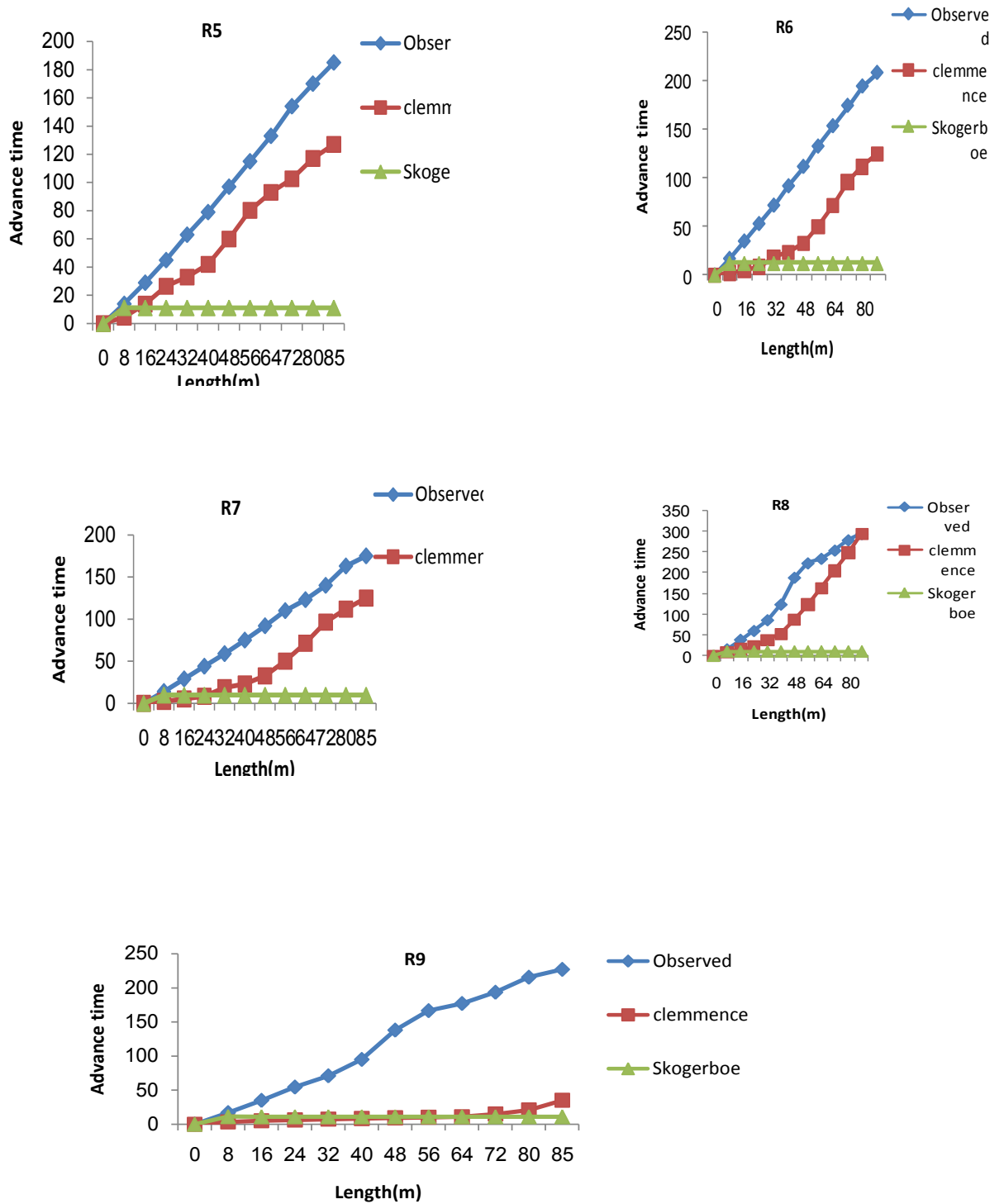


Figure 4.8: Predicted and observed advance time for different experimental furrows data with the (Skogerboe and Clemmence) models

4.5.2 Predicted and Observed Recession Time

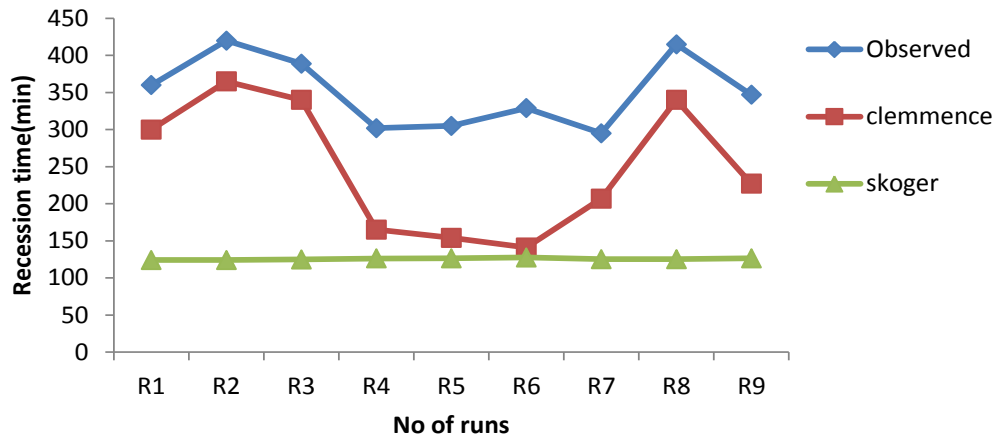
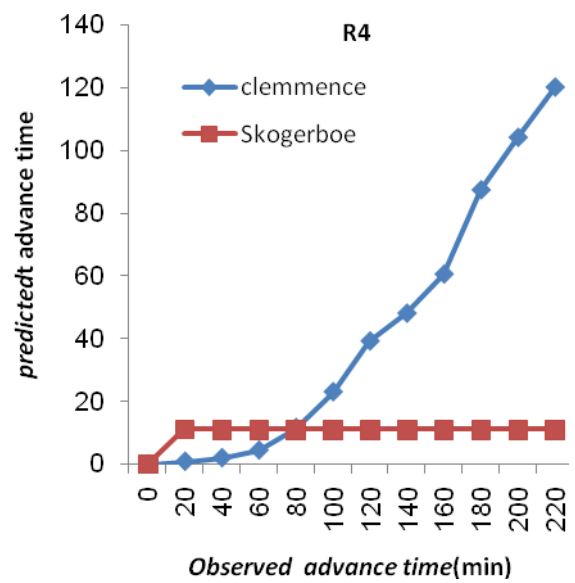
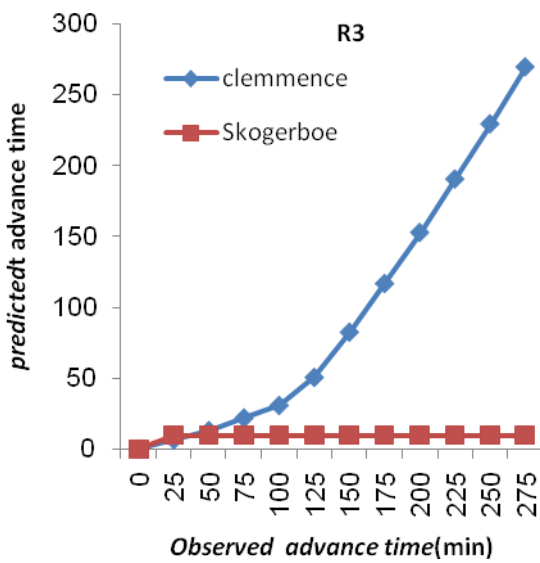
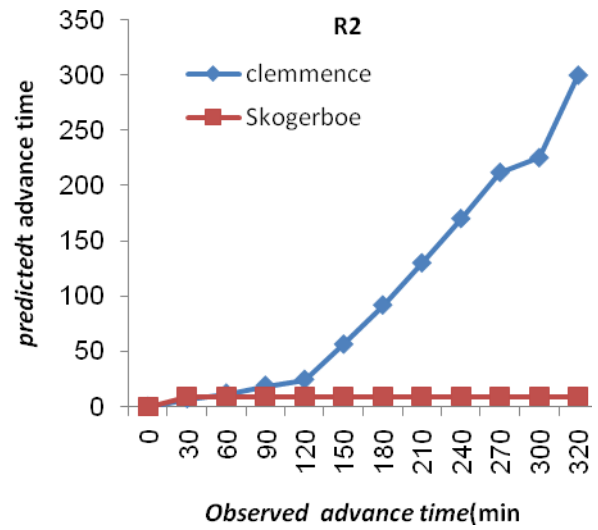
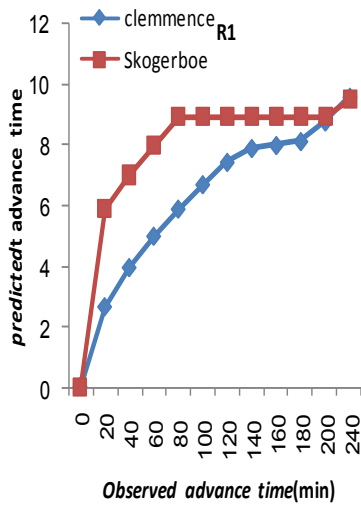


Figure 4.9: Predicted and observed recession time for different experimental furrows data with the (Skogerboe and Clemmence) models

The results predicted by the various models were compared with the field measured data and are presented in Figure (4.3) for the experimental furrow irrigation systems. The Clemmence and Skogerboe models the predicted recession times were several times smaller than the recession times measured (for example, predicted by Clemmence and Skogerboe models, the recession time in the downstream end of the furrow length was equal to 300 and 124.03 minutes respectively, whereas its measured value was equal to 360 Minutes for R1 data series).

Statistical test using T-test indicates that there is significant difference between the two models and the field data (Calculated T-test values are 5.39 and 1.24 for Skogerboe and Clemmence models respectively

4.5.3 Observed Versus Predicted Advance Time for the Total Data of Furrow with Two Models



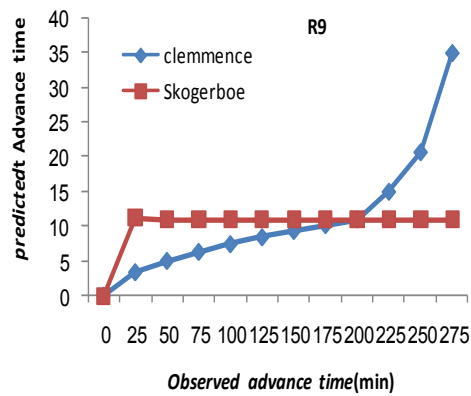
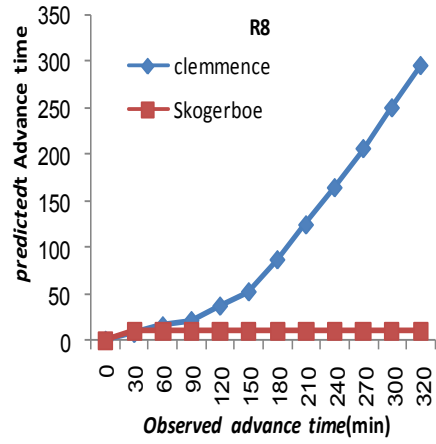
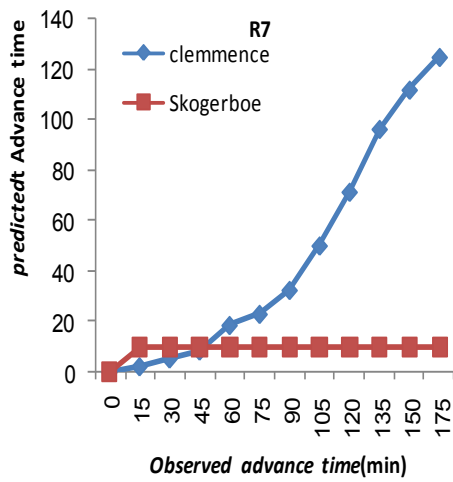
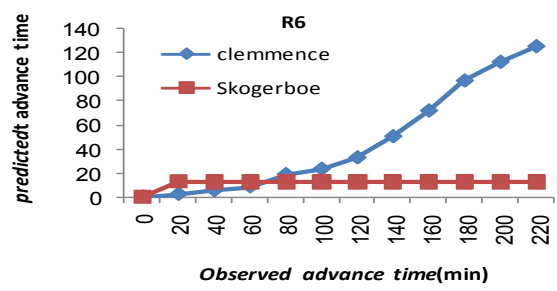
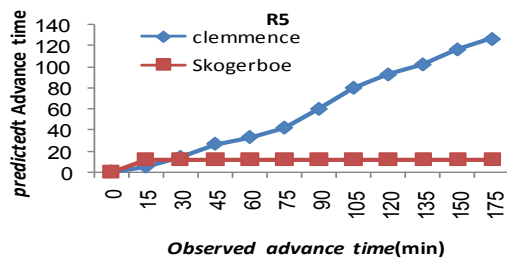


Figure 4.10: Observed versus predicted advance time for the total data of furrow with Skogerboe and Clemmence Models

4.5.4 Efficiency of the Two Models and Observed

Figure 4.11: shows the Efficiency as measured in the field in comparison with that predicted by the Skogerboe and Clemmence Models.

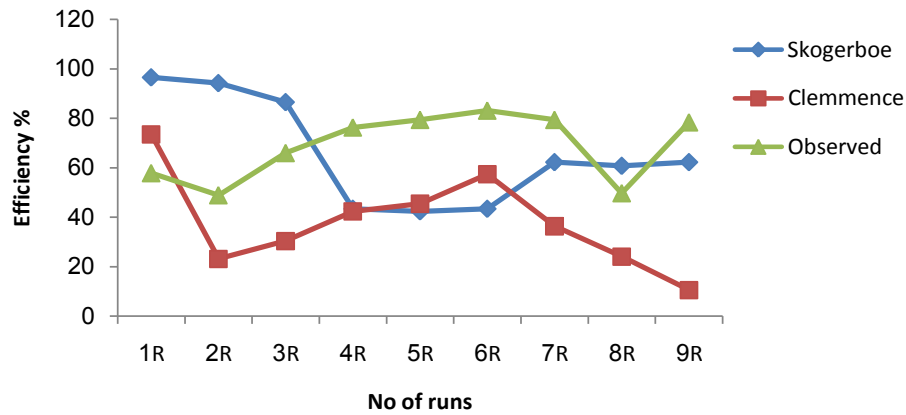


Figure (4.11) represents the relationship between the cut-back irrigation (Observed), skogerboe and Clemmence model

The application Efficiency of the Skogerboe model is typical from actual while Clemmence models deviate a little. Statistical test using T-test indicates that there is no significant difference between the two models and the field data for Skogerboe and Clemmence models respectively.

CHAPTER FIVE

MODEL DEVELOPMENT OF CUT-BACK USING VOLUME STORAGE EQUATION

5.1 Introduction

Surface irrigation methods are characterized by low application efficiency. Improving surface irrigation methods is of great importance especially in the light of secure and better use of water resources. **Alazba (1999)** stated that several models with various solutions have been established. The Volume Balance Model (VBM) is commonly used main surface irrigation design, evaluation and management, because the sophisticated models require extensive programming and high computer cost due to the long execution time. The VBM was used to develop explicit advance solution. The proposed advance solution was developed assuming that the roughness is characterized by Manning equation; therefore, the solution is valid for cases where the bottom slope is not equal to zero. The method is not appropriate to conditions for which the inlet stream area changes dramatically with time. **Mailhol et al. (1997)** showed that simplified analytical modeling options could be added to the basic advance-infiltration model for improving irrigation efficiency. The modeling option developed in this study concerned with the prediction of cutoff time and irrigation performance for Closed End Furrows (CEF). The simplified analytical model for (CEF) based on the mass conservation principle was successfully compared to field tests and numerical simulations. **Clemmens et al. (1999)** concluded that the factors that influence surface irrigation efficiency are numerous. Field length, basin width or furrow cross sectional shape, and slope defines the geometry. Soil infiltration and surface roughness parameters define the soil and crop conditions, while the inflow hydrograph defines the operation of the system. The only feasible way to study the combined influence of some of these

variables or indeed all of them at the same time is through simulation models. This article provides an introduction to the application of this technology to improving surface-irrigation performance. Several empirical equations are available for evaluating the friction slope. **Oyonarte and Mateos (2003)** reported that furrow irrigation models rarely consider the variability of the soil intake characteristics. However, such models are used more and more for the design, evaluation and management of surface irrigation systems. **Eldeiry et al. (2004)** studied furrow irrigation system designs for clay soils in arid regions. A volume balance model was applied to simulate Water flow in the furrow system. The design procedure requires the determination of the furrow geometry factors, the advance time, and the application efficiency.

The objective of this study was to develop simulation computer aided design models to improve surface furrow irrigation systems performance. Then to apply and validate models' outputs.

5.2 Materials and Methods

5.2.1 Field Experiment:

Three groups of furrows experiments (i.e. 26% slop1, 17% slop2, and 12% slop3) for models' validation were carried out on clay soil. The testing area was 85 m Length by 50 m width, discharge rate of (8.16, 7.72, and 6.37)L/sec

5.2.2 Model Objective:

A mathematical model based on the differential storage equation was developed to simulate field conditions. The model was verified with laboratory tests. Field experiments were also conducted to evaluate cut – back flow Furrow irrigation systems. The objective of the model is to evaluate the actual irrigation performance parameters with those calculated

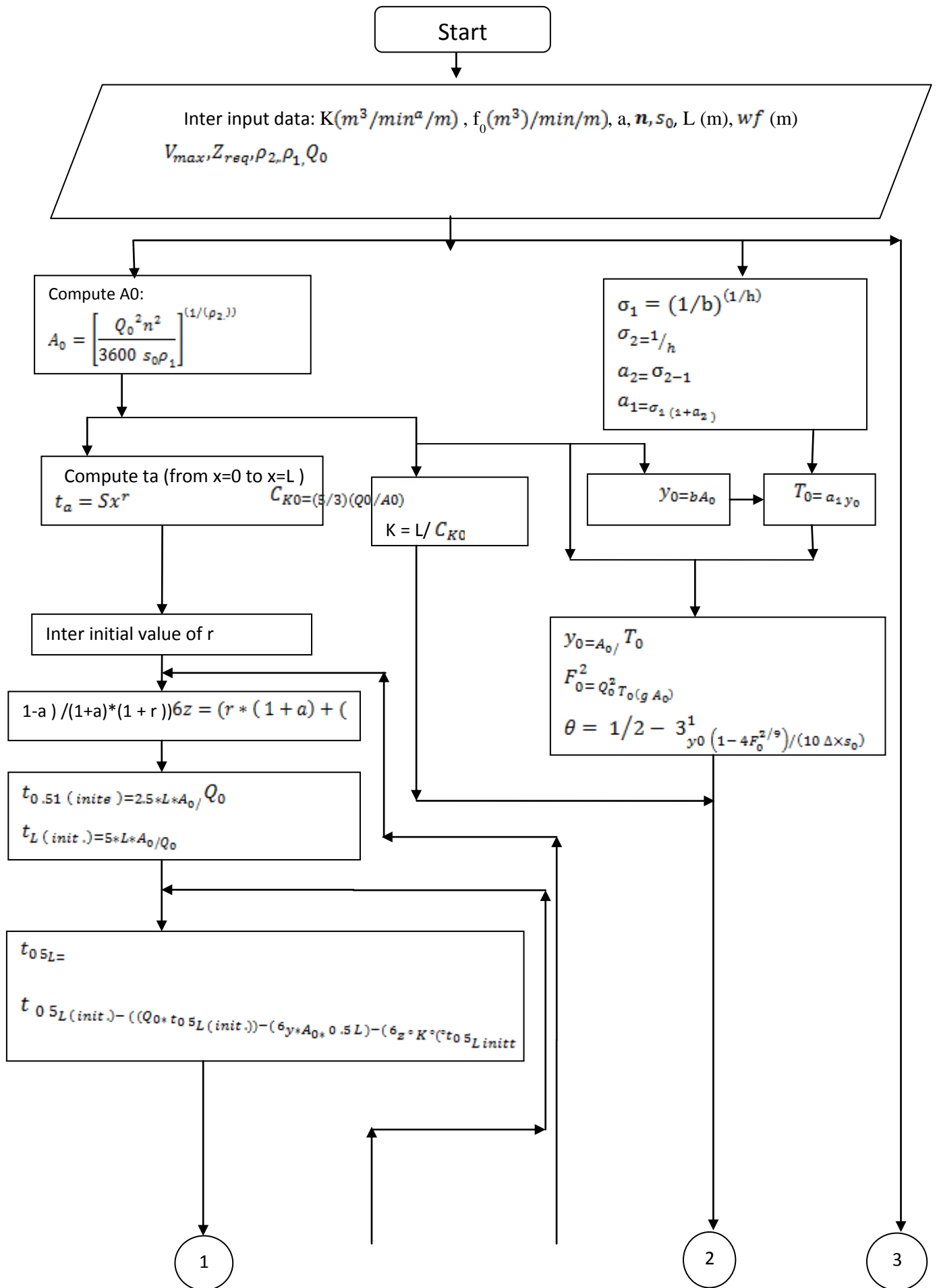
by the program and increase the efficiency of furrow irrigation system under different factors that affecting the system design.

5.2.3 Model Description:

The program has used the design equations for furrow irrigation to describe and evaluate the relations between length, inflow time, inflow rate, and field application efficiency. The sequence of the used equations shown in the flow chart of the furrow irrigation system fig (5-1).

5.2.4 Model Assumptions and Limitation:

The model utilizes units of SI system. It assumes that the user can measure infiltration characteristic using modified Kostiakov equation. Furrow geometry is assumed as parabolic shape.



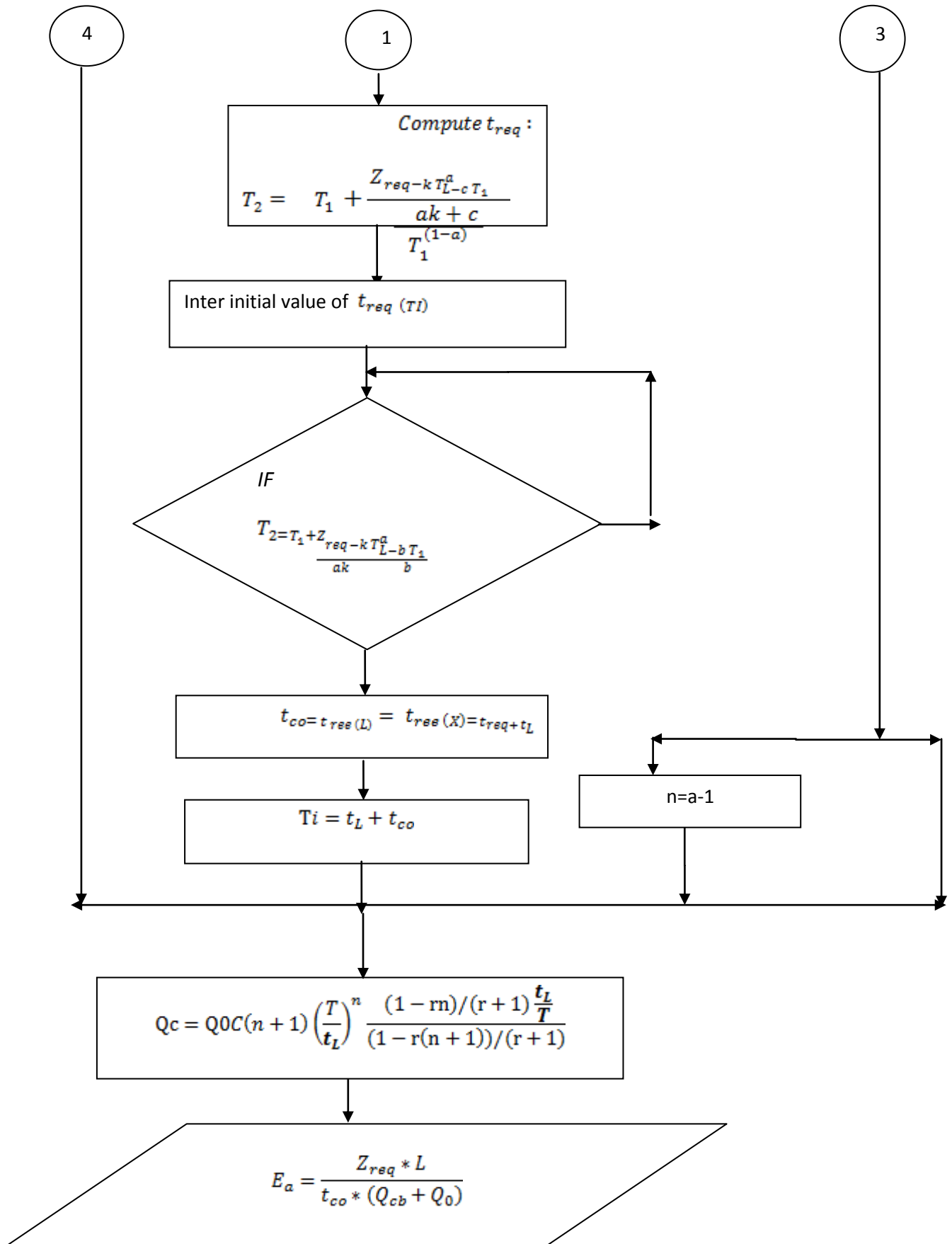


Fig (5.1): The Flow Chart

5.2.5 Design Equations

Model Inputs:

Consider collection of the following Design data:

5.2.5.1 Field Topography Includes:

infiltration coefficients (f_o, K, a), Manning roughness coefficient (n) (0.04), field slope (s_o), length of field (L) (m), width of furrow (w_f) (m), soil erosive velocity (V_{max}), water supply rate (Q_T), required depth of application (Z_{req}) and cross-sectional geometry parameters (ρ_2, ρ_1), furrow spacing (w) (m), r, σ_y surface shape factor (0.77).

5.2.5.2 Infiltration coefficients: The infiltration function has Kostiakov – Lewis characteristic form (Walker and Skogerboe, 1987):

$$Z = Kt_{opp}^a + f_o t_{opp} \quad (5.2)$$

Where: Z = cumulative infiltrated water volume (m³/m); t_{opp} = intake opportunity time (min); k = Intake constant (m³/min/m) a ; = intake power; and f_o = basic intake rate (m³/min/m).

5.2.5.3 Cross-sectional area: The cross-sectional area, A_0 is related to the hydraulic section, which is described by: (i) a wetted perimeter - area relationship; (ii) an area - hydraulic radius relationship; and (iii) an area - depth relationship.

Additionally, the size of A_0 is related to the inlet discharge, field roughness and field slope can be calculated through the uniform flow equation (Walker and Skogerboe, 1987):

$$A_0 = \left[\frac{Q_o^2 n^2}{3600 s_o \rho_1} \right]^{(1/(\rho_2))} \quad (5.3)$$

Where: n = Manning's roughness coefficient; s_0 = field slope; and p_1 and p_2 are the constants of the area -hydraulic radius relationship: $A^2 R^4 = p_1 A n^2$.

5.2.6 Design Process:

The steps needed in the design Processes are outlined below.

1. Calculated the maximum inflow discharge based on v_{max} : To calculate the maximum non-erosive flow rate, by Walker and Skogerboe (1985). The authors studied the maximum non-erosive flow rate as function of parameters obtained from the furrow dimension and proposed the following equation:

$$Q_{max} = \left[\frac{V_{max} \rho_2 n^2}{3600 s_0 \rho_1} \right]^{(1/(\rho_2 - 2))} \quad (5.4)$$

Q_{max} Is maximum inflow discharge, (V_{max}) is soil erosive velocity (ρ_2, ρ_1), is Cross-sectional geometry parameters, n is Manning roughness coefficient (0.04), (s_0) is filed slop.

2. Calculate required depth of application (Z_{req}):

Surface irrigation systems have a narrow range of target or required depth of application (Z_{req}) for which they are reasonably efficient and uniform.

Design approaches are often based on assuming that one end of the field or the other will receive the least infiltrated depth. Then, the inflow and application time are adjusted such that the required depth is infiltrated at that location.

3. Calculate the opportunity time required to infiltrate the desired application depth:

The time to infiltrate the required depth, τ_{req} , becomes an important design parameter. Following Clemmens, (2007). The infiltration opportunity time at any location, x , along the length of- run, $\tau_{opp}(x)$, is defined as the time between

Advance, $t_a(x)$, and recession, $t_r(x)$ or

$$T_{opp}(x) = t_R(x) - t_A(x) \quad (5-5)$$

At the head end of the field ($x = 0$), the opportunity time is equal to the recession time, or

$$t_{opp}(0) = t_R(0) = t_{co} + t_{lag} \quad (5-6)$$

Where t_{co} is the time of cutoff or application time and t_{req} the time required for the water depth at the upstream end to drop to zero after cutoff.

With the minimum depth at the downstream end of the field, furthest from the water source ($x = L$), advance and recession curves must be computed.

$$t_R(L) = t_A(L) + t_{req} \quad (5-6 a)$$

The time of cutoff that will produce the target depth at the downstream end is

$$t_{co} = t_A(L) + t_{req} - [t_R(L) - t_R(0) + t_{lag}] \quad (5-7a)$$

Where: the term in brackets is the time between cutoff and recession at the downstream end. Then the application time is found from:

$$t_{co} = t_A(L) + t_{req} - (V_y(t_{co}) / Q_{in}) \quad (5-6b)$$

4. Calculate normal depth.

5. Computation of Advance Time: Compute advance times to half field length and to end of field length computation of the cutoff time.

Computation of advance time: The time required for water to cover the field, the advance time, t_a , necessitates evaluation or at least approximation of the advance trajectory. Input data include the inflow discharge, Q_0 ; the field length, L ; the infiltration coefficients k , a , and o_f ; the field slope, S_0 ; and the flow cross-section area A_0 based on the cross-section geometry parameters ρ_1 and ρ_2 . The volume balance advance equation may be stated as:

$$t_a = S_x^r \quad (5-7 b)$$

It contains two unknowns, s and r . In order to solve them, a two-point advance trajectory is defined in the following procedure:

1. The power advance exponent r typically has a value of 10-1.1. The first step is to make an initial estimate of its value and label this value r_1 , usually setting $r_1 = 2.5$ to 1.67 are good initial estimates. Then, a revised estimate of r is computed and compared below.

2. Calculate the subsurface shape factor σ_z , can be found from (ASAE 1991):

$$\sigma_z = \frac{a+(r(1-a)+1)}{(1+a)+(1+r)} \quad (5-8)$$

3. Calculate the time of advance, t_L , using the following Newton-Raphson procedure:

a. Assume an initial estimate of t_L as T_1

$$T_1 = 5A_0L/Q_0 \quad (5-9)$$

b. Compute a revised estimate of t_L (T_2) Walker and Skogerboe (1987), Walker (1989) and Clemmens et al. (1998) as:

$$T_2 = \frac{T_1 - (T_1 Q_0) - (0.77L A_0) - (LK\sigma_z T_1^a) - (LT_1 f_0 / (1+r))}{Q_0 (aKL\sigma_z) / ((T_1^{1-a}) - ((Lf_0) / (1+r)))} \quad (5-10)$$

c. Compare the initial (T_1) and revised (T_2) estimates of t_L . If they are within about 0.001 minutes or less, the analysis proceeds to step 4. If they are not equal,

Let $T_1 = T_2$ and repeat steps b through c.

4. Compute the time of advance to the field midpoint, $t_{0.5L}$, using the same procedure as outlined in step 3. The half-length, $0.5L$ is substituted for L and $t_{0.5L}$ for t_L

$$T_1 = 2.5A_0L/Q_0 \quad (5-11)$$

5. Compute a revised estimate of r as follows:

$$r = \frac{\log 2}{\log(t_L/t_{0.5L})} \quad (5-12)$$

6. Compare the initial estimate, r_1 , with the revised estimate, r_2 . The differences between the two should be less than 0.0001. If they are equal, the procedure for finding t_L is concluded. If not, let $r_1 = r_2$ and repeat steps 2-6

Computation of the time required to achieve the required depth: The basic mathematical model of infiltration is the modified Kostiakov function:

$$z = k t_{opp}^a + f_o \quad (5-13)$$

Where Z is the accumulated intake in volume per unit length, m^3/m (per furrow or per unit width are implied), t_{opp} is the intake opportunity time in minutes, a is the constant exponent, k is the constant coefficient $m^3/min^a/m$ of length, and f_o is the basic intake rate, $m^3/min/m$ of length. In order to express intake as a depth of application, Z must be divided by the unit width. For furrows, the unit width is the furrow spacing, w_f . Values of k , a , b and w_f along with the volume per unit length required to refill the root zone, Z_{req} , are design input data. The design procedure requires that the intake opportunity time associated with Z_{req} be known. This time, represented by τ_{req} , requires a nonlinear solution to Eq. (5-13). The convenient method for those with programmable calculators or microcomputers is the Newton-Raphson procedure which is three simple steps as follows:

1. Make an initial estimate of τ_{req} and label it $(t_{req})_i$;
2. Compute a revised estimate of $(t_{req})_{i+1}$, T2:

$$(t_{req})_{i+1} = (t_{req})_i + \frac{(Z_{req} - K(t_{req})_i^a - f_o(t_{req})_i)}{\frac{aK}{((t_{req})_i^{(1-a)}) + f_o}} \quad (5-14)$$

3. Compare the values of the initial and revised estimates of τ_{req} $(t_{req})_i$ and $(t_{req})_{i+1}$ by taking their absolute difference. If they are equal to each other or within an acceptable tolerance of about 0.5 minutes, the value of

t_{req} is determined as the Result. If they are not sufficiently equal in value, replace $(t_{req})_i$ by $(t_{req})_{i+1}$ and repeat steps 2 and 3

Computation of the cutoff time:

$$T_{co} = t_{rec}(L) = t_{rec}(X) = tL + t_{req} \quad (5-15)$$

Where $t_{rec}(L)$ = recession time at the lower end of the field. $T_{rec}(X)$ = recession time at any distance X.

Computation of cut-back inflow rate: cut-back inflow rate determined if the initial inflow is decreased when the water reached $\frac{3}{4}$ of the furrow. In the model to calculate cut-back inflow rate based on the volume storage equation, in this model used different volume storage equations from three models (Clemmence, Skogerboe and Muskingum), is defined in the following procedure

1-Calculated volume storage

A-The Muskingum method assumes that the surface storage in the reach can be written as a linear function of inflow and out flow:

$$S1 = K\{(\theta * I) + (1 - \theta)O\} \quad (5-16a)$$

Where: S is the surface storage (m³), I and O are the inflow and the outflow respectively (m³/min) K and θ are Muskingum parameters

$$K = L / C_{ko} \quad (5-17)$$

$$\theta = 0.5 - 3y'_o(1 - 4f_o^2/9)/(10L s_o) \quad (5-18)$$

Where:

$$C_{ko} = \frac{5Q_0}{3A_0} \quad (5-19)$$

$$y'_o = \frac{A_0}{T_0} \quad (5-20)$$

And

$$f_o^2 = \frac{T_0 Q_0^2}{g A_0^3} \quad (5-21)$$

Where: Q_0 , A_0 and T_0 are the reference flow rate and the corresponding area and top width respectively.

$$T_0 = a_1 y_0 a_2 \quad (5-22)$$

$$\sigma_2 = 1/h \quad (5-23)$$

$$\sigma_2 = 1/h \quad (5-24)$$

$$a_1 = \sigma_1 (1 + a_2) \quad (5-25)$$

$$\sigma_1 = 1/b^{(1/h)} \quad (5-26)$$

B-Skoogerboe: A logarithmic transformation is used to linear the volume balance equations. (Walker and Skoogerboe, 1987)

$$V_s = \frac{(\ Q_0 t_L) - (\sigma_y A_0 L) - (1/(1+r)(f o t_L L)}{L} \quad (5-16 b)$$

Where: A_0 is cross-sectional area, Q_0 inflow rate, σ_y surface shape factor, t_L advance time, L furrow length

c- Clemmens: the volume in surface storage at the completion of advance is used to estimate the surface volume at cutoff. Experience has shown that this adjustment is reasonable in many cases (Clemmens et al. 1998).

$$V_s = \sigma_y * A_0 * L \quad (5-16c)$$

Where: V_s is volume in surface storage (m^3), σ_y is the surface shape factor (0.77), A_0 is cross sectional area (m^2), L is length of field (m)

2- Calculated the inflow volume at advance time, by equation:

$$V_i = Q_0 * t_L \quad (5-27)$$

Where V_i is inflow volume, Q_0 is inflow rate, t_L is advance time.

3-**Calculated the value of C:** value of (C) constant is less than one as suggested by wilke and smardon (1965)

$$C\% = \frac{V_i - V_s}{V_s} * 100 \quad (5-28a)$$

OR:

$$C\% = \frac{\text{Infiltration volume}}{\text{inflow volume}} C < 1 \quad (5-28b)$$

4- **Calculated the total irrigation time (min)**

$$T_i = t_L + t_{co} \quad (5-29)$$

5-**Calculated infiltration empirical constant (n):**

Accumulated infiltration function:

An empirical power function is usually used to express the infiltration intensity in terms of opportunity time of infiltration as given by Kestiakove equation (1932)of the from:

$$I = kt_{opp}^n \quad (5-30a)$$

Where: I is infiltration intensity (cm/min), t_{opp} is opportunity time of infiltration, k, n is infiltration empirical constant. n commonly range from (-0.2) to (-0.8).

However, in this analysis, the quantity of water expressed in depth (z) that will infiltration in a small unit length(L) of furrow after an opportunity time (t_{opp}) can be obtained by integrating equation (5-30a) between the limited 0 and t_{opp} thus :

$$d = \int_0^{t_{opp}} I dt = \int_0^{t_{opp}} \frac{k}{n+1} t_{opp}^{n+1}$$

$$n = a - 1 \quad (5-30b)$$

The Cutback ratio $\frac{Q_c}{Q_0}$ used by (Mohammed 1982) can be expressed as

$$\frac{Q_c}{Q_0} = C(n + 1) \left(\frac{T_i}{t_L} \right)^n \frac{(1-rn)/(r+1) \frac{t_L}{T_i}}{(1-r(n+1))/(r+1)} \quad (5-31)$$

Cutback inflow rate Q_c

$$Q_c = Q_0 C(n + 1) \left(\frac{T_i}{t_L} \right)^n \frac{(1-rn)/(r+1) \frac{t_L}{T_i}}{(1-r(n+1))/(r+1)} \quad (5-32)$$

Application efficiency: The application efficiency evaluated the adequacy of an applied irrigation, Used by (arter Walker, 1993):

$$E_a = \frac{Z_{req} * L}{t_L * (Q_{cb} + Q_0)} \quad (5-33)$$

To evaluate the suitability of the surface irrigation models, criteria were chosen to analyses the degree of the goodness of fit. These criteria can be **defined as follows:**

Error percentage

The deference between the calculated results and model results was determined by using the following equation:

$$\text{Error \%} = \frac{\text{Max.value} - \text{Min.value}}{\text{Maxvalue}} \quad (5-34)$$

5.3 Results and Discussion

5.3.1 Validation of the Model:

To validate the model, field experiments were implemented to determine the accuracy of Furrow design. This was done by comparing the calculated results and predicted output results. The sequence of the used equation is shown in the flow charts and Figs (5.1)

5.3.2 Model Comparison with Field Data:

Table (5-1): show the calculated results for furrow irrigation system during experiments. The error percent for the advance time t_a , net opportunity time t_{opp} , design inflow time Q and application Efficiency E_a was recorded.

Flow L/p	Slop %	Cut- back flow L/p				Advance time (min)				Opportunity time(min)				Efficiency			
		actual	Clemmence	Skogerboe	Muskingum	Muskingum	Skogerboe	Clemmence	actual	Muskingum	Skogerboe	Clemmence	actual	Muskingum	Skogerboe	Clemmence	actual
24.49	12	4.1	0.3	2.1	11.1	9.89	9.89	132.34	105.7	115.2	115.29	640	120	46.8	36.41	17.42	76.27
23.17	3.9	10.4			10.13	10.13	125.47	75.33	48.42					35.52	19.25	79.33	
19.12	3.2	10.4			11.03	11.03	170.35	129	48.42					32.58	17.11	83.08	
24.49	17	4.1	0.2	1.5	11.1	10.95	10.95	72.26	146	115.29	115.29	640	120	51.73	52.46	31.74	79.32
23.17	3.9	10.5			11.21	11.21	60	193.3	53.51					51.18	40.44	49.75	
19.12	3.2	10.5			12.18	12.18	110.70	182.3	53.51					46.93	26.42	78.33	
24.49	26	4.1	0.2	1	11.1	8.74	8.74	51.58	43.12	115.29	115.29	640	120	58.26	81.87	44.49	57.84
23.17	3.9	10.5			8.96	8.96	59.20	52.40	60.25					79.86	40.96	48.92	
19.12	3.2	8.6			9.75	9.75	94.17	79.67	67.69					73.19	31.14	65.95	

Statistic the advance time (Calculated error %values are 0.039, 0.93 and 0.93forMuskingum,skogerboe and Clemmence models respectively), Cut- back flow rate (Calculated error %values are 1.69, 0.69 and0.94forMuskingum,skogerboe and Clemmence models respectively), the opportunity time (Calculated error %values are 0.039, 0.039 and0.81forMuskingum,skogerboe and Clemmence models respectively).

5.3.3 Efficiency of the Three Models and Observed:

Figure (5-2) represents the relationship between the cut-back irrigation (actual), Skogerboe and Clemmence model. The Efficiency of the Skogerboe model is typical from actual while Clemmence and Muskingum models deviate a little. Statistical indicates that there is the error % (values are 0.92, 0.199 and 0.001 for Muskingum, Skogerboe and Clemmence models, respectively).

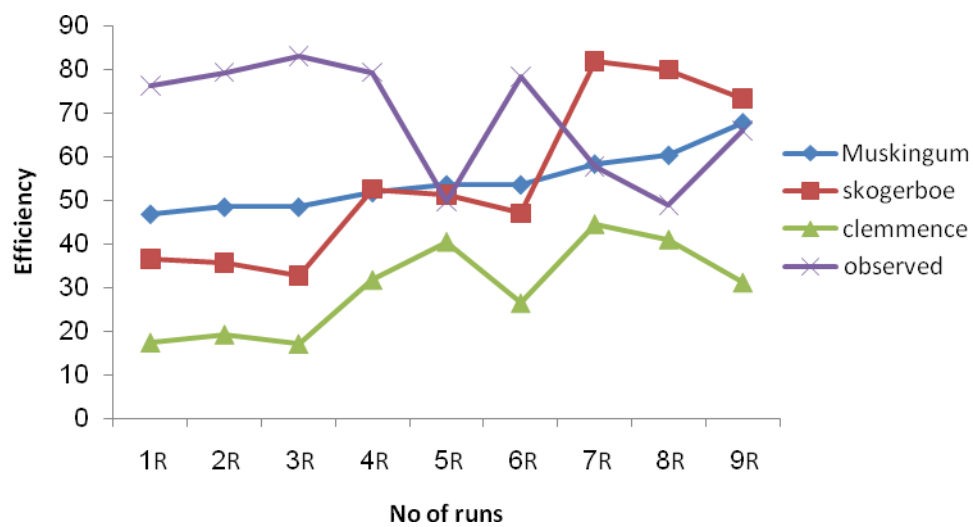


Figure (5.2): observed and predicted Efficiency

5.4 Model Application:

The input data collected from field is used as input in the developed Muskingum, Skogerboe and Clemmence models in order to estimate the application efficiency. And this data was input in Skogerboe and Clemmence models, to compared predicted output results(advance time, opportunity time, inflow rate, Cut- back inflow rate and application Efficiency)and % error of the program for the two models shows in table(5.2),(5.3)(5.4):

Table (5.2): Comparison predicted output results and % error of the program for the two models:

output	Clemmence developed model	Clemmence model	Std.Error
The opportunity time (top) min	640	124	0.81
Inflow rate Q, L/s	24.49	19.12	0.22
Cut- back inflow rate L/p	0.2	9.56	0.98
Slop m/m	26%	17%	0.54
Advance time (min)	51.59	11	0.79
Application Efficiency	44.49	89	0.50

Table (5.3): Comparison predicted output results and % error of the program for the two models

Output	Skogerboe developed model	Skogerboe model	Std.Error
The opportunity time (top) min	115.29	115.29	0
Inflow rate Q, L/s	24.49	24.49	0
Cut- back inflow rate L/p	1	0.35	0.65
Slop m/m	26%	26%	0
Advance time (min)	8.74	8.74	0
Application Efficiency	81.87	48.90	0.40

Table (5.4): Comparison predicted Muskingum developed model output results and % error of the program for the Skogerboe and Clemmence models

Output	Muskingum developed model	Skogerboe model	Std.Error	Clemmence model	Std.Error
The opportunity time (top) min	115.29	115.29	0	124	0.07
Inflow rate Q, L/s	19.12	24.49	0.22	19.12	0
Cut- back inflow rate L/p	8.6	0.35	0.96	9.56	0.10
Slop m/m	26%	26%	0	17%	0.35
Advance time (min)	9.75	8.74	0.10	11	0.11
Application Efficiency	67.69	48.90	0.28	89	0.24

CHAPTER SIX

CONCLUSIONS AND RECOMENDATIONS

6.1 Conclusion

In this study, using two types of inflow regimes include continuous flow and cut-back.

The present irrigation practices under field condition were evaluated and defined with the objective of improving the water management at the individual field level. From the result high application achieved at S1,Q1.

In the present study, three mathematical models compare with field data for the conventional irrigation including Muskingum, Skogerboe and Clemmence Models. Were tested by using the data from several field experiments for furrow irrigation systems. From the result the following conclusion can be drawn. The hydraulic behavior at the develop model don't significant difference between actual field data and Muskingum model for the application efficiency.

Comparison of the actual field experiment with results of simulation model for furrow show that in figure (3.1), (3.2) and (3.3).

There was no difference in the prediction of the advance and recession times between the Skogerboe and Muskingum approaches of the software.

The (Muskingum and Skogerboe) models the predicted recession times were several times smaller than the recession times measured, but the Clemmence model the predicted recession times were several times longer than the recession times measured.

- To increasing irrigation efficiency in furrow irrigation used cut-back technique .The cut-back technique achieved high efficiency compare with conventional irrigation show in figure (4.2). From the result high application achieved at S1, Q3.
- Tow mathematical models compare with field data for the cut-back technique including Skogerboe and Clemmence models ,the hydraulic

behavior at the develop model don't significant difference between actual field data and Skogerboe model for the application efficiency.

- Building new model to modify the Muskingum model by using the cut back procedure.
- Modify the Clemmence and Skogerboe cut back models by using the volume of surface storage equation to calculate the value of C.

6.2 Recommendation

1-Selection cutback technique to achieve high efficiency comparison with conventional irrigation.

2-Under the existing system of irrigation the developed model can be implemented to improve design and operation of on farm system.

3-To Simulate of irrigation performance the best choice is using the Skogerboe developed model for cut back.

4-For future research to improve the developed model by using surge irrigation.

REFERENCES

- Abdel Wahab**, D.M. 2005, Evaluation, Prediction and optimization of long furrow irrigation under Kenana conditions. PhD Dissertation, water Management and, irrigation Institute, University of Gezira, Wad Medani,Sudan. 135:413-420.
- Ahmed Eldeiry**, (2004).Furrow irrigation system design for clay soils in arid regions. ph.D. candidate ,department of civil engineering ,Colorado state university.Hydrology days (2004)
- Ahmed, M. S.** (2002).Application of the long furrow irrigation system in Kenana Sugarcane plantation. M.Sc thesis Faculty of Agriculture Department of soil science, University of Khartoum. PP: [180].
- Alazba, A.A.** (1999). Explicit volume balance model Solution. J. of Irri.and Drainage Eng. Vol. 125(5): 273-279.
- ASAE**, 1991: Evaluation of Furrow Irrigation Systems.- ASAE EP419, Standards 1991, American Society of Agricultural Engineers, St. Joseph, MI, pp. 644649.
- Azevedo, C. A. V.;** R. V. Pordeus; J. L. Silveira; V. L. ALima-de and J. Dantas, Neto (2003). Influence of the required water depth on the furrow irrigationperformance. IRRIGA 2003, 1, 51-62.
- BauderTA ,waskow RM** (2003) Evduation of various surface irrigation numerical models.JIrrig Drain Eng 129 :208-213.
- Bautista,E.,and wallender,w.w.**1985."spatial variability of infiltration in furrow",Trans.ASAE.28(6),1846-1851,1855.

- Burguete J., N. Zapata, P. García-Navarro, M. Maikaka, E. Playan, and J. Murillo.** 2009b. Fertigation in furrow and level furrow system. II. Model calibration, and practical application. *J. Irrig. Drain. Eng.* ASCE135:401-412.
- Burt, C. M., Clemmens, A. J., Bliesner, R. D., Merriam, J. L., and L. A. Hardy,** 2000: Selection of irrigation methods for agriculture.- ASCE On-Farm Irrigation Committee Report, ASCE, Reston, VA 129 pp.
- Childs,J.L.,wallender.W.W.,and Hopmans,J.W.,**1993."spatial and seasonal variation of furrow infiltration". *Journal of Irrigation and drainage Engineering,ASAE*,119(1) ,74-90
- Clemmens, A. J., W. R. Walker, D.D. Fangmeier, and L. A. Hardy.** 1998. "Design of surface systems". Chapter 14 In: *Design and Operation of FarmIrrigation Systems. ASAE Monograph Number 3 (2nd Edition)*, R. L. Elliott, ed. St. Joseph, Michigan.
- Clemmens, A.J.** (2007). Simple approach to surface irrigation design: Spreadsheet applications Sakia.orge-publish, <http://www.sakia.org/ej/w>, e-Journal of Land and Water, 2007, Vol. 1: 20-43.
- Clemmens, A.J.** and A.R. Dedrick, 1982: Limits for practical level-basin design.- *J. Irrig. Drain. Div.Am. Soc. Civ. Eng.* 108(IR2), 127 141.
- Clemmens, A.J.,** Camacho, E., and T.S. Strelkoff, 1998: Furrow irrigation design with simulation.-p.1135-1140. In *Int. Conf. on Water Resources Engineering Proceedings*, Memphis, TN. Aug. 3-7, 1998.
- Clemmens, A.J.;** Z. EI-Haddad and T.S. Strelkoff (1999). Assessing the potential for modern surface irrigation in Egypt. *Transaction of the ASAE*, Vol. 42(4): 995-1008.Delhi, India.

- Eldeiry, A. A.;** L. A. Garcia, A. S. A. El-Zaher, M. El-SherbiniKiwan.(2004). Furrow irrigation system design for clay soils in Arid regions. Hydrology Days.,Colardo State Univ., USA, P.42-54.
- Eldeiry, A., L. García,** H. El-Zaher, and M. Kiwan. 2004. Furrow irrigation system design for clay soils in arid .
- El-Dine, T. G.;** *Hosny, M. M. (2000). "Field evaluation of surge and continuous flows in furrow irrigation systems". Water Resources Management 14 (2): 77–87.*Engineering Department. Utah State University, Logan, Utah.
- FAO,** 1993. Annual review “A summary of the organization activities during 1993”.Food and Agriculture Organization of the United Nation FAO, Rome, Italy.
- Feyen, J., and D. Zerihun.** 1999. Assessment of the performance of border and furrow irrigation systems and the relationship between performance indicators and system variables. Agr. Water Manage. 40:353-362.
- Greminger,p.J.,Sud, y.k., and Nielson,DR.,** 1985."spatial variability in hydraulic corduetivity on water table drawdown. Transactions of the ASAE:40(2):371-375.
- Hanson B** (2005) Irrigation system design and management:impli-cation forofficient nutrient use.western Nutrient management conference,vol 6,salt lake city, UT,USA.
- HamedandAbdolmajid**(2011)Field Evaluation of Various Mathematical Modelsfor Furrow and Border Irrigation Systems.Department of Irrigation and Reclamation Engineering., University College of Agricultureand Natural Resources, University of Tehran, Karaj, Iran.Soil& Water Res., 6, 2011 (2): 91–101.

- Hillel, D., and P. Vlek.** 2005. The sustainability of irrigation. *Adv. Agron.* 87:55-84.
- Holzapfel, E.A., M.A. Mariño,** and J. Chávez-Morales.1984. Comparison and selection of furrow irrigation models.*Agr. Water Manage.* 9:105-125.
- Holzapfel, E.A., y J.L. Arumi (eds.)** 2010. Tecnología de manejo de aguas para una agricultura intensiva sustentable.209 p. Editorial Universidad de Concepción, Concepción, Chile (In press).
- Hsiao, T., P. Steduto, and E. Fereres.** 2007. A systematic and quantitative approach to improve water use efficiency in agriculture. *Irrig. Sci.* 25:209-231.
- Jurriens M., Zerihun D., Boonstra J., Feyen J.** (2001): SURDEV: Surface Irrigation Software, Design, Operation, and Evaluation of Basin, Border, and Furrow Irrigation. International Institute for Land Reclamation and Improvement, ILRI, Wageningen.
- Kennedy, D.N.** 1994: California Water Plan Update Vol. 1.- State of California Department of Water Resources, Sacramento, CA. 398 p.
- Khan, S., R. Tariq, C. Yuanlai, and J. Blackwell.** 2006.Can irrigation be sustainable? *Agr. Water Manage.*80:87-99.
- Kostiakov, A. V.** 1932. On the dynamics of the coefficient of water-percolation in soils and on the necessity for studying it from a dynamics point of view for purposes of amelioration. *Trans. Sixth Comm. Int. Soc. Soil Sci., Part A,* pp. 17-21.
- Kumar, R., and J. Singh.** 2003. Regional water management modelling for decision support in Irrigated agriculture. *J. Irrig. Drain. Eng. ASCE* 129:432-439.

- Lazarovitch, N., A.W. Warrick, A. Furman, and D. Zerihun.** 2009. Subsurface water distribution from furrow described by moment analyses. *J. Irrig. Drain. Eng. ASCE* 135:7-12.
- Lehrsch, G.A., R.E. Sojka, and D.T. Westermann.** 2000. Nitrogen placement, row, spacing, and furrow irrigation water positioning effects on corn yield. *Agron. J.* 92:1266-1275.
- Lewis M. K.** 1937. The rate of infiltration of water in irrigation practice. *Trans Am Geophys Union 18th Annual Meeting.* pp. 361-368.
- M. Mirabzadeh Associate Professor of Irrigation and reclamation Eng. Dept. Tehran University. Karaj. EFFECT OF CHANGING DISCHARG ON ADVANCE RATE ON SURGE IRRIGATION.**
- M. Sohrabi Associate Professor of Irrigation and Reclamation Eng. Dept. Tehran University. Karaj. myousef@ut.ac.ir, EFFECT OF CHANGING DISCHARG ON ADVANCE RATE ON SURGE IRRIGATION.**
- M.Ghobadi Nia Ph.D Student Irrigation and Reclamation Eng. Dept. Tehran University. Karaj. mghobadi@ut.ac.ir , mahdi.ghobadi@gmail.com, EFFECT OF CHANGING DISCHARG ON ADVANCE RATE ON SURGE IRRIGATION.**
- Mailhol, J.C.; M. Baqri and M. Lachhab (1997).** Operative irrigation modeling for real-time applications on closed-end furrows. *Journal of Irrigation and Drainage*, Vol. 11, pp: 347-366.
- Mohammed, H. I.(1982)** Hydraulics of long furrow irrigation with reference to Rahad Irrigation Project M. Sc. Thesis Faculty of Agriculture. University of Khartoum.

- Nielsen, D.R., J.W. Bigger** and **K.T. Erh.** 1973. spatial variability of field-measured soil-water. properties. *Hilgardia* 42(7);215-259.
- Oyonarte, N.A. and L. Mateos** (2003). Accounting for soil variability in the evaluation of furrow irrigation. *Transactions of the ASAE*, Vol.46(1): 85-94.
- Popova, Z., D. Crevoisier, P. Ruelle, and J.C. Mailhol.** 2005. Application of Hydrus2D model for simulating water transfer under furrow irrigation – Bulgarian case study in cropped lysimeters on Chromic Luvisol.p. 1-13. ICID 21th European Regional Conference, Frankfurt, Germany. 15-19 May. International Commission on Irrigation and Drainage (ICID), Newregions. *Hydrology Days* 42-53.
- Rice, R.C., D.J. Hunsaker, F.J. Adamsen, and A.J. Clemmens.** 2001. Irrigation and nitrate movement evaluation in conventional and alternate–furrow irrigated cotton. *Trans. ASAE* 44:555-568.
- Sarwar, A., W.G.M. Bastiaanssen, and R.A. Feddes.** 2001. Irrigation water distribution and long-term effects on crop and environment. *Agr. Water Manage.* 50:125-140.
- Skogerboe G.V. ,** 1969. Analysis of small water management structures in irrigation distribution system summary technical completion report. US.Clearinghouse for federal scientific and technical.Information.PB. 189391.logan, Utah state university.
- Soares, A. A.; R. A. Oliveira; M. M. Ramos; A. Rasch and J. H. T. D-Avila** (2000). Cutting-back furrow irrigation design - a new methodology. 20: 2, 119-129.
- Souza, F.** 1981. Nonlinear hydrodynamic model of furrow irrigation. Ph.D. Thesis. University of California, Davis, California, USA.

- Walker, W.R., and G.V. Skogerboe. 1987. Surface irrigation, Theory and practice. 386 p. Prentice-Hall, Englewood Cliffs, New Jersey, USA.
- Walker, W.R. 1989. Guidelines for designing and evaluating surface irrigation systems. Irrigation and Drainage Paper 45. FAO, Rome.
- Walker, W.R. 1993. SIRMOD. Surface Irrigation Simulation Software (Users Guide). Biological and Irrigation.
- Walker, W.R. and G.V. Skogerboe. 1987. Surface Irrigation: "Theory and Practice". Prentice-Hall Inc., Englewood Cliffs, New Jersey. 386 pp.
- Walker, W.R.; Skogerboe, G.V. (1987). *Surface irrigation: Theory and practice*. Prentice-Hall, Englewood Cliffs.
- Waskom RM (1994) Best management practices for irrigation. Bulletin H X CM-173, Colorado state university.
- Wilk, O.D. and Smerdon, E.T. (1965). A hydrodynamic determination of cut-back stream size for irrigation furrows. Trans. ASAE. 12. No. 5 paper 634-637.
- www.fao.org/docrep/t0231e03.htm. Food and Agriculture Organization FAO (2007). Food and Agriculture Organization. Water for food water for life. A Comprehensive assessment of water management in agriculture
- Zerihun, D., A. Sanchez, and K.L. Farrell-Poe. 2001. Analysis and design of furrow irrigation systems. J. Irrig. Drain. Eng. ASCE 127:161-167.