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A Computer Program for Agr-machinery Cost Estimation

برنامج حاسوبي لتقدير تكلفة الالات الزراعية

By

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Dec 2005

A thesis submitted in Partial Fulfillment of the Requirement for the Degree of Master of science in Agricultural Engineering

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December- 2015

Dedication

To my family,

Best friends and my colleagues

With love and respect

ACKNOWLEDGEMENT

I am greatly indebted to Dr. Mysara Ahmed Mohamed, my supervisor, for his guidance and support.

Deep thanks and gratitude are extended to Rainfed General Administration- South Kurdofan State, specially (Nizar & Hussein) for their assistance and support.

Thanks are also extended to teaching staff of Sudan University of Science and Technology college of Agricultural Studies department of Agricultural Engineering and to my colleagues.

Also, I want to express my deepest thanks to all who had been of great help and assistance

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Abstract

The computer program for machinery cost estimation (CP-Mace) is a Windows based software program that can be run on a Windows XP or higher system on computers. It is a user-friendly interactive program written in VISUAL BASIC 6 programming language for machinery management. It allows the user to interact with it by entering the required inputs and it will carry out the interactive calculations. The program enables the user to print out the output which is displayed on the screen.

The CP-Mace can predict the effective field capacity (EFC) for different implements (fed/hr- ha/hr), calculates the total cost for tractor and agricultural machine separately, calculate the total cost for the agricultural operation per feddan and per hour and finally estimates total annual costs of operating machinery for different field crops.

CP-Mace was successfully validated statistically (t-test) with reference to Habeela agricultural scheme data season 2014/2015 and Iowa State University model. The comparison reveals that there were no significant differences.

The results indicated that the CP-Mace program could be applied to any real-life case successfully and with confidence.

المستخلص

تم اعداد برنامج حاسوبي لتحديد تكلفة تشغيل الالات الزراعية (CP-Mace) القائم على بيئة ويندوز (XP) أو على الأنظمة الحديثة. وهو برنامج سهل الأستخدام كتب بلغة VISUAL BASIC6 وذلك لادارة الالات الزراعية،يتيح للمستخدم ادخال البيانات المطلوبة لمعالجتها حسابياً ، كما يمكن المستخدم من استخراج وطباعة المخرجات التي تظهر على الشاشة مباشرة.

برنامج CP-Mace يتنبأ بالسعة الحقلية الفعلية لمختلف الالات الزراعية (فدان/ ساعة- هكتار/ ساعة). ويحسب التكاليف الكلية لتشغيل الجرار والالة كل على حدة، كما يتنبأ البرنامج بتكلفة العملية الزراعية للفدان وفي الساعة، كما يقوم البرنامج بايجاد التكاليف الكلية السنوية للعمليات الزراعية لمختلف المحاصيل الحقلية.

تم التحقق من صحة ودقة البرنامج بالتحليل الاحصائي (اختبار T) بمقارنة احصائيات مشروع هبيلا الزراعي 2015/2014 وانموذج جامعة ولاية أيوا الأمريكية. أشارت المقارنة أنه لا توجد فروق معنوية. كما أشارت نتائج برنامج CP-Mace أنه يمكن تطبيقه على أرض الواقع بكل نجاح وثقة.

CHAPTER ONE

INTRODUCTION

1.1 Background:

Farm machinery plays an important role in agricultural production. It contributes a major capital input cost in most agricultural business. Farm machinery offers several potential improvements for farming system such as increased land and labor productivity, reduction of risk, increase of food quality and save of time.

Machinery management deals with determining the costs for performing a particular operation, selecting the best size and type of equipment for each application, matching machinery component in a complete system, establishing an effective maintenance program determining the optimum age for replacing a particular machine and scheduling farm operation for the best use of the machine (Osman 2011).

One of the important influencing profits in farm business is the cost of owning and operating farm machinery.

Farm machinery cost is one of the few costs that good management can minimize and learning how to accurately estimate machinery costs will aid in cutting costs. Accurate costs estimate play an important role in every machinery management decision when to trade, which size to buy and how much to buy (Deer &Company 1997).

High costs of machinery reduce profitability of agricultural production. Reduction of costs may be obtained through good organization and management. It depends on economic analysis by using computer programs for calculating costs of farm machinery. Computer programs are being used to assist in decision making about how to manage machinery effectively and efficiently, based on the estimated total cost and number of crops to be grown. They are most useful when there is an interaction exchange of information during program operation between the computer and the program user.

1.2 Problem definition:

Agricultural machinery is a major component of agricultural business and agricultural development programs. Most of the management decisions for farm machinery involve an accurate knowledge of costs and the determination of field machinery cost of operations is dependent on so many factors that each farm's machinery system must be treated as special case, because the cost of machinery remains a significant portion of the cost of production of most food and agricultural crops.

Efficient machinery management requires accurate machinery data in order to meet projected work and to perform field operation at optimum time and at minimum cost.

In most of irrigated and rain fed schemes in Sudan there is a lack of machinery reliable data system concerning costs determination for different field operations, and there is no definite approach to evaluate the economic performance of agricultural machinery in these schemes. High costs of machinery reduce profitability of agricultural production, and reduction of costs may be obtained through good management.

Computer programs is becoming increasingly important and appropriate to assist farm machines managers in decision making concerning calculation of costs of farm machinery.

1.3 Study objectives:

The general objective of this study is to develop a user-friendly computer software program for machinery cost determination as an aid for farm managers and agricultural engineers. The specific objectives of this study are:

1- To determine machine performance (effective field capacity) in order to perform agricultural operation in it's specific time.
2- To determine the cost for the tractors and implement selected per hour and unit area.
3- To develop cost determination program for total field operation cost.
4- To evaluate the cost of using different machines with different tractor sizes.

CHAPTER TWO
LITERATURE REVIEW

2.1 Farm Machinery:

Farm machinery is an important element and fundamental for agricultural development and crop production in modern agricultural of many countries. The main objectives of the machinery are to reduce the difficulties of farm operations and to maximize production.

Farm machinery is any equipment that farmers use to till, plant, cultivate, and harvest, including tractors, ploughs, discs, planters and combines (Omer 2013).

Agricultural machines and implements are often classified according to their operational function and their relation to the power unit as fully mounted, semi-mounted and drawn (pull type) implements. The mounted and semi-mounted are attached to the three point hitch of the hydraulic system but the drawn one is attached to the tractor draw bar.

2.2 Machinery Management:

Machinery management is the section of the farm management that deals with the optimization of the equipment phases of agricultural production. It is concerned with the efficient selection, operation, repair and maintenance, and replacement of machinery (Ruiyin *et al* 1999).

Machinery management deals with determining the costs for performing a particular operation, selecting the best size and type of equipment for each application, matching machinery component in a complete system, establishing an effective maintenance program, determining the optimum age for replacing a particular machine and scheduling farm operation for the best use of the machine (Osman 2011).

Farm machinery has improved the efficiency of farming dramatically over the years, the cost of owning and operating machinery can be excessive. Proper management and optimization of mechanized equipment are essential for reducing costs and maximizing profits, (Hunt 2001).

The goal of the good machinery manager should be to have a system that flexible enough to adapt to a range of weather and crop conditions while minimizing long-run costs and production risks. To meet these goals several fundamental questions must be answered. First, each piece of machinery must perform reliably under a variety of field conditions or it is a poor investment regardless of its cost (Wayne2009).

Today tractor is one of the most important power sources in agriculture. Effect of tractor power on agriculture is considerable, the use of modern technology during latter decades resulted in rapid growth of farm production.

Agricultural machinery is an important factor in reducing labor demands for farming and making it available to develop other industries. The process of matching tractor and implement may start at either the implement or tractor in other words, a tractor may be selected to match the implement or vice versa. In either case, for proper matching, one should be able to accomplish the following:

A. Predict the draft and power requirement of the implement taking into consideration factors such as depth and speed of operation, implement width and soil condition.

B. Predict the tractive capability and the drawbar power that can be developed by the tractor taking into consideration the factors such as vehicle configuration, weight distribution interactive device type, and soil conditions (Grisso *et al* 2002).

2.3 Machinery performance

A rate of machine performance is reported in terms of quantity per time. Most agriculture field machine performance is reported as unit of area per time (hectare/hr, fed/hr). Processing equipment performance is usually expressed as bushels or tones per hour. Such performance figures are properly called machine capacity.

Hunt (2001) reported that the capacities just calculated are theoretical capacities as distinguished from effective capacities. It is usually not possible to operate machine continuously nor at their rated width of action. Therefore, their effective or actual capacities will be substantially less than their theoretical or potential capacities.

Hunt (2001) described the time elements that involve labor, that are associated with typical operation, and that should be included when computing the capacities or cost of machinery related to the various farm enterprises:

1. Machine preparation time for storage and shop work.
2. Travel time to and from field.
3. Machine preparation time in the field both before and after operation.
4. Theoretical field time.
5. Turning and crossing time (machine mechanisms are operating).
6. Time to load or unload machine.
7. Machine adjustment time.
8. Maintenance time.
9. Repair time.
10. Operator's personal time.

2.3.1 Field capacity:

It is defined as the actual rate of field coverage by machine based on the total field time and is expressed as area per time (Kepner *et al* 1978)

Field capacity refers to the amount of processing that a machine can accomplish hour of time. Field capacity can be expressed as a material or area, basis the field capacity is:

According to (Hunt 2001) and (Wayne2009), effective field capacity can be calculated by the formula:

$C = \frac{Swe}{c}$………………………………………………….. (2. 1)

Where:

C = capacity in acre per hour.

S = speed in miles per hour.

w = effective width of the implement, feet.

E= efficiency, percentage.

C= constant, 8.25

$$Ca = \frac{vw\eta f}{10} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.2)$$

On a material basis, the field capacity is:

$$Cm = \frac{vwY\eta f}{10} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.3)$$

Where:

$Ca \equiv$ field capacity, area basis, ha/hr (Caf when ηf=1.0)

$Cm \equiv$ field capacity, material basis, Mg/hr (Cmt when ηf=1.0)

The term theoretical field capacity is used to describe the field capacity when the field efficiency is equal to 1.0, i.e, theoretical field capacity is achieved when the machine is using 100% of its width without interruption for turn or other idle time.

2.3.2 Field capacity and efficiency:

Cross (1995) illustrated that the field capacity is calculated using width and speed of machinery, adjusted for field efficiency. Following the ASAE Agricultural Machinery Management Standard "field efficiency accounts for failure to utilize the theoretical operating width of the machine, time lost because of operator capability and habits and operating policy, and field characteristics. Travel to and from field major repairs, preventive maintenance, and daily service activities are not included in field time or field efficiency. Time lost in the field may be due to turning and idle time, material handling time, cleaning clogged equipment, machinery adjustment, etc.

2.3.3 Field efficiency:

The theoretical time, Tt, required performing a given field operation varies inversely with theoretical field capacity and can be calculated using the following equation:

$$Tt = \frac{A}{Cat} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

Where:

$Tt \equiv$ theoretical time required to perform operation, hr.

$Ca t$ ≡ theoretical field capacity, ha/hr.

A ≡ area to be processed, ha.

The actual time required to perform the operation will be increased due to overlap, time required for turning on the ends of the field, time required for loading or unloading materials, etc. Such time losses lower the field efficiency below 100%. The following equation stated by Srivasava *et al* (2006) can be used to calculate the field efficiency:

$$\eta f = \frac{Te}{Te+Th+Ta} \quad \text{.. (2.5)}$$

Where:

ηf = field efficiency.

Te = effective time.

Th, Ta = lost time.

Wayne (2002) defined that the field efficiency is the ratio between the productivity of a machine under field condition and the theoretical maximum productivity. Field efficiency accounts for failure to utilize the theoretical operation width of the machine; time lost because operator capability and habits and operating policy; and field characteristics. Travel to and from a field, major repairs, routine maintenance, and daily service activities are not included in field time or field efficiency. Field efficiency is not a constant for a particular machine, but varies with the size and shape of the field, pattern of field operation, crop yield, moisture, and crop condition.

2.4 Power matching with machine:

2.4.1 Selection of tractor size:

Deciding the tractor size is to provide enough power, to get all important field operations completed on time and to provide sufficient annual use, so that costs will be minimized (ASAE 1993). Traction force is usually used to predict the tractor power required to pull a machine.

Selecting power matching with machine is one of the important decision parameters of agricultural mechanization planning and machinery management. There are many factors affecting the selection such as agricultural condition, farming requirement of soil and crops, management scale and economic condition (Depeng *et al* 1983).

Under known soil condition, implement draft, and working speed the tractor size can be calculated as Draw Bar power (DBHP).

DBHP = $\frac{F*S}{C}$ ………………………………… (2.6)

Where:

DBHP = Draw Bar horse power.

F = Machine total draft KN (ibsf).

S = Speed Km (m/hr).

C= constant 3.6, (375).

2.4.2 Selection of machine size:

The selection must be based on selecting proper size of machine for the proper unit, getting sufficient capacity to get the needed work to be done within the allotted time period and getting the maximum net profit. Therefore the selection of machine (width) can be estimated from the EFC.

W = $\frac{EFC*C}{SE}$ …………………………………... (2.7)

Where:

W = Machine width (m).

EFC = Effective field capacity, ha (fed)/ hr.

C = Coefficient or constant.

S = Speed Km(m)/hr.

E = Field efficiency (%).

2.5 Machinery cost:

Pandey *et al (*1986) stated that one of the important costs influencing profit in farming business is the cost of owning and operating farm machines. Machinery cost estimates play an important role in every machinery management decision and is required to be made at the research and development stage in order to guide the designer. It is made for commercial units to establish the hiring rates and to determine the cost of machinery inputs for effective crop production management.

The cost of operation of a farm machine as influenced by the size, quality and physical condition of the machine needs to be estimated at the time of it‘ s selection. An effective farm manager must also know the principles of cost and apply them when deciding to buy, lease, rent or share machinery (Schuler and Frank 2006).

Hunt (2001) reported that most of the management decisions for farm machinery involve an accurate knowledge of costs. The determination of field machinery cost of operation is dependent on so many factors that each farm's machinery system must be treated as a special case, significant difference use of machines, price levels, energy required, fuel costs, and labor costs .

Cross (1995) mentioned that the machinery ownership costs represent substantial portion of production expenses for both crop and livestock producer. Row crop, fruits, vegetables, and forages are all produced using increasingly specialized machinery and equipment. Machinery costs are difficult to calculate, particularly for individual enterprises or operations.

Srivasava *et al* (2006) reported that machinery costs include costs of ownership and operation as well as penalties for lack of timeliness.

2.5.1 Machinery cost types:

Lazarus (2009) mentioned that machine costs are separated into time related and use-related categories. Use-related costs are incurred only when a machine is used. Overhead includes time-related economic costs: interest, insurance, personal property taxes, and housing.

Kepner *et al* (1978) reported that the total cost of performing a field operation includes charge for the implement or machine, for the power utilized, and for labor. Machine costs divided into two categories:

2.5.1.1 Fixed costs:

They occur regardless of whether or not the machine is operated and are known as fixed or overhead costs. They are related to machine ownership and they are including depreciation, interest on investment, taxes, insurance, and shelter. The total cost per unit of work (acre, hour, etc.) can be decreased considerably by increasing the amount of use to distribute the overhead costs.

a) Depreciation:

It is a cost resulting from wear, obsolescence and age of a machine. It is a reduction in a machine value over a period of time.

Depreciation cost is designed to reflect the reduction in value over a period of time (Kaul and Egbo, 1985). Hunt (1979) stated that depreciation measures the amount by which the value of a machine decreases with passage of time whether used or not. The value declines because:

- The parts of machine are the economically irreparable mechanisms in a machine, for example, the basic frame may be worn or distorted.
- The expense of operating the machine at its original performance increases as more power, labor, and repair costs for the same unit of output are required; repair and adjustment can renew the machine but at an increased rate of cost.
- A new, more efficient machine or practices become available. When this situation develops the existing machine is said to be obsolete. The existing machine may be functionally adequate but because of new technology it is uneconomic to continue to operate it.
- The size of the enterprise is changed and the existing machine capacity is not appropriate for new situation.

Hunt (1979) and Kepner *et al* (1982), mentioned the following methods for common use in determining the annual value of depreciation.

Estimate value method: may be realistic determination. The amount of depreciation is the difference between the value of the machine at the end of each year and its value at the start of that year. Obviously the validity of such method depends on how responsible the value was determined.

Straight line method: the annual depreciation charge is expressed by the following equation:

$$D = (P - S)/L \text{ .... } (2.8)$$

Where:

D ≡ depreciation.

P ≡ purchase price.

S ≡ salvage or selling price.

L ≡ time between buying and purchasing, (year).

For general application in which the actual value of (S) is not known 10% of the purchase price may be appropriate use (Witney 1988).

Declining balance method: A uniform rate is applied each year to the remaining value (include salvage value) of the machine at the beginning of the year. The depreciation amount is different for each year of the machines live.

The relationship is expressed by the following equation:

$$D = V_n - V_{n+1} \text{ .... } (2.9)$$

$$V_n = pu(1 - R)^n$$

$$V_{n+1} = pu(1 - R)^{n+1}$$

Where:

D ≡ amount of depreciation charge for year n+1.

n ≡ number representing age of the machine in year at beginning of year in equation.

V ≡ remaining value at any time.

R ≡ ratio of depreciation rate used, normally between 1 and 2, for used machines the maximum rate is R =1.5.

Sum of year digits method: the digits of the estimate number of year of life are added together. This sum is divided into the number of years of life remaining for the machine including the year in equation. Amount of depreciation charge each year is the fractional part of the difference between purchase price and the salvage value:

$D = \frac{L-N}{YD}(P - S)$ .... (2.10)

Where:

D ≡ annual depreciation.

YD ≡ sum of year digits.

N ≡ age of the machine in years at the beginning of the year in equation.

L ≡ economic life in year.

P ≡ purchase price.

S ≡ salvage value or selling price.

The sinking-fund method: Hunt (1979) considered sinking fund method as a 5^{th} method, used by engineering economists. This method considers the problem of depreciation as one of established fund that will drew compound interest. Uniform annual payments to this fund are of such a size that by the end of the life of the machine, the funds and their interest have accumulated to an amount that will purchase another equivalent machine.

Depreciation and inflation rate:

The replacement of any machine is based on the accumulated values of money which may be not enough to purchase a new machine due to increase or decrease in the inflation rate. According to (Dahab 2000) the purchase price will be affected directly if the inflation rate is increases by more than 10%.

Kaul and Mittal (1984) suggested an equation combining the purchase price and the future price of a machine as follows:

$F = Pu(i + 1)^n$ .... (2.11)

Where:

F ≡ future value.

Pu ≡ purchase price.

i ≡ Constant inflation rate.

i ≡ Machine life.

Also, they suggested the effect of the inflation on the straight line method for determining depreciation as follows:

$$Dn = \frac{n}{L}(Pu(i + 1)^n - sa) \quad \text{.............................} \quad (2.12)$$

$$Cn = (Pu(i + 1)^n = DN$$

$$Du = dn - (cn - 1)$$

Where:

Dn ≡ accumulate depreciation to the year.

N ≡ number of year after the purchase price.

L ≡ machine life in year.

Sa ≡ salvage value of the machine.

Cn ≡ remaining value of the machine after n year.

Du ≡ depreciation value of the machine after the year.

b) Interest on investment:

Hunt (1979) reported that interest on investment in a farm machine is usually cannot be used for another productive enterprise. The suggested interest rate is 8%. The amount interested in a machine is greater during its early life than during later years similar to depreciation.

O'Callaghan (1990) and Winteny (1989) stated that, on calculating interest on a capital invested in the machine, it is customary to choose a constant rate of interest over the life of the machine and to calculate interest charged on the average investment in the machine during each year of its life. This can be shown be the following equation:

$$I = [\frac{(P+S)}{2}]Xr \quad \text{..............................} \quad (2.13)$$

Where:

I ≡ annual interest charge.

r ≡ rate of interest.

P ≡ purchase price.

S ≡ salvage value or selling price

c) Taxes:

Hunt (1979) assessed the annual cost of taxes to be about 1-5% of the purchase price when spread over 10-year life. In Sudan, taxes are about 1-5% of purchase price according to Ministry of Agricultural and Animal Resources (M.A.A.R) Khartoum State (1997).

d) Shelter:

Liljedhal *et al* (1979) found that a suitable shelter can be constructed and maintained for about 1% annually of the original cost stored equipment.

ASAE (1997) suggested an annual rate of shelter cost as 0.75% of the purchase price.

e) Insurance:

Hunt (1979) assessed that annual charge for insurance would be 0.25% of the original price. Liljedhal *et al* (1979) reported that the tractor may be covered by insurance, or the owner may select to carry the risk himself. They assumed that the annual charge for insurance would be 0.3% of the original cost. In Sudan, insurance is estimated at about 0.5% of the original cost (M.A.A.R) Khartoum state (1997).

ASAE (1983) stated that if the actual data of taxes, shelter, and insurance are known, the following percentages can be used, taxes 1%, shelter 0.75%, and insurance 0.5% or a total 2% of the purchase price.

2.5.1.2 Operating costs:

Expenses for items such as repair, maintenance, lubrication, fuel, oil, and labor are increased as a result of actual use of machine. They are known as operating costs. They include those cost that are incurred as a direct result of a machine being used. These costs vary as machine use varies.

a) **Fuel**: fuel and lubrication costs can be figured either by the hour or by the acre with knowledge of (1) the fuel consumption rate/hour and(2) the number of acre complete in one hour.

$$\text{Fuel}\ \frac{cost}{acre} = \frac{consumption\ per\ hour}{number\ of\ acres\ \frac{completed}{hour}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.14)$$

Lazarus (2009) reported that fuel cost is calculated by multiplying the fuel consumption by the price of fuel, with fuel consumption assumed to be 0.044 gallons of diesel fuel per PTO horsepower- hour on average for each implement type. Fuel consumption per acre is averaged across sizes within a given implement type. All power units, tractors, combines, trucks, etc., use diesel fuel. Lubrication cost is assumed to be 10 percent of fuel cost.

b) **Lubrication**: according to Nebraska Tractor Test data, a general rule of thumb that is applied for estimating the cost of lubrication. For example, the rule of thumb that is applied for power machinery is 15% of fuel costs. For non-power equipment 5% of the purchase price.

c) **Labor**: is calculated using the cost of labor per hour. Labor charges should be included in machinery cost calculations and should cover the total cost of labor including the average wage rates as well as benefits, taxes, and payroll overhead costs paid to the machine operation. Labor hours per acre are based on field capacity of machinery. A labor adjustment factor is used to calculate total labor hours for machinery operation, including time for locating, hooking up, adjusting, and transporting machinery.

$$\frac{labor\ cost\ per\ acres}{hour} = wage/hour \times acres \times labor\ factor \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2.15)$$

Lazarus (2009) reported that labor is charged at an hourly wage rate, which includes 30 percent benefits. The skilled labor rate is generally used with the planting and harvesting equipment and sprayers. Labor per acre for an operation such as plowing or disking is calculated by using the work rate on the implement. Less labor per acre is used in a disking operation that covers more acres per hour than in a plowing operation. A small amount of extra labor is added over and above machine time to allow for downtime for tasks such as making adjustments and filling sprayers and planters. The labor adjustment ranges from 2 percent additional time for tillage to 33 percent for spraying.

d) Repair and maintenance: repairs are fixed costs in some respects and operating costs on other respect.

Srivasava *et al* (2006) reported that costs for repair and maintenance are highly variable depending on the care provided by the manager of the machine. Some expenditure will always be necessary to replace worn or failed parts and/or to repair damage from accidents. Repair and maintenance costs tend to increase with the size and complexity, and thus with the purchase price of the machine. The formula for repair and maintenance costs estimate total accumulated repair costs based on accumulated hours of lifetime use.

Lazarus (2009) reported that repair and maintenance calculations are based on American Society of Agricultural Engineers formulas. The total cost is then divided by accumulated hours to arrive at an average per hour cost estimate. The amount of annual use of a machine is an estimate of the number of hours a commercial farmer would use that particular machine in one year.

Kepner *et al* (1978) reported that the cost for repair per year would be 1% of the purchase price plus an additional 1% for mounting and dismounting or 2% per year.

Table (2.1). An example of average unit accumulated costs.

End of year	Remaining value	R&M costs	Depr.	Int.	Acc. Depr.	Acc. Int.	Acc. R&M	Total Acc. Costs $	Acc. Use, ha	Unit Acc. Costs, $/ha
1	2000	10	1000	200	1000	200	10	1210	100	12.10
2	1400	50	600	136	1600	336	60	1996	200	9.98
3	1000	70	400	96	2000	432	130	2562	300	8.54
4	700	100	300	68	2300	500	230	3030	400	7.58
5	500	200	200	48	2500	548	430	3478	500	6.96
6	350	300	150	34	2650	582	730	3962	600	6.60
7	225	350	125	23	2775	605	1080	4460	700	6.37
8	125	450	100	14	2875	619	1530	5024	800	6.28
9	100	550	25	9	2900	628	2080	5608	900	6.23
10	75	600	25	6	2925	635	2680	6240	1000	6.24

Source: ASAE (2001).

Hunt (2001) mentioned that in equation form the total cost equation:

$$AC = \frac{(FC\%)P}{100} + \frac{CA}{SWE}[(RPM\%)P + L + O + F + T] \ldots\ldots\ldots\ldots \quad (2.16)$$

Where:

AC ≡ annual costs for operating the machine, \$/yr.

FC% ≡ annual fixed cost percentage, decimal.

P ≡ initial purchase price of the machine.

A ≡ annual use in acres.

S ≡ forward speed, miles per hour.

W ≡ effective width of action of the machine, ft.

E ≡ field efficiency, decimal.

RM ≡ repair and maintenance costs, decimal of purchase price per hour.

L ≡ labor rate, \$/hr.

O ≡ oil cost, \$/hr.

F ≡ fuel cost, \$/hr.

T ≡ cost of tractor use by the machine, \$/hr.

(T = 0 if self-propelled).

Table (2.2) Remaining value groups, wear-out life, and total repairs to wear-out life.

Machinery	Remaining value & fixed cost group No.	Estimated wear-out life, (hrs)	Total repairs in wear-out life (% of list price)
Tractor			
Two-wheal dr.	1	12,000	100
Four wheal dr.	1	16,000	80
Tillage			
Moldboard pl	4	2,000	100
Offset disk	4	2,000	60
Tandem disk	4	2,000	60
Chisel plow	4	2,000	75
Subsoiler	4	2,000	75
Field culti.	4	2,000	70
Spring tooth	4	2,000	70
Rolling packer	4	2,000	40
Rotary hole	4	2,000	60
Rolling harrow	4	2,000	40
Row cultivar	4	2,000	80
Planting			
Planter	4	1,500	75
Grain drill	4	1,500	75
Harvesting			
Picker Sheller Combine	4	2,000	70
Pull type			
Self-prop. Mower cond.	2	2,000	60
Sickle	2	3,000	40
Rotary			
	4	2,500	80
	4	2,500	100
Rake	4	2,500	60
Baler			
Large rect.	3	3,000	75
Large round	3	1,500	90
Forage harv.			
Pull type	3	2,500	65
Self-prop.	3	4,000	50
Potato	4	2,500	70
Other			
Fert. Spreader	4	1,200	80
Boom sprayer	4	1,500	70
Blower	3	1,500	45
Wagon	4	3,000	80

(Source: 2006 ASAE Standards)

Table (2.3) List of field efficiency, suggest forward speed and timelines constants.

Machine	Field efficiency	Suggested speed (mph)	Timeliness factor
Moldboard Plow	0.7-0.9	3-6	0.000 – 0.010*
Chisel Plow	0.7-0.9	4-6.5	0.000-0.010
Disks	0.7-0.9	3.5-6.5	0.000-0.010
Field Cultivator	0.7-0.9	5-8	0.000-0.100
Roller Packer	0.7-0.9	4.5-7.5	0.000-0.010
Row Cultivator	0.7-0.9	3-7	0.011
Planter	0.5-0.75	4-7	0.005
Grain Drill	0.55-0.8	4-7	0.005
Picker Sheller	0.6-0.75	2-4	0.003
Combine	0.6-0.75	2-5	0.003
Mower-conditioner, Pull	0.75-0.85	3-6	0.010
Mower-conditioner, Rotary, Pull	0.75-0.9	5-12	0.010
Mower-conditioner, Self-propelled	0.7-0.85	3-8	0.010
Baler	0.6-0.9	2.5-8	0.028
Forage Harvester, Pull-type	0.6-0.85	1.5-5	0.028
Forage Harvester, Self-propelled	0.6-0.85	1.5-6	0.028
Boom Sprayer	0.5-0.8	3-7	0.011

(Source: 2005 ASAE standards)

* Tillage timeline factor is dependent on its effect on planting.

2.6 Computers and Agricultural Machinery Management:

Computer programs are being used to assist farm managers and scientists in decision making about how to manage and select their machinery effectively (Oskan *et al* 1989). Computer programs for machinery management are most useful when there is an interaction exchange of information during program operation between the computer and the program user. They are becoming increasingly important in making certain type of machinery management-decisions and employed in some large farming enterprises.

Eardley *et al* (1991) draws the attention to the fact that computers cannot be expert in the human source, in fact, an expert system is nothing more than a computer system, which possesses a set of facts about a particular area of human knowledge, and by manipulating those facts in line with programming, the computer is able to make useful inferences for the end user.

A crop production machinery system model was developed by Ismail (1994) as a computer interactive model based on the concept of expert systems, which allow the user to interact with the program.

The results showed that increasing the number of crops in a crop rotation reduces the machinery cost by increasing machinery utilization. The number of crops also affects the field time of operation.

Downs *et al* (1990) developed a computer program to provide information that a farmer would need in making a typical management decision for tractor-implement systems. Kotzabarris *et al* (1990) developed a software for cost effective farm machinery selection and management.

Alam and Awal (2001), developed a computer program to select the proper power level based on farm size, cropping pattern, cultural practices, crop yield, purchase price of machinery cost and value of crop. The program was designed in order to minimize the total cost, the computations were carried out with a computer program written in the Basic. It was found that the level of power varied with the size of the farm land and cropping patterns. They concluded that mono crop system power (energy) and power cost requirement are greater than that in multi task system.

The result of a model developed by Singh and Holtman (1989) for selecting machinery showed that farm size allowed machinery to be used more efficiently for a lower cost per unit area. As farm size increased, the machinery cost per unit area is decreased. As farm size was doubled the required set of all tractors and equipment increased by 30 to 40 percent.

Aderoba (1989) developed a farm machinery selection model which takes into account value and cost of production, the available machinery mix, timeliness of operations and capital limitations. In order to plan and design a farm mechanization system, Konaka (1987) developed a program using a personal computer, which involved a farm machinery data base, farm operation data base and farm machinery utilization planning program. The optimal machinery set were analyzed, and the cost analysis of farm machinery utilization planning was shown in tables for comparison and selection of the optimum machinery sets and labors for particular cultivation systems. Moreover energy analysis was also performed.

An economical approach to agricultural machinery management internet- seminar was presented on June, 4^{th} 1999 introduced 7 papers from 4 continents, and were followed by an open discussion live on the internet. The papers presented included matching tractors and implements, the economic way, planning a cost effective machinery system for a farm, cost components and the calculation of the cost of agricultural machinery activities, and management approach towards agricultural machinery.

Grzechowiak (1999) reported a review of the most popular numerical optimization methods used in the modeling and design of agricultural machinery and the selection of operational parameters.

A computer simulation model, written in Basic language was implemented to present a set of mathematical models for determining the combination of farm power and machinery size for each level of agricultural mechanization based on human muscle, animal and tractor as primary sources of farm power (Opera, 1998). The objective function was to minimize total annual cost. The overall model also estimated the number of manual labors required to accomplish all or some field operation.

A micro computer model for agricultural machinery management (MACHINER) was developed and published by (ASAE, 1991). The program consists of three modules: record keeping, cost estimation and machinery selection. Machinery management standards from the ASAE and a site- specific parameters provided the mathematical base for the model. The model was successfully implemented on a commercial production of agriculture operations in Honduras, Central America. Major attributes of the program include a user friendly interface, efficient record keeping, and adaptability to different conditions.

A computer program was developed for use by farmers and contractors by Vanhala and Jarvenpaa (1994) to determine cost of farm machinery and machine combinations. It can be used to calculate costs in terms of the farm`s utilization capacity or the amount of outside contract work required to make acquisition of the machine profitable. The program also provides the user with a summary of costs for a specified chain of machines or for the farm`s entire machinery stocks.

Improvements were made to the agricultural machinery cost analysis program developed at North Carolina State University (Sowell, 1992). The programming required to port the program to Microsoft Windows is described. Characteristics of agricultural software and the benefits of agricultural user interface are discussed.

A model for computing farm machinery system (Com Farms) was developed by Lazzari and Mazzetto (1996) to analyze the mechanization problems of Italian arable farms. Once a given crop rotation and a list of operations per crop are entered, the selection offers the user a machinery set (tractors and implements) where each machine is defined in terms of type, number and size. Com farms can be run on PC-DOS plate form, and also with interface for Microsoft Windows.

Abraham (1995) developed a computer program for calculation of the fixed and variable costs of the operation of agricultural machinery in the Czech Republic. A detailed introduction to the computer program for the calculation of operation costs of machinery is presented along with output samples for machines and machinery sets.

A computer model (MACHSEL) was used by a North Central Oklahoma farm in 1991 to select and evaluate machinery complements for the given farm. The model can be used to estimate the fixed and variable costs of each alternative.

A computer program developed in Spain in 1990 to calculate fixed and variable costs of agricultural machinery including fuel and lubricants consumption, tax and insurance, depreciation, storage, and repair and maintenance. Methods of calculating annual costs are outlined on the program (Maquinas, 1990).

A new method of agricultural machinery planning is detailed by Boletin (1990) showing the mathematical bases used. The computer system collects and quantified machines and implements and schedules their use to give the minimum costs of machineries.

A computer model developed by Kletka and Sestak (1990) can be used as an aid to select and evaluate alternative machinery complement to given farms. In addition it can be used to estimate the fixed and variable costs of each alternative.

Isik and Sabanci (1993) developed a computer model to select optimum sizes of farm machinery and tractor power based on farm size, cropping patterns, soil properties and climate conditions. The model was designed in order to minimize total cost of farm machines and tractor.

Hetz (1986) validated a computer model to aid the selection of field machinery for wheat production in Chile. The effect of cultivated area, tillage intensity and crop rotation upon machinery needs and production cost were analyzed. It was concluded that as the cultivated area increased the cost per hectare decreased, as tillage intensity increased the size of the machinery system and the cost per hectare also increased, and as the number of crops increased the machinery system and cost per hectare decreased.

Ismail (1998) developed Crop Production Machinery System (CPMS) model to predict the machinery requirements and to determine the cost of production. Three crops, five implements and one tractor were used on 242.3 ha farm to demonstrate cost analysis. For cost analysis he concluded that multiple crops in a rotation will increase machinery and tractor utilization, and reduce costs and increase profits. The results of the model also shows that there was a saving of 631.42$ per crop if the full cultivator was used in a multiple crops operation rather than for single cropping farm. A comparison for the tractor and machinery costs between single cropping farm and the same crops in a crop rotation shows savings of 5672$, 5262$, 4216.21$, for corn, beans and wheat respectively.

Field machinery requirements were calculated for cash crop production system using the computer model described by Singh, *et al* (1989). The cash crop production system considered included ten crop rotation and three tillage systems. The results reported include unit values of tractor power, harvesting capacity and total annual machinery related oils, fuel and man-hours of labor. It was found that crop rotations have a strong influence on field machinery requirements. Multi-crop balanced rotations increased machinery utilization and decreased machinery requirements on a unit crop area basis. Machinery investment, annual machinery related over single-crop rotations, machinery utilization can be increased by following multi-crop balance rotations, rather than single-crop rotation. The machinery investment decreases by as much as 40% and the annual machinery related costs decreased by 30%. The results also showed that tillage intensity influenced tractor power and fuel requirements by 35% and the related costs were generally less than 15% for multi-crop rotations.

Singh and Holtman (1989) developed agricultural field machinery model for multi-crop farms based upon field work specifications, field operations, calendar dates, machinery capacity relations and mix of field crops. The results showed that depreciation costs per hectare gave a high value (31.36$/ha) followed by repair and maintenance cost (18.65$/ha) and (14.55$/ha , 6.28$/ha) for labor cost and fuel and oil costs respectively. It was found that crop rotation have a strong influence on field machinery requirements. A balanced crop rotation increases machinery utilization and decreases machinery requirements, machinery investment, and annual machinery related costs on a unit crop area basis. Machinery utilization can be increased by following multi-crop balance rotation.

2.6.1 Programming language:

A programming language is an artificial language designed to communicate instructions to a machine, particularly a computer. Programming languages can be used to create programs that control the behavior of a machine and/or to express algorithms precisely.

The earliest programming languages predate the invention of the computer, and were used to direct the behavior of machines such as Jacquard looms and player pianos. Thousands of different programming languages have been created, mainly in the computer field, with many being created every year. Most programming languages describe computation in an imperative style, i.e., as a sequence of commands, although some languages, such as those that support functional programming or logic programming, use alternative forms of description.

The description of a programming language is usually split into the two components of syntax (form) and semantics (meaning). Some languages are defined by a specification document (for example, the C programming language is specified by an ISO Standard), while other languages, such as Perl 5 and earlier, have a dominant implementation that is used as a reference (http.//en.wikipedia.org).

Definitions:

A programming language is a notation for writing programs, which are specifications of a computation or algorithm. Some, but not all, authors restrict the term "programming language" to those languages that can express all possible algorithms. Traits often considered important for what constitutes a programming language include:

i. Function and target: A computer programming language is a language used to write computer programs, which involve a computer performing some kind of computation or algorithm and possibly control external devices such as printers, disk drives, robots, and so on. For example PostScript programs are frequently created by another program to control a computer printer or display. More generally, a programming language may describe computation on some, possibly abstract, machine. It is generally accepted that a complete specification for a programming language includes a description, possibly idealized, of a machine or processor for that language. In most practical contexts, a programming language involves a computer; consequently, programming languages are usually defined and studied this way. Programming languages differ from natural languages in that natural languages are only used for interaction between people, while programming languages also allow humans to communicate instructions to machines.
ii. Abstractions: Programming languages usually contain abstractions for defining and manipulating data structures or controlling the flow of execution. The practical necessity that a programming language

support adequate abstractions is expressed by the abstraction principle; this principle is sometimes formulated as recommendation to the programmer to make proper use of such abstractions.

iii. Expressive power: The theory of computation classifies languages by the computations they are capable of expressing. All Turing complete languages can implement the same set of algorithms. ANSI/ISO SQL and Charity are examples of languages that are not Turing complete, yet often called programming languages. (http.//en.wikipedia.org).

2.6.2 Visual Basic:

VISUAL BASIC is a high level programming language which is devolved from the earlier DOS version called BASIC. BASIC means Beginners' All-purpose Symbolic Instruction Code. It is a very easy programming language to learn. The codes look a lot like English Language. Different software companies produced different versions of BASIC, such as Microsoft QBASIC, QUICKBASIC, GWBASIC, and IBM BASICA and so on. However, people prefer to use Microsoft Visual Basic today, as it is a well developed programming language and supporting resources are available everywhere. Now, there are many versions of VB existing in the market, the most popular one and still widely used by many VB programmers is none other than Visual Basic 6. There are also VB.net, VB2005, VB2008 and the latest VB2010. Both VB2008 and VB2010 are fully object oriented programming (OOP) language.

VISUAL BASIC is a VISUAL and events driven Programming Language. These are the main divergence from the old BASIC. In BASIC, programming is done in a text-only environment and the program is executed sequentially. In VB, programming is done in a graphical environment. In the old BASIC, you have to write program code for each graphical object you wish to display it on screen, including its position and its color. However, In VB, it is possible to drag and drop any graphical object anywhere on the form, and to change its color any time using the properties windows.

On the other hand, because the user may click on certain object randomly, so each object has to be programmed independently to be able to response to those actions (events). Therefore, a VB Program is made up of many subprograms, each has its own program code, and each can be executed independently and at the same time each can be linked together in one way or another. (www.vbtutor.net/lesson1.html.)

With VB 6, it is possible to create any program depending on the objective. For example, for a college or university lecturer, can creates educational programs to teach business, economics, engineering, computer science, accountancy, financial management, information system and more to make teaching more effective and interesting. If you are in business, you can also create business programs such as inventory management system, point-of-sale system, payroll system, financial program as well as accounting program to help manage your business and increase productivity. (www.vbtutor.net.)

2.6.3 SPSS for Windows:

SPSS for Windows is a widely used statistical package of computer programs designed to generate descriptive statistics and to perform inferential statistical analyses, it provides a wide variety of data manipulation capabilities, file creation, graphics, and reports in addition to both simple and highly complex statistical procedures. Output comes with helpful plot/chart/graphics information. SPSS handles report writing, data file management, and data massaging through a variety of transformation techniques, the windows facilities of SPSS provide most of this through menu/dialog box selections.

SPSS (Statistical Package for Social Sciences) was originally designed to run on a mainframe computer with a file of command lines entered to generate and run procedures for output. SPSS for Windows uses the “point and click” method to automatically build a command file for the user; a file of these “built” commands (a syntax file) may be saved for future use. So, for basic statistical needs, SPSS for Windows automates any programming and program running.

A spreadsheet-like Data Editor window permits data defining, entry/editing, and IO management; an output Viewer window provides output review, editing, and IO management, For users who want to directly control what SPSS does, a Syntax Editor window allows direct program development and execution, Graphics can be achieved through the usual “menu/dialog box selections” or “interactively”. A Chart Editor window is available to edit graphics; A Draft Viewer window can alternately display the output, the statistics tables in typewriter format, the graphics remaining in high-resolution, and the table borders using box characters for clean, non-break lines.

Finally there are Help windows for both general help and help with a given dialog box. In addition, specific help for most items in a dialog box is available with a right click of the mouse (Computer Services 2001).

CHAPTER THREE
MATERIAL AND METHODS

3.1 Materials:-

1- A computer lap top Compaq Presario C700
2- Computer high level programming language of VB6 software.
3- Machine cost data.

3.2 Methods:-

Computer high levels programming language Visual Basic 6, and equations of machinery costs, were used for the design of an independent computer program for estimating the machinery costs.

3.3 Data collection:

The input data needed to estimate total cost per feddan and per hour and the total costs for all crop operations include:-

The purchase price of power unit (agricultural tractor) and agricultural machines, the interest rate, taxes, insurance and shelter percentage of purchase price were used to calculate the annual fixed costs of tractor and agricultural machines. The fuel consumption, oils, labor wage, repair and maintenance costs were needed to estimate the variable costs.

The primary machine data was collected from Habeela agricultural scheme, South Kurdofan State for season 2014/2015 (table 3.1). The secondary data was from the Central Trading Company (CTC) Sudan 2015 and Sudanese agricultural bank (Kuku branch – Khartoum North).

3.4 Computer program structure:

The program is button menu driven; it is an interactive program when the user firstly prompts to enter data in text boxes which are linked to other fields through equations for data processing. The second step after the user crop name directly the program go to crop operation (tillage, planting, cultivation, ….. etc.), in any operation the user must enter implement and tractor data and then the program will calculate the effective field capacity (EFC) and the cost for using tractor and machine selected by the user.

The built-in data were made available for machine performance. They appear to help the user in case of lacking of his own data.

The computer model interfaces were shown in figures (3.1 to 3.5)

The general features of the program are shown in Figure (3.6) and can be summarized as follows:

1- The program is menu driven and user interactive.
2- Input data entry is made directly to the screen. The user is given the option to enter his own data or to use available built-in data.
3- The general equations adopted in the program were based on the equation out-lined by ASAE (2005), and Hunt (2001).
4- Program output will be displayed on the screen, and it includes effective field capacity, agricultural operation cost per hour and per unit area and crop total agricultural operations cost. Print out of each output sheet is available.
5- The program is set up to handle many field crops, and maximum four main field operations (tillage, planting, cultivation and harvesting).

3.4.1 First computer model interface.

Include:

a) The name of computer model.
b) The name of designer and supervisor.
c) Date of computer model.
d) Computer model start button.
e) About computer model button
f) Start computer model button.

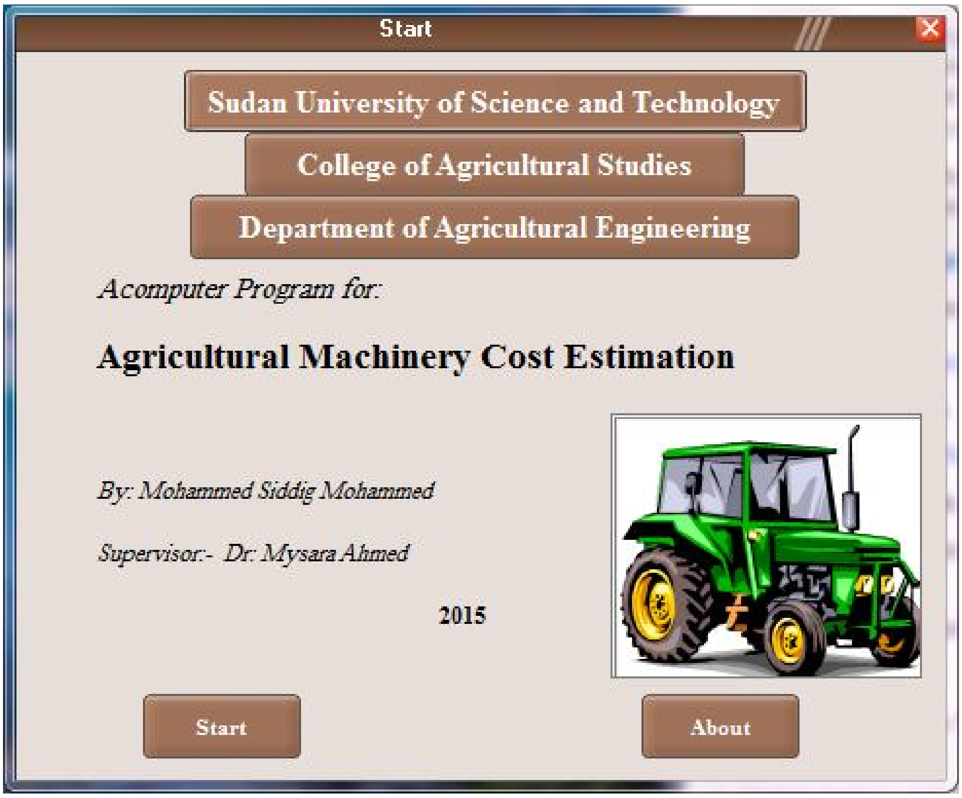

Fig (3.1). Interface of computer model.

3.4.2 Information about the computer model.

Include:

a) Information about computer model.
b) Back to previous interface.

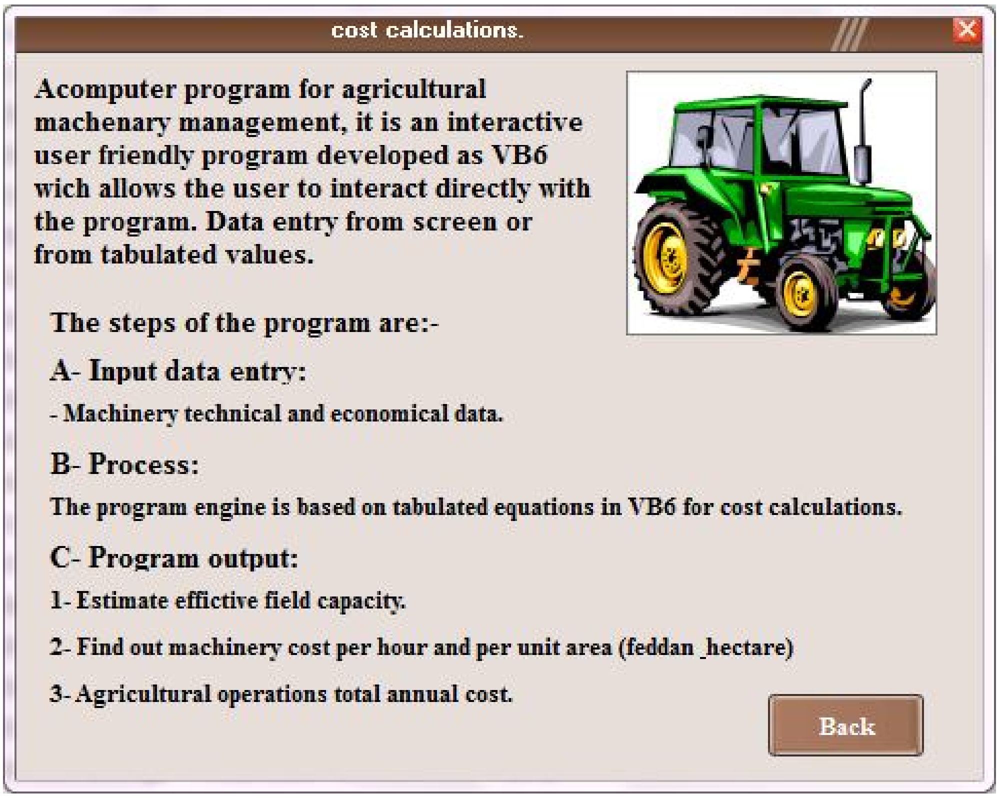

Fig (3.2). Information about computer model.

3.4.3 Input data interface.

Include:

a) Implement data.
b) Tractor data.
c) Calculate computer button.
d) Exit computer model button.

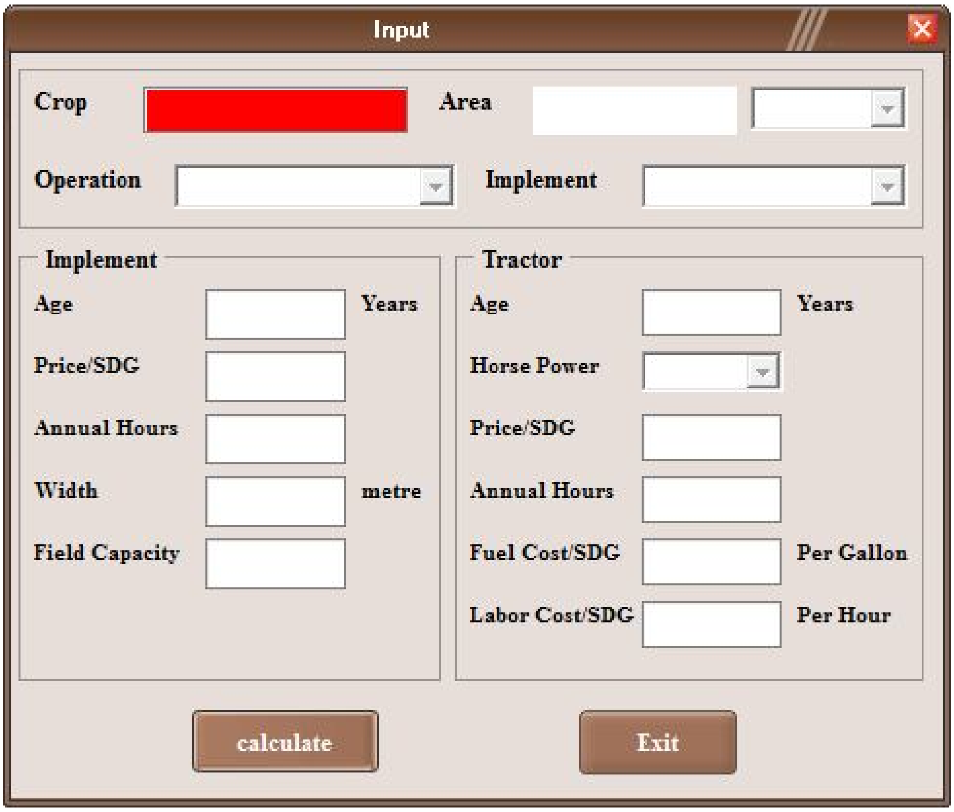

Fig (3.3). Input data on computer model

3.4.4 Output data interface.

Include:

a) Report computer model button.
b) New operation computer model button.
c) Exit computer model button.

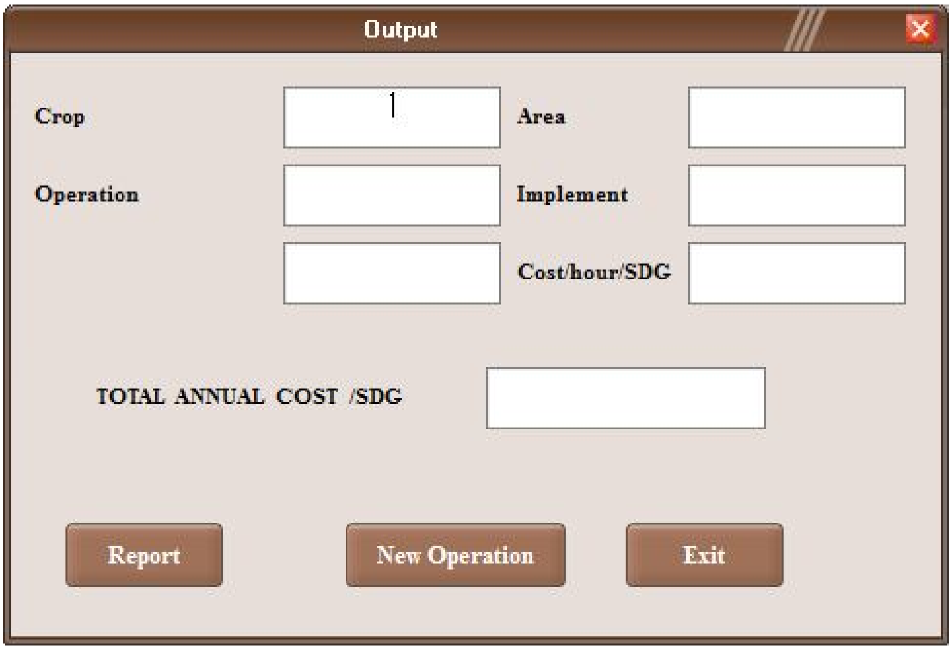

Fig (3.4) Output data on computer model

3.4.5 Report data interface.

Include:

a) Total data report.
d) Restart computer model button.
e) Print computer model button.
f) Exit computer model button.

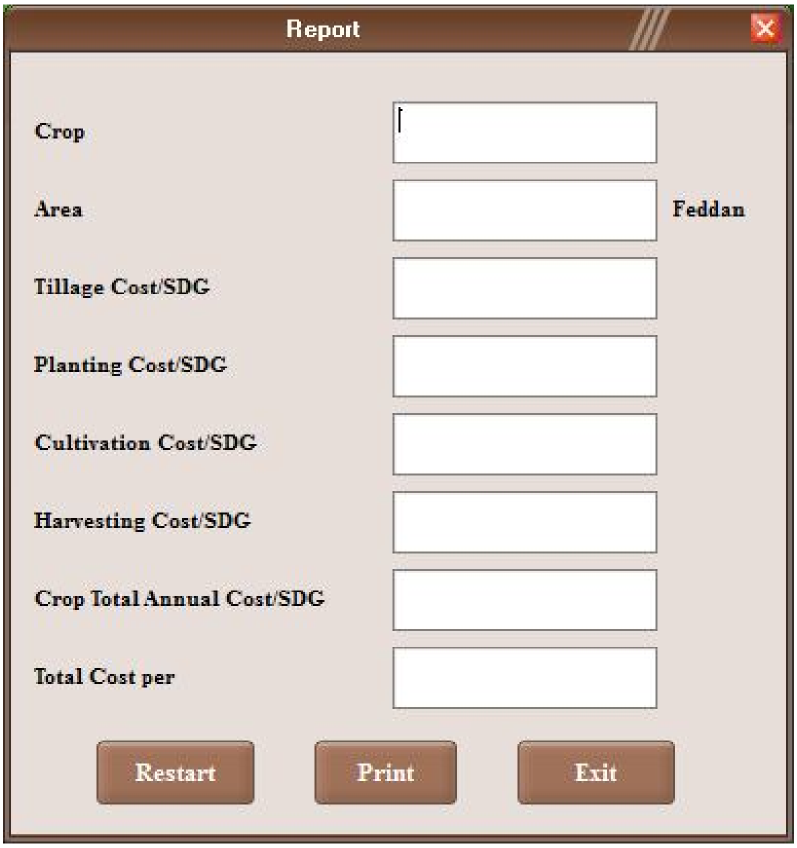

Fig (3.5) Report data on computer model

3.5 Computer model Engine:-

Calculations of Agricultural Machinery cost involve the following formulae's:

a) Field Capacity :

$C = \frac{Swe}{c}$………………………………………………….. (4. 1)

Where:

C = capacity in area per hour (fed/hr- ha/hr).

S = speed in km per hour.

w = effective width of the implement, meter.

E= effective efficiency, percentages.

C=constant, (4.2)- (10).

The width was input data entry. But the speed and the efficiency were built-in data.

b) Depreciation:

$D = (P - S)/L$ …………………………………………… (4.2)

Where:

D = depreciation (annual).

P = purchase price.

S = salvage or selling price.

L = time between buying and purchasing, (Age).

c) Interest on investment:

$I = \frac{(P+S)}{2} * r$……………………………….……………... (4.3)

Where:

I = annual interest charge.

r = rate of interest. (0.24 from Sudanese agricultural bank (Koko branch – Khartoum North for year 2015).

P =purchase price.

S = salvage value or selling price.

d) Taxes , Insurance and Shelter:

ASAE (1983) stated that if the actual data of taxes, shelter, and insurance are known, the following percentages can be used, taxes 1%, shelter 0.75%, and insurance 0.5% or a total 2% of the purchase price.

e) Fuel cost:
F= (0.044) hp*Gp (Lazarus 2009) ..……………… (4.4)
Where:
F = fuel cost per hour.
Hp = horsepower. (0.044) constant for diesel.
Gp= gallon price.

f) Oil and lubrication:
According to Nebraska Tractor Test data, 15% of fuel costs.

g) Labor cost:
From input data.

h) Repair and Maintenance:
R&M = (rm) pu ……………………………………….. (4.5)
Where:
R&M = Repair and Maintenance cost per year.
Rm = Repair and Maintenance factor.
Pu = purchase price.

i) Total annual cost for operating the machine:

$$AC = \frac{(FC\%)P}{100} + \frac{CA}{SWE}[(RPM\%)P + L + O + F + T] \ldots\ldots\ldots \quad (4.6)$$

Where:
AC = annual costs for operating the machine, \$/yr.
FC% = annual fixed cost percentage, decimal.
P = initial purchase price of the machine.
A = annual use in acres.
S ≡ forward speed, miles per hour.

W = effective width of action of the machine, ft.
E = field efficiency, decimal.
RM = repair and maintenance costs, decimal of purchase price per hour.
L = labor rate, $/hr.
O = oil cost, $/hr.
F = fuel cost, $/hr.
T = cost of tractor use by the machine, $/hr.
(T = 0 if self-propelled).

3.5 Computer model Assumptions:

1- The program employs international system units (SI).
2- It employs Sudanese local currency (SDG), without consideration to inflation rate in cost calculations.
3- It assumes a constant standard value for speed, efficiency and repair and maintenance factor for every agricultural machine.

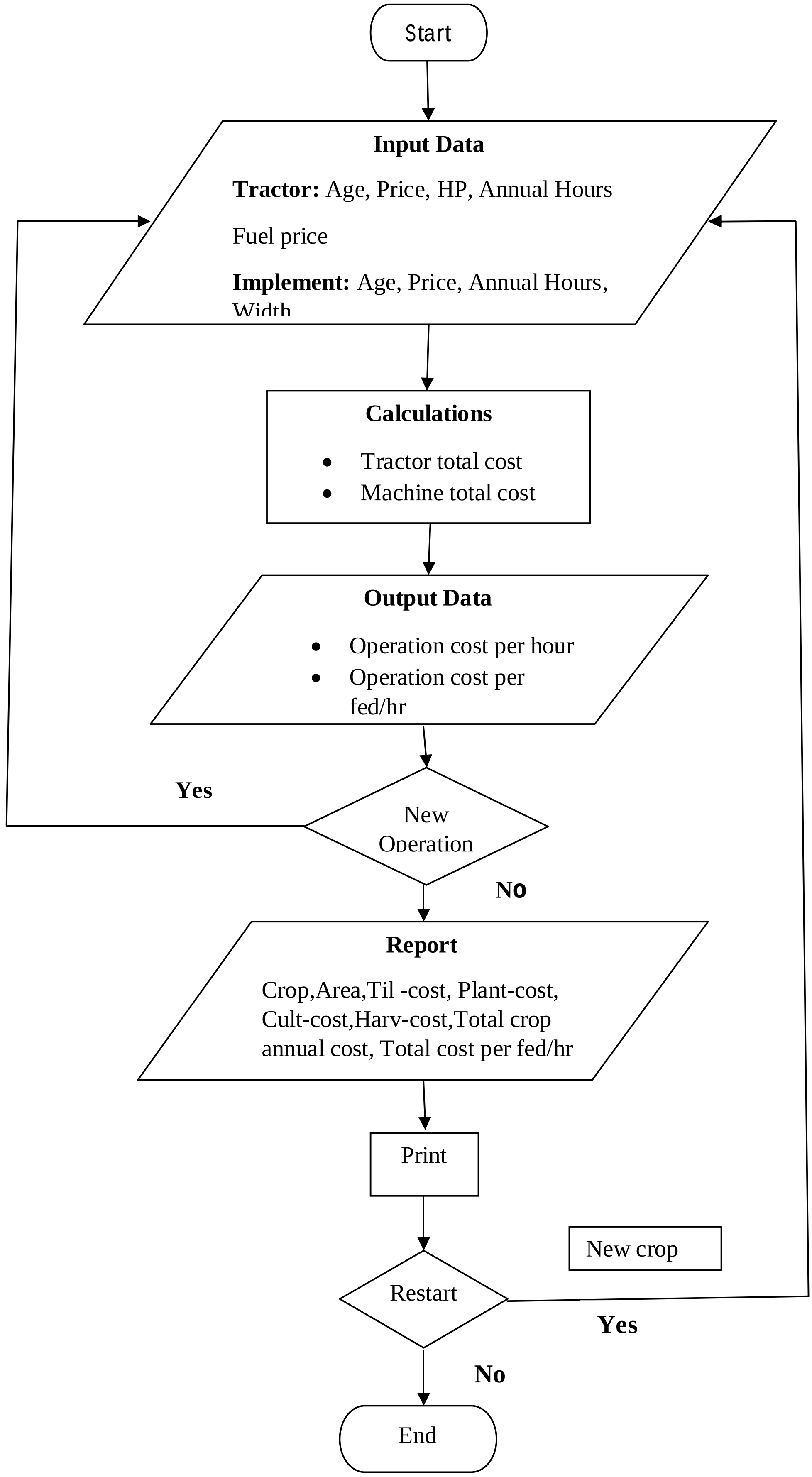

Fig (3.6) Computer model flow chart

Table (3.1) Habeela agricultural scheme data   2014/2015

Parameter	**Tactor**	**Wide Level Disc**
Machine width (m)	-	3.8
Operation speed	8 Km/h	-
Machine efficiency %	-	74%
Age	15	10
Purchase price SDG	200,000	40,000
Annual working hours	1000	500
Interest %	24%	24%
TIS (Task,Insurance,Shelter) %	2%	2%
R&M (Repaire&Maintenance) factor %	0.0001 per hr	0.0008 per hr
Labor (SDG/h)	3.5	-
Fuel price (SDG/gal)	20	-
Fuel consumption (gal/h)	0.044*80Hp	-

CHAPTER FOUR

RESULTS AND DISCUSION

4.1 CP-Mace verification:

The verification of any computer program is concerned with establishing whether the program is a true or sound representation of reality (Cheng *et al.*, 1992).

The verification aims to discover facts about the system under consideration in order to explain its structure and operation. Usually verification is made against established target such as published program or models or accepted field or research data (Burbur 2010).

The Cp-Mace program output was compared to the applied machinery system of Habeela agricultural scheme (South Kurdofan State) season 2014/2015.

CP-Mace succeeded to determine the effective field capacity of the wide level disc (WLD), which is 5.36 fed/h (2.2 ha/h). The result showed that this value for effective field capacity predicted by the program was identical to those of the Habeela scheme machinery system. Table (4.1) showed that the CP-Mace estimate of the total costs of the tractor (80Hp) and the wide level disc. These results were identical to those of Habeela scheme.

Table (4.1) Effective field capacity and total cost for the tractor and the wide level disc.

Parameters	**Habeela data**	**Cp-Mace**
Effective field capacity (fed/h)	5.4	5.36
Tractor total cost (SDG)/h	146.86	147.05
WLD total cost (SDG)/h	51.36	51.51

4.2 CP-Mace validation:

Validation of a computer model or program refers to study of program effectiveness or its suitability for satisfying the purpose for which it is built (Burbur 2010).

This can be achieved by comparing program output with machinery system of Habeela scheme for season 2014/2015 and Iowa state university model.

Table (4.2) The effective field capacity (fed/h) for four different agricultural operations.

Agric. operations	Cp-Mace program	Habeela data	Iowa state university model
Disc Harrowing (Off set)	2.84	2.835	2.88
Planting (Raw crop planter)	4.1	4.05	4.03
Cultivation (Cultivator)	3	3	3.1
Threshing (Thresher)	1.7	1.697	1.73

The results of the output values of effective field capacity (EFC) for four different agricultural operations namely, disc harrowing, planting, cultivation and crop threshing were shown in table (4.2). The values of (EFC) calculated by the Cp-Mace were found to be identical to the Habeela agricultural scheme data and the Iowa state university model.

Statistical analysis using t-test table (4.3), (4.4) reveals no significant differences between Pc-Mace, Habeela scheme data and Iowa university model.

Table (4.3) The statistical analysis (t-test) of the effective field capacity for CP-Mace and Habeela scheme data.

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 Program - Habeela	.00225	.00222	.00111	-.00128	.00578	2.029	3	.135

Table (4.4) The statistical analysis (t-test) of the effective field capacity for CP-Mace and Iowa state university model.

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 Program - Iowa.M	-.03000	.03742	.01871	-.08954	.02954	-1.604	3	.207

Table (4.5) showed cost/fed for four agricultural operations and crop total annual cost estimated by the Cp-Mace program and those collected from Habeela agricultural scheme.

Table (4.5) Cost/fed and crop total annual cost estimated by Cp-Mace and collected from Habeela scheme.

Agric. Operation cost (SDG)	Cp-Mace	Habeela data
Tillage (Off set disc)	81.11	80.74
Planting (Raw crop planter)	130.55	131.72
Cultivation (Cultivator)	59.79	58.90
Harvesting (Thresher)	119.52	120.05
Crop total annual cost	390,970	391,410
Total cost per feddan	390.97	391.41

All cost estimated by the Pc-Mace were found to be typical to the costs collected from Habeela agricultural scheme.

Statistical analysis using t-test showed non-significant differences between Pc-Mace program and Habeela scheme collected costs (table 4.6)

Table (4.6) statistical analysis (t-test) of cost/fed and crop total annual cost for CP-Mace and Habeela scheme data.

Paired Samples Test

	Paired Differences					t	df	ig. (2-tailed
				95% Confidence Interval of the Difference				
	Mean	d. Deviatio	td. Erro Mean	Lower	Upper			
Pair : program - Habee	.48000	.79.55885	.30460	1.9155	.95546	-1.002	5	.362

4.3 Sensitivity Analysis:

Sensitivity analysis of the model was run to show the effect of changing cultivated area and machinery purchase prices on Pc-Mace output. The two input parameters were changed a step of 30% upward from the input values adapted in Habeela agricultural scheme.

4.3.1 Model response to change in single input:

The effect of changing each of the Cp-Mace input parameters of cultivated area and purchase price of tractor and machinery on the outputs of operation cost/fed, operation cost/hr and total annual costs were examined for the case of Habeela agricultural scheme (season 2014/2015).

The purchase price was increased by 30%. Table (4.7) showed an increase in cost/hr (23%), cost/fed (18%) and total annual cost for different agricultural operations (18%) with increase in purchase price by 30%.

Table (4.7) Effect of increasing purchase price (30%).on costs.

Machinery cost (SDG)	Pc-Mace program	30% upward	Change %
Cost per hour	198.56	233.84	23
Cost per fed	37.04	43.63	18
Total annual cost	37040	43630	18

Cultivated area was also increased by 30%. Table (4.8) indicates an increase in total annual cost, and resulted in no change in cost per feddan and cost per hour with increase in cultivated area by 30%.

Table (4.8) Effect of changing cultivated area by 30% upward on machinery costs.

Machinery cost (SDG)	Pc-Mace program	30% upward	Change %
Cost per hour	198.56	198.56	-
Cost per fed	37.04	37.04	-
Total annual cost	37040	48152	30

4.3.2 Effect of changing multiple inputs on model output:

Changing both purchase price of tractors and machinery and cultivated area resulted in change in cost per feddan, cost per hour and total annual cost.

Table (4.9) Effect of changing multiple inputs (cultivated area& purchase price) on machinery costs.

Machinery cost (SDG)	Pc-Mace program	30% upward	Change %
Cost per hour	198.56	233.84	23
Cost per fed	37.04	43.63	18
Total annual cost	37040	56719	53

From table (4.9) the cost per hour increased by 23%, cost per feddan increased by 18% and the total annual cost increased by 53% from 37,040 SDG to 56,719 SDG. These results indicate that the increase in cultivated area has no effect on cost/fed and cost/hour.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions:

From this study, the following conclusions can be drawn:-

1- The CP-Mace is a user- friendly interactive computer software program which could be run for machinery cost estimation as an aid for machinery managers and agricultural engineers.

2- The CP-Mace was successfully validated in comparison to data from Habeela agricultural scheme season 2014/2015 and Iowa state university model. The comparison indicated that there was no significant difference between Habeela data, Iowa State University model and CP-Mace program.

3- The CP-Mace program calculates the effective field capacity (EFC) for different agricultural machines. The values of EFC calculated by the CP-Mace program for four machines were found to be identical to the values of Habeela agricultural scheme data and Iowa State University model.

4- The cost/fed for the different four agricultural operations and total annual cost of operating machinery for different crops estimated by CP-Mace were found to be identical to Habeela agricultural scheme data.

5- Sensitivity analysis by changing purchase price of machinery resulted in changes in cost per hour, cost per feddan and the total annual cost. And change of cultivated area resulted only in change of the total annual cost. These results indicate that the CP-Mace program is versatile, efficient, valid and can be used as an aid in decision making.

5.2 Recommendations:

1. The CP-Mace program is recommended to be used for improvement of farm machinery planning and scheduling.
2. The program is recommended to be used to accurately estimate machinery costs for effective and efficient machinery management.
3. Computer programs concerning machinery management is becoming increasingly important and appropriate to assist machinery managers in decision making.
4. The program can be improved in the future by generation of partial budget for machinery operating costs, it can handle prediction of breakeven point for machinery ownership or hiring, and consider the inflation rate in cost calculations.

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APPENDIX (A)

Table (1). T-test analysis in comparison the effective field capacity between CP-Mace and Habeela scheme data.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Program	2.8975	4	.96196	.48098
	Habeela.data	2.8953	4	.96290	.48145

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Program & Habeela.data	4	1.000	.000

Table (2). T-test analysis in comparison the effective field capacity between CP-Mace and Iowa state university model.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Program	2.8975	4	.96196	.48098
	Iowa.Model	2.9275	4	.94376	.47188

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Program & Iowa.Model	4	.999	.001

Table (3) T-test analysis in comparison cost/fed and crop total annual cost between CP-Mace and Habeela scheme data.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	program	65291.99	6	159549.03415	65135.62
	Habeela.data	65365.47	6	159728.59171	65208.92

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	program & Habeela.data	6	1.000	.000

APPENDIX (B)

Table (1) Data of purchase prices for machinery

Agricultural Machine	**Purchase Price**
Tractor 80Hp	200,000
WLD	82,000
Disc Harrow	55,000
Cultivator	20.000
Raw Crop Planter	225,000
Thresher	77,500

Source: - Central Trading company Limited (CTC) Sudan (2015)

APPENDIX (C)

Fig (1) Iowa state university model

Estimating the Field Capacity of Farm Machines

Ag Decision Maker -- Iowa State University Extension

Estimating the Field Capacity of Farm Machines

Enter your input values in shaded cells.

Type of Implement	Width (feet)	Speed (mph)	Field Efficiency-%	Field Capacity acres/hour	Field Capacity hours/acre
tandem disk (example)	24	6	80	14.0	0.07
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	
				-	

Row Equipment	No. of rows	Row width (in)	Speed (mph)	Field Efficiency-%	Field Capacity acres/hour	Field Capacity hours/acre
corn combine (example)	6	30	4	75	5.45	0.18
					-	
					-	
					-	
					-	
					-	
					-	
					-	
					-	
					-	

Version 1.0
Author: William Edwards
Date Printed:
12/06/2015

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