بسم الله الرحمن الرحيم

Optimization Model for Agricultural Machinery Selection in Elsuki Agricultural Scheme Using linear Programming

نموذج أمثل حاسوبي لإختيار الآليات الزراعية لمشروع السوكي الزراعي

باستخدام البرمجة الخطية

By

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DEDICATION

I dedicate this work for my father who is teaching me to success must work hard.

To the lady under whose eyes I am brought up, and taught me how to live in this difficult world, my mother.

To my brother and sisters, God bless them (Maali, Mohammed and Roqaya).

To my teachers at all my learning stages. They are like candles who burn themselves to give light for us.

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ABSTRACT

An optimization machinery model was developed to aid decision-makers and farm machinery managers in determining the optimal number of tractors, scheduling the agricultural operations and minimizing machinery total costs.

For purpose of model verification, validation and application input data was collected from primary & secondary sources from Elsuki Agricultural Scheme for season 2013-2014.

Model verification was made by comparing the numbers of tractors available at Elsuki Agricultural Scheme for season 2011-2012 with those estimated by the model. The model succeeded in reducing the number of tractors and operation total cost by 23%.

The effect of optimization model on elements of direct cost saving indicated that the highest reduction in cost is reached with depreciation, repair and maintenance (23%), minimum reduction cost is attained with fuel cost (22%).

Sensitivity analysis in terms of model response to change in model input for a single parameter for each of cultivated area and total costs of operation showing that. Increasing the operation total cost by 10% decreased the total number of tractors after optimization by 23% and total cost of operation was also decreased by 23%. Increasing the cultivated area by 10% , decreased by 12% (from 123 to 108 tractors) and total cost of operation was also decreased by 12% (16669206 SDG) to (14636376 SDG).

For the case of multiple input effect; increase of the area and operation total cost resulted in decrease of maximum number of tractors by 12%, and the total cost of operations also decreased by 12%.

It is recommended to apply the optimization model as pre-requisite for improving machinery management during implementation of machinery scheduling.

المستخلص

تم تطوير النموذج الأمثل بهدف مساعدة صانعي القرار ومديري الآلات الزراعية في تحديد العدد الأمثل للجرارات ، جدولة العمليات الزراعية وتقليل التكاليف الكلية لإستخدام الآلات الزراعية ، تم التحقق من صحة النموذج وتطبيقه وتم جمع الإحصائيات الأولية والثانوية من مشروع السوكي الزراعي لموسم 2013-2014 ولقد أدى تطبيق النموذج على مشروع السوكي إلى تقليل العدد الأصلي للجرارات وتقليل تكاليف تشغيل الجرارات والآلات الزراعية بنسبة 23%.

وأظهر تطبيق النموذج لنقصان في تكاليف الإهلاك والصيانة والإصلاح بنسبة 23% ، وأقل نسبة نقصان كانت في تكلفة الوقود 22%.

أوضح إختبار الحساسية ديناميكية النموذج وذلك بتغيير مدخلات النموذج (تكلفة العمليات الزراعية ، والمساحات) بزيادة تكاليف العمليات الزراعية بنسبة 10% أدت إلى نقصان عدد الجرارات والتكاليف الكلية للعمليات الزراعية بنسبة 23% ، أما زيادة المساحات بنسبة 10% أدت إلى نقصان عدد الجرارات من 123 إلى 108 جرار بنسبة 12% ، كما أدت إلى نقصان التكاليف الكلية للعمليات الزراعية بنسبة 12% (من 16669206 إلى 14636376 جنيه سوداني) ، أما زيادة المساحات وتكاليف العمليات الزراعية معاً فقد أدت إلى نقصان في عدد الجرارات بنسبة 12% والتكلفة الكلية للعمليات بنسبة 12%.

يوصى بإستخدام النموذج كمتطلب مسبق لتحسين إدارة الآلات الزراعية خلال تطبيق جدولة العمليات الزراعية.

CHAPTER ONE

INTRODUCTION

1.1 Back ground and justification*:*

Farm machinery is the part of farm management that deals with the optimization of the equipment used for agricultural production. It is concerned with efficient selection, repair, operation, maintenance and replacement of farm machinery (Hunt, 2001).

Farm machinery plays an important role in agricultural production. It contributes a major capital cost in most agricultural business since it is a major component of any agricultural planning and development strategy in many countries. Machinery selection of power unit and their machinery complement for farming operations, which is important part of machinery management decision that may lead to profit or loss for all or part of the farm enterprise (Wenging, *et al*., 1999). The use of an oversized fleet of tractor and machines results in higher costs and loss of fuel use efficiency. Inadequate machines set can extend the time scheduled for the different agricultural operations that can affect crop yields. Therefore, the wrong decision may lead to either over or under utilization of power units and machineries, and may ultimately lead to a huge pile of unused scrap in tractor grave yards and problem of financial debt (Mohamed, 2007). Putting together an ideal machinery system is not easy. Equipment that works best one year may not work well the next because of change in weather conditions or crop production practices. Improvement in design may make older obsolete and the number of hectors being farmed or the amount of labor availability may change. Because many of these variables are unpredictable, the goal of the good machinery manager should be to have a system that is flexible enough to adapt to arrange for weather and crop conditions while minimizing long-run costs production risks (Edwards, 2001).

Machinery management has increased in importance in today's farming operations because of its direct relation to the success of management in mixing land, labor and capital to return a satisfactory profit. The importance of machinery in the total farming operations is indicated by the machinery costs in relation to the total costs (Bowers, 1987).

Linear programming is a mathematical modeling technique designed to optimize the usage of limited resources. Successful applications of linear programming exist in areas of military, industry, agriculture, etc. (Taha, 1997). Currently optimum models were developed for machinery selection and optimization based on linear programming techniques. They aid in solving problems of machinery choice and minimization of machinery total costs.

1.2 Problem definition:

In the last decades, the Government of Sudan and Ministry of agriculture were attended to improve agricultural sector by establishing new agricultural projects and rehabilitation of existing ones. Unfortunately this approach has resulted in a large number of machinery from various types and sizes regardless, matching between tractors and their attachments (implements). All these had led to high cost of agricultural operation and resulted in an unbalanced distribution of machinery and the agricultural operations through the agricultural season and untimely field operations, which is the most problem faced farm manager. In order to solve these problems it's highly needed to use linear programming technique in machinery selection and scheduling in order to reduce the machinery total costs.

For Elsuki agricultural scheme, which is located in Sennar State, and one of the rehabilitation projects, the developed optimization model aimed to aid decision-maker and farm manager in determining the number of tractors, scheduling agricultural operation efficiently and minimizing machinery total costs.

1.3 Study objectives:

The objective of this study is to develop an analytical user-friendly computer optimization model for machinery management as an aid for decision-making, aiming to reduce total operations costs and to improve crop yields.

The specific objectives of this study are:

1. To reduce cost for the operation by model.
2. To develop a computer machinery model to determine optimum machinery sets using linear programming techniques.
3. To develop a computer cost determination software using Quantities System for Business (QSB).
4. To apply the model to analyze and improve performance of agricultural machinery for the case of Elsuki agricultural scheme.

CHAPTER TWO

LITERATURE REVIEW

2.1 **Machinery management:**

Agricultural machinery management is the section of farm management that deals with the optimization of the equipment phases of agricultural production. It is concerned with the efficient selection, operation, repair, and replacement of machinery, Participating in a wide range of operations, from initial operations of soil cultivation to production cost in different countries (Culpin, 1975).

2.2**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 (ha/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, will their effective or actual capacities 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.

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

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

Where:

C ≡ Capacity in area per hour (fed/hr).

S ≡ Speed in miles per hour.

w ≡ Effective width of the implement, feet.

e ≡ Effective efficient, percentages.

c ≡ Constant, (8.83)

2.3 **Field capacity:**

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

$Ca = \frac{swE_f}{10}$ ……………………………………(2.2)

On a material basis, the field capacity is:

$Cm = \frac{swYE_f}{10}$ ……………………………………(2.3)

Where:

Ca ≡ area capacity, ha/h.

S ≡ field speed, km/h.

W ≡ implement working width, m.

E_f ≡ field efficiency, decimal.

Cm ≡ material capacity, t/h.

y ≡ unit yield of the field, t/ha.

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.

2.3.1 **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.

2.3.2 **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:

$$Tt = \frac{A}{Cat} \quad \text{……………………………………………} \quad (2.4)$$

Where:

Tt ≡ theoretical time required to perform operation, hr.

Cat ≡ 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:

$$FE = \frac{Te}{Te+Th+Ta} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.5)$$

Where:

FE ≡ field efficiency.

Te ≡ effective time, hr.

Ta ≡ Time losses that are proportional to area, hr.

Th ≡ Time losses that are not proportional to area, hr.

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 account 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, preventive 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 **Machinery cost:**

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 suggest will have to develop his own individual standard costs use the average costs obtained by other only for comparison purpose.

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.

2.4.1 **Machinery costs 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.

Keneper, *et al* (1982) reported that the total cost of preforming a field operation includes charge for the implement or machine, for the power utilized, and for labor. Machine costs are divided into two categories:

2.4.1.1 **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.

2.4.1.2 **Operating costs:**

Expenses for items such as repair, maintenance, lubrication, fuel, oil, and labor are increased as a result of actual machine working hours . They are known as operating costs.

Depreciation:

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), mention the following methods for common use in determining the annual value of depreciation.

1- 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.
2- Straight line method: the annual depreciation charge is expressed by the following equation:

$$D = (P - S)/L \quad \text{..............................(2.5)}$$

Where:

$D \equiv$ depreciation.

$P \equiv$ purchase price.

$S \equiv$ 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).

3- 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 machine life.

The relationship is expressed by the following equation:

$$D = V_n - V_{n+1} \quad \text{......................................}(2.6)$$

$$V_n = pu(1-R)^n \quad \text{......................................}(2.7)$$

$$V_{n+1} = pu(1-R)^{n+1} \text{..................................}(2.8)$$

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.

pu ≡ purchase price.

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.

4- Sum of year digits method: the digits of the estimate number of years 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:

$$D = \frac{L-N}{YD}(P-S)\text{..................................}(2.9)$$

Where:

D ≡ depreciation annual.

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.

5- 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. It's found that according to (Dahab, 2000) the purchase price will be effected directly if the inflation rate 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:

$$F = Pu(i + 1)^n \text{..........................(2.10)}$$

Where:

F ≡ future value.

Pu ≡ purchase price.

i ≡ Constant inflation rate.

$n \equiv$ machine life.

Meaning that if n=1 and the inflation rate about 8% and the purchase price 150000 SDG the future price will be:

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

$F = 150000 * (0.08+1)^1$

F = 162000 SDG

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

$$Dn = \frac{n}{L}(Pu(i+1)^n - sa) \quad \text{(2.11)}$$

$$Cn = (Pu(i+1)^n = Dn \quad \text{(2.12)}$$

$$Du = Dn - (Cn - 1) \quad \text{(2.13)}$$

Where:

$Dn \equiv$ accumulate depreciation to the year.

$n \equiv$ number of year after the purchase price.

$L \equiv$ machine life in year.

$Sa \equiv$ salvage value of the machine.

$Cn \equiv$ remaining value of the machine after n year.

$Du \equiv$ depreciation value of the machine after the year.

- **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:

$$I = \left(\frac{(P+S)}{2}\right) r \text{ ....(2.14)}$$

Where:

I ≡ Annual interest charge.

r ≡ rate of interest.

P ≡ purchase price.

S ≡ salvage value or selling price.

- **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).

- **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.

- **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 not known, the following percentages can be used, taxes 1%, shelter 0.75%, and insurance 0.5% or a total of 2% of the purchase price.

- **Operation costs:**

Include those cost that are incurred as a direct result of a machine being used. These costs vary as machine use varies.

- 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.

$$\text{Fuel}\,\frac{cost}{acre} = \frac{consumption\ per\ hour}{number\ of\ acres\,\frac{completed}{hour}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.15)$$

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% or 15% (including grease) of fuel cost.

- 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.
- 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 machine.

$$\frac{labor\ cost\ per\ acres\ completed}{hour} = wage\ rate\ per\ hour \times number\ acres \times labor\ adjustment\ factor \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.16)$$

Lazarus (2009) reported that labor is charged at an hourly wage rate, which includes 30 percent benefits charge rates per hour for unskilled labor and for skilled labor. 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 33 percent for spraying.

- 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 table (2.1) and table (2.2). 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* (1982) 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

Table2.1An 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 $=\frac{(FC\%)P}{100}+\frac{CA}{SWE}[(R\&M\%)P+L+O+F+T]$ .... (2.17)

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.

C ≡ constant .

S ≡ forward speed, miles per hour.

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

E ≡ field efficiency, decimal.

R&M ≡ 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 2.2remaining 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. Four wheal dr.	 1 1	 12,000 16,000	 100 80
Tillage Moldboard pl Offset disk Tandem disk Chisel plow Subsoiler Field culti. Spring tooth Rolling packer Rotary hole Rolling harrow Row cultivar	 4 4 4 4 4 4 4 4 4 4 4	 2,000 2,000 2,000 2,000 2,000 2,000 2,000 2,000 2,000 2,000 2,000	 100 60 60 75 75 70 70 40 60 40 80
Planting Planter Grain drill	 4 4	 1,500 1,500	 75 75
Harvesting Picker Sheller Combine Pull type Self-prop. Mower cond. Sickle Rotary	 4 2 2 4 4	 2,000 2,000 3,000 2,500 2,500	 70 60 40 80 100
Rake Baler Large rect. Large round Forage harv. Pull type Self-prop. Potato	4 3 3 3 3 4	2,500 3,000 1,500 2,500 4,000 2,500	60 75 90 65 50 70
Other Fert. Spreader Boom sprayer Blower Wagon	 4 4 3 4	 1,200 1,500 1,500 3,000	 80 70 45 80

(Source: 2006 ASAE Standards)

- **Timeliness factor:**

Timeliness is a factor used to explain the importance of operation or to know the affection on production if the operation was done after specific time table (2.3).

Table.2.3. List of field efficiency, suggested forward speed and timeliness constants.

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

Source: 2005 ASAE standards

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

2.5 **Computer application in agriculture:**

Computer programs are being used to assist farm managers and scientists in decision- making about how to manage and select their machinery effectively (Oksana and Edward, 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-decision and employed in some large farming enterprises.

A crop production machinery system was developed by Ismail (1994) as a computer interactive model based on the concept of expert system, which allow the user to interact with the program. The result showed that increasing the number of crops in a crop production reduces the machinery cost and affects the field time of operation.

Alam and Awal (2001) developed a computer program to select the proper power level based on farm size, cropping patterns, 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 farm land and cropping pattern. They concluded that mono crop system power (energy) and power cost requirements are greater than that 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.

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 signs for each level of agricultural mechanization based on human muscles, 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 microcomputer for agricultural machinery management (MACHINER) was developed and published by (ASAE, 1991) the program consists of three modules: record keeping, cost estimating, and machinery selection. Machinery management standards from the ASAE and site-specific parameters provide the mathematical base for the model. The model was successfully implemented on a commercial production of agriculture operation in Honduras, Central America. Major attributes of the program include a user friendly interface and efficient conditions.

Isik and Sabanci (1993) developed a computer model to select optimum size of farm machinery and tractor power based on farm size, cropping patterns, soil properties, and climate condition. The model was designed in order to minimize total cost of farm machine and tractor. Field machinery requirements were calculated for cash crop production system using computer model described by Singh *et al*., (1989). The cash crop production system considered includes ten crop rotations and three tillage systems. The result reported include unit values of tractor power, harvesting capacity and total annual machinery related oils, fuel, and man-hours of labor. It was foreword that crop rotations have a strong influence on field machinery requirements. Multi-crop balanced rotation increased machinery utilization and decrease machinery requirement on a unit crop area bases. Machinery investment, annual machinery related over a single-crop rotation, machinery investment decreases, rather than single-crop rotations. The machinery investment decreased by 3%. The results also showed the tillage intensity influenced tractor power and fuel requirement by 35% and related costs was generally less than 15% for multi-rotations (Mohamed, 2007).

Mohamed Nour (2007) developed Machinery Management Computer Program (MMCP). The program estimate machinery performance and costs of owning and operating various farm machines, it contains four modules all lead to aiding the manager of the farm or scheme to take the correct optimum decision on managing his agricultural machinery. The MMCP model can predict field efficiency, field capacity, power and operating cost.

Mohamed (2007) developed Decision Model for Agricultural Machinery Management (DAMAMM). The program estimates the planned objectives of building machinery management program. Moreover, the model offers the opportunity to compare alternative course of action (different rotations) in terms of the verified objectives. The reduced the total cost of operations significantly in all crop rotations with maximum reduction achieved (49%) with four course rotation and minimum reduction with two course rotation (9%). Also it reduced the total number of required tractors (72hp) by 30%, 15%, and 17% for two, three and four course rotation respectively as compared to Rahad original design.

2.6 **Linear programming:**

2.6.1 **General overview:**

In its simplest form, linear programming is method of determining a profit maximizing combination of farm enterprises that is feasible with respect to a set fixed farm constrains. Early applications of linear programming in farm planning assumed profit maximization behavior, a single-period planning horizon (no growth), and a certain environment (no uncertainty about prices, yields, and also forth).

2.6.2 **Assumption of linear programming:**

A number of assumptions about the nature of the production process, the resources, and activities implicit in the linear programming model:

1. Optimization: it is assumed that an appropriate objective function is either maximized or minimized.
2. Fixedness: at least one constrain has a nonzero right hand side coefficient.

3. Finiteness: it is assumed that there are only a finite number of activities and constraints to be considered so that a solution may be sought.
4. Determinism: all coefficients in the model are assumed to be known constants.
5. Continuity: it is assumed that resources can be used and activities produced in quantities that are frictional units.
6. Homogeneity: it is assumed that all units of the same resource or activity are identical.
7. Additively: the activities are assumed to be additive in the sense that when two or more used, their total product is the sum of their individual products. That is no interaction effects between activities and permitted.
8. Proportionality: the gross margin resource requirements per unit of activities are assumed to be constant regardless of the level of the activities used. A constant gross margin per unit of activity assumes a perfectly elastic demand curve for the product, and perfectly elastic supplies of any variable inputs that may be used (Edwin, 1998).

A major proportion of all scientific computation on computers is developed to the use of linear programming. Briefly, the most common type application involves the general problem of allocation limited resources among competing activities in possible (i.e., optimal) way. More precisely, this problem involves selecting the level of certain activities that compete for scarce resources that are necessary to perform those activities. The choice of activity levels then dictates how much of each resource will be consumed by each activity. The variety of solutions to which this description applies is diverse, indeed, ranging from the allocation of production facilities to products to the allocation of national resources to domestic needs, from portfolio selection to the selection of shipping patterns, from agricultural planning to the design of radiation therapy, and so on. However, the one common ingredient in each of these situations is the necessity for allocating resources to activities by choosing the levels of those activities. Linear programming uses a mathematical model to describe the problem of concern. The objective linear means that all the mathematical functions in this model are required to be linear functions.

The word programming does not apply here to computer programming; rather, it is essentially a synonym for planning. Thus, linear programming involves the planning of activities to obtain an optimal result (Hillier, 2000).

The art and science of allocating scarce resources, decision making, and maximization problems to the best possible effect is called optimization. Techniques of optimization can be brought into a sight when doing scheduling, decision making, resource allocations, industrial planning, profit maximization, etc.

Its target is to find the best solution for a problem expressed in a numerical value, which can be economics, engineering, industrial, management, biological, physical etc. The first optimization technique goes back to guess; it is brought up to us as linear programming. Our contemplate was introduce the optimization while using the first optimization technique, to observe and apply this technique in real life problems.

Linear programming is the most capaciously used from the major technique for optimization. It is an old word which means planning. All of the underlying models of the real-word process are linear, so we can define linear programming as a method for planning using linear models. The mathematical optimization model is a model with an objective function and a set of constraints which are expressed in the form of a system of steps with inequalities or equations. Use the model in a decision making areas; basically begin with a real word problem which has many details and complexities, some applicable and some not. From this can tear the fundamental element for a model creation, and then choose a suitable algorithm or any other solution technique to apply the problem. These problem calculations in practice are carried out by computer software.

Linear implies that some practicable plans are limited by some linear inequalities, together with the quality of the plan which is also measured by a linear function of the required and calculated quantities.

Linear relations are used to model many different production problems, as big or the largest practical constrained problems, regularly solved are linear programs. Can observe a large number of constrains and variables when it comes to airline scheduling problem. (Miletic and Stojanov 2008).

In the age of intensive development of new technologies farmers encounter increasing amounts of information and have to make complex decisions in short time. The internet provides the farmers with various data, textual and graphical information, but most often dominates the information about the weather, answers to the most frequently-asked questions with only occasional analysis of economic activity and management, well-grounded conclusions and suggestions, or problem solutions. The value of modeling and optimization-based decision support significantly increases [Shim *et al.*, 2002; Pranevicius and Kurlavicius, 2003]. Optimal or nearly optimal solutions provide relevant information to revolve complex agricultural and environmental decision problems [Makowski *et al.*, 2001]. Operation investigation methods in agriculture are used to find the optimum characteristics of the research objects paying attention to time, resource, technological and other limitations. Mathematical programming methods are successfully to improve the planning of agricultural systems [Glen and Tipper, 2001]. Farmers are interested in having quantitative evaluation of the planned farm development management scenarios before making expensive investments into agricultural machinery solving of ecological problems in order to choose the best possible ones. Farmers want to optimize production structure and quality, minimize consumption of chemicals, energy and negative impact on environment. Today every farmer must know how much and what kind of agricultural production to manufacture, i.e. what field of agricultural production should be developed to be able to meet the complicated technological and environmental requirements, do not exceed the environmental pollution norms and to get the greatest possible profits. Hundreds of variables are interrelated with each other by complex functional relationships in such a planning problem of optimum agricultural production structure. Method of linear programming are often applied in solving this type optimization problems in agriculture [De Buck *et al.*, 1999; Annett and Audsley, 2002; Chen YuXiang *et al.*, 2004].

The suitable software is indispensable for a farmer to make scientifically based solution of strategic and operative farm management in real time. The investigation of the optimization and decision-support means suggested for the farmers showed that the choice the rather limited. The simplified farm models estimate only insignificant limitation as they lack the integrated approach to the interaction of farm internal elements and their interaction with the environment. One model, no matter how great it is, cannot solve all the farm problems thus the related model system must be created. The existing programs utilizing the mathematical programming algorithms require high qualification of the user as they have complex user interface, which is difficult to understand for a farmer besides they do not provide possibilities of integration with agricultural information systems. Some of the decision support systems proposed for the farmers did not reach the required level or were not user-friendly while other are too complicated or narrowly specialized. Still relevant is the creation of decision support system satisfying the farmers' great demands [McCown, 2002 and Kurlavicius, 2004]. For this purpose the prototype of the decision support system is described in the paper that helps to optimize the structure of agricultural production and to choose the best solution of strategic planning and agricultural business management. The user friendly interface is created for the agricultural specialists. (Kurlavicius, 2008).

Abdalla (2005) reported several individuals have contributed to the development of L.P. Abd Elaziz (1999) applied L.P for analysis of small private farms in the River Nile State; L.P was also applied in the modern and traditional agriculture of the Sudan. In the traditional farming of the Northern Sudan, L.P was used by Mohamed (1988) for evaluating new faba bean techniques in Northern Sudan, and Ahmed and Faki (1992 and 1994) for investigating the prospects of technology adoption in small pump schemes in Wad Hamid and Rubatab areas in the River Nile State.

Natsis, (2001) reported that an optimum farm machinery selection may reduce production costs considerably. In doing this, one has to take into account the size of the farm, the distribution of crops and crop rotation, cultural practices used throughout the year, farm machinery technical data and consumption costs for each operation. Moreover one has to take into account soil; crop and weather characteristics in order to reach a reliable prediction of the suitable days for field work throughout the year, which inevitable impose a time restriction in farm machinery operations. In the present work, linear programming was employed as a mathematical tool for providing the right selection of farm machinery, based on minimizing machinery operation costs, taking into consideration all above mentioned interrelated factors and constrains. For 400 ha of agricultural land, allocation for the cultivation of 4 different crops (wheat 200 ha, corn 100 ha, alfalfa 50 ha, and beans 50 ha), considering four different tractor sizes (44, 56, 76, and 148 kW), it was found that optimum agricultural machinery selection would include four 76 kW tractors and two 44 kW tractors.

Saglam.C, *et al* (2006) reported that the linear programming model allows an economic comparison to be made of tractor capacity and optimum size. For example, 57.5 kW tractors were used for 17.6 ha in Harran plan in Sanliurfa, Turkey.

According to the result of LPM, however, it was determined that the same tractor could operate 57.88 ha and 17.67 ha needed 20.48 kW tractors.

Abdalla (2005) applied linear programming model and the basic solution indicated that comparative and absolute advantages are not made use of, an income increased by 184% and 363% respectively broad beans, garlic and fennel, in Dongola locality. According to the result of the basic model wheat could be produced by 25%, when its price is increased by 20%, when its present productivity is increased by 25%. Linear programming model showed a land use that is very different from the current land use. The result allocation 4.0% feddans of the available land of Merowe locality to broad bean beside the areas restricted for tomato and onion crops. Wheat crop entered the plan at a level just satisfying the consumption requirement.

2.6.3**Linear programming methods:**

There are many procedures to solve L.P. problems:

1. Graphical solution method: where atypical L.P model may include thousands of variables and constrains, the idea gleaned from the graphical procedure lay for the development of the general solution technique called the simplex method.

The graphical procedure includes two basic steps:

- The determination of the solution space that defines the feasible solution that satisfy all the constrains of the model.
- The determination of the optimum solution from among all points in the feasible solution space.

2. The simplex method: the transition method from the geometric extreme (or corner) point solution to the simplex method lies in goal. First convert the model into the standard L.P from using slack or surplus variables to convert inequality constrains into equation.
3. Duality: in most L.P treatments, the dual is defined for various forms of the primal depending on the sense of optimization (maximization or minimization).

The variables and constrains of the dual problem can be constructed symmetrically from the primal problem as follows:

- A dual variable is defined for each of the primal constraint equations.
- A dual constraint is defined for each primal of the primal variables.
- The left-hand side coefficient equals the constraint coefficient of the associated primal variable. Its right-

hand side equal objective coefficient of the same primal variable.

4. Transportation model: is a special class of the linear programming problem. It deals with the situation in which a commodity is shipped from sources. The objective is to determine the amounts shipped from each source to each source to each destination that minimizes the total shipping cost while satisfying both the supply limits and the demand requirements (Taha, 1997).

2.7 **Critical Path Method (CPM):**

This program solves project scheduling problem which is procedure to schedule activities and find the critical path(s) for the project.

2.7.1 **Program Evaluation and Review Technique (PERT):**

This is similar process of CPM method. However, it is used for managing projects with probabilistic activity times. The whole procedure includes determining critical path (s) and computing the expected project completion time, it also involves the probability analysis.

2.8 **Verification and Validation:**

Verification: the evaluation of whether or not.

A model or a system complies with a regulation, requirement, specification, or imposed condition.

Verification is intended to check that a Product service or system meets a set of design specification in the development phase verification procedures involve performing special tests to model simulate a portion or the entirety, of a product, service or system, then performing a review or analysis of modeling results.

Verification: the process of evaluating work-products (not actual final product) of a development phase to determine whether they meet specified requirements for that phase.

Objections: to ensure that the product is being built according to the requirements and design specifications. In other words, to ensure that work products meet their specified requirements.

Verification and validation are the process of checking that a software system meets specifications and that fulfills its intended purpose. It may also be referred to as software quality control.

Validation is an independent procedure that is used for checking that a system, a model of software meets requirements and specifications and that if it fulfills its intended purpose.

Validation is intended to ensure a product, since or system result that meet the operational needs of the user.

Validation: the process of evaluating software during or at the end of the envelopment process to determine whether it satisfies specified business requirements.

Objections: to ensure that the product actually meets the user needs and that the specifications were correct in the first place.

In other words, to demonstrate that the product fulfills its intended use when placed in its intended environment. (Software testing fundamental at 2011)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Characterization of study area:

The study was conducted within the area of irrigated clay plains of Sudan in Elsuki Agricultural scheme, which is one of important irrigated schemes in Sudan, with total area of about 11,500 feddans.

The scheme is located in Sennar State about 291 Km south of Khartoum .It is subtended by latitude 14º-13º N and longitude 33º-34ºE .

Climate:

The climate is tropical climate , where the average rainfall is 400-500 mm per year, starting from mid- July until late September . Temperature ranging between 37-40C. Rainfall is reflected in the high humidity of up to approximately 80-85 % of the fall months, and in February, March and April , reaching almost 35% . In winter temperatures drop up to 12C on average.

The main crops grown are cotton, sorghum and sunflower with three course rotation.

3.2**Data collection:**

Machine data was collected for season (2011-2012)and season (2013-2014) from the Elkhyari Company for Agricultural services and crop data was collected from Elsuki Agricultural scheme (Alberayr office).

3.3 **Model development:**

3.3.1 **The optimization model:**

The mathematical optimization model is user-friendly, analytical model with an objective function and a set of constraints which are expressed in the form of system of steps with equalities or equations.

The main functions of the developed model are as follow:

1. Generates the optimum machinery sets to complete field operations at minimum total cost.
2. Maximization profit of each agricultural operation.

3.4 **Integer linear programming model structure:**

The structure of the model is shown in Fig (3.1) Input data are entered in two phases:

1. Crop data:

Defines the model decision variable and area to be executed.

2. Economic data.

Includes coefficient of decision variables costs (SDG/Fed) total number of machine required during the agricultural season.

The next step is to convert the crop and economic input data into standard matrix form which can be based to an integer linear programming (ILP) solver. Basically, a set-up data are used to define the model structure such as the number of column rows in the LP matrix after the matrix is defined. ILP solver is invoked. ILP solver is not formally a part of the model. A suitable solver must be available on the host computer, the Quantities System for Business (QSB) optimizer is used here for the purpose of the study. However, QSB can be loaded as part of the program installation process. Finally the solution solver creates reports which summarized decision variables values, their cost contribution, total minimum cost (SDG), shadow prices and slack or surplus values. The program technical specifications are show in table (3.2).

The simplex method is the easiest LP method, and is broadly used in many applications, but when solving large LP programs, it might be an advantage to have different, more time-efficient method to choose form. There are many different interior point methods to choose from, and they give a good approximate value to optimum, but their system needs to be solved. It is rather hard to solve all conditioned equation system with numerical method to get a correct solution. You might even get a completely wrong solution, (Miletic and Stojanov, 2008).

Table(3.1) Elsuki agricultural scheme data season 2013-2014:

Corp	Agricultural Operation	Area (fed)	Working hours/day (hr)	Program unit (No Tractor)	Production unit (fed/hr)	Daily Production(fed/day)	Operation cost (SDG/fed)	Total area cost (SDG/fed)
Cotton	Chiseling	5000	10	10	2.5	250	75	375,000
	Harrowing	5000	10	10	3	300	60	300,000
	Ridging	5000	10	10	4	400	40	200,000
	Planting	5000	10	7	3	210	65	325,000
	Herbicides	5000	10	6	10.8	648	10	50,000
	Fertilizer	5000	10	5	12.3	615	15	75,000
	Ridging	5000	10	10	4	400	40	200,000
Dura	Chiseling	6500	10	10	2.5	250	75	487,500
	Harrowing	6500	10	10	3	300	60	390,000
	Ridging	6500	10	10	4	400	40	260,000
	Planting	6500	10	7	3	210	65	422,500
Sun flower	Chiseling	6000	10	10	2.5	250	75	450,000
	Harrowing	6000	10	10	3	300	60	360,000
	Ridging	6000	10	1	4	40	40	240,000
	Planting	6000	10	7	3	210	65	390,000

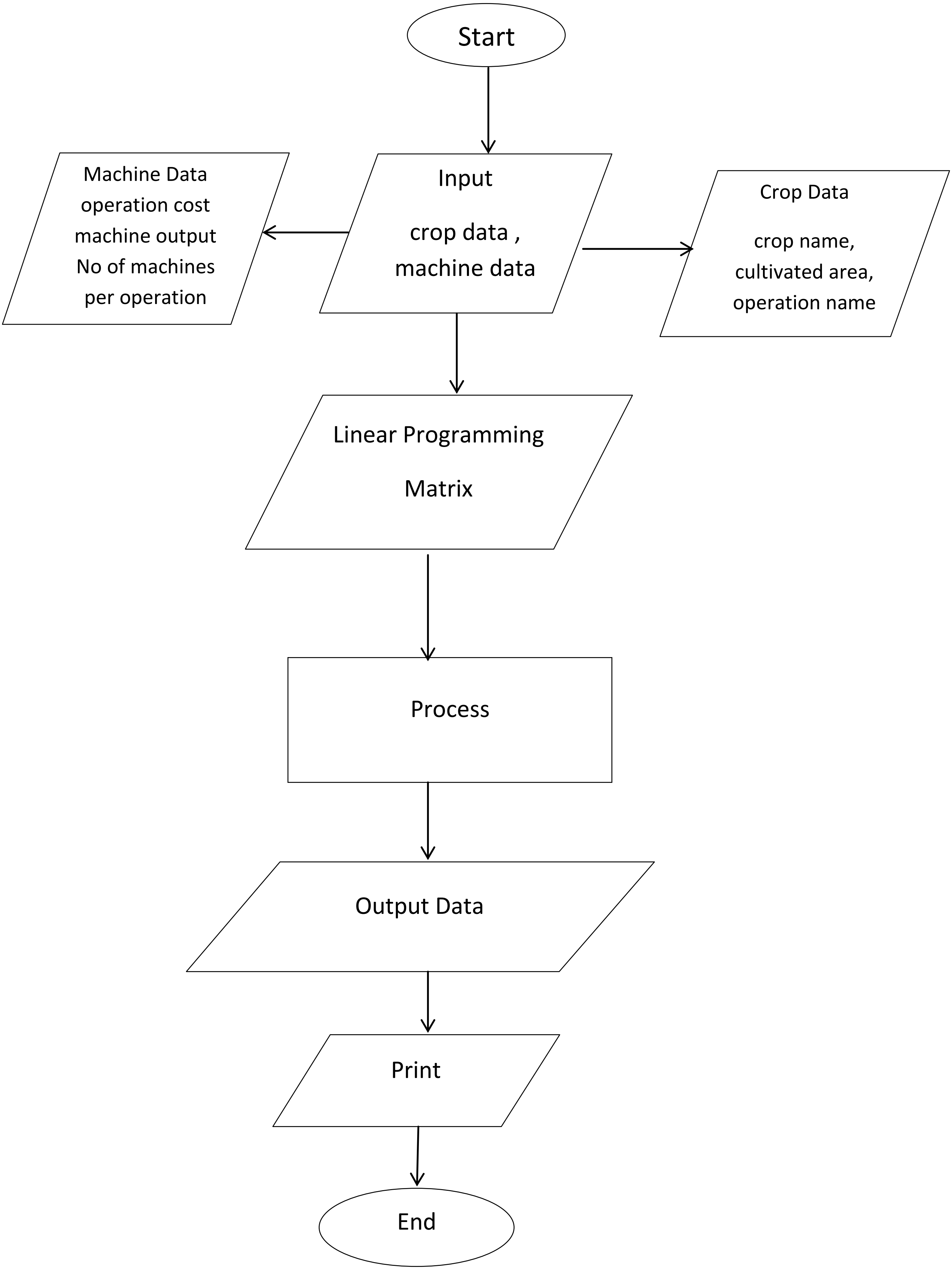


Fig. (3.1): Model flow chart

Table (3.2).program technical specification:

Item	Description
Program language	Visual basic and QSB in Excel environment, Excel 2003,
Program type	Button menu driven
Program flexibility	Inherited from Excel XP 2003, QSB and Visual basic
Program adaptability	Work under Windows, specially Developed under Windows XP
Program interface	Multi menu with automated control tools including one main menu and multi sub-menu
Units used	British units
Minimum required operating system	Windows 98
Space required on Hard disk	15.8 MB
Output available (displayed)	Available on screen option monitor display
Output printed	Available option for each interface
Minimum speed required	500MHz
Mouse activated menu	Available

LP in such situation can be used in this study as optimization by using Quantities System for Business (QSB) software program with simplex method for reducing the costs of the agricultural operation and soil producing the required amount of output by using the given facilities:

Min Z = $\sum_{j=1}^{n} C_j X_j$

Such that:

$$\sum_{j=1}^{n} a_j X_j$$

All I = 1 to m

And $X_j \geq 0$,   all j = 1 to n

Standard form of the model:

Minimize Z = $c_1X_1 + c_2X_2 + \cdots + c_nX_n$

Subject to the restructures:

$a_{i1}x_1$+$a_{i2}x_2$+…………+$a_{in}x_n \geq b_i$ for some values of i

The objective function used in this study is in the following form:

$$\sum_{i=1}\sum_{j=1} CijXij$$

J = 1, 2,…….. , 15

I = 1, 2, ……. , 4

Where:

C ≡ Total field operation cost (SDG/fed).

C ij ≡ Cost of operation j with crop I (SDG/fed).

X ij ≡ number of power units and machinery for operation j with crop i.

The model is subjected to some constraints that to be satisfied, these are specified as follows:

Constraint (1):

$$\sum aij\ tij\ xij = bi$$

Where:

a_{ij} ≡ Coefficient of the output of variable Xij (fed/hr).

t_{ij}≡ Time coefficient.

b_i ≡ Total area for I crop.

The constraint is related to the seasonal total cultivated area to be performed for all field operations, it is restricted by machine effective field capacity/day. Working days scheduling for operations which are both responsible of determining the optimum machine set.

Constraint (2):

$$\sum a_{ij}t_{ij}x_{ij} \ \geq t$$

Where:

t_{ij}≡time coefficient.

t ≡ total time for operation J and crop I.

Ensure that the total time can operate all schemes after optimization.

Constraint (3)

$$\sum a_{ij}c_{ij}\,x_{ij} \ \leq c$$

This constraint is ensuring that the total cost of the operations must be less than the cost of operations in the scheme of Elsuki before the optimization.

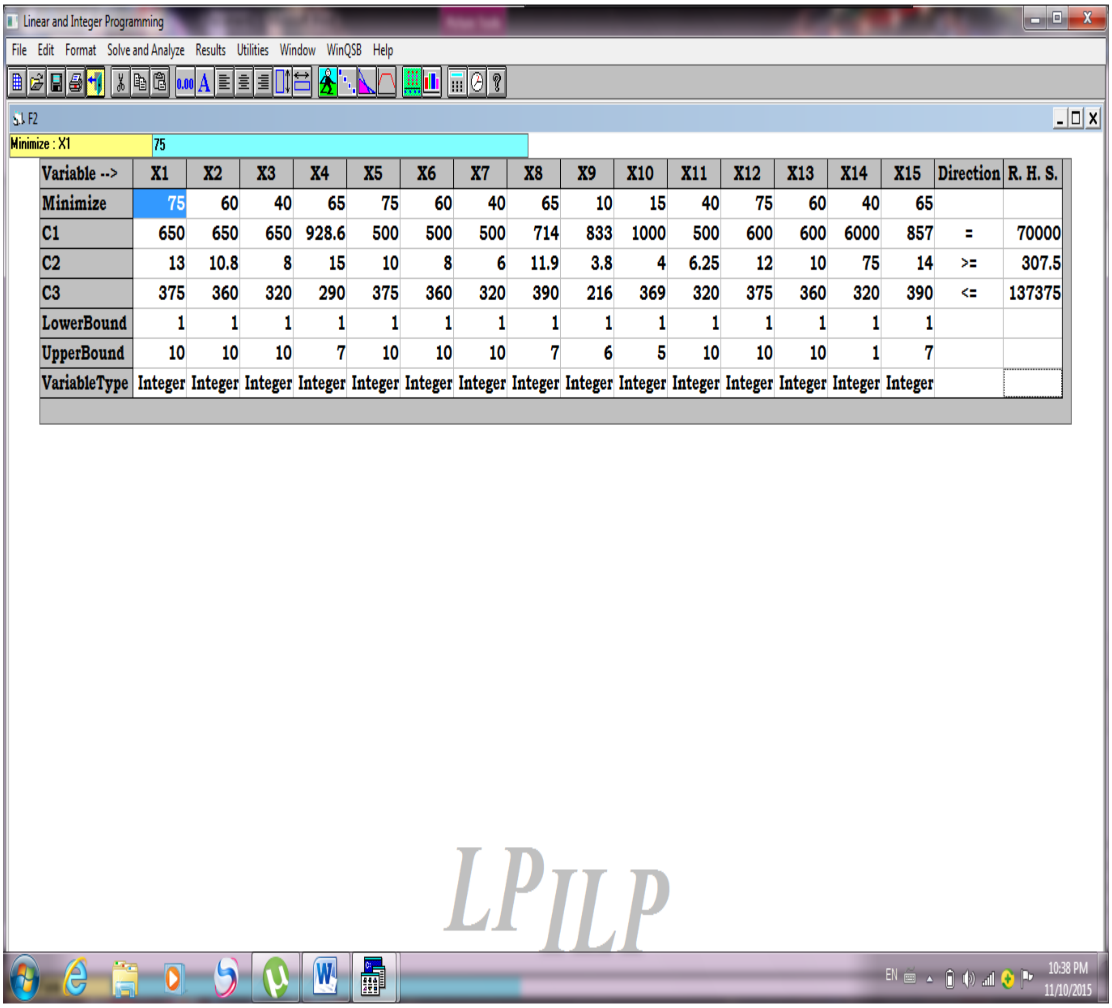
Constraint (4)

$$\sum x_{ij} \leq M$$

Where:

M ≡ total available machines for the agricultural season.

Ensure that the total number of machines for the agricultural season should be equal or less than the total available number of machine for the whole season.



Variable -->	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	Direction	R. H. S.
Minimize	75	60	40	65	75	60	40	65	10	15	40	75	60	40	65		
C1	650	650	650	928.6	500	500	500	714	833	1000	500	600	600	6000	857	=	70000
C2	13	10.8	8	15	10	8	6	11.9	3.8	4	6.25	12	10	75	14	>=	307.5
C3	375	360	320	290	375	360	320	390	216	369	320	375	360	320	390	<=	137375
LowerBound	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
UpperBound	10	10	10	7	10	10	10	7	6	5	10	10	10	1	7		
VariableType	Integer	Integer	Integer	Integer	Integer	Integer	Integer	Integer	Integer	Integer	Integer	Integer	Integer	Integer	Integer		

Fig (3.2): Model matrix format for Elsuki Agricultural scheme

3.5 **The program limitation:**

The program limitation may be summarized as follows:

1. The program was developed for four course rotation.
2. The program requires the installation of the optimization unit Quantitative System for Business(QSB) which works within the Excel medium.
3. The maximum number of integer variable is fifteen subjected to only four constraints with lower and upper bound.
4. The machinery set calculation enforces the round up decimals greater than 0.5.

Input data requirements:

A. Machinery performance data:
   - Field operations.
   - Programmed area (fed).
   - Machine used.
   - Operation costs (SDG/fed).
   - Operation time per hour.

B. Economic data:
   - Machinery and tractors purchase prices.
   - Interest rate value.
   - Fuel price.
   - Repair and maintenance.

3.6 **Agricultural operations costs:**

The total cost of performance a field operation includes charge for the implement or machine, for the power utilized.

1. Fixed cost:
1. Depreciation:

In this study it was calculated by the straight line method:

$D = \frac{P-S}{L}$

where:

L ≡ machine life in years.

- Shelter, Insurance, Taxes (SIT): for most machines these three costs are usually less than depreciation and interest. In this study (SIT) is calculated by 2% of purchase price to estimate the expense of all three of these costs.
- Interest: investment in machinery requires capital and should therefore be assigned a capital cost regardless of whether or not dollars are borrowed to purchase the machinery. If the money to purchase machinery is borrowed, the calculated interest cost should be at least large enough to cover the interest paid on the loan. It calculated by the following formula:

  $I = (p - s/2) \times r$

  Where……………………………

  I ≡ interest cost.

  p ≡ Machine price.

  s ≡ salvage Value.

  r ≡ interest rate.

2. Variable costs:

- Fuel:

Fuel costs can be figured either by the hour or by the feddan, with knowledge of the fuel consumption rate hour and the number of feddans complete in one hour:

- Repair and Maintenance:

In this study the cost for repairs per year calculated by 2% of purchase price was used by Kepner 1982.

- Lubrication: it was calculated as 15% of fuel cost.
- Labor: is calculated using the cost of labor per hour .
- Total operation cost:

The total operation cost was calculated by:

$$No\ of\ tractors\ (before\ and\ after\ optimizatin\ ) * cost\ of\ operation\ for\ one\ feddan.$$

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1**Model verification:**

Computer program verification is concerned with establishing whether the program is true or sound representation of reality (sheng *et al*.,1992).It is intended to check that the model or program meets a set of design specifications . It aims to ensure that the model is being built according to the requirements and design specifications. And it aims also to discover facts about a system under consideration in order to explain its structure and operation.

The model output compared to the applied system of Elsuki agricultural scheme for season 2011/2012. At that time 123 tractors were available to mechanize all actual operations.

The model succeeded in reducing the number of tractors, by 8% for Elsuki Agricultural scheme Appendix (B). This result agreed with, Abdoon 13% (2010) and Osman 12% (2011).

4.2 **Model validation:**

Validation of computer model is intended to ensure a system or a model result that meets the operational needs of the user. It concerns with model effectiveness or its suitability for satisfying the purpose of model building (Summers *et al* 1999). This can be achieved by comparing model output with real system machinery in Elsuki Agricultural scheme. The analysis will be the total number of tractors (power units), The total operating costs components of (fuel, labor, repair and maintenance costs).

4.3 Purpose of model building:

It was stated earlier that purpose of building machinery management programs includes :

- Minimization of total number of tractors (power units).

- Minimization of total costs of operations.
- Saving of operating costs.

Consequently, the developed computer optimization model will be validated by testing the achievement of these targeted objectives (Dent and Anderson, 1971).

4.3.1 Minimization of total number of tractors:

Table (4.1) shows the effect of optimization model in reducing the total number of tractors .It is reduced from 123 to 95 tractors and the improvement achieved as a reduction of 23%. Similar results were obtained by Abdoon 29.4% (2010). That for scheduling of the operations number and distribution of machinery for Rahad scheme for season 2004/2005. The result is also in agreement with Osman 12% (2011).

Table (4.1) Number of tractors before and after optimization:

Item	Before Optimization	After Optimization	Difference	Improvement %
Number of tractors	123	95	28	23%

The statistical analysis using t-test table (4.2) indicates that optimization of machinery reduced the total number of tractors for all operations significantly (p=0.022 or 0.05) with Elsuki Agricultural scheme.

Table (4.2) t-test for total number of tractors before and after optimization:

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	before - after	29.00000	1.41421	1.00000	16.29380	41.70620	29.000	1	.022

4.3.2 Minimization of total costs of operations:

Table (4.3) Shows the effect of optimization module on reducing the total costs of operations. The optimization model resulted generally in reducing costs of operation from 6790SDG to 4840SDG (29%). The result obtained due to the reduction of the total number of tractors resulted from the optimization model.

Table (4.3).Operations total cost before and after optimization:

Item	Before Optimization	After Optimization	Difference	Improvement %
Operations total cost (SDG)	6790	4840	1950	29%

The statistical analysis using t-test indicates that optimization of machinery reduced the total costs of all operations significantly (p=0.008 or 0.05) table (4.4).

Table (4.4) t-test for total costs of all operations before and after optimization:

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	before - after	1925.000	35.35534	25.00000	1607.345	2242.655	77.000	1	.008

The results are in agreement with Osman (2011). The result also agreed with Alam and Awal (2001). They concluded that mono crop system power and power cost requirements were greater than that in multi-crop system.

4.3.3 Saving of direct costs:

Direct costs include costs of depreciation, fuels, labor, repairs and maintenance costs. The effect of optimization model on elements of direct costs is shown in table (4.5). From the table it is clear that the highest cost saving is reached with depreciation, repair and maintenance cost (23%) and minimum cost saving is attained with fuel (22%). This may be attributed to the reduction in total number of tractors. These results are in line with Mohamed (2007) and Osman (2011).

Table (4.5) Direct cost of tractors before and after optimization:

Item	Before Optimization	After Optimization	Difference	Improvement%
Depreciation cost (SDG)	1500228.5	1158713.1	341515.4	23%
R&M cost (SDG)	15002.3	11587.1	3415.2	23%
Fuel cost (SDG)	1162444.4	900952.4	261492	22%
Total	2677675.2	2071252.6	606422.6	23%

Statistical analysis of the data using t-test indicated that optimization of machinery reduced the direct cost significantly (p=0.034 or 0.05) with Elsuki Agricultural scheme.

Table (4.6).t-test for direct costs of all operations before and after optimization:

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	before - after	9750.262	5240.80275	2620.401	1410.976	18089.55	3.721	3	.034

4.4 **Optimization model sensitivity analyses:**

4.4.1 **Optimization model response to change of single input:**

To study the effect of changing each one of the model inputs of cost of agricultural operation and cultivated area on the output of the maximum number of tractors and total cost of operations, the model parameters were examined for the case of Elsuki Agricultural scheme.

4.4.2 **Effect of changing agricultural operations cost by 10%:**

Table (4.7) shows the effect of changing costs of agricultural operations on maximum number of tractors. The significant effect on maximum number of tractors was shown as a decrease by 23% , Depreciation and R&M where decrease by 23% While the fuel cost was decreased by 22%, when the cost of operations was increased by 10%.

Table (4.7) Effect of changing agricultural operations cost by 10%.

	Before Optimization	After Optimization	Different	Percent
Number of tractors	123	95	28	23%
Total Price of Tractors (SDG)	16669206	12874590	3794616	23%
Depreciation (SDG)	1500228.54	1158713.1	341515.4	23%
Fuel (SDG)	1162444.377	900952.3767	261492	22%
R&M (SDG)	15002.2854	11587.131	3415.154	23%

4.4.3 **Effect of changing cultivated area by 10%:**

The cultivated area was increased by 10%. The increase of cultivated area indicates that there is a decrease in the maximum number tractors from 123 to 108 tractors and improvement is about 12%, likewise the total cost of operation decreased from 16669206 to 14636376 SDG with improvement about 12% table (4.8).

Table (4.8) Effect of changing cultivated area by 10%.

	Before Optimization	After Optimization	Different	Percent
Number of tractors	123	108	15	12%
Price (SDG)	16669206	14636376	2032830	12%
Depreciation (SDG)	1500228.54	1317273.84	182954.7	12%
Fuel (SDG)	1162444.377	1016144.377	146300	13%
R&M (SDG)	15002.2854	13172.7384	1829.547	12%

4.4.4 Effect of changing multiple inputs on model outputs:

Changing both cost of operations and cultivated area by the same percentage 10% upward resulted in a decrease of maximum number of tractors by 12%. And the total cost of operations also decreased by 12% (table 4.9) and it is clear the main effect come from area because the output of model from changing multiple inputs (cost, area) is same with the output of change of area alone.

Table (4.9) Effect of changing multiple input by increasing cost and area by 10% both.

Item	Before Optimizatio n	After Optimizatio n	Differenc e	Improvemen t %
Number of Tractors	123	108	15	12%
Price (SDG)	16669206	14636376	2032830	12%
Depreciation (SDG)	1500228.5	1317273.8	182954.7	12%
Fuel (SDG)	1162444.4	1016144.4	146300	13%
R&M (SDG)	15002.3	13172.7	1829.5	12%

Change increasing cost by 10% upward has no effect on model parameters while increasing cultivated area by the same percentage resulted in clear change of model parameters table (4.9).

CHAPTER FIVE

SUMMARY, COUNCLUSIONS AND RECOMENDATIONS

5.1Summary:

Machinery management is a complex process that deals with optimization of mechanized operations for agricultural production in dynamic and in uncertain weather conditions. This complexity arises from high investment, operating costs, intensified cropping patterns and different field times .

This study was directed to develop a model as a solution to aid in decision making to plan machinery efficiently. The model was planned to improve machinery management by determination of optimum machinery set for Elsuki Agricultural scheme, and this was achieved by employing linear programming techniques. Data were collected from primary and secondary sources from Elsuki Agricultural scheme and these data were tabulated and analyzed using descriptive statistics.

Model verification was made by comparing the number of tractors of Elsuki Agricultural scheme for season 2011-2012 with those estimated by the model. Validation test was made by considering the satisfaction of minimum number of tractors, minimum total costs and saving of direct cost.

Sensitivity analysis in terms of model response to changes in model input for a single parameter for each of cultivated area and operation cost showing that:

Increased operations cost by 10% showed no significant effect in total number of tractors after optimization and the total cost of operations.

Increased cultivated area by 10% indicates a decrease in the maximum number of tractors by 12%, and the total cost of operations was decreased by 12%.

Changing both cost of operations and cultivated area by the same percentage 10% upward resulted in decrease of maximum number of tractors by 12% and the total cost of operation also decreased by 12%.

5.2 Conclusion:

1. The model reduced the total number of tractors for Elsuki Agricultural Scheme by 23% for season 2013-2014.
2. The optimization model reduced the total cost by 23%. Due to reduction of total number of tractors.
3. Sensitivity analysis was run with respect to change of single input and compound inputs (cost of operation and cultivated area) on model output (max. number of tractors and total operations costs).
4. The impact of optimization algorithm on elements of direct costs (operating costs) showed that the highest cost saving is with depreciation and repair and maintenance (23%) and the minimum cost saving is attained with fuel cost (22%).
5. The optimization model is capable to estimate the planned objectives of building machinery management programs.

5.3 Recommendations:

1. It is recommended to apply the optimization model as pre-requisite for improving machinery scheduling system.
2. The model can be used for new agricultural projects to initiate new machinery system by determining machinery sets.
3. The model can be improved in the future by considering machinery scheduling using Program Evaluation Review Technique (PERT).
4. Model verification, application and sensitivity analysis need to be replicated by considering other complex values and a wide range of agricultural operations to be handled by the model.

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APPENDEX A

	22:31:49		Tuesday	November	10	2015
	Decision Variable	Solution Value	Unit Cost or Profit c(j)	Total Contribution	Reduced Cost	Basis Status
1	X1	10.0000	75.0000	750.0000	75.0000	at bound
2	X2	10.0000	60.0000	600.0000	0	basic
3	X3	10.0000	40.0000	400.0000	0	basic
4	X4	7.0000	65.0000	455.0000	0	basic
5	X5	1.0000	75.0000	75.0000	25.0000	at bound
6	X6	1.0000	60.0000	60.0000	10.0000	at bound
7	X7	10.0000	40.0000	400.0000	0	basic
8	X8	7.0000	65.0000	455.0000	0	basic
9	X9	6.0000	10.0000	60.0000	0	basic
10	X10	5.0000	15.0000	75.0000	0	basic
11	X11	10.0000	40.0000	400.0000	0	basic
12	X12	1.0000	75.0000	75.0000	15.0000	at bound
13	X13	9.0080	60.0000	540.4799	0	basic
14	X14	1.0000	40.0000	40.0000	40.0000	at bound
15	X15	7.0000	65.0000	455.0000	0	basic
	Objective	Function	(Min.) =	4,840.4800		
	Constraint	Left Hand Side	Direction	Right Hand Side	Slack or Surplus	Shadow Price
1	C1	70,000.0000	=	70,000.0000	0	0.1000
2	C2	964.6799	>=	307.5000	657.1800	0
3	C3	32,253.8800	<=	137,375.0000	105,121.1000	0

Fig 1 Model combined report for Elsuki agricultural scheme:

Appendix B

Table 1 Model Validation

Crop	Operation	Tractors Before	Tractor After	Different	Percent
Dura	Chiseling	9	9	0	
	Harrowing	9	9	0	
	Ridging	9	9	0	
	Planting	7	7	0	
Cotton	Chiseling	8	4	4	
	Harrowing	8	8	0	
	Ridging	8	8	0	
	Planting	7	7	0	
	Herbicides	6	6	0	
	Fertilizer	5	5	0	
	Ridging	8	7	1	
Sun flower	Chiseling	9	5	4	
	Harrowing	9	9	0	
	Ridging	1	1	0	
	Planting	7	7	0	
Sum		110	101	9	8%

Appendix C

Table 1 T-test analysis for number of tractor:

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	121.5000	2	2.12132	1.50000
	after	92.5000	2	3.53553	2.50000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	before - after	29.00000	1.41421	1.00000	16.29380	41.70620	29.000	1	.022

Table 2 T-test analysis for direct cost:

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	6745.0000	2	63.63961	45.00000
	after	4820.0000	2	28.28427	20.00000

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	before - after	1925.000	35.35534	25.00000	1607.345	2242.655	77.000	1	.008

Table 3 T-test for total cost:

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	before	59356.56	4	35231.87414	17615.94
	after	49606.30	4	29994.89877	14997.45

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	before - after	9750.262	5240.80275	2620.401	1410.976	18089.55	3.721	3	.034