ASSESSMENT OF THE UTILIZATION, MANAGEMENT AND OPERATING COSTS OF AGRICULTURAL TRACTORS IN THE CHEMELIL SUGAR BELT IN KENYA.

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ABSTRACT

The research undertook to study the utilization, management and operating costs of agricultural tractors used in the Chemelil sugar belt in Western Kenya. Historical cost data spread over a span of 16 years were obtained for 141 tractors operated by three different owners in the belt. The data was used to assess the level of utilization and operating costs and to test mathematical models for predicting tractor resale values, repair and maintenance costs, annual operating costs as well as establishing the factors that influence them.

It was found that tillage tractors in the belt had an average annual use of 1040 hours and transport tractors 1230 hours and that both category of tractors had restricted utilization due to limits imposed by maximum hectarage for tillage tractors and queuing discipline at the sugar factory and in the fields for cane transport tractors.

Mathematical models were formulated and tested for relation between ratio of tractor resale value to its current purchase price and depreciation age, relation between cumulative repair and maintenance costs expressed as a percent of initial purchase price and tractor age, cumulative

depreciation against tractor age and the ratio of tractor resale value to its annual operating cost against tractor age.

Multiple regression facility in the MSTATC version 1.41 computer software package was used to test the models. Important empirical relations were derived from the results of the tests. Qualitative factors were shown to influence the investigated quantities quantitatively and that the control of the qualitative factors could reduce operating costs.

A relation for predicting annual operating costs of a tractor basing on its replacement value was found. The relation could also be used to predict the tractor's optimal replacement point given the future purchase prices of similar or substitutive models. The trend of actual depreciation was found to defy the basic assumptions of accounting depreciation models. It was demonstrated that due to high inflation rates it is not possible to assign terminal salvage values to tractors in good running order, their age notwithstanding.

DECLARATION

I, Ogweno Samuel Roger Onyango, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has not been submitted for any degree award in any other University.

Signature.................................. Date..11/.12./.1992

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DEDICATION

To my mother, Flora Ahono Ny'Ouko.

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LIST OF SYMBOLS

A_c annual cost, K£

A_{co} annual ownership cost, K£

$\bar{A}_{co}$ annual ownership cost including recurrent insurance, K£

AC_{op} annual operating cost, K£

ACRS accelerated cost recovery system

ASAE American Society of Agricultural Engineers

$\alpha(n)$, $c(n)$, $f(n)$ and $\Gamma(n)$ continuous functions of n

β partial regression coefficients

cdf cumulative depreciation factor

C_d yearly depreciation charge

C_{dn} depreciation charge in the nth year

C_{pp} current purchase price, K£

dm rate of machinery depreciation

D dummy or binary variable

D_{ac} cumulative depreciation

D_{acn} cumulative depreciation in year n

D_{bp} drawbar power , kW

DB declining balance

DDB double declining balance

ϵ error term

EAC(c) equivalent annual cost of challenger, K£

EAC(d) equivalent annual cost of defender, K£

Ed total energy demand, kWh

ED_{bp} equivalent drawbar power, kW

E_{fi} energy demand for field operation i, kWh/ha

E_{ti} energy demand for transport operation i, kWh/t-km

E_{pi}	energy demand for processing operation i, kWh/t
f_c	fixed cost percentage
f_p	fuel price, K£/l
F	fuel cost, K£/l
F_d	draft , kN
f_{mv}	fair market value, K£
f_{mvn}	fair market value after n years of use, K£
H_b	annual hours of breakdown
H_d	annual tractor downtime hours
H_yP	hydraulic power, kW
i_i	investment interest rate
i_f	annual rate of inflation
i_n	net interest rate
i_r	real interest rate
k	purchase price per $P_{to}P$, K£/kW
K£	Kenya pounds
K^*	desired level of investment, K£
L	tractor life in hours
L_y	tractor life in years
L_c	labour cost , K£
L_{ci}	labour cost for operation i, K£
LSM	least squares method
M	level of actual investment, K£
Mi	mass of product processed in operation i , t
n	tractor depreciation age, years
n_a	actual tractor age, years
n_0	tractor operation age, years
N	period of ownership

NPV_m	total present mortgage cost, K£
O_c	oil cost, K£
OL	oil and lubricants cost, K£
P_c	performance costs, K£
P_{max}	rated engine power, kW
$P_{to}P$	PTO power, kW
P_p	initial purchase price or first cost, K£
P_{ur}	power utilization ratio
R	ratio of cumulative repair and maintenance cost to current purchase price
R_m	current repair and maintenance costs, K£
R_{mc}	cumulative repair and maintenance costs, K£
R_{mp}	R_m as decimal of P_p, K£
R_{mpp}	accumulated R_m as a percent of P_p
R_{mcpp}	accumulated R_m as percent of C_{pp}
R_{mn}	R_m in the nth year of use, K£
R_{mIn}	R_m and recurrent insurance cost in the nth year of use, K£
s	operating speed , km/h
SFD	sinking fund depreciation
Si	distance in kilometres for transport trip i
SYD	sum of year digits
SLD	straight line depreciation
S_v	salvage value, K£
T	timeliness cost, K£
Ti	timeliness cost for operation i, K£
T_0	operation time , h/ha
τ	total annual use, h

τ_a	average annual use, h
τ_{ac}	accumulated use, h
μ_i	annual use for operation i, h
$(\mu_f)_i$	annual use for field operation i, h
$(\mu_o)_i$	annual use for other purpose i, h
$(\mu_p)_i$	annual use for processing operation i, h
$(\mu_t)_i$	annual use for transport operation i, h
U_f	total annual use for field operations,h
U_o	total annual use for other operations, h
U_p	total annual use for processing operations, h
U_t	total annual use for transport operations, h
V_c	variable costs, K£
w	effective implement width, m
W_i	payload for transport trip i, t

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1 INTRODUCTION

Due to the twin effect of escalating production costs and that of falling or static commodity prices, the economic performance of agricultural production is facing enormous pressure to consider other farm power management strategies. Farm power being the highest and the most expensive single input in any mechanised agricultural production system ; agricultural tractor managers are challenged to find better methods of costing farm power. Agricultural tractors play a central role in the provision of farm power in modern agricultural production systems. This places agricultural tractor investment and replacement decisions among the most important that producers have to make in agricultural production systems.

Hetz and May (1986) noted that such decisions were critical because they involve a high proportion of total production cost attributable to farm power and due to their infrequency and irrevocability. In order to make a sound decision as to when to replace an old tractor or which new tractor to select requires a thorough knowledge on costs of ownership of tractor. Information on tractor costs can only be obtained if day-to-day records on the tractor costs are kept both by tractor owners and operators. As Singh (1987) correctly observed in India most farmers in developing countries have low education and do not keep records of their tractor expenses. It has been observed that most farmers in Kenya even those with good levels of education consider record keeping as an additional expense and a waste of stationery. Some private companies involved in contracting agricultural tractors either for tillage or transport in the sugar belt also prefer not to keep cost records and when they do the records are generally incomplete rendering the whole exercise futile. The problem of paucity of information has also been observed to affect public companies where the infrastructure and facilities including personnel are already on the ground to facilitate the exercise. The lack of a standard format for recording tractor costs has been observed to be a serious problem in accounting for the profitability of the use of tractor.

The operation costs of agricultural tractors, level of utilization and hence productivity can only be accurately determined from complete and properly kept records. As suggested by Hunt (1986) cost records of machinery operations should be kept to provide the following information:

1. Deductible expenses of the machinery operations.
2. Cost of production data.
3. Information on which to base equipment replacement or investment decisions.

The tractor operator is an indispensable part of a tractorised production system. The level of training and personal disposition to work or the machine can significantly influence the operating costs of a tractor and its useful life. Kolawole (1972) observed that frequent implement breakdown was due to improper handling by operators. Although an important factor influencing machinery costs; it would be difficult to observe the effect of operator training, motivation or disposition to work or tractor in a situation where a tractor has multiple operators, as is the case with most companies or farmers operating a fleet of tractors. In certain cases the operators are hired on a casual basis and can not therefore be assigned to a particular machine for a length of time that would render the effects observable.

The level of utilization of a tractorised system can be used as indicator as to whether the right investment decision was made right from the beginning. The utilization of a tractor is indicated by the annual hours worked. This study undertook to assess the level of utilization, management and economics of operating agricultural tractors in the Chemelil sugar belt. The main agricultural activities identified in the belt were land preparation, including secondary tillage, crop maintenance and cane haulage to the sugar factory.

The main objective of the study was to assess the level of utilization, management and costs of operating agricultural tractors in the Kenyan sugar cane growing industry.
The specific objectives were:

(a) To conduct a survey on different categories of agricultural tractors being used at the Chemelil sugar belt and to evaluate their levels of utilization, management and operating costs.

(b) To identify factors that affect these levels.

(c) To develop empirical mathematical models for estimating operating costs of agricultural tractors and determining their optimal replacement time.

2 LITERATURE REVIEW

2.1 Utilization of Agricultural Tractors

The utilization of an agricultural tractor may be defined in terms of the number of hours spent by the tractor on various assignments. This may be ploughing, interrow cultivation , spraying or transport. The utilization can therefore be stated either as the accumulated quantity of work accomplished by the tractor within a given time interval or simply as the accumulated hours of use within a specified interval of time.

Hunt (1983) expresses tractor utilization accumulated hours of use but prefers to express implement utilization in terms accumulated work quantity accomplished. Adelhem and Steck (1976) and Singh (1987) presented tractor utilization data in terms of total annual hours of use for various assignment including leisure trips. Park (1990) presents his work using both working days and accumulated area worked as a measure of utilization of other field machinery as well as tractors.
For tractors involved in tillage work, spraying, harvesting operations and other field operations the stated methods are adequate. However, for tractors involved in transport utilization can alternatively be stated in terms of accumulated payload hauled over a period of time.

It is more practical to state tractor utilization in hours of use for whatever operation assigned to the tractor. It is also usual to state the utilization of field machinery e.g ploughs, harrows, trailers etc in terms of the accumulated work done i.e area ploughed, area harrowed, or the payload or tonnage.

The level of utilization may be indicated by the operational age of the tractor or the machine defined as the quotient of total accumulated use in hours and average annual use in hours per year by Witney (1988). The operational age of the tractor in turn affects the depreciation rate of the tractor and will to a large extent affect the market valuation of the tractor if offered for resale. A quantity referred to as depreciation age and defined as the average of operational age and actual age is a major factor influencing tractor resale values.

Misungu (1990) made a further distinction in tractor utilization hours in terms of productive and non-productive hours. Productive hours are those in which the tractor is engaged in useful work. It does not include the preparation time nor the travel time from base to the fields. This distinction may be important in precise revenue analysis but is of no useful consequence in the calculation of tractor operating costs.

Total Annual Use τ is a major index of tractor or a machine utilization in any given year. If a breakdown on the hours according to each operation exists then more insight can be gained in valuation of the tractor since certain operations are more demanding than others. For example an hour ploughing is definitely more demanding than one hour spraying

Mathematically this can be expressed as:

$$\tau = \Sigma\mu_i \qquad \text{....(2.1)}$$

where: μ_i = Annual use in hours for operation i

where the subscript i identifies the operation ranging from field work, transport, stationary work or even use for leisure.

More precisely an expression for a multi-use tractor can be written thus:

$$\tau = \Sigma(\mu_f)_i + \Sigma(\mu_t)_i + \Sigma(\mu_p)_i + \Sigma(\mu_0)_i \qquad \text{...(2.2)}$$

where : $(\mu_f)_i$ = annual use in hours for field operation i

$(\mu_t)_i$ = annual use in hours for transport operation i

$(\mu_p)_i$ = annual use in hours for processing work i

$(\mu_0)_i$ = annual use in hours for any other purpose i

Equation (2.2) can be re-written as:

$$\tau = U_f + U_t + U_p + U_0 \qquad ...(2.3)$$

where: U_f = annual use for field operations, hours.

U_t = annual use for transport operations, hours.

U_p = annual use for processing operations, hours.

U_0 = annual use for purposes other than the above, hours.

Over a period of life of the tractor the term Average Annual Use τ_a becomes a more important indicator of tractor utilization. For the purposes of evaluating the operational age of machine especially in market value valuation exercises, a value of τ_a has to be assumed. Witney (1988) assumes 1000 hours as average annual use for most tractors. Accumulated use over the machine life is another indicator which has been used as a measure of utilization. Most tractors have an accounting life (L) of about 12 000 hours according Hunt (1983). Accumulated Use τ_{ac} expressed as a fraction of the expected accounting life L, can also be an important parameter.

Indirectly, tractor utilization can be expressed in terms of the tractor Downtime Hours H_d. This refer to the number of hours the tractor has not been used either due to mechanical breakdown, unavailable operator's personal time, unfavourable field or weather conditions. This quantity expressed as a fraction of τ_a can be an indirect indicator of utilization although, it unfairly penalizes the tractor especially if the vagaries of weather are considered. The tractor can only be fairly judged if it failed to work due mechanical breakdowns or other malfunctions rendering it unable to work. This introduces the concept of Breakdown Hours H_b. This refers to the hours spent by the tractor in the repair workshops either undergoing repairs, waiting for spares or undergoing routine maintenance. H_b expressed as a fraction of expected τ_a can be used as an index of comparing utilization.

2.2 Management of Tractors

Management of agricultural tractors is concerned with the efficient selection, operation, repair and maintenance, and replacement of old or technologically obsolete units. Management also aims at reducing production costs and maximum utilization of both labour and machinery.

2.2.1 Selection of Tractors

The tractor is essentially a power source. The problem of selection of a tractor is that of determining the power level required for the range of activities planned. Mismatched power systems are a major cost burden to a mechanised farm. As observed by Witney (1988) the wrong choice of a machine can only be corrected by tying more capital to advance the date of machine replacement. Inadequate tractor capacity may mean yield losses due to untimely operations, whereas over capacity is likely to introduce the risk of greater soil damage which may again express itself as yield losses.

Matching tractor capacity depends on a number of factors; but above all on the total energy demand for the range of operations to be undertaken and expected throughput of work within a given interval of time.

The energy demand for various operations can be deduced from the following basic relations:

$$E_d = \Sigma(E_{fi})A_i + \Sigma(E_{ti})W_iS_i + \Sigma(E_{pi})M_i \quad \text{...(2.4)}$$

where: E_d = total annual energy demand in kW-hr.

E_{fi} = energy per unit area required by field operation i (kW-h/ha)

A_i = hectarage covered by operation i

E_{ti} = Energy needed to transport one metric tonne over a distance of one kilometre(kw-hr/t-km) in trip i.

W_i = Pay load in metric tonnes in trip i

S_i = Distance in kilometres for trip i.

E_{pi} = energy required to process one metric tonne processing operation i (kw-hr/t)

M_i = mass of product in metric tonnes processed in operation i.

For tillage operations energy demand is given by:

$$E_f = 10D_{bp}/sw \quad ...(2.5)$$

$$= D_{bp}T_0$$

where: D_{bp} = actual drawbar power in kW

E_f = energy demand for tillage operation in kW-hr/ha

s = operating forward speed in km/h

w= effective implement width in m

T_0 = operation time in h/ha

Hunt (1983) observed that energy requirement per unit area is constant regardless of the tractor or implement size when typical field speeds are used.

Zhengping *et al.* (1986) expressed the total equivalent PTO power required by a field operation as:

$$P_{to}P = ED_{bp} + R_oP + H_yP \qquad ..(2.6)$$

where ED_{bp} = equivalent drawbar power in kW

R_oP = PTO rotary power in kW

H_yP = hydraulic power in kW.

Hydraulic power is only a minor component of $P_{to}P$ and can conveniently be ignored. For ploughing, harrowing and planting:

$$P_{to}P = ED_{bp} \qquad ...(2.7)$$

since no rotary power is required by the operations. Estimating the tractor power starts with an estimate of the drawbar power required. Thus:

$$D_{bp} = F_d s/3.6 \qquad ...(2.8)$$

F_d = Draft in kN

s = working speed in km/h

Drawbar power can be converted to the equivalent PTO power by the following relation:

$$ED_{bp} = D_{bp}/(0.96T_e) \qquad ...(2.9)$$

0.96 = assumed tractor internal power transmission efficiency.

T_e = tractive efficiency

= (drawbar power)/(axle power)

Alternatively the power size of the tractor can be deduced in terms of its annual cost (Hunt 1983).

$$A_c = fP_p/100 + \tau\{R_{mp} + L_c + OL + F + T\} \qquad ...(2.10)$$

where: A_c = annual cost K£/h

f = Fixed cost percentage.

P_p = Purchase price in K£

R_{mp} = repair and maintenance costs per hour as a decimal of P_p, K£/h

L_c = Labour costs in K£/h

OL = Oil and lubricants cost in K£/h

F = Fuel costs (K£/h)

T = Timeliness costs (K£/h)

Hunt (1983) expresses P_p in terms $P_{to}P$ as :

$$P_p = kP_{to}P \qquad ...(2.11)$$

k = purchase price per $P_{to}P$ (K£/kw)

Hence annual cost in terms of tractor power becomes:

$$A_c = fkP_{to}P/100 + \tau\{\Sigma L_{ci} + \Sigma Ti\} \qquad ...(2.12)$$

L_{ci} = Labour cost (K£/h) for operation i

T_i = Timeliness cost (K£/h) for operation i

More precisely:

$$A_c = fkP_{t0}P/100 + \{(U_f + U_t + U_p)\Sigma L_i + U_f\Sigma Ti)\} \quad ...(2.13)$$

This equation assumes zero timeliness cost for transport and processing operations. The optimum power level required is obtained by minimising this equation.

Hunt (1983) arrived at the following relation.

$$P_{t0}P = \sqrt{[100/fk\{(U_f + U_t + U_p)\Sigma L_i + U_f\Sigma T_i\}]} \quad ...(2.14)$$

The tractor manager should be well acquainted with the pertinent selection factors not forgetting the existing tractor capacity before deciding to invest.

2.2.2 Operation of Tractors

Kampe (1971) recognized lack of record keeping as a serious limitation in machine cost analysis. Culpin (1986) noted farmers could calculate their own costs of operations by keeping records of annual use, repairs and replacement of part, fuel, lubricating oils, grease, license, insurance and housing.

Once the tractor has been purchased, a history file should be opened for it to record periodical summaries of its activities; including cumulative machine hours, hours of breakdown, downtime hours, work rates, fuel consumption, lubricants consumption, repair and maintenance dates and cost. Information like the frequency of replacement of a part or component if recorded over working life of the tractor could provide useful information for improvement of part or component design. Larson (1977) noted that farmers should be able to know which machine parts to stock and those to get from the dealers and suggested that lower cost items with high incidence of breakdown should be stocked by the farmers to reduce downtime costs.

The next concern of management involves task allocation considering available tractor capacity, operator performance and tractor performance, and available workdays . Tractor performance should be matched with operator

performance as suggested by Hunt (1983). This is to ensure the tractor capacity and operators' abilities is fully and optimally utilized. Tractor operation can only be traced through properly kept records.

Records are usually derived from daily activities reports. This will enable the machinery manager to monitor the performance of the fleet on a daily basis. The daily activity report should essentially contain information on work accomplished at the end of the day, fuel drawn, hour-meter readings at the start and at the end, lubricants if any used, any malfunctions noted by the operator or a fault report, and any repairs done in the field or workshop.

The daily reports are then compiled to yield periodical records: monthly, and annual summaries. From these the manager can trace the performance of individual tractors and can be guided into making useful inferences about the tractors and their operators.

2.2.3 Tractor Repair and Maintenance

Tractor maintenance is the work done on the tractor to keep it in good working order and to prolong its working life. This includes daily oil check, greasing, battery inspection, engine-tuning, replacement of worn out parts as in engine overhaul. Maintenance for each tractor must follow a well planned schedule of which both the operator and the manager should be well aware. Usually maintenance work is graded as daily, seasonal, or done after a certain number of machine hours have been clocked or after a designated number of hours of work. However, unplanned or unscheduled maintenance may be done as and when necessary.

Repair works are usually undertaken to replace broken parts or malfunctioning components. As observed by Fairbanks *et. al* (1971), Hunt (1983) and Witney (1988) the repair costs are difficult to estimate because the repair jobs occur at random. They are usually dealt with as and when they occur. Experienced managers would know the failure rates of certain components in a given tractor and stock those parts in anticipation of a breakdown in order to avoid delays due to requisition on demand (Larson 1977).

2.2.4 Tractor Replacement

The need to replace a tractor may arise due to accident damage, inability to cope with increased power demand, old age or technological obsolescence. O'Callaghan (1988) defines the economic replacement model as the point in the physical life of the machine at which the total annual costs reaches a minimum.

Hunt (1983) relies on the knowledge average annual use τ_a, to relate the expected repair and maintenance costs R_a to the annual fixed costs f_c and defined the replacement point as that at which accumulated costs divided by accumulated use, τ_{ac} is a minimum.

A replacement decision is a choice between the present asset invariably called the Defender and a currently available list of replacement alternatives termed Challengers. Riggs (1977) and O'Callaghan (1988) considered replacement problem by comparing cash flows for both the challenger and the defender over an interval of time - the remaining life of the defender in terms of equivalent annual cost calculations (EAC). The fair market value of the defender, or its resale value in a perfectly competitive market is taken as the defender's worth when replacement is contemplated.

Alternatively the defenders resale value is considered as a positive cash flow that offsets part of the challenger's initial purchase price which can be assumed to be replacement price of the defender. The net differences between the cash flow of the defender and challenger are then compared for the remaining economic life of the defender.

For instance the defender's market value after n years of use can be taken as $f(n)*C_{pp}$ and this can be related to expected cash outflows in form of operating costs such that if the future replacement price is known then equivalent annual cost comparisons can be made entirely in terms of the future replacement price.

$R_{vn}(d) = f(n)*C_{pp}$ ...(2.15)

where: $R_{vn}(d)$ = Resale value of defender after n years.

C_{pp} = Current purchase price of similar tractor model

= Challenger's list price.

It can also be postulated that the operating cost of a tractor are related to the challenger's list price by the following equation.

$C_{op}(n) = c(n)f(n)*C_{pp}$ ...(2.16)

$C_{op}(n)$ = operating cost after n years of use.

c(n) , f(n) = are continuous functions of depreciation age for all values of $n > 0$.

2.3 Tractor Ownership and Operating Costs

Accurate knowledge of ownership and operating costs is essential to economic management of machinery particularly in replacement and investment decisions (Hassan and Larson, 1978). The costs are designated as fixed or variable. The ownership costs according to Audsley and Wheeler (1978) and Witney (1988) are capital invested, the interest due on capital invested , recurrent repair and insurance charges.

The operating costs are the sum of ownership costs and costs due to use namely; fuel and lubricants and operator wages and performance costs. These costs are loosely designated as fixed and variable.

2.3.1 Tractor Fixed Costs

The ownership or fixed costs include depreciation, interest on investment, shelter, taxes and insurance and sometimes operator wages depending on the labour laws in force or on whether the labour is permanent or seasonally hired.

a) Depreciation Costs

Depreciation is defined as the loss in value of an asset with passage of time, use or due to technological advances. It is recognized as a capital expense for purposes of tax analysis. This permits two concepts of depreciation to exist side by side: depreciation as the true loss in value of an asset and depreciation as a deductible business expense.

There are several methods of depreciation used for the latter purpose namely: straight line depreciation (SLD), sum of year digit depreciation (SYD), declining balance depreciation

(DB), double declining balance method (DDB), sinking fund depreciation (SFD) and accelerated cost recovery system (ACRS).

1. Straight Line Depreciation: This assumes an equal reduction in value for each year of ownership and that the asset has a scrap or salvage value at the end of its economic life. Mathematically this is expressed as:

$$D_{acn} = (P_p - S_v)/L_y \qquad \ldots(2.17)$$

where : D_{acn} = cumulative depreciation after n years.

P_p = initial cost or purchase price.

S_v = salvage or scrap value

L_y = life of asset in years.

This method is preferred because it is simple to use but it fails to account for rapid depreciation of assets in the initial years.

2. Sum of Year Digit Method (SYD): This a rapid writeoff technique by which the value of an asset is written off in the first one third of its life (Blank and Tarquin, 1976). The depreciation charges are very high in the first few years but decrease rapidly in the later years of the assets life.

$$C_{dn} = (L_y - n + 1)(P_p - S_v)/S \qquad \ldots(2.18)$$

where: C_{dn} = depreciation charge for the nth year.

$S = L_y(L_y+1)/2$ = sum of year digits.

3. Declining Balance and Double Declining Balance Method : Both are rapid writeoff techniques. The depreciation charge for any year is determined by multiplying a uniform percentage by the book value at the end of the previous year.

$$C_{dn} = Bv_{n-1}x/L_y \qquad \ldots(2.19)$$

where Bv_{n-1} = book value of asset at the end of previous accounting year

and $0 \leq x \leq 2$.

When $x = 2$ then the method is double declining.

x/L_y = depreciation rate = $1 - (S_v/P_p)^{1/Ly}$

If salvage value is reached prior to life, L_y no additional depreciation charge may made thereafter according to Blank and Tarquin (1976). They also observed that this generally occurs for short lived assets i.e those with less L_y than five years or for assets with large salvage values i.e S_v greater than $0.2P_p$

4. Sinking Fund Depreciation: This is a fund established to accumulate a given future amount through a collection of uniform series payment (Riggs, 1976). As with the other models it assumes a salvage value at the end of the tractors useful life. If interest is not considered the annual depreciation charge is constant, however, the charge usually earns interest at a predetermined interest rate.

$$D_{acn} = [(P_p - S_v)i/(1+i)^{Ly-1}]x[(1+i)^{Ly-1}]/i \quad ...(2.20)$$

where: D_{acn} = cumulative depreciation in the nth year

5. Accelerated Cost Recovery System: this system of depreciation was introduced in the USA in 1981 by statutory law termed the "The Economic Recovery Tax Act of 1981" which stipulates a statutory recovery periods of three, five, ten or fifteen years determinable when first depreciation is charged. It has provision for tax relief in the year the asset is purchased i.e it increases capital recovery through investment tax credit. Capital expense is deducted from the first cost before computing the ACRS depreciation amount (Blank and Tarquin, 1976).

All the depreciation models discussed above are silent about the effect of inflation on depreciation charges. As they stand they fail to account for changes in estimated salvage values due to inflation and need to be modified to trace the true trends of tractor depreciation.

In order to account for effects of inflation, in depreciation models Witney (1988) and Schoney and Rinholm (1989) related the fair market value or resale value to the current purchase price of a similar model or perfectly substitutive model of the machine. They referred to economic depreciation as opposed to accounting depreciation; as the loss in fair market value (f_{mv}) of a capital asset. They related the fair market value of a machine in the n^{th} year of ownership to the current purchase price of a similar machine thus:

$$f_{mvn} = \alpha \beta^{n} C_{pp} \qquad \text{....(2.21)}$$

where: f_{mvn} = fair market value of machine in year n

α, β = are estimated parameters depending on machine type

n = machine age in years.

C_{pp} = current new replacement cost

= current purchase price of a similar machine.

f_{mv} are based on 'As Is' auction values. New replacement costs are based on current investment requirements exclusive of trade-in values.

Future market value of a currently owned machine are based on future new replacement costs and machine age. In projecting future nominal market value an adjustment in future new prices C_{pp} is included. In effect, annual estimates of f_{mv} are inflated by a factor $(1 + i_f)^n$

where: i_f = annual inflation rate and n = the number of years in the future.

This compares well with the observation of Prior (1987) when he defined the rate of machinery depreciation by the relation:

$$d_m = M/K^* \qquad \ldots(2.22)$$

where: M = level of actual investment

≈ remaining value of asset ≈ f_{mvn}

K^* = the desired level of investment

≈ current new replacement cost.

Witney (1988) derived an expression which is similar to the foregoing empirical relations of the form:

$$(R_{vn})/C_{pp} = \Gamma(n) \qquad \ldots(2.23)$$

where: R_{yn} = resale value of an n year old machine.

= fair market value of an year old machine.

C_{pp} = current purchase price.

$\Gamma(n)$ = function of operational age, n

To evaluate the operational age of a machine an average annual use, τ_a of 1000 h was assumed.

All these models are based on varying rates of depreciation and on market value of machines. Prior (1987) demonstrated that models based on constant depreciation rates were significantly inferior to those with varying rates.

Hunt (1983) derived an expression for accumulated depreciation which also emphasizes the importance of the market place remaining value of the form:

$$D_{ac} = (0.205 + 0.053n - 0.00064n^2)P_p \qquad ...(2.24)$$

where: D_{ac} = accumulated depreciation through n years of use.

(b) Interest on Investment

This is a direct expense on borrowed capital or the opportunity cost of own capital. Kampe (1971) suggested charging interest on machine market value at the beginning of the accounting year. Adelhem and Steck (1976), Pandey and Ojha (1986), and O'Callaghan (1988) all agreed that it is customary to choose a constant rate of interest over the life of the machine and calculate interest charges on the average investment.

Hunt (1983) preferred to consider interest charges along with shelter costs, tax costs, and insurance costs and expressed these as a percentage of the purchase price P_p.
The manner of assessing the average investment depends on the method of depreciation followed.

Inflation affects the real cost of borrowing. It is therefore more sensible to talk of real interest rate. This is defined by Witney (1988) as the total repayment related to the purchasing power of the loan

$$i_r = \left[\frac{(1 + i_i)}{(1 + i_f)} - 1\right] \qquad \ldots(2.25)$$

where: i_r = real interest rate.

i_i = investment rate.

i_f = inflation rate.

Alternatively Net interest rate can also be used to account for effects of inflation.

$$i_n = i_i - i_f \qquad \ldots(2.26)$$

When the capital is borrowed it is more realistic to consider the mortgage costs in terms of annual mortgage payments. However when dealing with current expenses or actual cash flows, the nominal interest rates or maximum bank lending rates give a clearer view of interest charges (Bartholomew, 1981).

(c) Insurance Costs

Agricultural tractors need to be insured against various risks including accident damage, theft, and fire. Insurance premiums are usually payable annually and are negotiated on the basis of the extent of cover required. Most companies require the customer to pay equal annual payments over the whole life of the machine.

(d) Shelter Costs

Machinery housing while having no direct influence on rate of depreciation, can improve the market valuation of a machine. Shelter costs may be determined by considering the investment costs of the housing structure. In case of open yard parking of tractors the opportunity cost of the best alternative use for the parking area plus the investment costs in fencing off the area.

(e) Tax Costs

Tax may be levied on agricultural tractors how much this is depends on the tax policies in force. Apart from road licensing agricultural tractors and equipment are currently exempted from tax.

2.3.2 Variable Costs

These are costs that vary with tractor use. They comprise fuel and lubricants costs, maintenance costs. Repair costs although a varying cost does not directly depend on use since failures which call for repairs occur at random (Hunt, 1983 and O'Callaghan, 1988). Maintenance costs is such a minor component of the variable costs that it has customarily been lumped with repair costs.

(a) Tractor Repair and Maintenance Costs.

Repair and maintenance costs are those expenses necessary to restore or maintain technical soundness and reliability of the machine (Morris 1988). They are attributable to wear and tear, random failure of parts and accidents. Repair costs comprise cost of replaced parts, including tires and tubes, and labour directly attributable to particular repair and maintenance jobs, and where appropriate a general charge for workshop overhead expenses. Repair and maintenance costs are expressed in three different ways:

1: As a constant cost per tractor-hour (K£/h)

2: As cost per tractor hour as percent of the tractor's purchase price at a particular point in the machine's working life.

3: As a constant cost per unit area (tillage and harvesting tractors) in (K£/ha)

The second method has been more popularly used by many researchers in this area. Bowers and Hunt (1970) derived a relation between accumulated repair and maintenance costs and accumulated use of the form:

$$R_{mpp} = 0.076(\tau_{ac}/120)^{1.6} \qquad \ldots(2.27)$$

R_{mpp} = accumulated repair and maintenance costs as percent of P_p.

Ward *et al.* (1985) also derived a similar expression:

$$R_{mpp} = 0.042(\tau_{ac}/120)^{1.895} \qquad ...(2.28)$$

These equations closely agree a similar relation contained in ASAE Yearbook (1987) of the following form:

$$R_{mpp} = 1.2(\tau_{ac}/1000)^2 \qquad ...(2.29)$$

Morris in (1988) also arrived at a relation of a similar form:

$$R_{mpp} = (0.0996\tau_{ac}^{1.4775})10^{-3} \qquad ... (2.30)$$

Hassan and Larson (1978) compared the accumulated repair and maintenance cost expressed as percent purchase price P_p with accumulated use expressed a percent of tractor life L and arrived at the following result:

$$R_{mpp} = 0.00171[(100\tau_{ac}/L^*)^{2.41}] \qquad ...(2.31)$$

where: L^* = the economic life in hours for the combine; the magnitude assumed by the author was not quite clear but in general 12000 hours is used in this study.

They also arrived at a polynomial relation when they compared accumulated repair and maintenance cost as percent of P_p accumulated use in 100 tractor hours, H_h.

$$R_{mpp} = 1.9H_h + 5.8H_h^2 - 0.7H_h^3 + 0.0004H_h^5 \qquad ...(2.32)$$

Hunt (1983) compared accumulated repair and maintenance costs as a ratio to the current purchase price P_p or list price of a similar machine against accumulated use in 1000 hours and arrived at a polynomial function of the following kind:

$$R = c_1H_t + c_2H_t^2 + c_3H_t^3 \qquad ...(2.33)$$

R = ratio of accumulated repair and maintenance costs to the current purchase price.

H_t = units of accumulated use in 1000 h

c_1, c_2, c_3 = constants for specific machines.

Peterson and Milligan (1976) compared the ratio of accumulated repair cost to the current purchase price of the self propelled potato harvesters expressed as a percentage with the ratio of accumulated use as a percent of machine life L, and derived the following relation:

$$R_{mcpp} = 0.127(100\tau_{ac}/L)^{1.4} \qquad ...(2.34)$$

where: R_{mcpp} = accumulated R_m as percent of current purchase price

Any one of these empirical relations can be used to predict repair and maintenance costs of a tractor, however, their major limitation is that they tend to be area specific and may not have taken into account other contributory factors.

(b) Fuel, Oil and Lubricants Costs.

The tractor is only a power source offering traction services to other implements. Fuel and oil costs are therefore chargeable to the implement used. Fuel consumption is related to the engine loading for any given assignment. Witney (1988) suggested that most tractors operate at an average 55% of maximum PTO power annually.

Engine oil consumption is also related to the engine power rating. It is difficult to estimate the consumption other oils like transmission oils, hydraulic fluids but these are generally considered to be a minor component of the oil costs. Witney (1988) estimated specific fuel consumption by this equation:

$$S_{fc} = 2.64P_{ur} + 3.91 - 0.2\sqrt{(738P_{ur} + 173)} \qquad ...(2.35)$$

where: S_{fc} = specific fuel consumption (1/Kwh)

P_{ur} = power utilization ratio = (power demand)/$P_{to}P$

Fuel cost is then estimated by the equation :

$$FC = S_{fc} x P_{to} P x f_p \qquad ...(2.36)$$

where: f_p = fuel price (K£/1)

According to Witney (1988) oil cost is estimated by:

$$O_c = 0.02169 + 0.0059P_{max} \qquad ...(2.37)$$

where: P_{max} = rated engine power.

Table 2.1: Fuel and oil consumption for diesel engines of various power outputs.

Max power output $P_{to}P$ (kW)	Fuel consumption, (l/h) at max power	at 55% max power	oil consumption l/100 h
25	13	8	4
50	26	15	5
75	38	23	7
100	51	30	8
125	64	38	10
150	77	45	11

(Source : Witney, 1988)

(c) Tractor Labour Costs.

Like fuel and lubricant costs, labour costs is usually charged to the implement being used in a given operation. Labour is charged at hourly rates. Either manhours or machine hours can be used. Experienced managers can correlate machine hours to given manhours.

2.3.3 Performance Costs

Tractor performance costs are directly linked to its ability to accomplish a given activity within a planned schedule of time. It is the penalty for failure to achieve the stated objective due to undercapacity, mechanical unreliability or for any reason directly attributable to the tractor. O'Callaghan (1988) defined the performance costs in terms of machine performance matrix in a tractor assignment problem. In this matrix each tractor has a performance rating depending on its measured abilities and reliability. In general performance costs are alternatively expressed as timeliness costs.

The performance cost of a tractor rated with respect to specific operations can be calculated from the following matrix as suggested by O'Callaghan (1988)

Tractor	Operation		
	O_1	O_2	O_j
T_1	a_{11}	a_{12}	a_{1j}
T_2	a_{21}	a_{22}	a_{2j}
.	.	. ...	.
.	.	. ...	.
.	.	. ...	.
T_i	a_{i1}	a_{i2}	a_{ij}

$0 < a_{ij} \leq 1$

Where a_{ij} : is the performance rating for tractor i when doing operation j relative to other tractors in the fleet which could do the same operation.

The performance cost according to O'Callaghan (1988) is given by:

$$P_c = (1/a_{ij} - 1)(F_c + V_c + L_c) \qquad ...(2.38)$$

where: F_c = fixed costs, K£

V_c = variable costs, K£

2.4 Annual Costs of Ownerships from Actual Cash Flows.

Determination of annual costs of tractor ownership arise from four types of cash flows according to Audsley and Wheeler (1978) and Witney (1988). These are:

1. Capital cost of buying the tractor.
2. Recurring annual repair and maintenance costs and insurance charges.
3. Interest paid on borrowed capital.
4. The income from selling the tractor.

Audsley and Wheeler (1978) expressed annual costs of tractor ownership as:

$$A_{co} = \left[\frac{P_p + \Sigma(R_{mn}w^n - R_{vn}w^n)(w-1)}{w(w^N - 1)} \right] \qquad \ldots(2.39)$$

where: $w = (1 + i_f)/(1 + i_i)$ = inflated discount factor.

R_{mn} = the current value annual repair cost in the n^{th} year.

N = period of ownership, years

Witney (1988) modified this equation to include the recurrent insurance cost and used the present mortgage cost instead of purchase price P_p. Thus:

$$A_{co} = \frac{\{ NPV_m + \Sigma[R_{mIn} + 0.01RV_{(n-1)}] - R_{vn}w^N\}(w-1)}{w(w^N - 1)}$$

...(2.40)

where: A_{co} = present annual ownership cost modified to include recurrent insurance costs, K£.

NPV_m = total present mortgage cost, K£

R_{mIn} = annual repair and maintenance cost and insurance cost, K£

Insurance is charged at 1% of the remaining value of the tractor at the close of the preceding year.

3. MATERIALS AND METHODS.

3.1 Location of Study Area.

Data for this study was collected from Chemelil Sugar Company, Nyaroche Farm and ADC Kimwani Complex Farm. All the three are based in the same agronomic zone usually referred to as the Chemelil Sugar Belt. The belt lies close to the equator at about 35°E longitude, and is about 50 km south east of Kisumu town. It is located on the southern slopes of the Nandi escarpment and extends down to the basin of river Nyando. The map of Kenya showing the location of study area is shown in the appendix A.

3.2 Source of Data.

Tractor costs data for Chemelil sugar company was obtained from monthly summary cost sheets a sample of which is shown in fig. 3.1. below. The data was taken only for tractors operated by the Engineering and the Transport and harvesting Sections of the Company's Agricultural department. The monthly summary sheets were summed up to give yearly costs for all tractors in the mentioned departments purchased between January 1975 and December 1990.

CHEMELIL SUGAR COMPANY LIMITED F.W.R.F 2

FIELD WORKSHOP MOBILE EQUIPMENT BY RECORD

MAKE........ PERIOD....... YEAR........

									Total KShs	
Plant Nos										
Vehicle Nos										
Tyres and Tubes										
R & M Materials										
R & M Labour										
R & M Outside										
Lubricants										
Servicing										
Puncture										
Total Period Expenditure										
Fuel										
Operator Wages										
Depreciation										
Taxes/Licence										
Insurance										
Total Expenditure										
Hours/Miles/km										
Cost per hr/mile/km										
Litres of Fuel used										

Fig. 3.1 A Sample of tractor cost sheet used by Chemelil Sugar company.

Other relevant information on management and operation of the tractors was obtained from monthly, quarterly and annual reports. This included monthly tractor hours, repair and maintenance materials cost, repair and maintenance labour charges, tires and tubes cost, lubricants cost, fuel cost, operator wages, depreciation charges, interest charges, and licence charges.

The data for tractors owned by Kimwani ADC farm was obtained from tractor daily log sheets with monthly totals for cumulative tractor hours, quantity of fuel used, quantity of lubricants used and details of repair and maintenance. The quantities were converted to costs by multiplying by respective weighted average item price over the month and these were in turn summed over the year to find annual totals over a similar span of time. A sample of the daily log sheet is shown in fig. 3.2 . Besides the log sheet each tractor in the farm had a repair and maintenance ledger in which all details of repair and maintenance was entered including costs of spares. A total of 141 tractors were investigated.

FARM..........   TRACTOR LOG SHEET

TRACTOR No.......   REG No.......   MAKE......   MODEL......

MONTH.......   YEAR.......

Date	Field No	Operation	Hour Meter OUT	Hour Meter IN	Total Hours	Fuel issued	Lubes* issued	Breakdown and repairs
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
.								
.								
.								
30								
31								

* Lubes refer to lubricants i.e oils, hydraulic fluids and grease

Fig 3.2 Sample Tractor Log sheet (Courtesy of Kimwani ADC complex Farm.)

The data obtained from Nyaroche farm were extracted from individual tractor files where documents like fuel issue notes, lubricants issue notes, repair records, service records, invoices for outside repairs were filed. The tractors' log sheet files yielded information like tractor hours, for given assignments, fuel drawn in litres, oil drawn in litres. The repair and maintenance cost were summarised at the rear of the log sheet. Fuels and lubricants were reported as quantities. These had to be converted to the costs by multiplying by weighted average annual unit prices obtained from the farms' stores records. This had also to be done for some spares replaced without indicating the cost. Labour charges were taken from the wages roll for the workshop staff in charge of repairs and maintenance and apportioned to each tractor according to its frequency in the repair shed.

The information obtained was summed to give annual cost for each year of tractor ownership. These were then recorded in data sheets for each tractor throughout its period of ownership.

Data on tractor purchase prices both for new and used were obtained from sales records of dealer companies. Resale values of used tractors were obtained from actual auction records and trade in values record by dealers, and from the records of the Chemelil Sugar Company and the other farms covered in the study. Personal interviews with property valuers provided rational valuation techniques assuming the tractors were in good running condition and are disposed of in a competitive market.

Data on insurance costs were obtained from the annual returns records of Chemelil sugar company. Only comprehensive cover was considered for sake of uniformity in this study. The average value of the net premiums paid as a percent of estimated remaining values were computed from for a sample of two years for which complete records were secured. The mean value of 1.765 % of the estimated remaining value was used to compute the premiums payable at the beginning of each accounting year for comprehensive cover of the insured tractor, basing on the fair market value. Fair market value was assumed to be for all practical purposes identical to the remaining or undepreciated value of the tractor at the beginning of the accounting year.

Interest charges were based on maximum bank lending rates for the years in the study span. Interest was also charged on the remaining value of the tractor at the beginning of the accounting year. The bank lending rates applicable during the study span are shown in table C1 in the appendix.

Tractor road license charges were obtained from various circulars (1975-91) issued by the Ministry of Transport and Communications. The shelter charges are shown in table C2. Depreciation charges were computed using tractor remaining values predicted by a model as discussed in section 3.4.1.

Shelter charges were estimated by considering the best alternative use for the open parking space assuming a tractor requires about 25 m^2 of space for parking and manoeuvring. This figure was arrived at by measuring the space occupied by an average tractor in the models considered and providing space allowance for manoeuvring the tractor. Sugar cane income foregone was computed using typical cane yields per hectare for the area multiplied by the prevailing cane prices.

The investment on the parking lot fencing was charged at a flat interest rate assuming a 50 year fence life as from 1970 when the three enterprises started operating. It was also assumed that the parking yard requires re-murraming every five years and the cost of doing so was also charged at a flat interest rate at equal instalments in the five years.

The sum of interest charges due to fencing investment and due to recurrent murramming and the income due sugar cane yield foregone was computed for each year spanning 1970 to 1991 and the values for each year taken as the shelter charge for each tractor. The shelter estimated charges are shown in table C3 in the appendix.

3.3 Operation and Management Information.

Information on operation and management of the tractors was obtained by personal observation and interviews with the managers, supervisory staff and tractor operators and from management and organization records. Common points emerged from the three cases : A daily routine starting with jobs or activity assignment, execution, supervision and monitoring and evaluation. These were manifested in form of daily performance reports, breakdown reports, supervisors reports and weekly evaluation and monitoring reports.

3.4 Data Processing.

Data spreadsheet for each tractor covered in the study were made using Lotus 123 computer package. Statistical models were processed using MSTATC version 1.41 computer package. To facilitate comparison of cash flows in different years for different tractors the real Kenya pounds were converted to actual Kenya pounds by multiplying by the factor $(1 + i_f)^n$ for all cash flows before 1983 and by a deflation factor $1/(1 + i_f)^n$ for cash flows after 1983 as suggested by Riggs (1977), Blank and Tarquin (1983), Hunt (1983), and Morris (1988). 1983 was significant because it was the mid-year for the the study span. It was therefore chosen as a base year and all costs expressed in terms of 1983 prices using applicable deflation and inflation factors.

Average inflation rate for the period 1975-80 was 10.8% as reported by World Bank (1986) and for the period 1981-91 was 12% as indicated by various Kenya Statistical Abstracts(1981-91). These values were used in processing data.

To facilitate analysis, all the tractors covered in the study were divided into three categories according to power range. Power range I for all tractors with up to 80HP PTO power, power range II for all tractors between 80 and 120 HP and power range III for all tractors with more than 120 HP.

3.5 Model Formulation and Testing.

Four models were proposed and tested using multiple and polynomial regression techniques assisted by MSTATC statistics computer package. The following relations were studied using the models in satisfying objective (b) of the study :

1. The relation between the ratio of tractor resale value after n years of use to its current purchase price and the tractor depreciation age.

2. The relation of cumulative tractor repair and maintenance costs expressed as percent of its 1983 purchase price versus (a) its depreciation age, (b) its operation age and (c) its actual age.

3. The relation of cumulative depreciation of a tractor expressed as a fraction of its initial purchase price versus its (a) depreciation age, (b) operation age and (c) actual age.

4. The relation of the total operating costs per hour versus (a) depreciation age, (b) operation age and (c) actual age.

5. The relation between ratio of tractor resale value to its annual operating costs against tractor (a) depreciation age (b) actual age and (c) operation age.

3.5.1 Relation between Ratio of Tractor Resale Value to its Current Purchase Price and Tractor Age .

Values of the ratio of tractor resale values and respective depreciation ages were randomly picked from the individual tractor data spreadsheet and a data matrix consisting of the explanatory variables and dummy or binary variables was constructed and analyzed using the method suggested by Johnston (1972). The data matrix is shown in the appendix D. Effects of interaction between the influencing variables was not investigated, in this and in the subsequent models. A preliminary scatter plot of the values of the ratio against values of depreciation age and a consideration of the factors postulated to affect the relationship; suggested the testing of the following model :

$$\ln(R_{vn}/C_{pp}) = \beta_0 + \beta_1 n + \beta 2n^2 + \beta_3 D_3 + \beta_4 D_4 + \beta_5 D_5 + \beta_6 D_6 + \beta_8 D_8 + \beta_9 D_9 + \beta_{11} D_{11} + \beta_{12} D_{12} + \beta_{14} D_{14} + \beta_{15} D_{15} + \epsilon \quad \ldots(3.1)$$

$\beta_0, \ldots \beta_{16}$ are partial regression coefficient estimated by least square method.

n = depreciation age in years.

$D_3, D_4 \ldots D_{16}$ are dummy variables introduced in the model to account for qualitative factors.

ϵ = error term.

D_3 = 1 if make of tractor was Ford and 0 otherwise.

D_4 = 1 if make of tractor was Same and 0 otherwise.

D_5 = 1 if make of tractor was MF and 0 otherwise.

D_6 = 1 if make of tractor was International and 0 otherwise.

D_7 = 1 if make of tractor was classed heavy plant and 0 otherwise.

D_8 = 1 if tractor was used for tillage operations and 0 otherwise.

D_9 = 1 if tractor was used for transport operations and 0 otherwise.

D_{10} = 1 if tractor war used for other operations and 0 otherwise.

D_{11} = 1 if tractor was owned by Chemelil Sugar company and 0 otherwise.

D_{12} = 1 if tractor was owned by Nyaroche farm and 0 otherwise.

D_{13} = 1 if tractor was owned by Kimwani ADC complex farm and 0 otherwise.

D_{14} = 1 if tractor was in power range I and 0 otherwise.

D_{15} = 1 if tractor was in power range II and 0 otherwise.

D_{16} = 1 if tractor was in power range III and 0 otherwise.

D_7, D_{10}, D_{13} and D_{16} were deliberately omitted from the model so as to avoid the problem of linear dependence when each attribute was considered alone and to permit solution of the multiple regression matrix.

Restricting the contribution of all the qualitative factors to zero i.e putting $\beta_3 = \beta_4 = \beta_5 = ... = \beta_{16} = 0$ the following prediction equation was obtained by regression.

$$R_{vn}/C_{pp} = EXP(-0.204n + 0.00753n^2) \quad ...(3.2)$$

This equation was used to predict the resale values of the tractors covered in the study. It was assumed that if the tractors were resold in a competitive market then their resale values were identical in every respect to their remaining values or their fair market values after n years of use. The normal distribution and constancy of variance of errors was examined by plotting the predicted response or one of the independent variables against the residuals as suggested by Draper and Smith (1966) and Snedecor and Cochran (1989).

The result of examination of residuals showed the assumptions of the distribution, constancy of variance and zero means of errors were upheld. Cumulative depreciation charges of the tractors were computed by subtracting their predicted remaining values discounted for inflation from the tractor initial purchase price, and the yearly depreciation charge by the difference between cumulative depreciation between consecutive accounting periods. The prediction equation obtained from the model is discussed in more detail in chapter 4. Thus :

$$D_{ac(n)} = P - R_{vn}/(1+i_f)^n \qquad \ldots(3.3)$$

and annual or yearly depreciation as the difference between successive accounting years. Thus:

$$C_d = D_{ac(n)} - D_{ac(n-1)} \qquad \ldots(3.4)$$

where: C_d = yearly or annual depreciation

$D_{ac(n)}$ = cumulative depreciation through n years of use.

By further manipulation of the model, the effect of tractor make, type of operation, ownership and tractor power range on the ratio or resale value to current purchase prices were investigated. For example the effect a Same tractor, doing tillage work, and owned by Chemelil company and in the power range II was investigated by finding the conditional expectation subject to the listed conditions thus:

$$E(\ln(R_{vn}/C_{pp})/\ D_4 = 1,\ D_8 = 1,\ D_{11} = 1,\ \text{and}\ D_{15} = 1) = \beta_0 + \beta_{1n} + \beta_2 n^2 + \beta_4 + \beta_8 + \beta_{11} + \beta_{15} + \epsilon \qquad \ldots(3.5)$$

This reduced model was used to test for the joint effect of make, type of operation, ownership and power range on R_{vn}/C_{pp} ratio.

The statistical significance of individual attributes were tested by holding the values of corresponding parameters equal to zero. For example the null hypothesis that type of operation has got no effect on Rvn/Cpp values was tested by setting $\beta_8 = \beta_9 = 0$ and the resulting reduced model investigated by least square methods.

Thus: H_0: $\beta_8 = \beta_9 = 0$ against the alternative that

H1: Not the null; yields the following reduced model or restricted model.

$$\ln(R_{vn}/C_{pp}) = \beta_0 + \beta_1 n + \beta_2 n^2 + \beta_3 D_3 + \beta_4 D_4 + \beta_5 D_5 + \beta_6 D_6 + \beta_{11} D_{11} + \beta_{12} D_{12} + \beta_{14} D_{14} + \beta_{15} D_{15} + \epsilon \qquad \ldots(3.6)$$

The parameters were investigated by least squares method (LSM).

3.5.2 Cumulative Tractor Repair and Maintenance Cost as Percent of Purchase Price versus Tractor Age

In this model cumulative tractor repair and maintenance cost was postulated to be influenced by its age , make, type of operation, and power range. A preliminary scatterplot of cumulative repair and maintenance cost expressed as a percentage of its 1983 purchase price against depreciation age suggested a power function of the following type:

$$R_{mpp} = cn^{k} \qquad ...(3.7)$$

and hence the need for log-log data transformation. The effect of the qualitative variables were investigated using dummy variables incorporated in the power function model as shown in the following equation:

$$R_{mpp} = cn^{b1}d3^{b3}d4^{b4}d5^{b5}d6^{b6}d8^{b8}d9^{b9}d11^{b11}d12^{b12}d14^{b14}d15^{b15} \qquad ..(3.8)$$

d1, d2 ..., d15 are the contribution of the qualitative variables discussed in the previous model.
n = depreciation age in years.

This function was linearized to give the following model:

$$\ln(R_{npp}) = \beta_0 + \beta_1 N' + \beta_3 D_3 + \beta_4 D_4 + \beta_5 D_5 + \beta_6 D_6 + \beta_8 D_8 + \beta_9 D_9 + \beta_{11} D_{11} + \beta_{12} D_{12} + \beta_{14} D_{14} + \beta_{15} D_{15} + \epsilon \quad \ldots(3.9)$$

β_0, β_1, ... β_{16} are as before partial regression coefficients determined by Least Squares Method with the aid of MSTATC computer package.

N' = log of actual age

D_3, D_4, ...D_{15} take the same values as in the previous model and are the log transform of d1, d2, ...d15 in the power function equation 3.7 above.

This was repeated for tractor operation age and actual age. As before five classes of tractor make, three categories of owners, three types of operation and three different power ranges were considered with depreciation age, operation age and actual age as the quantitative variables each in turn. Errors were found to be normally distributed with zero means and constant variance by examination of residuals.

3.5.3 Cumulative Depreciation versus Tractor Age

Cumulative depreciation calculated from consecutive tractor remaining values were expressed as a ratio to tractor purchase price and a model similar to the foregoing one used to predict its relation to tractor age and to investigate the effect of make, power range, ownership and type of operation on the variable. A preliminary scatterplot suggested fitting a second degree polynomial function and the following model was tested:

$$D_{ac}/P_p = \beta_0 + \beta_1 n + \beta_2 n^2 + \beta_3 D_3 + \beta_4 D_4 + \beta_5 D_5 + \beta_6 D_6 + \beta_8 D_8 + \beta_9 D_9 + \beta_{11} D_{11} + \beta_{12} D_{12} + \beta_{14} D_{14} + \beta_{15} D_{15} + \epsilon \qquad \ldots(3.10)$$

This was repeated for age of operation and actual age of the tractor.

3.5.4 The Relation between the Ratio of Tractor Resale value to its Annual Operating Cost and Tractor Age

The ratio of tractor resale value to its annual operating cost in the nth year of use was plotted against tractor age and the resulting exponentially decaying trend indicated that the following model could be fitted:

$$\ln(R_{vn}/AC_{op}) = \beta_0 + \beta_1 n + \epsilon \qquad \ldots(3.11)$$

This model was used to predict annual operating costs in terms of the current purchase price (C_{pp}) of a similar model of the tractor so that replacement analysis could be amenable to computation entirely in terms of the tractor current purchase price or replacement price.

3.5.5 Tractor Replacement Analysis.

The model for replacement was built on the basis that there was a relation between defender's resale value and hence its current purchase price and its age and the annual operating cost such that all equivalent annual cost computations could be carried out entirely on the basis of the current purchase price taken to be; by similar reasoning the Challenger's purchase price. The decision to retain or replace the defender was taken after comparing the equivalent annual cost (EAC) as suggested by Scarborough and Hunt (1973) and Riggs (1977) for the rest of defender's economic life with the EAC for the Challenger(s) over the same period at a predetermined minimum acceptable rate of return (MARR). The annual operation cost for the tractor was estimated by the using model:

$$AC_{op}(n) = C_{pp}(n)*f(n)*c(n) \qquad \ldots(3.12)$$

$AC_{op}(n)$ = annual operating cost in the nth year of use

$C_{pp}(n)*f(n)$ = resale value of the tractor in year n.

then the equivalent annual cost for the defender EAC(d) for its remaining economic life was given by :

$$EAC(d) = \Sigma[f(n)C_{pp}(n) + \alpha(n+1)C_{pp}(n+1)(1 + i_m) + \ldots + \alpha(L_y)C_{pp}(L_y)(1 + i_m)^{(Ly-n)}]A(n) \qquad \ldots(3.13)$$

$\alpha(n) = f(n)c(n)$

L_y = economic life of the tractor for which replacement was considered.

$A(n)$ = annuity factor for n years at rate of i_m

i_m = MARR

The equivalent annual cost for the challenger(s) EAC(c) was:

$$EAC(c) = \Sigma[C_{pp}(n) + \alpha(1)C_{pp}(n+1)(1 + i_m) + \ldots + \alpha(L_y-n)C_{pp}(L_y)(1 + i_m)^{(Ly-n)}]A(n) \qquad \ldots(3.14)$$

Decision was made on the basis of the difference:

$$EAC(c) - EAC(d) = \delta \qquad \ldots(3.15)$$

If $\delta >= 0$ the defender can be retained at least for one year. The defender is replaced if δ is negative.

4. RESULTS AND DISCUSSION.

A total of 141 tractors with complete records were covered in the study. All tractors covered in the study were single purpose tractors. Cane loaders were considered as tractors in a class of their own. However, motor graders and excavators were classed together with tillage tractors. The details of the tractors are contained in appendix B.

4.1 Tractor Utilization.

Utilization of tractors was reported in terms of hours of transport operations or tillage operations. Tractors with 80 HP and below were exclusively used for cane transport. Tractors with between 80 and 120 HP were mainly used for tillage work, with those in the lower range being used exclusively for lighter tillage operations like light harrowing ,furrowing, and inter-row cultivation.

In Chemelil Sugar Company nucleus estate and in the adjoining outgrowers farms where the soils are typical black cotton soils with high clay content and poor drainage characteristics, a mandatory ploughing depth of 40 cm meant that ploughing whether by mouldboard or disc plough had to be done by tractors with at least 90 HP. Similarly operations like ripping, clearing and spent ratoon crop destruction was confined to tractors with higher power.

Nyaroche Farm and Kimwani ADC Farm being located where the soils were lighter with lower clay content and better drainage characteristics required on average lower power for similar tillage operations. Tillage operations in these two farms were accomplished with 90HP tractors or less.
Table 4.1 shows the utilization of tractors according to power range.

The average annual use for transport tractors was 1230 hours; and for tillage tractors for 1040 hours annually with a variance of 200 hours and 400 hours respectively. The use of tillage tractors was at Chemelil sugar company was restricted to an annual budget of about 400 hectares of land preparation work save for occasional request for land preparation services by the neighbouring outgrowers schemes, it is not easy to know how much the tillage tractors would have done if the restriction did not exist.

Table 4.1 Utilization of tractors according to power range

Power Range	Tractor type	Make/Model	Number of units	Type of Operation
I	2 -Wheel Drive	Ford 5000	16	cane transport
		Ford 5600	1	cane transport
		Ford 6000	15	cane transport
		Ford 6600	13	cane transport
		Same Synchro 80	11	cane transport
		MF 375	2	cane transport
		MF 390	3	cane transport
		MF 290	2	cane transport
	4-Wheel Drive	Same Saturno 80	12	light tillage
		Same Mercury 85	7	cane transport
		Ford 7610		light tillage
		International 844	4	light tillage
		MF 194	1	light tillage
II	4-Wheel Drive	Same Panther 90	7	light tillage
		Same Panther 95	1	medium tillage
		Same Drago 120	9	medium tillage
		Same Laser 100	2	medium tillage
		MF 298	6	medium tillage
		MF 399	1	medium tillage
	Crawlers	CAT D5	3	heavy tillage
III	4-Wheel Drive	Same Laser 130	1	heavy tillage
		Case International	3	heavy tillage
		MF 2645	1	heavy tillage
	Motor Graders	CAT	2	roads grading
	Crawlers	CAT D6	1	heavy tillage
		CAT D7	2	heavy tillage
		Komatsu D60F	2	heavy tillage
	Loaders	JCB Excavator/loader	1	excavation /loading
		Cameco SP3000	6	cane loading
		Bell cane loader	2	cane loading

Table 4.2 Tractor Activities in the Chemelil Sugar belt.

Operation	Chemelil	Nyaroche	Kimwani	Tractor and Machinery Combination
Clearing	H	H	H	Crawler + Dozer
M/B Ploughing	H/M	H/M	H/M	C, 4-WD + NARDI Plough
Disc Ploughing	H/M	H/M/L	H/M/L	C, 4-WD + ROM Plough
Ripping	H	H	H	C, 4-WD + ripper
1st Harrowing	H/M	H/M/L	H/M/L	C, 4-WD + ROM Disc
2nd Harrowing	H/M/L	M/L	M/L	C, 4-WD + ROM Disc
3rd Harrowing	M/L	L	L	4-WD + Disc
Levelling	H	H	H	C + Dozer
Furrowing	L	L	L	4-WD + Ridger
Drainage	L	L	L	Crawlers/4-WD
Sub-soiling	H	H	H	C, 4-WD + sub soiler
Tining	L	L	L	4-WD,2-WD + tines
Cane loading	M	M	M	Cameco
Cane transport	L	L	L	2-WD + 10t trailer

H = High power demand (>120HP), M = medium power demand (80< HP<120)

L = low power demand (< 80HP) C= Crawler tractor.

The transport tractors were restricted on the number of trips they could make in a day because of the queuing at the factory and the process of loading in the fields and in certain cases distance from the factory. To investigate the true utilization potential of the transport tractors it would be necessary to test a queuing model to determine the tractor arrival rates, service rates at all the calling stations and the duration it takes to complete the cane reception and unloading exercise including all the accompanying formalities. A similar exercise would be necessary to determine the rates and duration of loading at fields within given radii from the factory.

It seems therefore that within the cited limitations, the tractors are fully utilized . The graph in fig 4.1 show the trend of tractor utilization with age. The trend confirms the foregoing observations on annual use.

4.2 Management and Operation

4.2.1 Information.

Chemelil Sugar Company and Kimwani ADC complex farm had similar procedures for the process of data and information collection. This was manifested in the form of daily, weekly, monthly and annual performance reports, breakdown reports, supervisors reports. Ideally these reports were meant to trace the performance of individual tractors and the entire fleet, but it was noted the process of information collection and record keeping was not always complete. This was observed in partially completed documents of first entry and even in monthly cost summaries. In all cases it was observed that fairly accurate records on individual tractor fuel and lubricants costs, repair and maintenance costs were kept. Information on the ownership costs like depreciation, interest charges, license, and a major running cost like operator wages were conspicuously missing from the cost sheets. Whereas monthly cost summaries are important, annual cost summaries should be more handy for any quick decision process.

4.2.2 Usefulness of the Information.

One major problem noted was the scatteredness of the information. The information about depreciation charges, operator wages,insurance premiums were scattered in other sections and could not be readily accessed as they were disorderly lumped in groups making it difficult to trace the costs' components for individual tractors. Information about tractor purchase prices could only be found in pieces and more reliable data had to be traced back to the sales agencies. Insurance premiums returns records were scanty and more information had to be sought from the insuring agencies although insurance is a major annual expense for the enterprises.

Partially or incomplete records have no value, are a waste time and funds and cannot aid in decision making process. The information consumer sections should store information in readily consumable form. In a large establishment co-ordination of information flow is a prerequisite requirement to understanding the business.

The problem of paucity of data or information gaps require unnecessary effort and expenses to bridge, before a useful decision could be made. This could lead to the wrong decision being made or the right decision being delayed due to the problem of scatterdness of information. In smaller establishments this problem may seem tolerable but not without cost.

The proximity and informality between sections make this problem seem tolerable in the sense that the whole process of data acquisition could be re-initiated or restarted over and over again, even for data which already exist but was not readily accessible to the decision maker due the problems cited, more cheaply than in a larger establishment.

The problem stems from disregard to the basics or the discipline of tractor record-keeping and lack of standardized format for documents of primary entries. This emphasizes the need for increased awareness of the need for clear, comprehensible and complete records and reports. A standard format is necessary if useful and comparable information is to be deduced from the reports. The format of these reports should be simple and not overloaded with information since the operators who have the double responsibility of making first entries, usually have limited levels of literacy. It is part of management duty to train operators and (supervisory staff where applicable) in the exercise, so that documents of first entry report factually. The weekly, monthly, quarterly and all the other summaries can only reflect the primary entries.

Strict book-keeping and stores procedures must be adopted in cases where the farm has got facilities for bulk purchase of spares, fuel and lubricants. This can facilitate costing of all consummables issued against an individual tractor. All items accepted or requisitioned by the farm's stores must have unit prices chargeable with overhead storage charges. These are derived either from the price quotations, pro-forma invoices, delivery notes(if it contains the price) or ordinary invoices and then modified by a factor to cover overhead storage charges. For farmers operating few tractors, bulk storage may not be justified and naturally they have to make purchases for fuel, lubricants and spares as and when need arises.

In such cases, receipts for all purchases should be filed after details have been entered in appropriate documents of first entry. This includes any repair work done by service workshops. Delivery notes from suppliers should always be accompanied with price quotations for the items ordered and delivered. When goods whose unit prices are not known are accepted into stores, the entire process of record keeping breaks down as the consumption of such items can not be easily charged or costed against any particular tractor. This problem is compounded by late invoicing and sometimes for very large enterprises; by double invoicing which can be due to fraud or negligence.

Machinery managers should strike a rapport with their suppliers to exercise the discipline of quoting their prices as and when they deliver the goods requisitioned, as that is the only way the costs of the items consumed by each tractor can be traced.

4.2.3 Tractor Costs Management

The major problem noted here was with the use of cost centres. This concealed information on the expenses of individual plants and only tractors whose costs were not charged to cost centres could be covered in this study. In cost centres operating charges were lumped up for groups or categories of machinery and it was not possible to trace the performance of a given tractor or machinery. Whereas it could be argued that this cut costs for management of a large fleet of tractors, it conceals too much information and is prone to abuse .

4.2.4 Tractor Selection

It was observed that selection of tractors for tillage and transport was guided by prevailing restrictions. For example in Chemelil Sugar company most plots or farms required a minimum ploughing depth of 40 cm (O.Misungu, personal communication, 1991) especially in areas with black cotton clays. Although the agronomic justification for this requirement was not established, the implication on the energy demand for tillage was quite obvious. Besides activities like ripping, ratoon destruction and sub-soiling in themselves required pushing the baseline for energy demand up.

Another factor which was observed to affect the selection of tillage tractors was the existing implements. Because of good repair and maintenance facilities the existing implements had lived beyond their originally estimated life and were still in good working condition. Whatever the factors were for their selection initially, were no longer material and the fact observed was that the major implements were not due for replacement in the immediate future and had for that reason become another base for tractor selection due to their individual and specific energy demands.

Transport tractors were selected based on the cane weighbridge restriction at the sugar factory. The weighbridge could only accept a maximum loaded trailer weight of 10 metric tonnes(Anon, personal communication, 1991). It was not established whether 10 tonnes was the safety limit for the weighbridge, but as a restriction it was noted to be an important limiting selection factor for both transport tractors and their trailers. Selection of tractors in the other two farms were based on similar factors, but as observed in 4.1 were modified by specific prevalent conditions existing on the farms.

4.3 Empirical Relations

A number of empirical relations were derived relating various tractor costs to its depreciation age, actual age and operation age. These included the relation between tractor resale value to its depreciation age, cumulative repair and maintenance costs as a factor initial purchase price and tractor age, cumulative depreciation against tractor age and the annual operation cost against tractor age.

4.3.1 Tractor Resale Value against its Depreciation Age.

The results of the model discussed in section 3.4.1 showed there was a high correlation between the natural logarithm of the ratio of tractor resale value to its current purchase price with its depreciation age and the square of depreciation age. The restricted model in which all the qualitative factors were assumed to have zero influence on the response yielded the prediction equation 3.2 with a correlation of 0.838. This equation compares very well with the equation Witney (1988) found. The results of the multiple regression of the full model in equation 3.1 is shown in Table 4.3 below.

Table 4.3 : Extract of results of MSTATC multiple regression of Tractor Resale value prediction model

Variable	Regression coefficient	Standard error	Probability	Significance at 0.05
n	-0.125	.0061	0.000	s
n^2	0.0078	.000126	0.000	s
D_3	0.0077	.0078	0.921	ns
D_4	0.1696	.0684	0.014	s
D_5	0.0625	.0782	0.425	ns
D_6	-0.0447	.0837	0.595	ns
D_8	0.0451	.084	0.592	ns
D_9	0.049	.0965	0.613	ns
D_{11}	-0.142	.038	0.000	s
D_{12}	-0.231	.0541	0.000	s
D_{14}	-0.222	.0723	0.003	s
D_{15}	-0.142	.0664	0.034	s

R^2 = 0.832 s= significant ns = not significant.

From the table , it was observed that, type of operation had no significant influence on tractor resale value. Of the tractor makes considered only Same had a significant influence on resale values and it was noted that both ownership and power range significantly affected the resale values.

These results are confirmed by the ANOVA generated by partial F-test criterion used by Draper and Smith (1966) and Steel and Torrie (1986) showing the contribution of each group variable. The results are shown in Table 4.4 below.

From the ANOVA table it was confirmed that all the postulated group qualitative variables except type of operation affected the tractor resale values.

A test for the joint effect of the factors that significantly influenced the resale values namely the joint effect of make, ownership and power range yielded a series of prediction equations subject to given restrictions

For example the resale value of a five year old Same tractor in all the three farms, and three power ranges are tabulated in Table 4.5

Table 4.4 : ANOVA showing effect of group qualitative variables on tractor resale values.

Source of Variation	df	Sum of Squares	Mean Sum of Squares	F	Prob
Main effects	2	14.702556	7.3513	290	0.000
due to Make	4	0.633489	0.1584	6.2	0.000
ownership	2	0.534035	0.267	10.5	0.000
power range	2	0.245676	0.1228	4.8	0.000
operation	2	0.007472	0.004	0.2	0.82 ^{ns}
error	128	3.242662	0.02536		
Total	140	19.36985			

$R^2 = 0.832$

Table 4.5 : Tractor resale value prediction equation for five year old Same tractors in Chemelil sugar belt

Prediction equation	Owner	Power range	R^2
1. $R_{v5} = 0.361C_{pp}$	D_{13}	D_{16}	0.815
2. $R_{v5} = 0.537C_{pp}$	D_{13}	D_{15}	0.800
3. $R_{v5} = 0.540C_{pp}$	D_{13}	D_{14}	0.813
4 $R_{v5} = 0.544C_{pp}$	D_{11}	D_{16}	0.793
5 $R_{v5} = 0.466C_{pp}$	D_{11}	D_{15}	0.782
6. $R_{v5} = 0.446C_{pp}$	D_{11}	D_{14}	0.792
7. $R_{v5} = 0.505C_{pp}$	D_{12}	D_{16}	0.784
8. $R_{v5} = 0.454C_{pp}$	D_{12}	D_{15}	0.776
9. $R_{v5} = 0.326C_{pp}$	D_{12}	D_{14}	0.796

From the table it emerged that the resale value of a five year old Same tractor in power range three are $0.361C_{pp}$, $0.544C_{pp}$ and $0.505C_{pp}$. It was noted that the Chemelil tractors fetched more money in terms of resale value than the other two farms. In both power range I and II category Kimwani tractors attracted a higher resale value than either Chemelil or Nyaroche.

Similar equations could be written for other tractor makes provided it is indicated in the regression of the full model that the make contributed or affected the resale values significantly; otherwise the general equation derived assuming no qualitative influence applies.

4.3.2 Cumulative Repair and Maintenance Costs against Tractor Age.

The model showed better correlation between tractor cumulative repair and maintenance costs expressed as a percentage of initial purchase price with actual tractor age than with either depreciation age or operation age. The examination for residuals in the model indicated that the assumptions of normalcy of error distribution, constancy of error variance and zero means had not been violated. These results are shown in Table 4.6 below.

Table 4.6 : Prediction equation for cumulative repair and maintenance costs

Equation	R	s
1. $R_{mpp} = 4.11 n_a^{1.58}$	0.841	0.347
2. $R_{mpp} = 3.2 n_0^{1.56}$	0.797	0.386
3. $R_{mpp} = 3.3 n^{1.615}$	0.827	0.360
4. $R_{mpp} = 152.34(\tau_{ac}/L)^{1.555}$	0.797	0.386

n_a = actual age, n_0 = operation age s = standard error

The correlation between the common logarithm of repair and maintenance cost as percent of initial purchase price was 0.841, 0.797, 0.827 and 0.797 with the common logarithm of actual age, depreciation age, operation age and utilization ratio respectively.

The equations deduced from the results agree in character and form with those reported by Bowers and Hunt (1970); Peterson and Milligan (1976); Hassan and Larson (1978); Ward *et. al* (1985) and Morris (1988). Comparative estimates of repair and maintenance costs basing on the work of other reseachers are shown in table 4.7 to illustrate close agreement for repair costs at 3600h, 6000h and 9600h of cumulative use with the findings of other researchers. The differences are attributable to effects of ownership, type of operation and possibly other qualitative factors.

Using the equations in table 4.6; the cumulative repair and maintenance costs of a five year old tractor in terms of its initial purchase price using actual age, operation age and depreciation age were $0.53P_p$, $0.394P_p$ and $0.444P_p$ respectively. Either depreciation age or operation age gave lower values of repair and maintenance costs and were not considered any further in the analysis.

The variation between tractor repair and maintenance cost with tractor utilization ratio (τ_{ac}/L) is shown in fig. 4.2. This graph indicates that after about six years of use the repair and maintenance costs start escalating rapidly and replacement of the tractor should be considered.

Fig. 4.3 indicate the effect of tractor make, on repair and maintenance costs. From the graph it appears that Ford tractors generally have excessively high R_{mpp} than the other makes. This could be explained in part by the fact that the initial purchase prices for this make of tractors were comparatively low. This is true for all Ford tractors bought before 1980. While this may be the case, other inherent design factors can not be ruled out without further investigation.

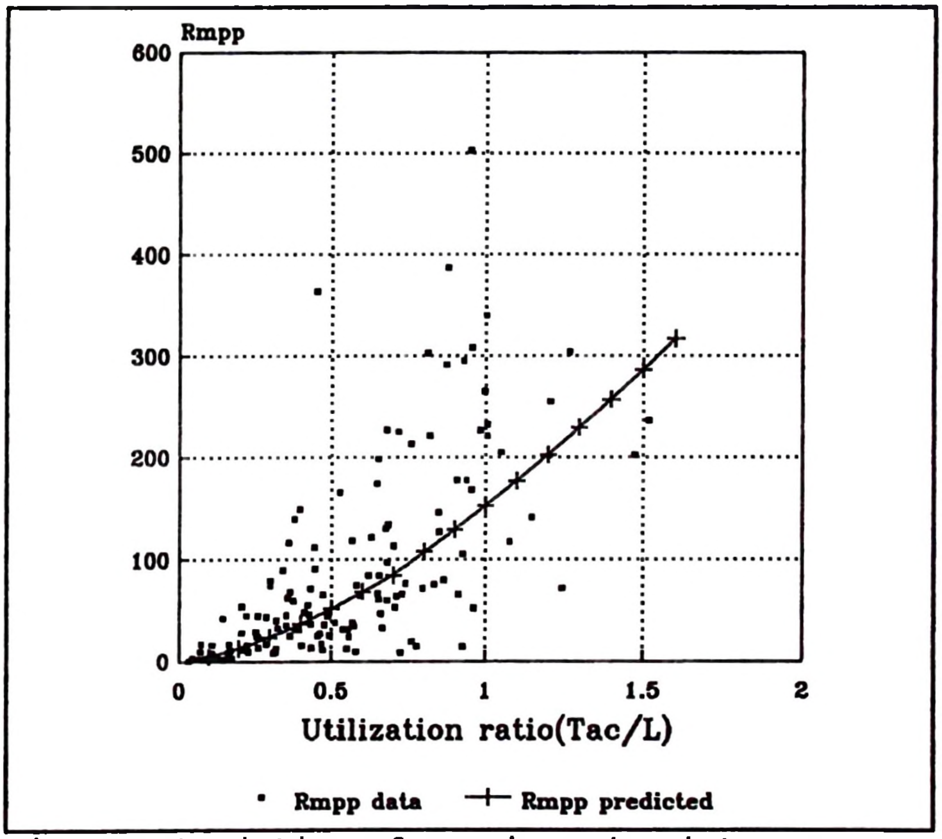

Fig. 4.2 Variation of repair and maintenance costs with tractor utilization ratio

Table 4.7: Comparative repair costs estimates.

Equation	source	cumulative repair and maintenance cost as percent P_p at 3600h	6000h	96000h
$R_{mpp} = 0.076(\tau_{ac}/120)^{1.6}$	Bowers and Hunt 1970	17.55	39.73	84.3
$R_{mpp} = 0.127(\tau_{ac}/120)^{1.4}$	Peterson and Milligan 1976	14.85	30.36	58.63
$R_{mpp} = 0.00171(100\tau_{ac}/L)^{2.41}$	Hassan and Larson 1978	6.20	21.26	66
$R_{mpp} = 0.042(\tau_{ac}/120)^{1.895}$	Ward *et. al* 1985	26.45	69.63	169.67
$R_{mpp} = 1.2(\tau_{ac}/1000)^{2}$	ASAE 1987	15.55	43.2	110.6
$R_{mpp} = (0.0996\tau_{ac}^{1.4775})10^{-3}$	Morris 1988	17.89	38.06	76.22
$R_{mpp} = 152.34(\tau_{ac}/L)^{1.555}$	Ogweno (this study)	23.43	51.85	107.7
$R_{mpp} = 4.11n_a^{1.58}$ *	Ogweno (this study)	23.32	52.26	110

* assumes an average annual use of 1200 hours

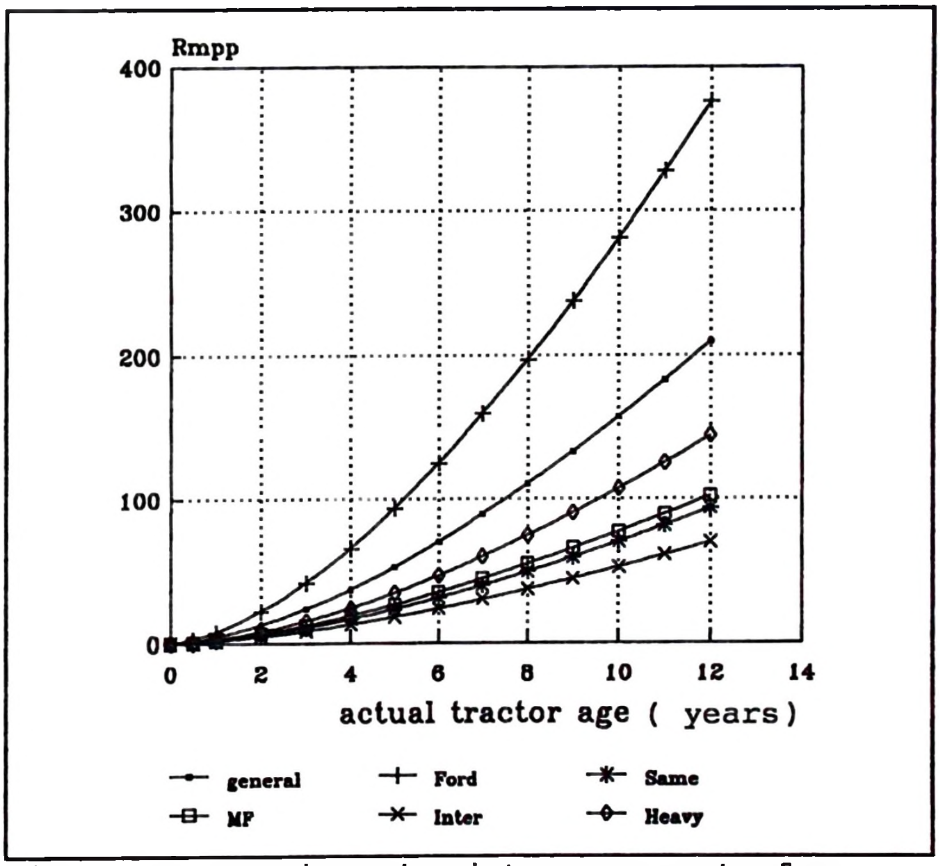

Fig. 4.3 : Repair and maintenance costs for different makes of tractors in Chemelil sugar belt.

From the regression of the full model in equation 3.9 each group factor had a significant contribution to the response variable. The extract of results of an MSTATC multiple regression printout is shown on table 4.8 below.

The contribution of each group was demonstrated by the fact that each had a representative with a significant level of contribution. This was further confirmed by the partial F-test criterion to find the level of contribution of each qualitative group of variable in as far as they influenced the response surface.

The results of these test are summarised in the ANOVA generated and shown in Table 4.9.

The effect of type of operation on cumulative tractor repair and maintenance costs was clearly demonstrated by the graphs shown in figure 4.4. It is seen that the cane loaders had the highest R_{mpp}, followed by tillage tractors. Transport tractors had the lowest bill. This relation can readily find use in the fiscal budgets and forward planning of recurrent estimates for repair and maintenance component.

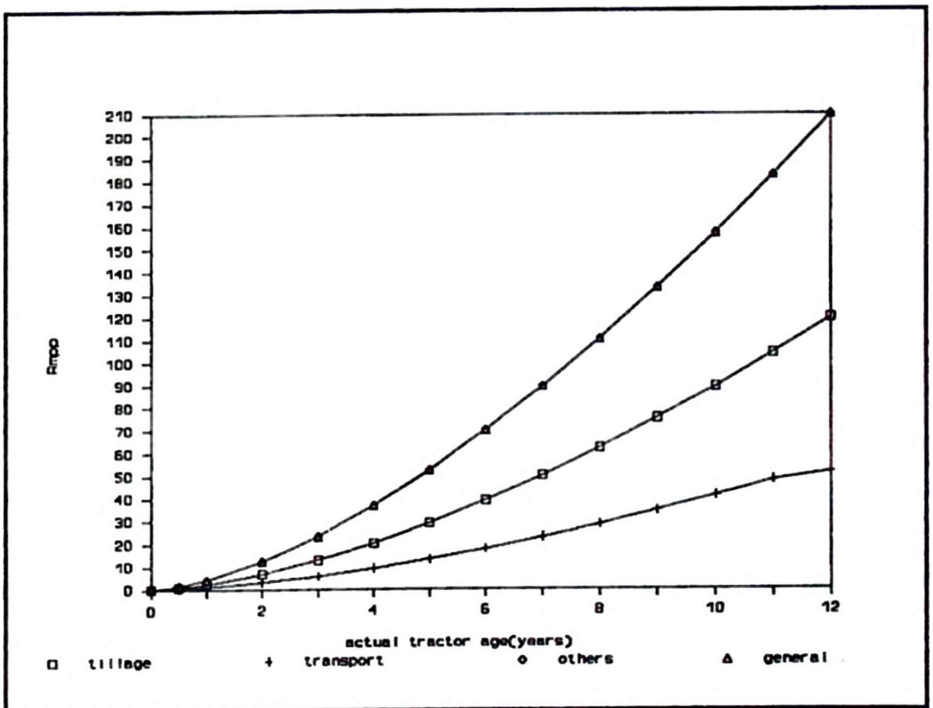

Fig. 4.4: effect of type of tractor operation on repair and maintenance costs.

Table 4.8: Extract of results of MSTATC printout showing the effect of individual variables cumulative repair and maintenance costs.

Variable	Regression coefficient	Standard error	Probability
D_3	0.284	0.106	0.000
D_6	-0.246	0.129	0.058
D_8	-0.244	0.110	0.029
D_{11}	0.154	0.0587	0.01
D_{14}	0.241	0.115	0.039
N	1.6237	0.0646	0.000

R^2 = 0.867 All variables which did not contribute at 0.1 level of significance were omitted.

N' = common log of actual age of tractor

Table 4.9: ANOVA showing the effect qualitative factors on tractor cumulative repair and maintenance costs

Source of Variation	df	Sum of Squares	Mean Sum of Squares	F	Prob
Main effect	1	45.94237	45.94237	783	0.000
due to Make	4	1.989316	0.497329	8.5	0.000
Operation	2	0.493243	0.246615	4.20	0.000
Ownership	2	0.720463	0.3603215	6.14	0.000
Power range	2	0.263586	0.131793	2.25	0.100
Error	129	7.566449	0.058655		
Total	140	56.975427			

R^2 = 0.87

The joint effect of make, type of operation, ownership and power range was found to be significant for Ford and International tractors only. The results are illustrated in table 4.10 below by prediction equations for Ford tractors under different ownership, power range and for transport operations.

From the equations the cumulative repair and maintenance costs for a five year Ford tractor used in cane transport was found to be $1.15P_p$, $0.703P_p$ and $0.69P_p$ at Chemelil, Nyaroche and Kimwani respectively.

From the results it was observed that the Ford tractors used for cane transport in Chemelil sugar company had unduly higher cumulative repair and maintenance costs than either those at Kimwani or Nyaroche. The five year cumulative repair and maintenance costs for a Ford tractor used at Chemelil was over 60 percent higher than of its neighbours The explanation for such a big difference may be attributed to other qualitative factors not accounted for by the model.

Table 4.10: Joint effect of make, ownership, type of operation and power range on the cumulative repair and maintenance costs of Ford tractors

Equation	owner	power range	type of operation	R^2
1. $R_{mpp} = 7.887n_a^{1.665}$	D_{11}	D_{14}	D_9	0.836
2. $R_{mpp} = 4.822n_a^{1.665}$	D_{12}	D_{14}	D_9	0.824
3. $R_{mpp} = 4.97n_a^{1.6343}$	D_{13}	D_{14}	D_9	0.828

4.3.3 Cumulative Depreciation against Tractor Age.

With the assumption of no qualitative influence on the response the model yielded the following prediction equations with actual tractor age, depreciation age and operation age These equations agree in form and character with that expressed by Hunt (1983).

$$D_{ac} = (0.0765 + 0.1345n_a - 0.00878n_a^2)P_p \qquad ...(4.1)$$

$$D_{ac} = (0.0762 + 0.12n - 0.007n^2)P_p \qquad ...(4.2)$$

$$D_{ac} = (0.142 + .087n_0 - 0.0042n_0^2)P_p \qquad ...(4.3)$$

Cumulative depreciation factor (cdf) was defined as the ratio of cumulative depreciation to initial purchase price of the tractor. From the equations the cumulative depreciation factor for a five year old tractor was 0.53, 0.5 and 0.472 when actual age, depreciation age and operation age were used respectively. A trend graph is shown in fig 4.5 showing the cumulative depreciation factors as predicted by the three equations over the life of the tractor.

A comparison with the conventional depreciation models indicated that it was not possible to assign a terminal salvage value for a tractor where inflationary effects were in play, but it was clearly indicated that somewhere between the sixth and the seventh year the tractor attracted its lowest possible salvage value and by extension of the previous argument its resale value. The model remotely approximates the double declining model in the first few years of working life but they soon part ways, when inflation effects take over after about four years from whence the tractor tends to appreciate.

The model could therefore be said to approximate the real life situation, when tractor remaining values or fair market evaluation is undertaken in each accounting or reporting year. The remaining or resale values calculated using the model and other depreciation models are shown in Fig 4.6.

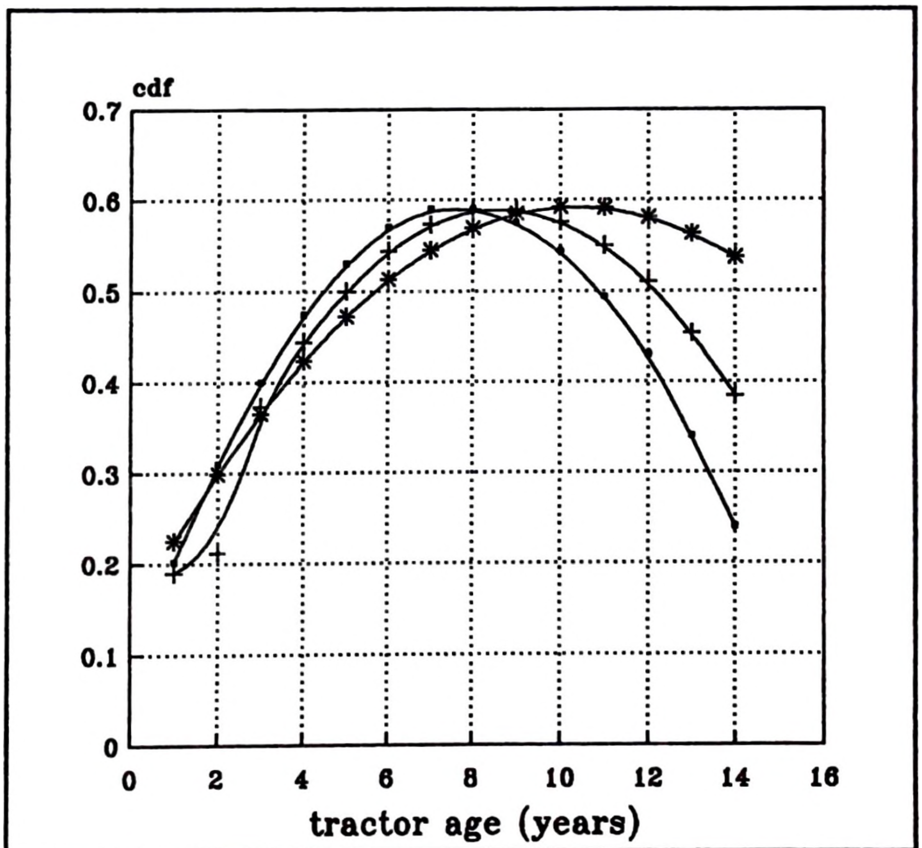

Fig. 4.5 trend of cumulative depreciation as a ratio of purchase price against tractor age.

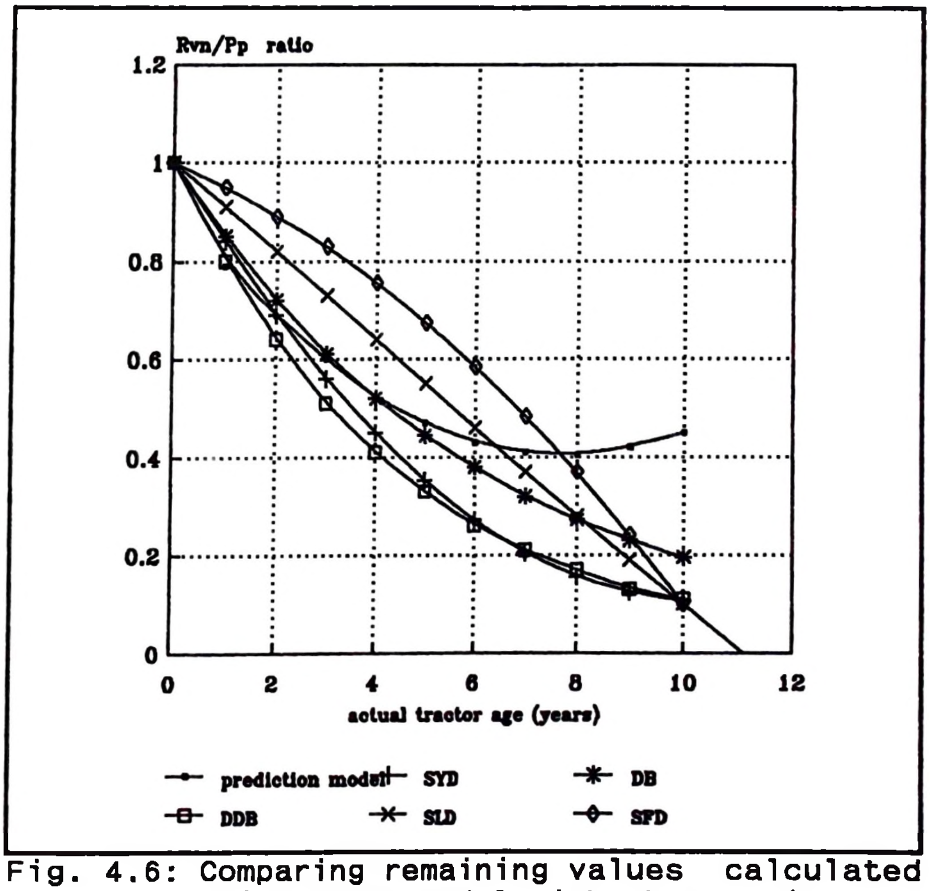

Fig. 4.6: Comparing remaining values calculated using study model with those using conventional models

In the absence of inflationary effects and appreciative characteristics, the cumulative depreciation curve is expected to level off at a level coinciding with salvage value where no more depreciation would be charged; but as was observed the curves reached their peak at a cdf of 0.6 and started to descend. This suggested that high rates of inflation possibly coupled with holding gains on popular tractor models caused the value of the tractors to appreciate. It is observed that between seven to eight years of ownership there is a point of inflexion where depreciation is literally zero and beyond this point is pure appreciation. How far this appreciation could go can not be explained easily. In effect, it is not possible to assign a terminal salvage value to the tractor as long as it is in good running order.

The MSTATC printout for the full model indicated that only Same tractors affected cumulative depreciation to purchase price ratio significantly. Type of tractor operation had no significant effect. The results were shown in Table 4.11. Insignificant variables were omitted.

Table 4.11 : Extract of MSTATC printout showing variables which significantly affected cumulative depreciation

Variable	Regression coefficient	Standard error	Probability
n_a	0.055	0.0045	0.000
n_a^2	0.008065	0.00125	0.000
D_4	0.21	0.106	0.053
D_{11}	-0.137	0.0418	0.002
D_{14}	-0.141	0.0516	0.008
D_{15}	-0.172	0.0513	0.002

R^2 = 0.763

From the foregoing it was necessary to test for joint effect of factors for Same tractors only. The results for the test for joint effect of factors are equations summarised in table 4.12 below. The rest of the makes that did not feature significantly are assumed to obey the general prediction equation.

The effect of non- contributing factors were not included in the equations.

From the table of joint effect equations the extent of influence of the qualitative factors was further investigated to find the quantitative implications of the joint effect of factors on the response surface. From the equations it is fairly obvious that there are quantitative differences varying from effect of ownership, power range and type of operation whether affecting singly or jointly.

The family of curves figures 4.6a, b and c lent more clarity to the quantitative differences derived from the equations.

In the equations Chemelil was represented by the dummy variable D_{11}, Nyaroche by D_{12} and Kimwani by D_{13}. In the legends Figs 4.6a, b and c, cdfC1.. cdfC6 are cdf curves for tractors in Chemelil for equations in the table
from 13 to 18., cdfK1..cdfK6 represents Kimwani equations from 7 to 13 in the table, and cdfN1..cdfN6 represents Nyaroche in the same order.

Table 4.12 : Joint effect of factors affecting cumulative depreciation of Same tractors

Joint effect Equations	Factors			R-Square
	owner	op	power	
1. $D_{ac} = (0.0156 + 0.12n - 0.0066n^2)P_p$	D_{12}	D_9	D_{14}	0.724
2. $D_{ac} = (-0.013 + 0.12n - 0.0065n^2)P_p$	D_{12}	D_9	D_{15}	0.754
3. $D_{ac} = (0.174 + 0.126n - 0.007n^2)P_p$	D_{12}	D_9*	D_{16}	0.758
4. $D_{ac} = (0.084 + 0.12n - 0.0065n^2)P_p$	D_{12}	D_8	D_{14}*	0.739
5. $D_{ac} = (0.06 + 0.12n - 0.0064n^2)P_p$	D_{12}	D_8	D_{15}	0.751
6. $D_{ac} = (0.17 + 0.125n - 0.0068n^2)P_p$	D_{12}	D_8	D_{16}	0.772
7. $D_{ac} = (0.20 + 0.121n - 0.0068n^2)P_p$	D_{13}	D_9	D_{16}	0.696
8. $D_{ac} = (0.053 + 0.118n - 0.0064n^2)P_p$	D_{13}	D_9	D_{15}	0.719
9. $D_{ac} = (0.137 + 0.115n - 0.0064n^2)P_p$	D_{13}	D_9	D_{14}	0.689
10. $D_{ac} = (0.24 + 0.121n - 0.0065n^2)P_p$	D_{13}*	D_8	D_{16}	0.702
11. $D_{ac} = (0.153 + 0.12n - 0.0062n^2)P_p$	D_{13}	D_8*	D_{15}*	0.693
12. D_{ac}** $= (0.096 + 0.12n - 0.0063n^2)P_p$	D_{13}	D_8	D_{14}	0.681
13. $D_{ac} = (0.083 + 0.123n - 0.0067n^2)P_p$	D_{11}	D_9*	D_{15}	0.726
14. $D_{ac} = (0.27 + 0.128n - 0.0073n^2)P_p$	D_{11}	D_9*	D_{16}	0.714
15. $D_{ac} = (0.11 + 0.12n - 0.0068n^2)P_p$	D_{11}	D_9*	D_{14}	0.692
16. $D_{ac} = (0.093 + 0.123n - 0.0067n^2)P_p$	D_{11}	D_8*	D_{15}*	0.727
17. $D_{ac} = (0.164 + 0.12n - 0.0067n^2)P_p$	D_{11}	D_8	D_{14}*	0.704
18. $D_{ac} = (0.254 + 0.127n - 0.007n^2)P_p$	D_{11}	D_8	D_{16}	0.727

* = factor not significant ** = Same as a factor not significant

op = operation

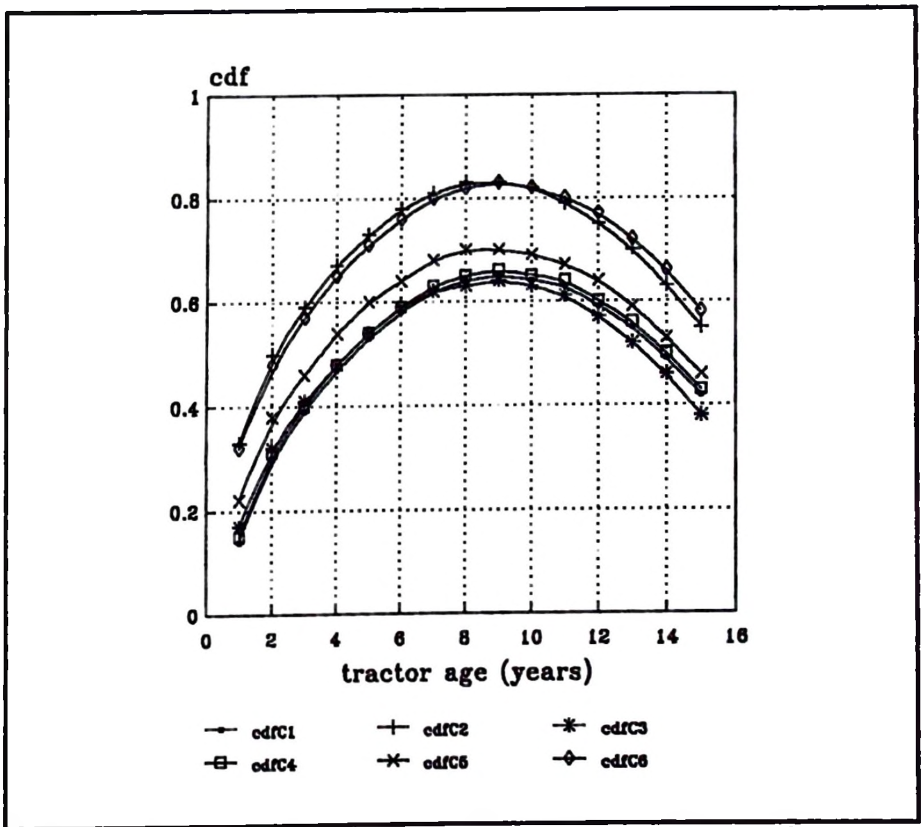

Fig. 4.7a: Joint effect of factors affecting cumulative depreciation of Same tractors at Chemelil Sugar Company.

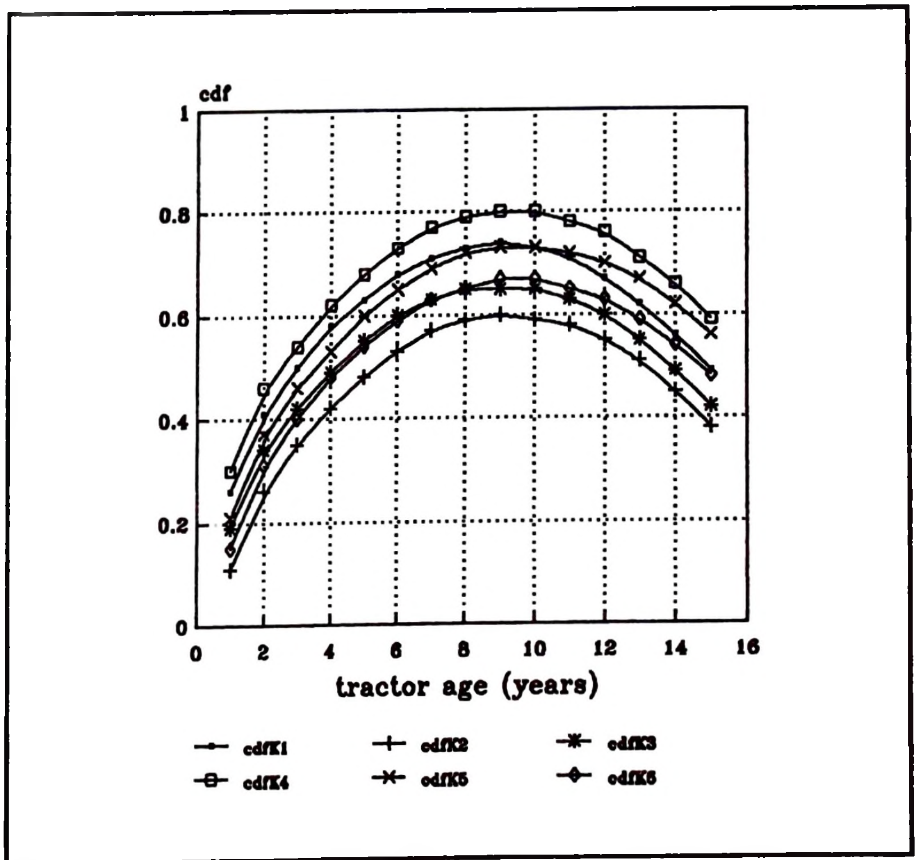

Fig.4.7b: Joint effect of factors affecting cumulative depreciation of Same tractors at Kimwani farm

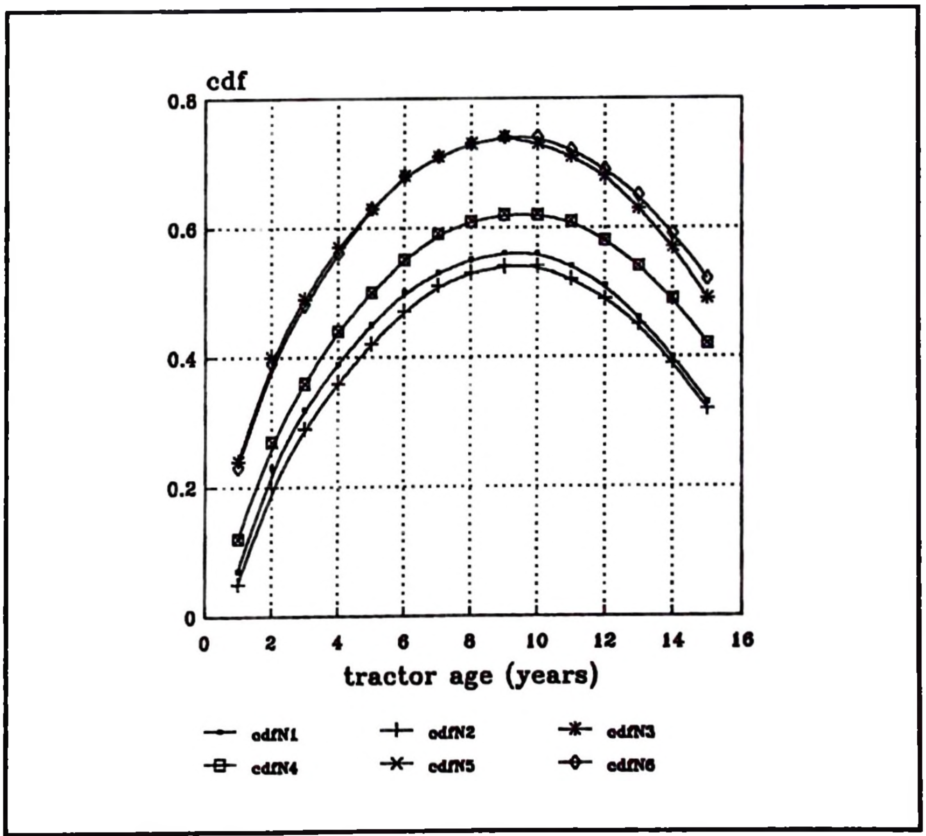

Fig. 4.7c: Joint effect of factors affecting cumulative depreciation of Same tractors at Nyaroche farm

4.3.4 Operating Cost per Hour against Tractor Age.

The operating cost per hour correlated positively with $r = 0.267$, 0.244 and 0.265 with actual age, depreciation age and operation age respectively. Bukhari et al (1988) also reported a similarly low level of correlation between annual use in hours and operation cost per hour in Pakistan. The level of correlation found was thought to be too low to offer any meaningful interpretation of the model. Although operation cost per hour increases with tractor age; age alone could not sufficiently account for the increase. This could have been due to disproportionately high, relatively inert components like repair and maintenance and the 'fixed costs'. They were considered inert in this respect because they were not influenced by use. In this study, the inert components were about 54.6 % of total operating cost per hour.

4.3.5 Ratio of Tractor Resale Value to Annual Operating Cost against Tractor Age.

The natural logarithm of the ratio of tractor resale value to its annual operating cost was negatively correlated to depreciation age, operation age and actual tractor age with $r = 0.786$, 0.767 and 0.765 respectively. The following equations were derived from the results of testing the model in equation 3.12 :

with actual tractor age.

$$AC_{op} = 0.537R_{vn}\exp(0.1745n_a) \quad ...(4.4)$$

with operation age:

$$AC_{op} = 0.557R_{vn}\exp(0.134n_0) \quad ...(4.5)$$

and with depreciation age:

$$AC_{op} = 0.533R_{vn}\exp(0.157n) \quad ....(4.6)$$

The annual operating cost for a five year tractor was estimated to be 1.285, 1.954 and 2.19 times the resale value of the tractor in the fifth year of use, using actual age, operation age and depreciation age respectively.

The equations were re-written in terms of current purchase prices of the tractors thus:

$$AC_{op} = 0.537C_{pp}\exp(-0.02n_a + 0.00754n_a^2) \quad ....(4.7)$$

$$AC_{op} = 0.557C_{pp}\exp(-0.032n_0 + 0.00498n_0^2) \quad ....(4.8)$$

and

$$AC_{op} = 0.533C_{pp}\exp(-0.047n + 0.00753n^2) \quad ...(4.9)$$

The tractor resale values assumes inherent inflation effects and there would be no need to account for future inflation when predicting a future operation cost. These equations can therefore be applied directly to determine operation cost of a given tractor in a given year.

The equations could be applied in tractor replacement analysis using equivalent annual cost calculations. The graphs in fig 4.6 show the trend of annual operation cost over the working life of a tractor. It must be noted that the operation cost predicted by these equation assume an annual use of about 1200 hours, but as have seen before the items like repair and maintenance can be modified by type of operation, ownership and make. So it would be necessary to make allowances for those qualitative influences. This observation does not deride the importance of the equation for estimating future tractor costs, since the equation was derived from the regression of the explanatory variables.

It is also instructive to observe that the equations do suffer the limitation of area specificity and hence restricted applicability . A more general equation could be arrived with more representative data.

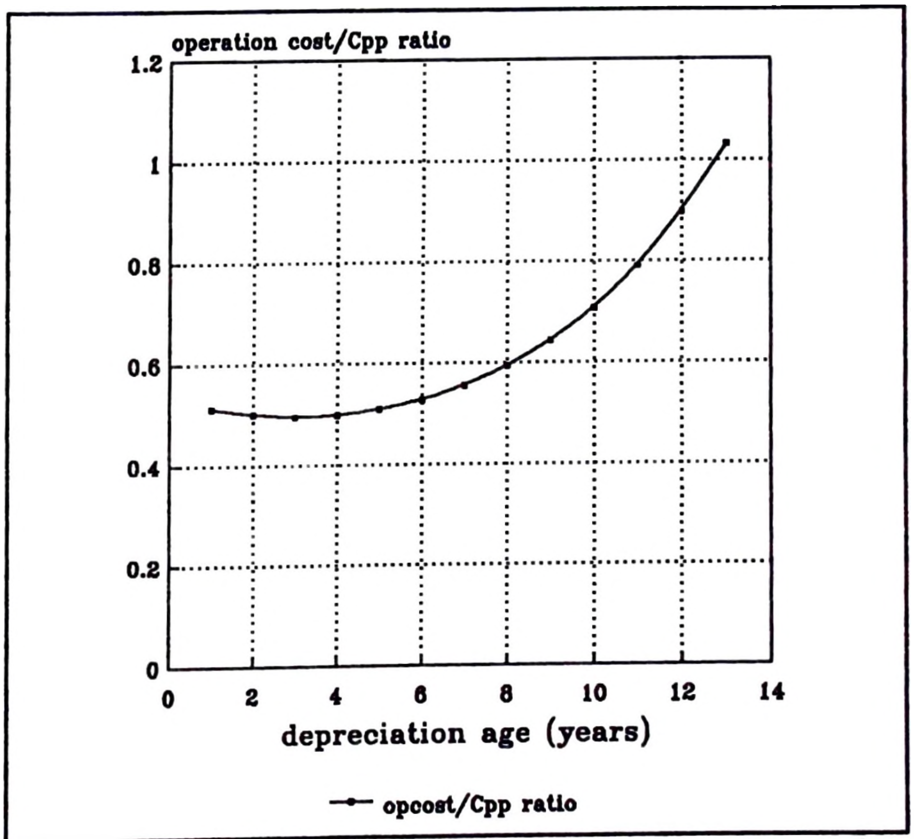

Fig. 4.8: Estimation of future tractor operation costs

4.4 The Impact of the Findings

Tractor units are indispensable farm power input in medium or large scale agricultural production system. The cost of purchasing and running these units have been galloping rapidly as the recent trends show. This makes them the single most expensive investment on the farms. Their efficient management is a limiting requirement for optimization of agricultural production costs.

4.4.1 Tractor Operation and Management Data.

It is obvious that any management system must have a resource of data for it to make and effect decisions for the good of the business. Record keeping as it is done now was observed to be a useless formality.

Increasing awareness on the importance of record keeping by way of seminars and short courses both for management personnel, entry clerks and tractor operators and standardizing record keeping documents could improve the management of tractors.

The study revealed that no standard format for keeping tractor or agricultural machinery operation records existed

This was reflected by the various records studied in the survey; they were in all sorts of forms: exercise books, files, ledgers, loose sheets and all differing in character and content. Since the will and the means and the superstructure already exists all that is required is an internal reorganization subject to increased awareness on the importance of the record keeping exercise. For decision purposes the annual summaries are more readily useable but it must be stressed they can only be obtained from primary documents.

Individual tractor reliability is an important investment parameter and can assist the tractor owners in future investment decisions. A simple way of indicating tractor reliability is by observing the frequency of mechanical breakdown and the magnitude of annual breakdown hours. It was noted that this information could not be found anywhere for all the tractors covered in the study. It is recommended that any standard tractor record keeping should include this item. This would in due course of time reveal inherent design defects common in the tractor make or model which may interfere with its operation and utilization.

4.4.2 Applicability of Empirical Findings.

(a) The empirical findings agree fairly closely with other workers in the field of study. The prediction equation for tractor resale values agree with a similar equation reported by Witney (1988) and also by Schoney and Rinholm (1989). The values obtained by using it for estimating tractor resale values are typical resale values provided the inherent assumptions are not violated.

The effect of qualitative factors are quite clearly demonstrated by the equations. It is seen that the qualitative factors like make, ownership and power range manifests themselves quantitatively on tractor resale values. If for example good ownership is translated to mean good tractor care, timely maintenance, good operator training, good operator working relations and conditions then one can expect better resale values.

The fact that the effect of interaction between variables were not investigated does not indicate or infer their absence, but was simply a limitation in the scope of the study. It is however, thought that the effects of interaction could be quite significant.

5 CONCLUSIONS AND RECOMMENDATIONS.

It is obvious that tractors will remain a permanent feature in the process of cane production in the Chemelil sugar belt. The management of the tractors whether in transport assignment or tillage could be improved by maintaining better records. The analysis completely ignored the tractor performance costs because of lack of data. This should not be seen to belittle the significance of performance costs as part of machine operating costs. The following recommendations are presented:

(a) Annual use records should include cumulative tractor hours, downtime hours and breakdown hours to enable periodical assessment of tractor utilization and reliability.

(b) There is need for training, motivation and increased awareness of the need to keep complete records.

(c) It is not possible to assess the potential of tractor utilization in the belt, until all the operational constraints have been identified, modelled and studied.

(d) The use of equation 3.2 for general prediction of tractor resale values is recommended since it is lent credence by its close agreement to one obtained by Witney (1988) As observed tractor resale values were not affected by type of operation, but where appropriate adjustments must be made for effects of good or bad ownership, make of tractor and its power range or size. The magnitude of the adjustments would normally reflect on the prices quoted for 'as is' basis. It is observed that the reliability of tractor resale value data may sometimes be influenced by factors other than those considered in the model.

(e) The financial implication due to different management strategies (due to difference in ownership) has been indicated although it is not possible from the empirical relations to prescribe definite solutions. It can be seen that under different management regimes, the repair bills of identical makes of tractors could be quite different not necessarily due to the randomness of repair jobs but due to implicit management factors.

(f) The evaluation of tractor remaining values using the model discussed defies the assumptions of the conventional models; but reflects the actual trend of depreciation or appreciation of agricultural tractors.

(g) The applicability of the derived empirical relations within the belt is recommended. The tractor resale values or remaining values, repair and maintenance costs and future operation costs can be estimated using the related equations found. In all the three cases there is need for further investigation using a broader data base to permit application outside the belt.

(h) Future research should also be directed at determining tractor performance indices for various assignments to permit estimation of performance costs as part of operating cost. It would also be important to investigate the extent of the influence of effects of interaction between the participating variables in the models discussed.

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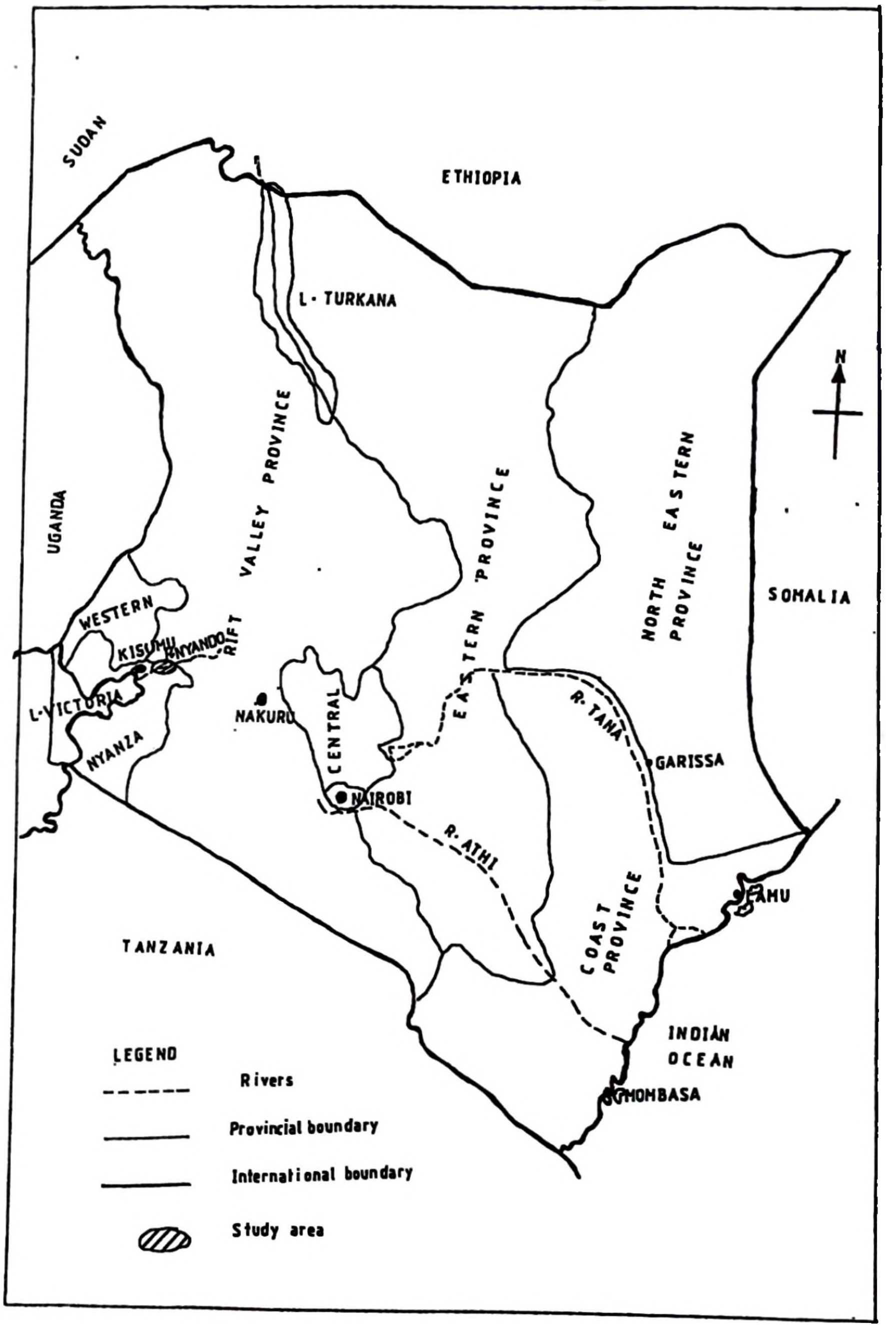
APPENDICES

APPENDIX A



Map of Kenya showing the location of study area

APPENDIX B

Table A4.1 Summary of tractors covered in the study

Tractor Make/Model	HP	Owner: Chemelil	Nyaroche	Kimwani	Total number of units	Type of operation	Average annual use (hours)
		number of units owned					
Ford 5000	65	16	-	-	16	transport	1165
5600	67	-	-	1	1	transport	1209
6600	68	7	4	4	15	transport	1057
6610	70	-	-	13	13	transport	1286
7610	90	-	-	2	2	tillage	1002
Sub-total		23	4	20	47		
Same Mercury	85	-	7	-	7	transport	1405
Drago	120	7	2	-	9	tillage	945
Saturno	80	11	1	-	12	tillage	823
Synchro	80	11	-	-	11	transport	1385
Laser	100	2	-	-	2	tillage	1800
Laser	130	-	1	-	1	tillage	1330
Panther	90	7	-	-	7	tillage	921
Panther	95	-	-	1	1	tillage	1381
Sub-total		38	11	1	50		
Massey Fergusson							
194 4WD	73	-	1	-	1	tillage	1060
290	68	-	-	2	2	transport	1003
298 4WD	95	5	-	1	6	tillage	1081
390	70	-	-	3	3	transport	1329
375	61	-	-	2	2	transport	1256
399	95	-	-	1	1	tillage	1240
2645	130	-	-	1	1	tillage	2194
Sub-total		5	1	10	16		
Inter 844	80	4	-	-	4	tillage	808
Case Inter	130	3	-	-	3	tillage	661
Sub-total		7	-	-	7		
CAT grader	150	1	1	-	2	tillage*	886
D5	90	3	-	-	3	tillage	985
D6	180	1	-	-	1	tillage	998
D7	150	2	-	-	2	tillage	1566
Sub-total		7	1	-	8		
Komatsu D60F	180	2	-	-	2	tillage	2227
Bell Loader	90	-	-	2	2	cane loading**	1313
Cameco SP3000	120	6	1	1	8	cane loading**	1613
JCB excavator	90	1	-	-	-	tillage*	595
Grand-total		89	18	34	141		

Source: Tractor inventory records (1975-91) for Chemelil Sugar company, Nyaroche Farm and Kimwani ADC complex Farm.

* = operation grouped under tillage for analysis purpose.

** = operation grouped under 'others' in the analysis

APPENDIX C

COST DATA

Table C1: Bank lending rates 1975 - 91

Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Lending rate %	8.5	8.5	9.0	9.5	9.5	10	14	16	15	14	14	14	14	15	15.5	17*	18*

Source : Various Kenya Statistical Abstracts (1975-89) * = own estimates data not available.

Table C2: Road licence charges for agricultural tractors (KShs) 1973-91

Type of tractor	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Motor Graders	40	40	40	40	40	40	40	100	200	200	200	500	500	1000	1000	1500	1500	1500	1500
Crawlers	40	40	40	40	40	40	40	100	200	200	200	200	500	1000	1000	1500	1500	1500	1500
Loaders	40	40	40	40	40	40	40	100	200	200	500	500	500	1000	1000	1000	1500	1500	1500
Wheeled	40	40	40	40	40	40	40	100	100	100	200	200	200	500	500	500	500	500	500
Trailers	200	200	200	200	200	200	200	200	200	200	200	1500	1500	2000	2000	2000	2000	2000	2000

Source: Ministry of Transport and Communication; various circulars (1975 -88)

Note: 20 KShs is equivalent to one Kenya pound (K£)

Table C3: Estimated tractor shelter charges in KShs (1975-91)

components of shelter charge	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Interest on fencing	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71
Recurrent costs	61	61	61	61	61	61	202	202	202	202	202	385	385	385	385	385	385
Income foregone	18	21	25	27	27	27	30	30	36	48	48	64	64	76	96	106	106
Total (KShs)	150	163	157	159	159	159	303	303	309	321	321	321	520	520	532	552	1092

Source: own estimates
Income foregone was calculated basing on cane yield data for the belt. Mean yield was taken as 180t/ha

APPENDIX D

RAW DATA PLOTS

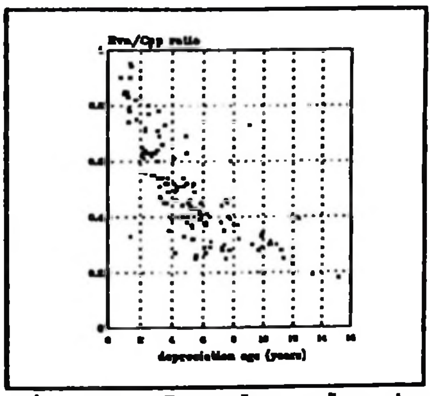


Fig D1: Resale value to current purchase price ratio versus depreciation age

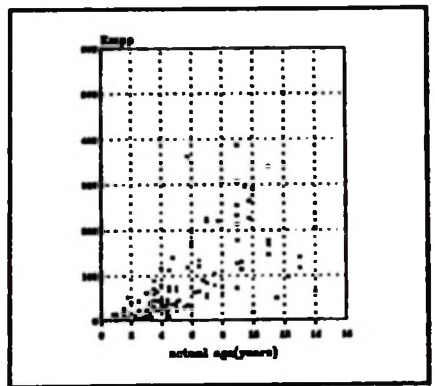


Fig.D2: Scatterplot of R_{mpp} against actual tractor age

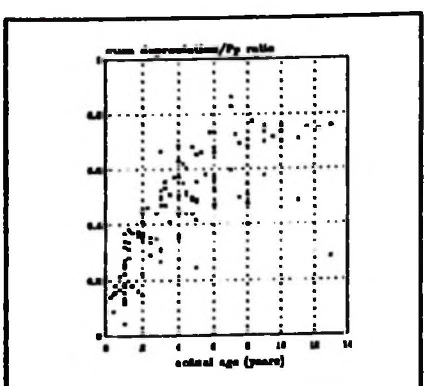


Fig D3: Cumulative depreciation as ratio of P_p versus tractor age

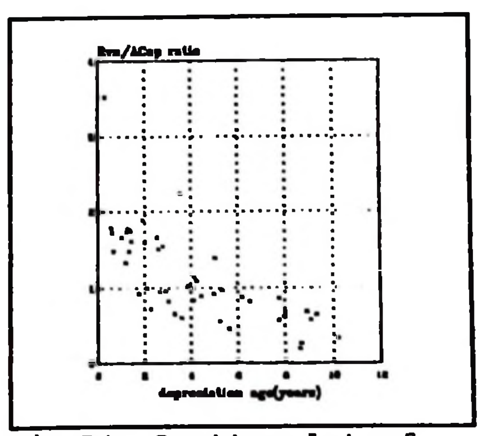


Fig.D4: Scatterplot of Rvn/ACop against depreciation age.

APPENDIX E

CONSTRUCTION OF DATA MATRIX.

Table E1: Data matrix for tractor resale value to current purchase price ratio

Case No	D_0	n	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}	D_{11}	D_{12}	D_{13}	D_{14}	D_{15}	D_{16}	$LN(R_{vn}/C_{pp})$	n^2
1.	1	2.10	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.433	8.39
2.	1	1.16	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.969	1.35
3.	1	3.10	0	0	1	0	0	0	1	0	0	0	1	1	0	0	-0.609	3.61
4.	1	7.46	0	0	1	0	0	0	1	0	0	0	1	1	0	0	-0.770	6.07
5.	1	5.28	0	0	1	0	0	0	1	0	0	0	1	1	0	0	-0.673	0.08
6.	1	4.92	0	0	1	0	0	1	0	0	0	0	1	0	1	0	-0.648	0.01
7.	1	2.26	0	0	1	0	0	0	1	0	0	0	1	1	0	0	-0.467	7.49
8.	1	12.43	0	0	0	0	1	0	0	1	0	0	1	0	1	0	-0.944	55.26
9.	1	3.06	0	0	1	0	0	1	0	0	0	0	1	0	0	1	-0.342	3.76
10.	1	7.14	0	1	0	0	0	1	0	0	0	0	1	0	1	0	-0.978	4.59
11.	1	7.68	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-1.280	7.20
12.	1	2.30	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.440	7.28
13.	1	3.73	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.717	1.61
14.	1	4.71	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.625	0.08
15.	1	10.38	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-1.191	28.98
16.	1	2.52	0	0	1	0	0	0	1	0	0	0	1	1	0	0	-0.219	6.14
17.	1	2.70	0	0	1	0	0	1	0	0	0	0	1	0	1	0	-0.478	5.28
18.	1	4.44	0	0	1	0	0	1	0	0	0	0	1	0	1	0	-0.673	0.31
19.	1	9.94	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-1.238	24.41
20.	1	1.24	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.182	14.12
21.	1	1.83	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.166	14.57
22.	1	1.03	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.168	15.75
23.	1	4.62	0	0	0	0	1	0	0	1	0	0	1	0	1	0	-0.681	0.15
24.	1	7.65	0	0	0	0	1	0	0	1	0	0	1	0	1	0	-0.916	7.03
25.	1	1.36	0	0	1	0	0	0	1	0	0	0	1	1	0	0	-0.106	13.22
26.	1	6.42	1	0	0	0	0	1	0	0	0	0	1	0	1	0	-0.926	2.00
27.	1	4.89	1	0	0	0	0	0	1	0	0	0	1	0	1	0	-0.656	0.01
28.	1	1.21	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.174	14.34
29.	1	10.50	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-1.174	30.28
30.	1	4.62	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.823	0.14
31.	1	3.70	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.660	1.68
32.	1	6.20	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.986	1.44
33.	1	2.31	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-0.582	7.26
34.	1	6.43	1	0	0	0	0	0	1	0	0	0	1	1	0	0	-1.241	2.03
35.	1	5.53	0	0	0	0	1	0	0	1	0	1	0	1	0	0	-1.332	0.28
36.	1	9.95	0	0	0	0	1	1	0	0	0	1	0	0	0	1	-1.079	24.48
37.	1	3.13	0	1	0	0	0	1	0	0	0	1	0	0	0	1	-0.247	3.48
38.	1	11.22	0	1	0	0	0	1	0	0	0	1	0	1	0	0	-1.273	38.68
39.	1	2.50	0	1	0	0	0	1	0	0	0	1	0	0	1	0	-0.260	6.26
40.	1	7.74	0	1	0	0	0	1	0	0	0	1	0	0	1	0	-1.259	7.52
41.	1	4.10	0	1	0	0	0	0	1	0	0	1	0	0	1	0	-0.660	0.82
42.	1	0.80	0	1	0	0	0	0	1	0	0	1	0	0	1	0	-0.100	17.64
43.	1	1.43	0	1	0	0	0	1	0	0	0	1	0	0	1	0	-0.694	0.50
44.	1	2.15	0	1	0	0	0	0	1	0	0	1	0	0	1	0	-0.470	8.13
45.	1	2.08	0	1	0	0	0	0	1	0	0	1	0	0	1	0	-0.475	8.56
46.	1	8.34	1	0	0	0	0	0	1	0	0	1	0	1	0	0	-1.136	11.13
47.	1	4.75	1	0	0	0	0	0	1	0	0	1	0	1	0	0	-1.100	0.07
48.	1	9.71	1	0	0	0	0	0	1	0	0	1	0	1	0	0	-1.280	22.14
49.	1	6.47	1	0	0	0	0	0	1	0	0	1	0	1	0	0	-1.171	2.16

Case No	D_0	n	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}	D_{11}	D_{12}	D_{13}	D_{14}	D_{15}	D_{16}	$LN(R_{vn}/C_{pp})$	n^2
50.	1	13.39	0	0	1	0	0	1	0	0	0	1	0	0	1	0	-1.682	70.39
51.	1	3.11	0	1	0	0	0	0	1	0	0	1	0	0	1	0	-0.519	3.57
52.	1	5.77	0	1	0	0	0	0	1	0	0	1	0	0	1	0	-0.887	0.59
53.	1	7.38	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.211	5.65
54.	1	2.30	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-0.340	7.29
55.	1	5.30	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.146	0.08
57.	1	5.24	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.191	34.85
58.	1	3.24	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-0.759	3.10
59.	1	7.20	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.248	4.83
60.	1	6.16	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.324	1.34
61.	1	5.35	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.146	0.13
62.	1	7.78	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-0.936	7.73
63.	1	3.98	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-0.947	1.04
64.	1	3.81	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.041	1.42
65.	1	7.32	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.041	5.38
66.	1	10.56	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.191	30.91
67.	1	5.22	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-0.989	0.05
68.	1	5.01	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-0.794	0.00
69.	1	4.93	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-0.981	0.00
70.	1	5.49	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.366	0.24
71.	1	7.48	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.398	6.17
72.	1	2.22	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-0.501	7.73
73.	1	1.01	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-0.174	15.95
74.	1	3.50	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-0.794	2.24
75.	1	5.28	1	0	0	0	0	0	1	0	1	0	0	1	0	0	-1.016	0.08
76.	1	6.04	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-1.238	1.09
77.	1	4.66	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-0.921	0.11
78.	1	2.69	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-0.601	5.33
79.	1	2.89	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-0.601	4.45
80.	1	5.74	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-0.944	0.55
81.	1	1.75	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-0.281	10.60
82.	1	1.281	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-0.594	4.78
83.	1	5.17	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-0.814	0.03
84.	1	3.81	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-0.711	1.41
85.	1	5.42	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-0.719	0.18
86.	1	1.99	0	1	0	0	0	1	0	0	1	0	0	1	0	0	-0.108	9.05
87.	1	4.15	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-0.711	0.73
88.	1	2.95	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-0.465	4.22
89.	1	4.26	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-0.666	0.55
90.	1	1.28	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-0.296	13.88
91.	1	2.66	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-0.460	5.48
92.	1	6.22	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-0.899	1.49
93.	1	9.06	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-1.099	16.49
94.	1	4.99	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-0.929	0.00
95.	1	2.79	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-0.459	4.88
96.	1	7.97	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-1.000	8.84
97.	1	5.75	0	1	0	0	0	0	1	0	1	0	0	1	0	0	-0.868	0.57
98.	1	8.24	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-1.005	10.50
99.	1	3.06	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.448	3.77
100.	1	3.36	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.411	2.70
101.	1	7.54	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.792	6.45
102.	1	4.10	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.488	0.82
103.	1	9.88	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-1.115	23.80

Case No	D_0	n	D_3	D_4	D_5	D_6	D_7	D_8	D_9	D_{10}	D_{11}	D_{12}	D_{13}	D_{14}	D_{15}	D_{16}	$LN(R_{vn}/C_{pp})$	n^2
104.	1	7.18	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.828	4.73
105.	1	1.44	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.058	12.65
106.	1	1.36	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.052	13.27
107.	1	5.50	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.844	0.23
108.	1	3.54	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.320	2.14
109.	1	2.45	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.462	6.50
110.	1	4.90	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.467	0.01
111.	1	3.20	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.377	3.29
112.	1	5.36	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.650	0.13
113.	1	4.73	0	1	0	0	0	1	0	0	1	0	0	0	1	0	-0.677	0.07
114.	1	2.70	0	0	0	1	0	1	0	0	1	0	0	0	0	1	-0.594	5.30
115.	1	2.12	0	0	0	1	0	1	0	0	1	0	0	0	0	1	-0.462	8.32
116.	1	3.65	0	0	0	1	0	1	0	0	1	0	0	0	0	1	-0.796	1.83
117.	1	1.38	0	0	0	1	0	1	0	0	1	0	0	1	0	0	-0.312	13.12
118.	1	1.36	0	0	0	1	0	1	0	0	1	0	0	1	0	0	-0.622	2.69
119.	1	5.82	0	0	0	1	0	1	0	0	1	0	0	1	0	0	-0.934	0.67
120.	1	1.95	0	0	0	1	0	1	0	0	1	0	0	1	0	0	-0.516	9.30
121.	1	2.87	0	0	1	0	0	1	0	0	1	0	0	0	1	0	-0.462	4.54
122.	1	5.13	0	0	1	0	0	1	0	0	1	0	0	0	1	0	-0.768	0.02
123.	1	3.72	0	0	1	0	0	1	0	0	1	0	0	0	1	0	-0.616	1.63
124.	1	1.30	0	0	1	0	0	1	0	0	1	0	0	0	1	0	-0.232	13.68
125.	1	1.70	0	0	1	0	0	1	0	0	1	0	0	0	1	0	-0.194	10.89
126.	1	4.21	0	0	0	0	1	1	0	0	1	0	0	0	1	0	-1.313	0.62
127.	1	7.76	0	0	0	0	1	1	0	0	1	0	0	0	0	1	-0.514	7.62
128.	1	4.86	0	0	0	0	1	1	0	0	1	0	0	0	0	1	-0.368	0.02
129.	1	5.87	0	0	0	0	1	1	0	0	1	0	0	0	0	1	-0.799	0.76
130.	1	9.25	0	0	0	0	1	1	0	0	1	0	0	0	0	1	-1.217	18.04
131.	1	4.23	0	0	0	0	1	1	0	0	1	0	0	0	1	0	-0.779	0.59
132.	1	2.32	0	0	0	0	1	1	0	0	1	0	0	0	1	0	-0.330	7.21
133.	1	6.07	0	0	0	0	1	1	0	0	1	0	0	0	1	0	-1.008	1.15
134.	1	7.22	0	0	0	0	1	1	0	0	1	0	0	0	0	1	-1.266	4.91
135.	1	12.00	0	0	0	0	1	1	0	0	1	0	0	0	0	1	-1.448	48.79
136.	1	1.35	0	0	0	0	1	0	0	1	1	0	0	0	1	0	-0.251	13.30
137.	1	3.55	0	0	0	0	1	0	0	1	1	0	0	0	1	0	-0.662	2.10
138.	1	11.37	0	0	0	0	1	0	0	1	1	0	0	0	1	0	-1.366	40.58
139.	1	3.21	0	0	0	0	1	0	0	1	1	0	0	0	1	0	-0.679	3.22
140.	1	15.14	0	0	0	0	1	0	0	1	1	0	0	0	1	0	-1.704	102.76
141.	1	7.23	0	0	0	0	1	0	0	1	1	0	0	0	1	0	-1.252	4.96

The column n^2 was modified square of depreciation age. It was modified by subtracting a number close to the mean depreciation age (in this case five) in order to avoid the problem of extemely high correlation in regession of the model.

APPENDIX F

EXAMINATION OF RESIDUALS

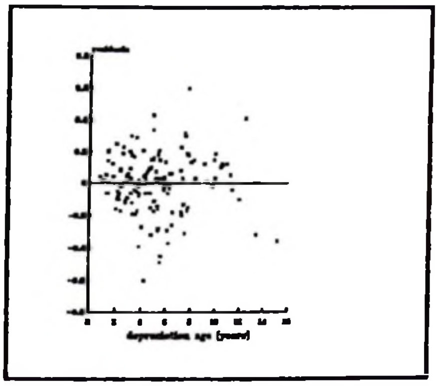


Fig F1: Ratio of tractor resale value to current purchase price ratio vs depreciation age model

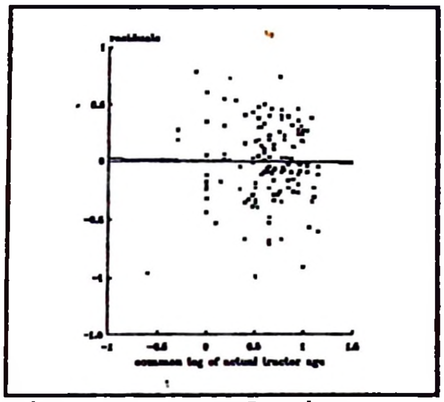


Fig. F2: Cumulative tractor repair and maintenance cost as percent of P_p against age model

Fig. F3: cumulative depreciation as percent of P_p against age model

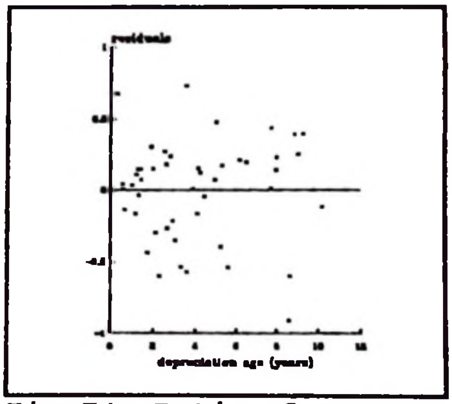


Fig.F4: Ratio of tractor resale value to annual operating cost against tractor age model