Institut für Landtechnik
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REPAIR COSTS OF TRACTORS AND COMPARISON OF MECHANIZATION STRATEGIES UNDER TANZANIAN CONDITIONS

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Freising, August 2000 Sylvester Michael Mpanduji

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A	Present annual ownership cost, Tshs
$A(n)$	Annuity factor for n years at rate of i_m
$A_{op}(n)$	Annual operating cost in the n^{th} year of usage
A', B' and b	Constant of the power functions
BC_n	Balancing charge, Tshs
BV_{n-1}	Book value of asset at the end of the previous accounting year, Tshs
C_H	Total health cost, Tshs
C_L	Annual Labour cost, Tshs
C_o	Annual lubricant cost, Tshs
c_m	Annual treatment cost per ox, Tshs/ox
c_d	Annual dipping cost per ox, Tshs/ox
c_v	Annual vaccination cost per ox, Tshs/ox
c_w	Monthly wage of draft animal labourer, Tshs
$c.v$	Coefficient of variation
CA_n	Capital allowance, Tshs
$C_{rp}(n).f(n)$	Resale value of the tractor in n^{th} years
D_n	Depreciation at any year n^{th}, Tshs
D_v	Damage value
$EAC(c)$	Equivalent Annual Costs of the challenger, Tshs
$EAC(d)$	Equivalent Annual Cost of the defender, Tshs
F_c	Fuel costs, Tshs
F_f	Total feed cost, Tshs
f_p	Fuel price, Tshs/l
i	Interest rate, %
i_i	Investment interest rate, %
i_l	loan interest rate, %
i_m	Minimum acceptable rate of return
i_r	Rear interest rate, %
I_n	Annual interest charge, Tshs
j	Inflation rate, %
K	Material damage constant
k_1 and k_2	Resale exponent factor
k_f	Cost of producing feed per animal, Tshs
L	Economical life of the machine, in years
L_a	Economical live of draft animal, in years
M	Sequence annual payment (Mortgage), Tshs
M_i	Local maximum height occurring at time t
$m_i^{r/c}$	Corresponding rainflow minimum
N	Life of asset, in years
N_a	Total number of draft animals (oxen)
n_{ap}	Number of pairs of draft animals

N_{S}	Number of cycles
NPV_m	Present total mortgage cost, Tshs
NPV_r	Present annual costs of repairs and insurance, Tshs
NPV_s	Present resale value, Tshs
NPV_t	Present value of tax deductible allowance, Tshs
P	Purchase price, Tshs
P_a	Purchase price of a cattle, Tshs
$P_{a,I}$	Initial price of draft animal, Tshs
P_o	Tractor power, kW
R_n	Annual repair costs, Tshs
RU	Power utilisation ratio
S	Salvage value, Tshs
S_t	Amplitude, mm
S_a	Salvage cost of draft animal
S_A	First year correction factor
S_B	Annual depreciation factor
S_{FC}	Specific fuel consumption, l/kW h
S_n	Salvage value of a machine at n^{th} year, Tshs
t	Time, age
TAR	Total accumulated repair costs, % of purchase price
w	Inflated discount factor
W_t	Live weight of a cattle, kg
$\bar{x}$	Mean values (utilisation level/repair costs)
X	Accumulated hours of use
Y	Accumulated repair costs, in DM
Z	Average fuel consumption, l/h
δ	Determination factor between challenger and defender tractors
β	Material damage exponent
σ	Standard deviation
2WD	Two wheel drive tractor
4WD	Four wheel drive tractor
ASF	Arusha Seed Foundation
ATNESA	Animal Traction Network for Eastern and southern Africa
BF	Burkina Faso
BOT	Bank of Tanzania
CARMATEC	Centre for Agricultural Mechanisation and Rural Technology
Case IH	Case International
CRDB	Co-operative Rural Development Bank
DM	Deutsch Mark (Germany currency)
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
IBRD	International Bank for Reconstruction and Development (World Bank)
IITA	International Institute of Tropical Agriculture
IPI	Institute of Production Innovation
KTBL	Board of Trustees for Technical and Buildings in Agriculture (Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V.)

MALDC	Ministry of Agriculture, Livestock Development and Co-operatives
MF	Massey Ferguson
MOR	Morogoro region
NAFCO	National Agricultural and Food Corporation
OTC	Ox Training Centre
PTO	Power Take Off
RFC	Rainflow Cycles
SHY	Shinyanga region
SIDO	Small Scale Industries Organisation
TANWAT	Tanganyika Wattle Company Limited
TEMDO	Tanzania Engineering Manufacturing and Design Organisation
TPC	Tanganyika Planting Company Limited
TRAMA	Tanzania Tractor Manufacturing Assembly Plant
TZ	Tanzania
Tshs	Tanzania Shillings
UFI	Ubungo Farm Implements
UNIDO	United Nation Industrial Development Organisation
URT	United Republic of Tanzania
ZZK	Zana Za Kilimo

1. INTRODUCTION

1.1 Problem statement

Agriculture in Tanzania has been the major source of the country export earnings. It has the potential to provide the agricultural based local industries with raw materials and also to provide adequate food for the rapid growing population. However the agricultural production in Tanzania is still very low. Expansion of agricultural production could be carried out by increasing more area under-cultivation or by the use of other modern technologies. The modern technologies are designed to increase the output per unit area of land. These include better management of soil, increasing utilisation of high yielding varieties, expanding fertiliser use, controlling pests and diseases, better management of irrigation and water resources.

The use of modern technologies is still low in Tanzania, however the adoption rates have been reported to be at least higher than that of putting more land under-cultivation [55]. On the other hand, agricultural production may be raised by increasing the productivity of land already under-cultivation, but the overall increase in production depends greatly on bringing more land under-cultivation.

Tanzania has a big potential in agriculture as reflected in its favourable man to arable land area ratios, diverse agro-climates, substantial untapped and under-utilised resources in crop and livestock production. Tanzania has an arable land of about 45 million hectares. Currently only about 5 million hectares (10%) of these are under-cultivation [94]. Suppose the area under-cultivation is increased from the current 10% to 30% of the total arable land and also the use of modern technologies is maintained, then the country should be able to feed herself and to produce enough food and cash crops for export in other countries.

There are many constrains which contribute to the failure to use the enormous potential. One of the constrains lies in the lack of adequate farm power. Current field operations requiring machinery and equipment for crop and livestock production in the country are dominated by 90% small hand tools and animal drawn implements. The current low level of application of mechanical power contributes to the low level of agricultural activities and thus low agricultural productivity. Agriculture in Tanzania is essentially rain-fed because less than 4% of the cultivated land is under irrigation [27]. However rainfall seasons in many places are characterised to be short. This necessitate the completion of key farming tasks such as ploughing, planting and weeding to be carried out in a short time span. When using hand tool's technology to accomplish these tasks only a small area of less than 1 ha can be handled.

In order for the country to use her agricultural potential, there is a need to expand and improve mechanised agriculture at all level of power application. However agricultural mechanisation with tractors has been a controversial issue. On one hand there is no question about the need for higher agricultural production through the increase use of mechanical power. On the other hand the contribution of mechanical power in agricultural production has been observed by Tanzanian agricultural planners mainly economists to be unreliable, costly and inefficient. These observations have made the government in the past to adopt cautious policies regarding the promotion of this technology. Consequently since 1969 the encouragement of the government has been put more on the use of draft animal technology [91].

However MREMA AND MREMA (1993) [62] argued that draft animal technology is not the solution to agricultural expansion in most of African countries. They stated that there are many constraints to its adoption, these include inter alias lack of profitability, environmental problems, lack of animals, competing demands for livestock products, lack of implements, etc. They further argued that draft animal power is likely to play a leading role in agricultural production in only 30% of cultivated area because the technology is suitable mostly in semi-arid and dried parts of the semi-humid zones. If farmers with a livestock husbandry tradition can settle in these areas then they are likely to intensify arable crop production.

When examining the green revolution that has turned Asian countries from importers of food to exporters [2, 38], a number of reasons have been advanced for the change. Amongst other things the increased utilisation of tractors has played an important role.

The statistical data on tractor use in Asian countries in the last 50 years (table 1) shows that the number of tractors in use in India has increased from less than 10000 in 1950 to more than 1.4 million in 1997. This indicates that Asian farmers would not be buying these tractors if they were not using them economically and making profit.

Table 1: Growth of tractor population used for Agricultural production in Different Countries (1950 - 1997). Source: FAO Production Year Books 1958 - 1997[28]

Year	India	Malaysia	Morocco	Tanzania
1950	9 000			
1960	31000			1 500
1970	148 000	7 776	24 684	17 000
1980	393 000	12 500	32 000	15 898
1990	1 063 012	26 000	39 155	6 000
1995	1 400 000	43 295	41 000	7 000
1997	1 450 000	43 300	43 226	7 600

Nevertheless, this is not to say that draft animal technology has not played any role in the Asian green revolution. Of course it has played a role, but if one moved higher level of biochemical technologies (both in quality and quantity) then one has also to move to higher levels of physical technologies. That is to move from draft animal technology to mechanical power technology. MISRA (1991) [59] revealed that, draft animal technology in India contributes to 12.8% of the total cultivated area, whereas tractor technology contributes to 76.5% of the total area.

Furthermore, the need for tractor use in the Tanzania is being stimulated by the fact that the population in the country is increasing at a faster rate than the growth in agricultural production. According to IBRD (1989) [37] data, the population is growing at a rate of 2.8% per annum. The prediction shows therefore that by the year 2010 the population will be twice as many as were in 1990. However, the growth in agricultural production has averaged to 2% over the past 30 years. The result has been the decline of per capita food production and increased food imports at a rate of 7% a year. To reverse the situation requires that food production should be increased by over 4% per year.

Additionally the increase of rural to urban migration is found to be critical to the change. In Tanzania urban population is increasing at a rate of 6.9% per annum and doubling every 10 to 12 years [37, 105]. Since the urban dwellers rely on food supply from rural areas, this therefore increases the pressure on the rural areas to produce even more food. However it is the educated and young people who migrate from rural to urban areas to liberate themselves from the drudgery associated with the hand-tools technology agriculture leaving aged people in the villages. Data collected in 1990 in Tanzania shows that more than 50% of heads of rural households are 45 years old or above [93]. For a country with a life expectancy of 51 years [37], it is indeed facing the problem of aged rural population. The older people remaining in the rural areas can not in any case be expected to increase the agricultural productivity for the country.

Considering all the mentioned cases, then it is obvious that the area under-cultivation in Tanzania could be increased substantially if tractor technology is encouraged and promoted by the government. The user of the technology can not be the small scale peasant farmer who is aged as we have seen. These must be the young and educated people who can perform agricultural activities as medium scale commercial farmers. This argument is also in agreement with the prediction made by the „Tanzania Vision Agriculture 2025" (KASHUNDE *et al.*, 1999 [42]). They stated that if agriculture in Tanzania is to be expanded, then the current farming community (80% of the population) need to change from small peasant dominated farmers to commercial medium scale holder farmers.

Small scale peasant farmers are unlikely to lead to a significant growth in agricultural productivity and overall production in the medium and long term. For sustainable agricultural growth in the medium and long term there is need to change the policy from emphasis on small scale peasant farmers to medium scale commercial farmers. That does not mean small scale peasant should be ignored. Instead by focusing on development of medium scale farmers, it is anticipated that they will be able to set up and support sustainable institutions for input supply and output recovery, through which small scale peasant farmers can benefit from the services to improve their agriculture.

To increase the contribution of the tractor technology in Tanzania, it is necessary therefore to undertake an economical and technical study. The study should base on data to be collected in the country because the required conditions for successful use of tractor will be established. Draft animal power technology should also continue to be encouraged to farmers engaged in cultivating small areas. Otherwise draft animal technology is hypothesised in this study as uneconomical for the farmers engaged in large land areas inasmuch as compared to utilisation of tractor technology.

Agricultural machinery involves large investment of capital. BROWN AND SCHONEY (1985) [20] estimated that machinery and building ownership costs accounted for nearly 25% of the total production costs in wheat production systems of Canada. Other estimations of machinery related costs have been reported to be as higher as 35% of the total production costs [21, 102]. The profitability of this investment depends on many factors, some of which cannot be influenced by the machine owners, such as the producer price, interest rate, taxation and inflation. Under these conditions, the achievement of sustained profit requires the development of sound management practices.

Currently there is lack of any approved management practice package suitable for the country condition. As a result of this, machinery has been operated blindly resulting in heavy losses of high investment costs. UNIDO (1983) [90] and FAO (1995) [28] reported about 45% to 60% of the total tractor population in Tanzania were out of use because of repair problems.

It is also acknowledged that there are significant differences in machine use, price levels, energy requirements, fuel and labour costs, operator misuse levels, etc. All these indicate that field machinery costs are area and country specific, time dependent and largely influenced by socio-political forces of the day with formulated policies that affect the farmers directly or indirectly. For example the applicability of the limits of the models for estimating machinery operating costs suffers from rapid changes in prices and technology, policy differences as well as variation in social environment. The determination of machinery operation costs is dependent on so many factors that each machinery system must be treated as unique [36]. HUNT (1983) [36] and WITNEY (1988) [106] developed models for estimating machinery operating costs. The model states that the costs of using agricultural machinery are simply the sum of:

fixed + variable costs

The fixed costs components comprise of depreciation, interest, taxation, insurance and housing. The variable costs components consist of fuel and lubricant costs, repair and maintenance costs. The machinery manager must strive to minimise the variable costs and aim at higher productivity to maximise profit. There is very little one can do to influence the fixed costs once the machines have been selected and bought. However the success of the management of agricultural machinery in minimising the operating costs depends on the existence of information and data on the level of utilisation, repairs costs, optimum replacement time and all other limits that contribute in management decisions. Unfortunately such information and data are not established in Tanzania. This study was thus initiated with the objective to develop these important factors in management of tractor technology in order to stimulate agricultural productivity in Tanzania.

1.2 Hypotheses

Failure to increase agricultural productivity in Tanzania is attributed to the government policy. This is because the government policy stresses only on the use of draft animal technology and at the same time considers mechanical power to be inappropriate. The policy could be right in the sense that the end user of the technology is considered to be a peasant farmer. However since the implementation of this policy more than 30 years ago the agricultural productivity has remained stagnant [37]. The number of agriculture tractors has dropped from 17 000 in 1970 to about 6000 units in 1990 and most of the peasant farmers have not adopted animal traction technology.

The cost of living in the country is going up very rapidly and the majority of the people are becoming poor and poor with time. The WORLD BANK (1994) [109] reported that the average annual income level of rural people in Tanzania is about Tshs 42000, equivalent to DM 110. With this income it is definitely impossible for the people to afford balanced diets, housing and the basic social services. To improve the life standard income must first be improved to a level that will reflect the actual cost of living.

According to the recommendation of the WORLD BANK, (1994) [109], an average income of about 70 times the present annual income is needed for a family of 6 people in order to have their basic requirements covered. All that money has to come from the farmers pocket regardless of the government contribution in social services. In that case the farmer has to cultivate an estimated area of about 30 hectares per year for subsistence and for family development needs. A farm of that size can not be cultivated by use of hand hoes or draft animals when using family labour. The use of animal draft technology and hired labour for such an area will be too expensive. The only way to handle such an area is to use tractor either own or hire.

1.2.1 General

The general hypothesis of this study state that the use of tractor technology in Tanzania if promoted will increase agricultural production. This is because apart from its high initial costs, the cost of output power of this technology is cheaper than that of animal draft power. Also tractor technology has more potential to put large area under-cultivation and if used based on the economics of scale, its annual cost per unit area of cultivated land could be lower than that of using draft animals.

1.2.2 Specific

Tractor technology is considered inappropriate in Tanzania because very subjective criteria are used to decide when and how to operate tractor profitably. There is no data published indicating the required level of tractor utilisation in terms of hours per year or minimum farm sizes required to be cultivated per year. There is no information for prediction of repair costs and on recommended optimum period for tractor replacement. Additionally there is no published data that indicate the annual costs of using draft animals in areas with and without tradition in cattle keeping. The annual costs of owning and using tractors are unknown and information on how best can the farmer minimised the costs in Tanzania is unavailable. Had this information been available then the users of tractor technology could be advised accordingly based on objective facts that could help them to increase the probability of utilising the technology profitably.

1.3 Objectives of the study

The main objective of this study is to provide the economic and technical information (repair regime) for tractor use under Tanzanian conditions necessary for good decision management. Such data can be obtained by evaluating the problems and costs associated with the use of tractors in Tanzania.

The specific objectives of the study are:

1. To evaluate tractor repair costs, by investigating tractors annual repair costs at different consecutive years of usage and then to develop mathematical functions that could be used for prediction of repair costs.

2. To develop a software programme for prediction annual costs of tractors for different levels of utilisation.

3. To determine the optimum replacement time of tractors based on the total annual cost model.

4. To evaluate the total annual ownership costs of draft animals for areas with tradition and non tradition in cattle keeping.

5. To compare total annual ownership costs of using tractors with that of using draft animals for different sizes of farms.

2. AGRICULTURAL MECHANIZATION IN TANZANIA

2.1 General information about Tanzania

The united republic of Tanzania lies in the tropical savannah region of east Africa between longitudes 29° and 40° east and between latitudes 1° and 11° south (figure 1), with a total area of 945,027 km^2. The country has a population of about 30 million and the population growth rate stands at 2.8%.

Agriculture is the mainstay of the Tanzanian economy. It employs more than 85% of the workforce in the country and accounts for 80% of the country's exports. Agriculture has a role to feed the population and to supply raw materials for the industrial sector, moreover it is a vital market for domestic industrial goods. Crop production is the largest sector in agriculture, contributing approximately 61% to the agricultural Gross Domestic Product (GDP). The study conducted by the government of Tanzania and the World Bank between 1990 and 1992 estimated that food crop production dominates the agricultural economy by contributing 55% of the agricultural value added [95]. Livestock production accounts for 30%, whereas traditional commercial crops, namely coffee, cotton, cashew-nuts, sugar, pyrethrum, tea, tobacco and sisal, account for another 8% and fishing and hunting contribute to 6%, whilst forestry 1% of the agricultural value added.

Considering rainfall pattern, altitude and farming system, Tanzania can be divided into four main agro-economic zones [76]:

1. The semi-arid central area consisting of four regions, Dodoma, Singida, part of Arusha and part of Iringa with a rainfall of less than 500 mm per annum. The main activities in these areas are livestock keeping and cultivation of food crops especially sorghum and maize.

2. The coastal area which covers Mtwara, Lindi, Coast, Morogoro, Tanga and Ruvuma region receives between 500 and 1000 mm of rainfall. Agriculture and fishing are the main activities in the area. The main food crops grown include rice, composite maize, cassava and groundnuts.

3. The western area which includes Mwanza, Mara, Shinyanga, Tabora, Kigoma and Rukwa region, receives 1000 to 1500 mm of rainfall. Both crop production and livestock keeping are practised intensively.

Area: 945.027 km²
Population: 30 Mill.

Figure 1: Map of Africa and Tanzania

4. The highland area covers six regions, Kilimanjaro, the rest of Arusha, Mbeya, Kagera and some parts of Tanga and the rest of Iringa. The average rainfall is above 1500 mm. Crop production and livestock keeping is important in these regions, but livestock keeping tends to be inclined toward zero grazing. The main crops grown in these areas include maize, beans, plantains and potatoes.

Agriculture production in Tanzania is performed by 80% of the population. Out of these 73% are small scale peasant farmers, 2% small-to-medium scale commercial farmers and 5% are involved in large-scale modern farms. However the small scale peasant farmers dominate the production by contributing to about 80% of crop and 99% of livestock production.

It is estimated that the total area under cultivation in Tanzania is about 5.1 million ha. This is based on the figures of physically cultivated area of between 3.4 million ha and 4.5 million ha and allowing for inter-cropping and sequential planting particularly in areas with two modal rainfall patterns. 85% of the cultivated area is estimated to be under food crops. A breakdown of the area under food crops indicates that cereals are by far the most important food crops in Tanzania accounting for 58% of the total planted area. Maize being the leading cereal crop provide one third of all calories consumed. Recently rice has also become important due to good returns it fetches in the urban markets. Other important food crops grown include cassava, sweet potatoes, sorghum and millet. Others are wheat, beans, plantains, variety of vegetables and fruits. The remaining area is used for growing cash crops including coffee that accounts for 31.5% of the total export earnings. This is followed by cotton which accounts for 20% of the total export [56]. Other cash crops grown are sisal, tobacco, tea, cashew-nuts, pyrethrum, sesame, flowers and cardamom.

2.2 Tractor mechanization in Tanzania

2.2.1 Tractor population

Tractor mechanization for cultivation, farm transport, and processing took off in Tanzania since around 1950s. Initially these tractors were used on foreign owned estates growing tea, coffee, sisal, tobacco and wheat. By the early 1960s the number of tractors rose to around 1600 units. The number of tractors increased fast because of the emergence of a number of private commercial Tanzanian farmers of medium to large scale farms. The Tanzanian farmers used the tractors mainly in production of maize in Iringa, wheat in Arusha and cotton in Shinyanga [44, 45].

The class of Tanzanian farmers was mainly encouraged by the newly independent government through an easy access to land. There was also good access to tractor credits from the co-operatives, national development credit agency, private Tanganyika farmers association, and private tractor dealers. Nevertheless the farmers did not depend on extension services, or back-up services from the government. The mechanization move was informal and the farmers easily acquired the management skills by their own means or by observing neighbouring settlers (where these were present). The farmers achieved high capacity utilisation of their equipment by entering into contracts hire service arrangements with other small farmers and peasants. In areas with short tillage season the tractor fleet was moved seasonally to other areas with different rainfall patterns to undertake contract ploughing for economical capacity utilisation.

During the period from 1960 to 1970 the tractor population expanded to about 17,000 units [49, 110]. Most of these tractors were being supplied to government mechanised capital intensive estates and to the village development block farming schemes. The village schemes were established after nationalisation of medium and large scale private farms in 1967. However many of these schemes failed due to the following main reasons [63, 80]:

1. Lack of competent management and strict supervision.
2. Poor training of the personnel responsible for operating, repairing and maintaining the equipment, inadequate workshop and repair facilities, lack of skilled and responsible operators.
3. Lack of adequate availability of cash and credit when needed.
4. Inefficient utilisation of the machinery.
5. Dishonest among the operators, managers and committee members.

Partially due to these early failures the government plan from 1969 stressed on the use of draft animal power instead of tractors [91]. Although mechanization with tractors continued to expand on state large scale farms, the government plan caused the population of tractors to decrease from 17,000 tractors in 1970 to less than 16,000 tractors in 1989 [55] and by 1990 only about 6000 tractors were operational. The rest were out of order due to various technical and management aspects [28].

The government of Tanzania was the sole importer of tractors during the period from 1970 to 1984. It imported tractors from different countries including Great Britain, Japan, India, United State of America, Germany, etc. The number of tractors imported during this period are shown in figure 2.

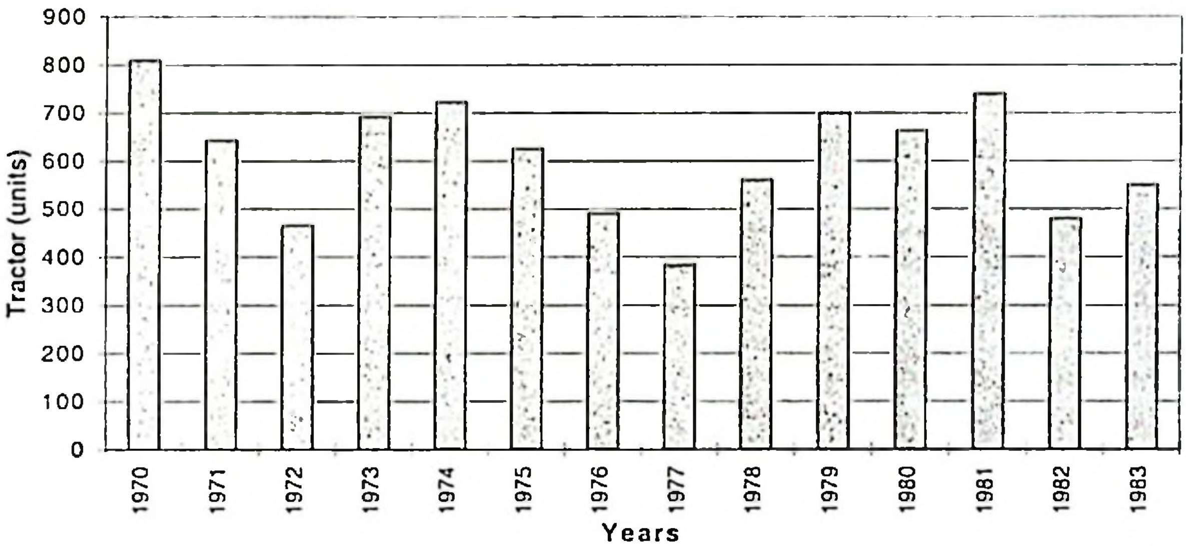

Figure 2: Import statistics of tractors in Tanzania for the year 1970-1984
Source: URT 1989 [92]

In 1985 the importation of tractors from abroad was stopped in the name of import substitution and instead tractors were obtained from Tanzania Tractor Manufacturing Assembly Plant (TRAMA). TRAMA was established in 1982 as a joint venture between the State Motor Corporation and the Valmet tractor company of Finland. The share capital of the Tanzania government was 90% and the remaining 10% was owned by the Valmet tractor company of Finland. The roles of this company were to:

1. Manufacture Valmet tractors after obtaining the licence from Valmet company of Finland.

2. Incorporate locally manufactured parts and components in Valmet tractors.

3. Provide after sale service to customer through its service workshops and established dealer workshops in all regions.

4. Sell tractors-drawn implements and spare parts to customers.

5. Train customers and dealer representatives so as to ensure adequate after-sales service and maintenance of tractors.

The production of Valmet tractors started in 1983 at the assembly plant. The first two years of production was mainly of assembling imported disassembled parts [61]. In 1985 it started to incorporate locally made parts into tractors. The production trend of TRAMA from 1983 to 1990 is as shown in figure 3.

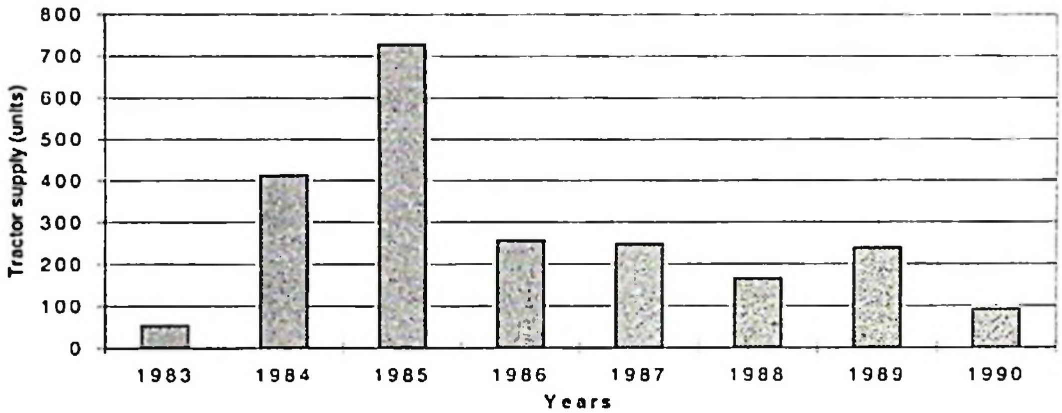

Figure 3: Local supply of tractors in Tanzania (1983-89)
Source TRAMA, 1991 [89]

A study administered by TRAMA (1989) [88] revealed that the annual minimum requirement of new tractors in the country is between 1500 to 2000. This is the number of tractors required to meet the demands of the existing and the newly re-opened farms. Unfortunately the numbers of tractors since 1970 to 1990 have been varying between 300 and 800 units per year, indicating a serious shortage of mechanical power in the country.

In the late 1980s the government changed the development strategy policy from socialism oriented economy towards market oriented economy. The change of policy resulted into private companies to be allowed to import tractors from abroad. The tractors imported by private companies were cheaper and much more reliable than those manufactured by TRAMA. This effect declined the production of Valmet tractors in the early 1990s and by mid 1990s TRAMA had to stop tractor production altogether. However on the other hand the change of policy resulted in the increase of the operating tractors from 6000 in 1990 to about 7000 units in 1995 [28].

2.2.2 Tractor makes

There are more than 10 different tractor makes operating in Tanzania as shown in figure 4. Massey Ferguson tractors are leading in terms of population units. This is followed by Ford, Valmet, and Case International tractors. Other makes are John Deere, Swaraj, Deutz, Same, Kubota, Tinkabi, etc.

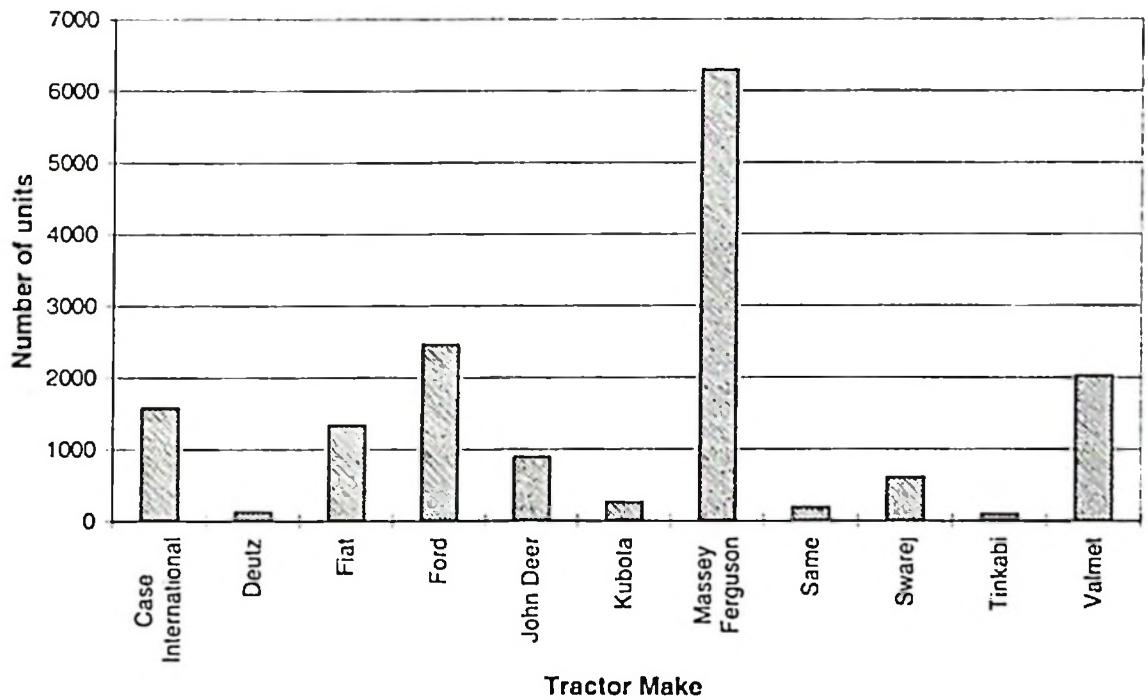

Figure 4: Tractor makes in Tanzania up to December 1989
Source: MALDC, 1991 [55]

The distribution of tractors by regions (figure 10 on page 55) shows that Arusha region has the highest population followed by Morogoro, Shinyanga and Kilimanjaro regions. Kigoma region has the lowest number followed by Ruvuma, Lindi and Mtwara regions.

2.2.3 Research in tractor mechanization

Tractor mechanization research in Tanzania is a theme which receives the least attention from the National Agricultural Research, Training and Extension Services [55]. Most of the data continually used for farm machinery management, planning, academic and by research is either data from USA or Europe or guess estimates. Even though the need for collection of machinery data for the nations was explored by FAO panel of experts in 1978 [26].

Nevertheless, few researchers have made some efforts to remedy the situation. Some of the attempts include the reports on the investigation of the scope for mechanization, machine, implement requirements and level of utilisation of tractors in Tanzania [10, 23, 75, 112]. Most of these reports concluded that tractors in Tanzania were then highly under utilised. The main reasons reported were:

1. Lack of skilled operators.
2. Lack of adequate repair and maintenance infrastructure.
3. Lack of management skills especially regarding spare parts management.
4. Lack of awareness of the costs of operating farm machinery.

HATIBU *et al.*, (1992) [32] reported on the investigation of the status of facilities for repair, maintenance and spare part supply for tractors in Morogoro region. They concluded in their findings that the necessary facilities for repair and supply of spare parts are available in Morogoro, but these vary from one place to another. The repair facilities and spare parts availability in urban areas are much better than in villages.

SIMALENGA (1989) [77] developed a model for prediction of number of suitable field work days for agricultural tractors under Tanzanian condition. The model was based on the historical weather data in time of good and bad years. Using the model he determined the average field working days for tillage and planting operations. In the case of tillage operation, the work days determined vary between 19 and 50 days, whereas for planting operation, the range was found to be 10 to 19 days. Additionally, based on the determined field work days he proposed an appropriate method which can be used for machinery and implement selection.

MWOMBEKI (1992) [64] reported on the agricultural machinery replacement policies of tractors operated under the National Agriculture and Food Corporation (NAFCO) farms. He critically found out that replacement policy was not based on any scientific analysis.

Exhaustive literature review has shown that very little information is available on repair costs and total annual costs of operating farm tractors in Tanzania. Instead, the report on the National Agricultural Mechanization Programme [55] has revealed that one type of information which is absent from agricultural extension material in Tanzania is information on farm machinery management.

Additionally, limited amount of work related to tractor mechanization has been reported from other African countries, such as Nigeria (KOLAWOLE, 1978 [46]), Swaziland (HENDERSON, 1985 [33]) and in Burkina Faso (KANDO AND LARSON, 1990 [41]). KOLAWOLE dealt with the aspect of tractor contracting operations in Western Nigeria. He showed that annual usage of tractors was held down by frequent equipment breakdown, untimely availability of spare parts, inadequate repair facilities and lack of incentives for the operators. The study further highlighted that group owners tended to achieve a higher level of tractor utilisation than individual owners. HENDERSON studied the economics of tractor operation in Swaziland and recommended that more emphasis should be placed on record keeping, tractor selection and training of operators. KANDO AND LARSON reported on the repair and maintenance cost in Burkina Faso. They found out that the repair and maintenance costs were higher in Burkina Faso during tractor early life than the predicted repair costs using the ASAE and Australian data.

2.3 Mechanization with animal draft power

2.3.1 Background

Animal draft technology was first introduced in Tanzania more than 70 years ago by missionaries and settlers. Tanzanian farmers began to adopt the technology in Mbeya, Iringa, Arusha and in the Lake zone mainly between 1930 and 1940. The number of ox-ploughs rose from 155 to 80,000 units from 1930 to 1960 [43, 49]. The adoption of draft animal technology in the early period was linked with a number of reasons. Some of these were due to development of estate farming and a market in food crops in Iringa and Arusha areas. In Lake zone areas it was linked with the increased cotton prices together with the existence of an open almost treeless land frontier.

According to figure 5 the ox-plough population from 1961 to 1973 increased by only 10,000 units. The small increase was explained to be due to the eagerness of the government of the newly independent states to bring a fast and radical change to the agricultural sector by use of tractors [44]. However after changing the policy in 1969 in favour of animal traction technology the number of ox-ploughs rose to over 110,000 from 1973 to 1983.

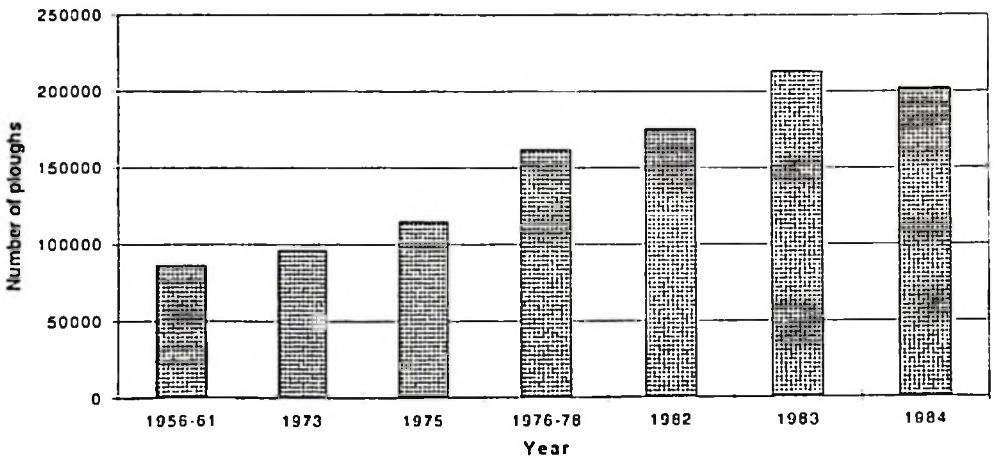

Figure 5: Population of ploughs in Tanzania (1956 - 84)
Source: Kjaerby F, (1986) [44]

Between 1974 and 1982 the government set up two implement factories to increase the availability of the draft implements. The Ubungo Farm Implement factory (UFI) was established in Dar es salaam in 1974 and Zana za Kilimo factory (ZZK) was set up in Mbeya in 1982. Additionally, to popularise draft animal technology over 60 ox-training centres (OTC) were established in different parts of the country. The objective of the OTCs was to promote draft animal technology by conducting training courses to the regional and district agricultural mechanization officers and also to the village ox-trainers.

Political leaders, and especially the President frequently urged farmers to adopt animal draft power. Nevertheless the main limitation to the wider adoption of ox-ploughing have been tsetse fly infestation and lack of a tradition of animal keeping in some areas. Likewise some farmers treat animals just like human being therefore there is no way they can use animals for draft work. Other reasons are those mentioned by MREMA AND MREMA (1993) [62].

2.3.2 Types of animals used for draft power

Oxen (*East African Zebu* cattle) and donkeys are the most common species in Tanzania used as draft animals. Oxen are the main animals used for agricultural activities. The use of female cattle for draft purpose is not yet widespread, perhaps due to belief that oxen are the only sort of cattle which can be worked. Donkeys are mainly used for transport either as park animals or for pulling carts.

Tanzania has about 12 million *East Africa zebu* cattle concentrated in the north and north east of the country. The colours of this cattle are black, red, white, mixtures of black and red or white. In 1984 there were estimated to be just over one million working animals, out of which about 840,000 were oxen and 220,000 were donkeys (table 2).

Table 2: Population draft animals in Tanzania (1984)
Source: MALDC (1984) [54]

Region	*Working Oxen*	*Donkeys*
Arusha	67 556	107 768
Coast	15	383
Dar es salaam	0	23
Dodoma	18 182	30 268
Iringa	53 322	3 847
Kagera	863	96
Kigoma	201	2
Kilimanjaro	3 491	6 477
Lindi	22	2
Mara	107 949	5 519
Mbeya	44 045	4 695
Morogoro	651	1 827
Mtwara	10	3
Mwanza	103 729	6 051
Rukwa	45 481	3 825
Ruvuma	93	40
Shinyanga	247 078	11 281
Singida	72 480	22 759
Tabora	71 032	8 166
Tanga	172	4 244
Total	**836 373**	**217 276**

2.3.2 Past researches in animal traction technology in Tanzania

There are about 5 institutions actively involved in animal traction researches and manufacturing of draft animal implements. These institutions include CARMATEC, TEMDO, IPI, SIDO and Uyole Research Centre. However most of the researches carried out by these institutions have concentrated on development and testing of tillage implements, weeding implements and ox-carts. One of the examples of these researches was carried out by Uyole Research Centre for testing the performance of animal drawn cultivators for maize production in the southern highland of Tanzania. This work was reported by Kwiligwa *et al.*,(1992) [49]. They revealed that there were no marked differences in field capacity between the two cultivators tested (i.e. Cossul inter row cultivator and over the row cultivator developed by Mbeya Oxenization Project). The use of cultivators alone reduced labour input for weeding by 80%. When the cultivators were used in combination with manual weeding, the labour inputs were reduced by 40% in comparison to weeding using only hand tools.

Combination of manual weeding and the use of cultivators gave the best weed control. The use of cultivators only gave poorer weed control which reduces yield advantage.

Other researches on animal draft power have been reported by individuals. Some of them has been dealing with care and management of work oxen. For example LUZIGA *et al.*, (1992) [53] reported on animal traction use in Tabora region. Whereby they found out that the use of draft animals in semi-arid areas like Tabora is affected by inadequate nutrition during dry season. Therefore the draft animals are normally so weak to perform agricultural activities at the start of cultivating season. They suggested that farmers should be educated and advocated to establish fodder banks to cater for dry seasons. MGAYA *et al.*, (1992) [58] on the survey of care and management of work oxen practised in Tanzania found out that only few farmers, about 30% supplemented their working animals with crop residues and by-products during the working season. FISHER (1992) [29] presenting his experience in animal traction technology reported that animal traction technology must be introduced gradually, in a certain sequence and not all at once and there must be an economic basis to run the technology profitably. SYLWANDER AND SIMALENGA (1997) [85] have been dealing with gender issues in animal traction. Their main focus of their research is to make sure that animal draft power reduces human being's drudgery.regardless whether is a man or a woman.

Very little literature has been published to address the economics of usage of draft animals in relation to the size of farms under-cultivation. However, a number of blanket statement has been made with regard to the cheapness of the technology as compared to tractors. Most likely these were based only on the initial price of the technologies.

3. BASICS OF MACHINERY AND ANIMAL DRAFT COSTS

3.1 Definition of machinery maintenance and repair

Maintenance and repair works are measures taken to maintain and restore the performance of the machine. These measures aim at prolonging the life span of the machine. The familiar bath - tub curve (figure 6) is used to distinguish different failure rates of the machine that can occur at different period of ownership. The bath-tub curve comprises mainly with three regions, namely early-life failures (infantile mortality), mid-life (random) failures and wear-out period.

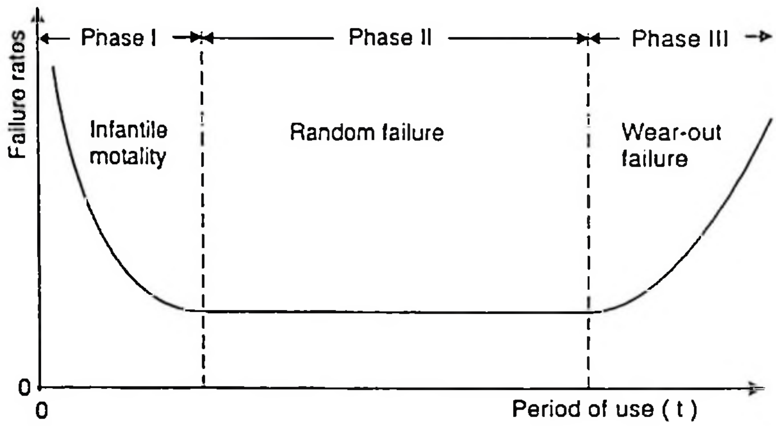

Figure 6: The failure rates of components of the machine with time (bath-tub)

The early-life failures are normally caused by built-in defects, installation errors, incorrect materials, etc. Mid-life failures are caused by random effects external to the component, for example operating changes, overloading, accidents, etc., whilst wear -out failure occurs due to the result of mechanical fatigue, corrosion, etc.

The term maintenance can be defined as the work done to ensure that failure does not occur before a specified life of the component has reached. This includes cleaning, daily oil check, greasing, battery inspection, engine tuning and the general check-up of the machine. Usually maintenance work is graded on daily and season bases. Maintenance costs consist mainly of labour costs.

Repair works are undertaken to replace different parts of the machine. These include both scheduled and unplanned replacement of parts as elaborated in figure 7. The unplanned replacements of part occur due to broken or malfunctioning of components. The repair costs are normally due to material costs, labour costs and other costs (such as transport costs for buying spare parts). As observed by FAIRBANKS *et al.* (1971) [25], HUNT (1983) [36] and WITNEY (1988) [106] the repair costs are difficult to estimate because of the unplanned repair works which occur randomly. They are usually dealt with as and when they occur. Experienced tractor owners or managers would know the failure rates of certain components in a given tractor and therefore they can be prepared to tackle the problem.

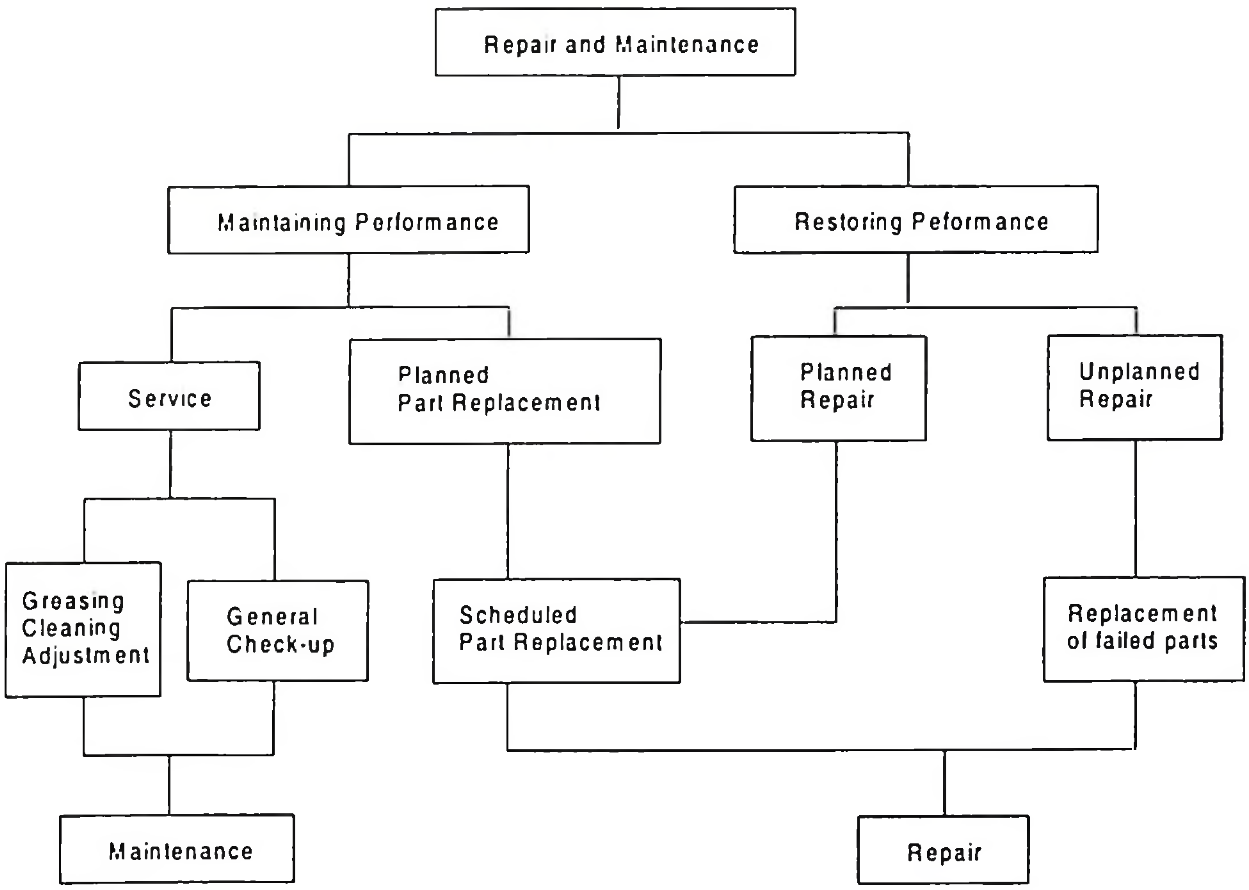

Figure 7: Systematic diagram for defining maintenance and repair
Source: Wendl (1992) [103]

3.2 Methods used for determination of repairs

There are basically two methods used for determination and prediction of components failure. These include:

1. Diagnostic technique
2. Questionnaire

The Diagnostic technique is a method commonly used in aircraft industries but of recently it has been adopted in some trucks industries. The methods involve studying the natural circles of the components of the machines at different work loads. To simplify the processes of studying the time of failures, JOHANNESSON (1998) [39] developed a simulation model based on Rainflow Cycles (RFC) for random fatigue. In the developed model a series of different load was modelled as a switching random load by using a hidden Markov model.

The fatigue tests of materials in the simulation model are performed with constant amplitude loads. However when dealing with variable amplitude loads, like random loads another form of equivalent load cycles are used for counting. This method is known as rainflow counting based on the rainflow cycles. Figure 8 represent a definition of the rainflow cycle.

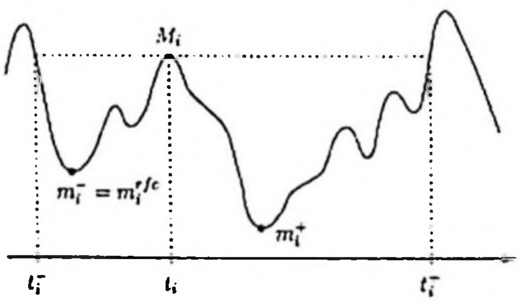

Figure 8: Definition of the rainflow cycle
Source: Johannesson (1998) [39]

The rainflow cycles are often measurements of stress variations at some point of the machine. During simulation a vast amount of rainflow cycles data are normally recorded. The data reduction is provided by calculating a rainflow matrix for the measured load. The damages due to the loading are then calculated using the Palmgren-Miner linear cumulative damage hypothesis. Mathematically expressed as:

$$D_v(t) = \sum_{t_i \le t} \frac{1}{N_{S_i}} \quad \text{............} \qquad (3.0)$$

The sum is extended over all cycles in the load completed at time t and N_{S_i} is the cycle life obtained from S-N curves with the constant amplitude S_i

$$\frac{1}{N_{S_i}} = K S_i^{\beta}, \qquad S_i = \frac{M_i - m_i^{rfc}}{2} \quad \text{..............} \qquad (3.1)$$

A constant K and the damage exponent β are material parameters. The fatigue failure of a material occurs when D_v exceeds one.

The advantage of this method is that it predicts the periods of failure of the components more accurately, but the disadvantage lies on the fact that it requires specialist equipment which makes it prohibitively expensive to be used in the farming industry.

The questionnaire method was detailed discussed by WENDL (1983) [101]. It incorporates the use of structured and non structured questionnaire. It has the advantage of using the past recorded data where available. In that case it enables collection and prediction of repairs within a short span of time and additionally this method is relatively cheap. Most of the repair studies in the past have used this technique. However the disadvantage of this method lies on low accuracy level of predicting the periods of failures.

3.3 Annual cost of machinery

Accurate knowledge of calculating the ownership and operating costs is essential to economic management of machinery particularly in investment and replacement decisions. The average annual cost and the actual cash flows methods are some of the mathematical models used for determination of the annual cost of farm machinery.

3.3.1 Average annual cost method

With the average annual cost method, the annual cost is calculated by averaging the cost components of the machinery over the full period of ownership. The annual cost components are made up with the fixed and variable costs.

3.3.1.1 Fixed costs

Fixed costs are the ownership costs that do not vary with the use. The cost components include depreciation, interest on investment, insurance, and housing.

3.3.1.1.1 Depreciation

Depreciation is defined as the lessening in value of the machine with passage of time. If the cost of depreciation is neglected profit will appear to be higher than it really is by an amount equal to the depreciation that has taken place. A common classification for depreciation of the asset value includes that of physical and functional depreciation. Physical depreciation results from a deterioration in the machine ability to render its intended service. This could be due to wearing off of metallic parts such as piston rings, bushes, etc. Functional depreciation results from a change in the demand for the services of machine. The changes may occur because it is more profitable to use a more efficient developed machine, or there is no longer work for the machine to do, or the work to be done exceeds the capacity of the existing machine.

Depreciation for accounting purposes is predicted in accordance with one of several mathematical functions [87]. However the choice of the particular model to represent the depreciation value over time involves also estimation of the life of the machine and its salvage value. The mathematical functions include:

1. Straight line method
2. Declining balance method
3. Sum of the years digits methods and
4. Sinking-fund method of depreciation.

1. Straight line method

This is regarded as the simplest method because the model assumes an equal reduction in value for each year of ownership. However this method fails to account for rapid depreciation of assets in the initial years. Mathematically this is expressed as:

$$D = \frac{P - S}{N} \quad \ldots\ldots\ldots \qquad (3.2)$$

Where: D= depreciation rate per year for N years

P= purchase price

S= salvage value

N = life of asset in years

2. Declining balance method

The method assumes that the machine value decreases at a faster rate in the early portion of its service life than in the later life. By this method a fixed percentage is multiplied times the actual value of the machine at the previous year. Thus the value of the machine decreases through out the time as does the size of the depreciation charge. Mathematically the model is expressed as:

$$D_n = BV_{n-1}k \quad \ldots\ldots\ldots\ldots \qquad (3.3)$$

where: D_n = depreciation charge at the n^{th} year

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

k = depreciation rate = $1-\left(\frac{S}{P}\right)^{\frac{1}{N}}$

P = purchase price

S = salvage value

N = life of asset in years

BLANK AND TARQUIN (1976) [13] noted that, if the depreciation value became equal to salvage value prior to life N of the asset no additional depreciation charge should be made for the preceding years. However they noted that this effect generally occurs for short lived assets with N less than five years or for assets with large salvage values greater than 20% of the purchase price.

3. Sum of the years digits method

The model assumes that the value of the machine decreases at a decreasing rate. If the machine has an estimated life of N years. The sum of years for any number of years N can be computed from the expression

$$\sum_{n=1}^{N} n = 1+2+......+(N-1)+N = \frac{N(N+1)}{2} \quad .... \qquad (3.4)$$

The depreciation charge in any year n can be expressed as:

$$D_n = 2\frac{N-n+1}{N(N+1)}(P-S) \quad .... \qquad (3.5)$$

where: D_n = depression at any year n between 1 and N^{th} year

P = purchase price

S = salvage value

N = life of asset in years

The sum of the years digits method of depreciation produces larger depreciation charges in the early life of the machine but decreases rapidly in the later years.

4. Sinking - fund method

The model assumes that the value of the machine decreases at an increasing rate. One of a series of equal amounts is assumed to be deposited into a sinking fund at the end of each year of the machine life. The sinking fund is ordinarily compounded annually and at the end of the estimated life of the machine, the amount accumulated equals the total depreciation of the machine. The depreciation charge during any year is the amount deposited into the sinking fund at the end of year and the amount of interest earned on the sinking fund during the year. Mathematically the value for the sinking-fund annual payment (*SFP*) and the value of depreciation, D_n at the end of the nth year are expressed as:

$$SFP = (P - S)\frac{i}{(1+i)^N - 1} \quad .... \quad (3.6)$$

$$D_n = (P - S)\left[\frac{(1+i)^N - (1+i)^n}{(1+i)^N - 1}\right] + S \quad .... \quad (3.7)$$

where: D_n = depression at any year n between 1 and N^{th} year

n = any year between 1 and N years

P = purchase price

S = salvage value

N = life of asset in years

i = interest rate

Another model commonly used in USA only is called Accelerated Costs Recovery System (ACRS). This system of depreciation was introduced in the USA in 1981 by statutory law termed the „The Economic Recovery Tax Act of 1981" which stipulated 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 [13].

Comparing these methods using a machine with 10 years life expectancy, 10% salvage value and 8% interest rate shows that the straight line, declining balance, the sum of the digits and the sinking-fund methods of depreciation all lead to different depreciation value-time functions (figure 9). Since the information on depreciation is needed for making decisions, therefore one of the methods can be selected.

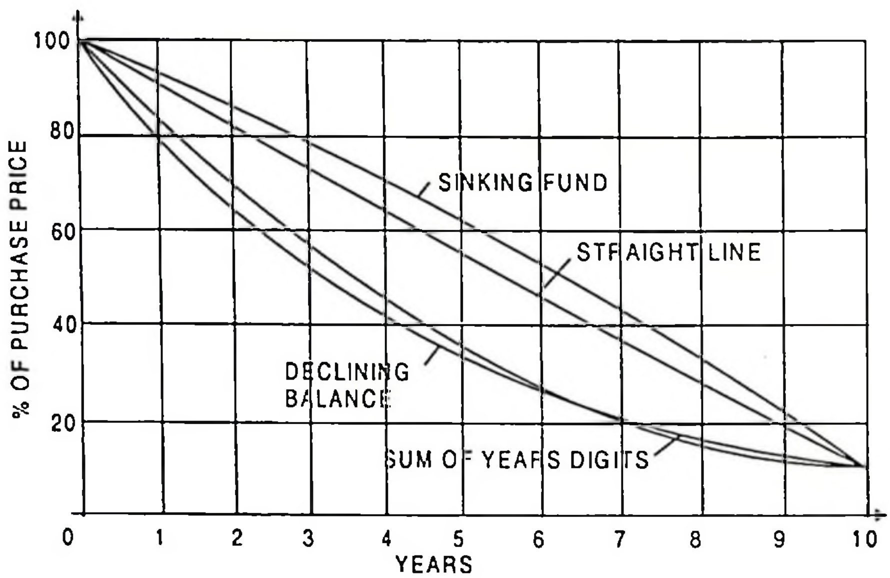

Figure 9: Depreciation values using different depreciation methods

3.3.1.1.2 Interest on investment

Interest on investment is the rate of gain received from the investment sometimes called opportunity costs or is a direct expense on borrowed capital. Usually the rate is stated on per year basis and it represents the percentage gain realised on the money committed to the investment. ADELHELM (1976) [1] and O'CALLAGHAN (1988) [65] 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) [36] preferred to consider interest charges along with housing, tax, and insurance costs and expressed these as a percentage of the purchase price *P*. The manner of assessing the average investment depends on the method of depreciation used.

Inflation affects the real cost of borrowing. It is therefore more sensible to talk of real interest rate. WITNEY (1988) [106] defined real interest rate as the total repayment related to the purchasing power of the loan. Mathematically is calculated as:

$$i_r = \left[\frac{(1+i)}{(1+j)} - 1\right] \quad \text{............} \quad (3.8)$$

where: i_r = real interest rate

i = normal interest rate

j = inflation rate

3.3.1.1.3 Salvage value

Salvage value is the remaining value of an asset after its economic life. PEACOCK AND BRAKE (1970) [69] developed a logarithmic prediction function for determination of the salvage values. The function expresses the current salvage value of an *n* years old machine as a decimal proportion of the current initial purchase price. That is:

$$S_n = S_A (S_B)^n P \quad \text{..................} \quad (3.9)$$

where: S_n = salvage value at n^{th} year

S_A = first year correction factor

S_B = annual depreciation factor

P = initial purchase price

ASAE (1986) [3] established the values of S_A and S_B for tractors as 0.68 and 0.92 respectively.

Another method for estimation of salvage value was developed by AYRES AND WAIZENCKER (1978) [6]. Their method proposes that the salvage value of an n years old vehicle is related to the current purchase price of an equivalent new vehicle by an exponential function expressed as:

$$S_n = P[\exp(-k_1 n)] \quad .... \qquad (3.10)$$

where: S_n = salvage value at n^{th} year

k_1 = constant exponent depending to some extent on vehicle type.

P = initial purchase price

The values of exponent k_1 established for the two-wheel and four-wheel drive tractors are 0.2 and 0.24 respectively. These values represented about 97% of the salvage values variation.

Despite this high value of representation, WITNEY AND SAADOUN (1986) [107] under close inspection of the same problem revealed that the salvage value determined by AYRES AND WAIZENCKER (1978) [6] function tended to be overestimated for one and two years old machines. Therefore in order to eliminate this error they modified the function by inclusion of a second order exponent. In that case they expressed the function for salvage value at any year n as:

$$S_n = P[\exp(-k_1 n + k_2 n^2)] \quad .... \qquad (3.11)$$

where: S_n = salvage value at n^{th} year

k_1 and k_2 are resale exponents.

P = initial purchase price

The values of resale exponents (k_1 and k_2) established by WITNEY AND SAADOUN (1986) [107] are listed in table 3 for two-wheel and four-wheel drive tractors.

Table 3: Resale parameters for first order k_1 and second order k_2 for 2WD and 4WD tractors. Source: WITNEY AND SAADOUN (1986) [107]

Machine Type	Resale exponents		Explanation of data, %
	k_1	k_2	
All 2WD tractors	0.24	0.005	98.01
All 4WD tractors	0.28	0.007	97.89

Comparison of salvage values obtained using the above three functions (figure 10 and 11) show that the model function developed by PEACOCK AND BRAKE (1970) [69] estimates different values as compared to the other functions. The PEACOCK AND BRAKE (1970) [69] function predicts low salvage values of assets at early age and high salvage values after long time of use. However the other functions [6, 107] predict approximately the same salvage values.

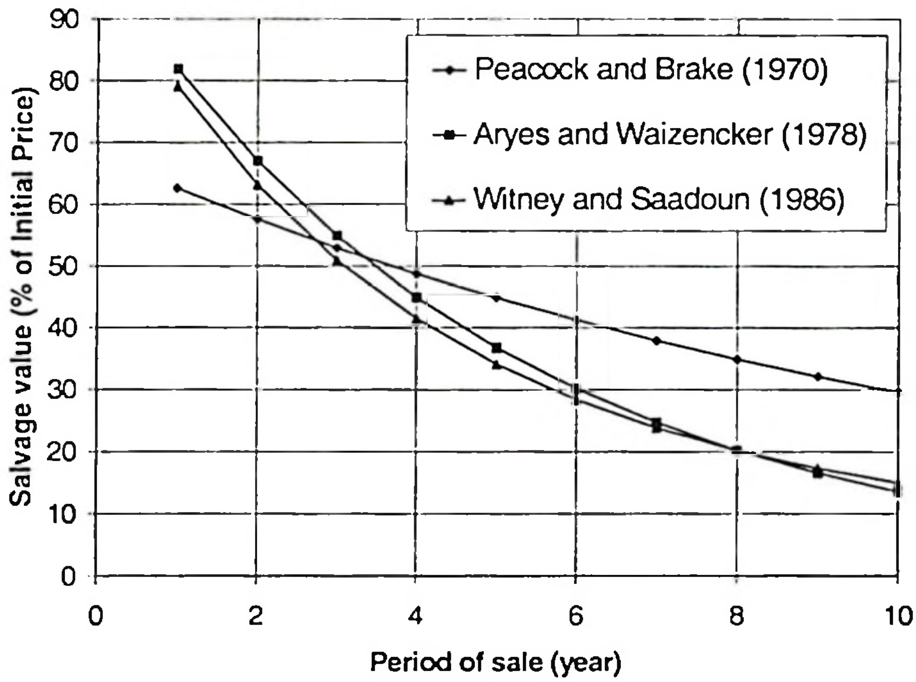

Figure 10: Comparison of salvage values using different methods (2WD tractors)

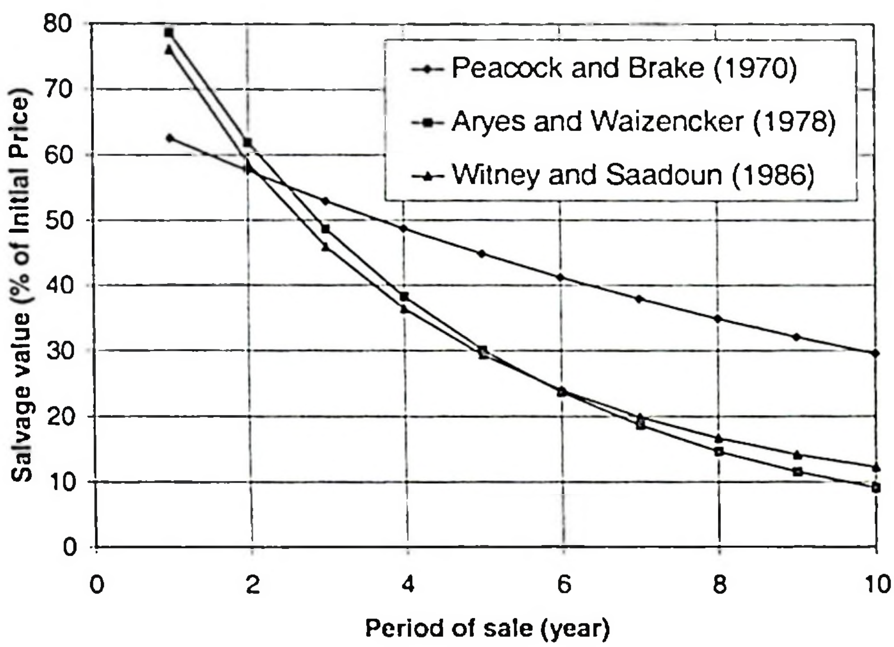

Figure 11: Comparison of salvage values using different methods (4WD tractors)

3.3.1.2 Variable costs

Variable costs of a machinery are defined as the costs which increase proportionally with the amount of operational use. This include repair, fuel, lubricant, and oil costs.

3.3.1.2.1 Repair costs

Repair costs are those expenses necessary to restore or maintain technical soundness and reliability of the machine [60, 102]. They are attributable to wear and tear, random failure of parts and accidents. Repair costs consist of costs of replaced parts and labour costs directly attributable to particular repair jobs. Repair costs are mainly expressed in one of the three forms:

1. As a constant per hour of machine time.
2. As a constant per unit area (tillage and harvesting tractors).
3. As accumulated cost expressed as a percentage of the tractor purchase price.

The later method has been more popularly used by many researchers in this studies. The studies include the repair costs models based on a survey conducted in 1970 [3]. The model expressed repair costs as:

$$TAR = 1.2\left(\frac{X}{1000}\right)^{2.03} \qquad (3.12)$$

where: TAR = accumulated repair costs as a percent of Purchase price
X = accumulated hours of use

Other repair cost studies for 2WD and 4WD were based on an earlier nation wide survey in the USA. The functions were characterised with lower levels of repair costs at higher levels of usage, but at 500 hours and below the functions gave higher repair costs. The established functions were:

For two-wheel drive tractors:

$$TAR = 0.12\left(\frac{X}{120}\right)^{1.5} \qquad (3.13)$$

and for four-wheel drive tractors:

$$TAR = 0.1\left(\frac{X}{120}\right)^{1.5} \qquad (3.14)$$

where: TAR = accumulated repair costs as a percent of purchase price
X = accumulated use

BOWER AND HUNT (1970) [17] predicted accumulated repair costs at any given point of the machines' life as:

$$TAR = RC_1 \times RC_2 \times L^{RC_3} \qquad (3.15)$$

where: TAR = total accumulated repair costs measured at L
L = percent of machine life at the point where repair costs are calculated
RC_1 = a constant that express the ratio of TAR to purchase price at $L = 100\%$
RC_2 and RC_3 = constants determining the shape of repair costs curve

$RC_2 \times L^{RC_3} = 1$ when $L = 100\%$

FAIRBANKS *et al.*, (1971) [25] using data from members of a farm management association, probably with better standards of management and maintenance practices developed the following equation:

$$TAR = 0.00014X^{2.19} \text{ ....} \qquad (3.16)$$

where: TAR = total accumulated repair cost
X = accumulated operating hours as a percentage of total operating hours.

Another function model was developed by HUNT (1983) [36] for tractors with life up to 4000 hours. The function model was expressed as:

$$TAR = X + 0.0195\left(\frac{X}{1000}\right)^2 - 0.00223\left(\frac{X}{1000}\right)^3 \text{ ....} \qquad (3.17)$$

where: TAR = total accumulated repair cost
X = hours of accumulated use

WARD *et al.*, (1985) [98] also developed two function models, one for 2WD and another for 4WD tractors engaged in forest work mainly for trailer transportation, hedge trimming with hydraulically driven rotary saw, grass mowing and some other miscellaneous tasks. The functions were expressed as:

For two wheel drive tractors:

$$TAR = 0.042X^{1.895} \text{ ....} \qquad (3.18)$$

For four-wheel drive tractors:

$$TAR = 0.4055X^{1.923} \text{ ....} \qquad (3.19)$$

where: TAR = total accumulated repair cost

X = total accumulated use hours as a percent of 12000 h

MORRIS (1988) [60] also derived a model of similar form as above. The function was mathematically expressed as:

$$TAR = 0.0996 \times 10^{-3} \times X^{1.4775} \quad \text{..........} \quad (3.20)$$

where: TAR = Total cumulative repair cost (% of initial price)

X = cumulative hours of use

KANDO AND LARSON (1990) [41] using data from Burkina Faso developed a prediction function similar to those developed in Europe and USA. The function model was expressed as :

$$TAR = 5.08\left(\frac{X}{1000}\right)^{1.45} \quad \text{.........} \quad (3.21)$$

where: TAR = Total cumulative repair cost (% of initial price)

X = accumulated hours of use

Other models were developed in Germany by WEIERSHÄUSER (1989) [99] and WENDL (1991) [102]. WEIERSHÄUSER (1989) [99] using data from KTBL established the function for four-wheel drive tractors as:

$$Y = 12.29X^{0.75} - 9.4432X + 1.610282X^{1.25} \text{.........} \quad (3.22)$$

where: Y = accumulated repair costs in DM

X = accumulated hours of use

WENDL (1991) [102] using data collected from repair documents which were kept by repair shops established repair costs for four wheel drive tractors as:

$$Y = 0.106389X^{1.5} \quad \text{.............} \quad (3.23)$$

where: Y = repair costs in DM

X = accumulated hours of use

Additionally WENDL (1991) [102] revealed that about 35% of the total accumulated repair costs in German accounts for the labour charges.

Therefore from the above repair costs functions review, it can be concluded that a considerable number of models for cumulative repair costs as percentage of purchase price has been developed. Most of these models were represented using power functions this could be due to the fact that the power function representation is simple because it takes into account only the costs and time of failure. The difference in the model functions could be attributed by the difference in specific area of tractors use and the difference in the amount of repair variation in terms of time between failures.

3.3.1.2.2 Fuel and oil costs

Tractor is a power source offering traction services to other implements. Fuel and oil consumption in tractor is governed by the amount of energy demanded at the draw-bar or at the Power Take-Off (PTO).

Estimation of fuel consumption mainly diesel can be made using different models suggested by a number of researchers [47, 104, 106]. The use of suggested models can be applicable for tractors with no established standards because most of tractor manufacturers of recent establish specific standards for estimating average fuel consumption of their tractors. Technical agricultural data books such as KTBL (1998/99) [48] also publish these kind of information.

Oil consumption is defined as the volume of engine crankcase times the recommended oil replacement change intervals. KRUGER AND LOGAN (1980) [47] estimated that, hourly oil consumption is approximately to 15% of the hourly fuel consumption.

Therefore fuel and oil costs can be determined by multiplying the average fuel/oil consumption by the respectively unit price of fuel/oil.

3.3.1.3 Other costs

Other costs in the context of this report are those fundamental expenses which are indirectly charged to tractors. The costs include the insurance, housing, tax and labour costs.

3.3.1.3.1 Insurance costs

Agricultural tractors are usually insured against various risks including accident damage, theft, fire, etc. 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.

3.3.1.3.2 Housing costs

The housing while having no direct influence on the rate of depreciation can improve the market value of a machine. Housing cost may be determined by considering the investment costs of the housing structure. In the case of open yard the cost of housing is equal to the investment costs in fencing off the area. In Tanzania however most of tractor owners do not have special housings for tractors rather tractors are normally parked outside their houses.

3.3.1.3.3 Tax and licensing costs

The amount of tax paid on agricultural machinery depends very much on the country's tax policies in force. Apart from road license agricultural tractors and equipment in Tanzania are currently exempted from tax.

3.3.1.3.4 Labour costs

Labour costs are usually charged to the implement being used in a given operation. Labour is charged at hourly rates either in terms of man hours or machine hours. Experienced managers can correlate machine hours to given man hours.

3.3.2 Actual cash flows method

Actual cash flows is a method which involves three types of cash flows in the calculation of the annual cost for owning and using a machine. This include:

1. The capital cost with interest charges repayable by equal mortgage instalments.
2. The recurring annual repair and insurance charges.
3. The income from selling the machine.

AUDSLEY AND WHEELER (1978) [5] used the method to express the annual cost of machinery as:

$$A = \frac{(P + \sum_{n=1}^{N} R_n w^n - S_N w^N)(w-1)}{w(w^N - 1)} \quad \text{........................} \quad (3.24)$$

where: $w = \frac{1+j}{1+i}$

A = annual cost of machine ownership.

P = the initial capital cost.

R_n = the current value of the repair cost in the nth year.

S_v = the salvage value at the end of year N

N = the number of years the tractor is owned.

j = the inflation rate.

i = the interest rate.

w = inflated discount factor

If the purchase price P is agreed to be repaid by the amount in equal instalments M (mortgage) per year, then the value of P in equation 3.24 is replaced by a sequence of annual payments M. The final equation developed by AUDSLEY AND WHEELER (1978) [5] remains unchanged except that P is replaced by the term:

$$P = \sum_{n=1}^{N} \frac{M}{(1+i_l)^n} = \left[\frac{(1+i_l)^N - 1}{i_l(1+i_l)^N}\right] M \quad \ldots\ldots\ldots\ldots \quad (3.25)$$

where: P = purchase price

M = annual payment (mortgage)

i_l = loan interest rate

N = ownership period

WITNEY AND SAADOUN (1989) [108] modified this equation by including the annual repayment of loan, interest, recurring annual insurance charge and the effect of tax relief on the interest charges. Their final form of the equation for the present annual ownership cost was represented by the following equation:

$$A = NPV_m + (1-t)NPV_r - NPV_s - tNPV_t \quad \ldots\ldots\ldots \quad (3.26)$$

where: $NPV_m = M\sum_{n=1}^{N} \frac{1}{(1+i_l)^n}$ or

$$NPV_m = P\frac{i_l(1+i_l)^N[(1+i_l)^N - 1]}{i_l(1+i_l)^N[(1+i_l)^N - 1]}$$

$$NPV_r = \sum_{n=1}^{N}[R_n + 0.01S_{(n-1)}]w^n$$

$$NPV_s = S_N w^N$$

$$w = \frac{(1+j)}{(1+i_l)}$$

$$NPV_t = \sum (CA_n + I_n)/(1+i_l)^n - BC_N/(1+i_l)^N$$

$$CA_n = 0.25P(1-0.25)^{(n-1)}$$

$$BC_N = \sum_{n=1}^{N} CA_n + S_N - P$$

$$I_n = Pi_l \frac{(1+i_l)^N - (1+i_l)^{(n-1)}}{(1+i_l)^N - 1}$$

A = present annual ownership cost
M = annual mortgage payment
NPV_m = present total mortgage cost
NPV_r = present annual cost of repairs and insurance
NVP_s = present resale value
CA_n = capital allowance
BC_N = balancing charge
I_n = annual interest charge
S_N = resale value
P = purchase price
w = inflated discount factor
i_i = investment interest rate
i_l = loan interest rate
j = inflation rate
t = marginal tax rate

However the inflation rate and bank interest rates for the loan and investment has to be assumed to be constant throughout the period of investment. Additionally WITNEY AND SAADOUN (1989) [108] assumed that:

1. The insurance cost for each year be equal to 1% of the salvage value of the tractor at the end of the previous year $S_{(n-1)}$.

2. The annual rate of capital allowance for taxation purpose was taken to be equal to 25% on a diminishing basis.

3.4 Optimum machine replacement time

Replacement of existing equipment by other equipment becomes necessary because of inadequate capacity, low efficiency, failure, technological development or other factors. Generally, the replacement process can be divided into two categories depending on the life pattern of the machine involved.

1. The equipment deteriorates or become obsolete because of the use or introduction of new developed machine.

2. The equipment does not deteriorate but is subject to failure or accident.

The replacement study is therefore essential to determine the time at which the replacement is economically necessary by minimising costs or maximising profit. Although no generalised solution for the replacement problem of the equipment has been developed, many models have been introduced and solution have been found with various sets of assumptions.

FAIRBANKS *et al.*, (1971) [25] proposed two models for farm machinery based on the annual average costs and the another based on the probabilistic model. The overall objective of the models was to minimise annual costs.

The average annual costs model was developed by considering the following assumptions:

- The straight line method was used to determine the depreciation cost.
- The accumulated repair cost and obsolescence charge used in the model are expressed by power functions $B't^n$ and $A't^n$ respectively. B', A', and n are constants.

Using this model they established the economic life of the farm machinery as:

$$L = \left[\frac{(P-S)}{(A' + B')(n-1)} \right]^{\frac{1}{n}} \qquad (3.27)$$

where: L = economic life of the farm machine.

P = purchase price

S = salvage value

In the case of the probabilistic model, they considered that a piece of equipment can either fail completely so that it has to be scrapped with no salvage value, or it may suffer a minor defect which can be repaired. Therefore the nature of failure and the repair of equipment are random variables depending on age, t. Then let the probability that the equipment will not have to be scrapped before age t be defined by the function $f(t)$, and the conditional probability that it will need repair during the interval t to $t+dt$, given that it is in running order at age t was expressed by the function $r(t)dt$. The probability of needing a repair or of complete failure is dependent on the age of the equipment and not the previous repair history

They suggested that it may be economical to replace equipment at some fixed age L, thus avoiding the high risk of repairs with advancing age. The situation of the equipment being subject to repair is when the equipment will need a repair in the interval t to $t+dt$, while not having to be scrapped before age L. Thus the joint probability of the above situation was expressed as $f(t)r(t)$. Then the expected repair costs was established as:

$$R\int_0^L f(t)r(t)dt \quad \text{.........................} \qquad (3.28)$$

therefore the total expected cost is:

$$C = P + R\int_0^L f(t)r(t)dt \quad \text{....................} \qquad (3.29)$$

where: $P =$ a complete replacement cost.
$R =$ repair cost

Hence the expected cost per unit time C_E, is:

$$C_E = \frac{P + R\int_0^L f(t)r(t)dt}{\int_0^L f(t)dt} = \quad \text{......................} \qquad (3.30)$$

A condition to be satisfied by L for minimum expected cost was obtained by differentiating equation C_E and then L was calculated for $\frac{\delta C_E}{\delta t} = 0$. The final results yielded were expressed as:

$$\frac{P[f(L)r(L) - f(0)r(0)]}{[f(L) - f(0)]} \quad \text{.................} \qquad (3.31)$$

Thus If the functions, $f(t)$ and $r(t)$ are known, the optimum replacement time L that satisfies for minimum cost can be evaluated using equation 3.31.

LEATHAM AND BAKER, (1981) [51] addressed the problem of replacement decision by calculating the total annual costs over an infinite horizon for each possible year of ownership and then selecting the year with the lowest cost. PERRY AND NIXON, (1991) [71] agreed also to this model of the minimum annual costs, however they emphasised that the repair costs and the annual use are the most important factors in making the replacement decisions. Similarly HUNT, (1983) [36] defined the replacement time as that time at which the accumulated costs using the average annual cost model divided by the accumulated use gives the minimum value.

The findings of FAIRBANKS *et al.*, (1971) [25], LEATHAM AND BAKER (1981) [51], HUNT (1983) [36] and PERRY AND NIXON (1991) [71] seems not to differ because all of them suggest that the decision as to time for replacement depend only on the accumulated costs between the capital costs and the repair costs. The point at which the accumulated cost is minimum (figure 12) represent the optimum time for replacement.

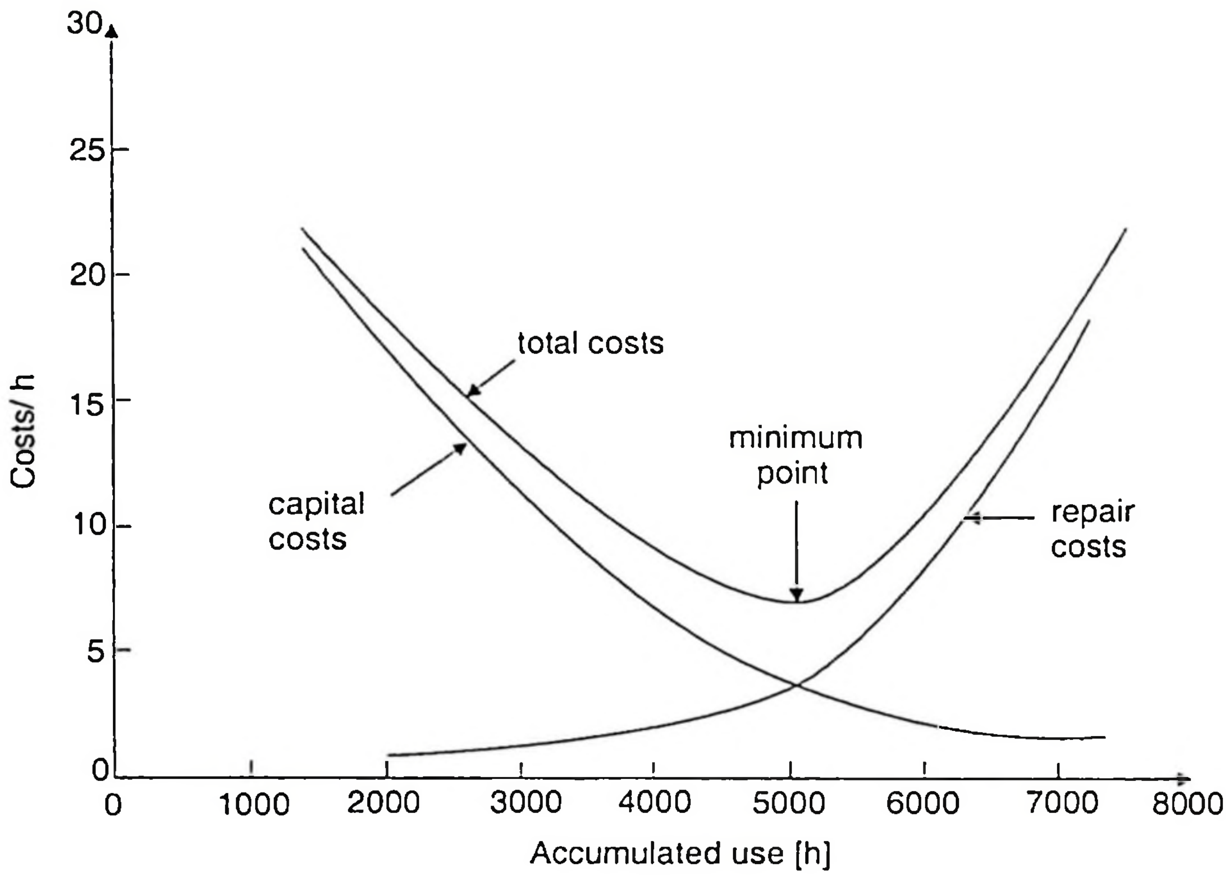

Figure 12: The representation of the optimum replacement period (minimum point)

Other replacement criteria is based on the present machine customarily called the defender and a currently available list of replacement alternatives termed challengers. O'CALLAGHAN (1988) [65] considered the replacement problem by comparing cash flows of the challenger and defender over an interval of time. The fair market value of the defender, or its resale value in perfectly competitive market is taken as the defenders worth when replacement is decided.

Alternatively, the defenders resale value is considered as a positive cash flow that offsets part of the challengers 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.

Mathematically it can be assumed that the annual cost of machine operation be estimated using a model:

$$A_{cop}(n) = C_{rp}(n).f(n).c(n) \quad .... \quad (3.32)$$

Where: $A_{cop}(n)$ = annual operating cost in the n^{th} year.

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

Then the equivalent annual cost for the defender $EAC(d)$ for its remaining economic life are given by:

$$EAC(d) = [f(n)C_{rp}(n) + a(n)(n+1)C_{rp}(n+1)(1+i_m) + ... + a(L)C_{rp}(L)(1+i_m)^{(L-n)}]A(n) \quad ...... \quad (3.33)$$

where: $a(n) = f(n)C_{rp}(n)$

L = economic life of the tractor for which replacement was considered

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

i_m = minimum acceptable rate of return.

The equivalent annual cost for the challenger(s) are estimated as:

$$EAC(c) = [C_{rp}(n) + a(1)C_{rp}(n+1)(1+i_m) + ... + a(L-n)C_{rp}(L)(1+i_m)^{(L-n)}]A(n) \quad ...(3.34)$$

Therefore the decision will be made on the basis of the difference:

$$EAC(c) - EAC(d) = \delta \quad ...... \quad (3.35)$$

If $\delta \geq 0$ the defender can be retained at least for one year. However if δ is negative then the defender has to be replaced.

3.5 Draft animal technology

Animal traction technology has a long history in agricultural production. It has played and it stills plays an important role in meeting the power requirements of the farmers in developing countries. Cattle, buffaloes, donkeys, mules, horses, camels, elephant and other working animals are normally used to provide power for crop cultivation and transport. Draft animals are also used for other activities such as water raising, milling, logging, land levelling, road construction, etc.

Animal power is used in virtually every environment and on every continent in the world. However there are few countries within the developing countries with long tradition of using animal draft power. These include Ethiopia, India, Indonesia, Nepal, North Africa and most of Latin America [83]. In these areas large numbers of draft animals, including oxen, cows, bulls, donkeys, mules, horses, buffaloes, and camels have been used for soil land cultivation and transport. In most of the Sub-Saharan regions, animals (oxen and donkeys) have been used for long periods traditionally for transportation by nomads and traders, but animal drawn implements have not been used in traditional farming systems. These have been introduced recently some 60 to 70 years ago. Although cows dominate the cattle population, they are seldom used for draft operations. The draft oxen are shackled in pairs using withers yokes and mostly two or three people are used to control a team of two oxen.

Experience has shown that a pair of draft oxen is capable of working 4 ha per season [30, 82]. MGAYA *et al.*, (1992) [58] revealed that oxen in Tanzania usually start working when they are about three years of age. However it will depend much on the adequacy of their feed. Animals reared under poor conditions start with more than 5 year of age. The average working performance is five hours per day for agricultural operations and normally draft animals are used for an average period of 5 to 7 years before being sold [11, 31, 66].

PEARSON AND SMITH (1992) [70] reported that the management of draft animals in most places is greatly influenced by the importance of the animals placed in a farming system. This is influenced by the fact that animals are used along side with other sources of power, namely manual and mechanical. There are many factors that might influence the relative proportional use of these power sources in any particular area. Taking an example of an area with high population pressure, in expanding area under-cultivation the use of animal power becomes less available because of lack of area for grazing. Therefore farmers in these areas use to greater extent manual labour than animal power. TEMBO (1989) [86] stated that shortage of animal power in the communal lands in Zimbabwe is a major constraint to increase productivity of these areas. A shortage of animal power is often made worse by drought and disease outbreaks that reduce the populations of all animals, including those used for draft. Following good harvests mechanised power is more available as farmers can afford to hire tractors. Other important factor connected to the use of animal technology is the costs incurred in the processes of owning and using it. This of course dictates the profitability and the ability of the farmers to switch between power sources.

3.6 Annual costs of draft animals

Very little literature has been published to address the issue on the annual cost of using animal draft power. However few attempts to remedy the situation has been made in terms of estimating the cost components of the technology [22, 66]. The cost components of animal traction technology can be determined by considering the sub-systems that build the technology. At the centre of the technology, there are three sub-systems relating to draft animals, to the implements pulled and to the operators. The draft animals cost systems incorporate the capital, interest, feed and health. Other cost components are shelter, mortality, training and the amount incurred due to compensation. The implements cost systems include capital, interest and repair and maintenance costs, whereas the operators cost systems are made up mainly with the labour costs.

Therefore in calculating the annual costs of draft animals a similar methods used for tractor power technology could be used but with minor modifications. In this case the purchase price will be the cost of acquisition of animals. The interest rate will be charged on the capital costs. Other costs to be considered will include the salvage value, health, feed, shelter, labour and others.

3.6.1 Capital costs

These are the costs for acquisition of animals to be used for traction work. Normally the purchase price of draft animal is directly proportional to their live weight.

Mathematically can be expressed as:

$$P_a = k_a \sum_{i=1}^{N_a} W_i \quad (3.36)$$

where: P_a = purchase price of oxen.

k_a = costs per kg of live weight.

W = live weight of oxen.

N_a = total number of oxen.

BELL AND KEMP (1986) [11] revealed that in Sierra Leon draft oxen are bought with about 160 kg live weight and they are normally used for a period of five to six years before being sold. Within this period they attain an average live weight of about 340 kg. That means the salvage value of the draft animals after five or six years is higher than the purchase price. A similar argument is also advanced by CORBEL (1986) [22], who stated that in Sierra Leone the ox salvage value in real terms is higher than the initial purchase price, but unfortunately he could not quantify the real appreciation value over years.

3.6.2 Interest on the capital costs

The cost of using money has a large effect on the total costs of owning and using draft animals. Just like in any other investment the interest has to be paid for the borrowed capital. Current interest rates are used each time in calculating the interest to be paid on the capital cost. In the analysis of annual costs of draft animals, interest costs can be calculated by considering the current interest rate, the purchasing costs of draft animals and the expected salvage values.

3.6.3 Feeding costs

The food eaten by draft animals is used in most cases to provide energy. The requirements for proteins, vitamins and minerals other than maintenance are negligible for animals unless they are growing, pregnant or lactating [70]. A centre for tropical veterinary medicine in United Kingdom established tables for predicting total energy requirements, food intake and change in live weight of draft oxen [50].

However the tables developed are applicable to places where quality feed is available.

The most important commodity from draft animals is the work output. The amount of work output of an animal is directly proportional to its live weight. The larger the animal the higher the draft force it can generate. This means the larger the animal the less stressed it will become while carrying out a particular task as compared to smaller animals. Nevertheless, in order for draft animals to have substantial live weight, the farmer must provide sufficient feed (quantity and quality) at the time when the animals are required to work.

Number of literature [7, 8, 53] indicate that animals in Sub-Sahara regions are traditionally left to graze freely on range throughout the year. Therefore feeding of the work animals during the rain season is not considered as a problem due to the availability of forage. However during the dry season natural pasture tends to be inadequate. This affects the live weight of draft animals by reducing them to a very poor state by the time they are required to work at the beginning of rain season. To counteract this problem some ways of improving the nutrition status have been proposed. These include, the use of crop residual that can be collected from the field and stored for use when required. This could also be supplemented with protein rich oil cakes or cotton seeds where available. Other way is that of establishment of fodder banks, which can be used to feed animals at the start of rain season. In places with good rainfall shrub legumes such as *Leucaena leucocephala* and draught resistant legume such as *Macroptilium*, *Trifolium* and *Stylosanthes* could be grown [40]. *Leucaena* could supply oxen with green foliage throughout the year. One hectare of *Leucaena* can supply enough dry matter (5500 kg) to feed a pair of oxen per season.

The cost components of the feed systems can be established depending on the feeding system used. If the traditional method of providing nutrition to animals is used then the cost components will be only that of labour used in taking care of the animals during grazing. However when one adopts the methods to cater for draft animal during the dry season then additional costs have to be included. This will depend on the number of draft animals available because the size of the feed farm is directly proportional to the number of animals.

Mathematically these can be expressed as:

$$F_f = N_a k_f \quad \text{................} \quad (3.37)$$

where: F_f = total feed costs

N_a = total number of animals

k_f = costs of producing feed per animal

3.6.4 Health costs

The major diseases of draft animals known to occur in east Africa include *rinderpest, black quarter, trypanosomiasis* and *contagious bovine*. Other diseases are *foot rot, pleuropneumonia*, external and internal parasites. Also there are diseases caused by nutritional shortages of key minerals and diseases originating from poor sanitary conditions under which animals are maintained in the night. There is evidence that diseases reduce work output of draft animals and the additional stress of work indoctrinates draft animals to disease [35, 100].

Helminth parasites are thought to be a major cause of unfitness and low expectancy of working donkeys. The study by SAMUI AND HUGH (1990) [74] is one of the few investigations that attempted to quantify the financial and production losses due to a disease in draft animals. They estimated that the cost of draft oxen being affected by *bovine dermatophilosis* in Zambia was 428 Kwacha (DM 380) per affected ox. This was based on loss due to reduction in area of land ploughed and lowered income from hire of animals. A dead draft animal cannot work and so land cultivation and crop productions suffer. In places where farmers rely on a single animal this can have a serious consequence. Even where a pair of animals is used, the loss of one of a pair, especially just before or during the working season can be critical. Therefore effort to prevent and to treat immediately diseases in areas with draft animals are economically justified. This could be carried out by practising good management, by use of local medicines or industrial drugs.

Determination of the health costs is done by considering three main health cost components. These include costs for spraying or dipping performed to protect animals against flies and ticks, costs for vaccination performed to protect animals against out-break diseases and costs for drug administration incurred for treatment of sick animals.

The annual health costs are expressed as:

$$C_{H} = \left(c_{d} + c_{v} + c_{m}\right)N_{a} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.38)$$

where: c_d = annual costs for dipping per ox.

c_v = annual cost per ox for vaccine.

c_m = annual cost per ox for medicine.

N_a = number of draft oxen.

C_H = total annual health cost

3.6.5 Shelter costs

Shelter from animal point of view is defined as a structure which protects animals from harsh weather. In most part of Sub-Sahara countries farmers build cheap form of housing with either a shed or just a paddock. Other farmers do not build houses instead animals are either brought close to their houses at night or allowed into their houses [7]. The cost implication from this kind of shelters is minimal.

LUKINDO (1992) [52] suggested that the health, strength and life spans of draft animals can be improved if animals are provided with a good shelter. The shelter can be a simple structure that needs to have any form of shed, wide openings and which takes care of stocking densities. In that case increasing the number of draft animals will increase the total shelter cost.

3.6.6 Labour costs

Labour is the main productive resource of the draft animal technology. The family and hired labour is used to perform both farm operations and to take care of the animals during grazing. During agricultural activities in most parts of Africa three people work with a team of two oxen, whereas in most parts of Asia only a single person is required [67]. The family labour is normally not paid for the work performed while hired labour is paid in cash plus daily meals for the work done. The amount of cash paid to the hired labour differs from place to place. However, the amount depends much on the agreement between the owner and the labourer. According to CORBEL (1986) [22] the hired labour costs could be equated to the minimum wage paid by the government to labourers in the villages and he additionally proposed that the family labour in the cost analysis be considered inasmuch as the hired labour, especially during the cultivation season.

3.6.7 Insurance costs

Farmers usually do not insure their animals against mortality although the chances of occurrence are so high. For example BANGURA (1986) [7] revealed that 25% of the work oxen died in one of the project in Sierra Leone. The high mortality rate was associated with heavy infestation of *fly stomoxys*. CORBEL (1986) [22] reported 8% of the draft oxen offered as a loan to 167 families by Koinadugu Integrated Agricultural Development Project died. The reasons for the mortality were 4% due to diseases and other 4% because of accidents. Therefore it is important for farmers to save a certain amount of funds that can be used to insure draft animals. According to previous reports this is estimated to be equal to 8% of the purchase price.

3.6.8 Compensation costs

Compensation costs are important payment to be included in the cost analysis. These costs are incurred when the draft animals damage crops during grazing or injure people. The estimated amount per animal per year is normally about US$ 2 [22].

4. Material and Methods

4.1 Determination of tractor costs in Tanzania

4.1.1 Study area

Data for this study was collected from five regions in Tanzania. The regions incorporated Arusha, Iringa, Kilimanjaro, Morogoro and Tanga. The collections of data from large scale farms were obtained in all five regions but for small-to-medium scale farmers data were obtained only from two regions, namely Arusha and Morogoro. The choose of the regions was based on the tractor population estimation of the year 1989 as shown in figure 13. Arusha region has the highest population of tractors in Tanzania followed by Morogoro region, then Kilimanjaro, Shinyanga and Iringa in that order. The location of these regions is shown in figure 14.

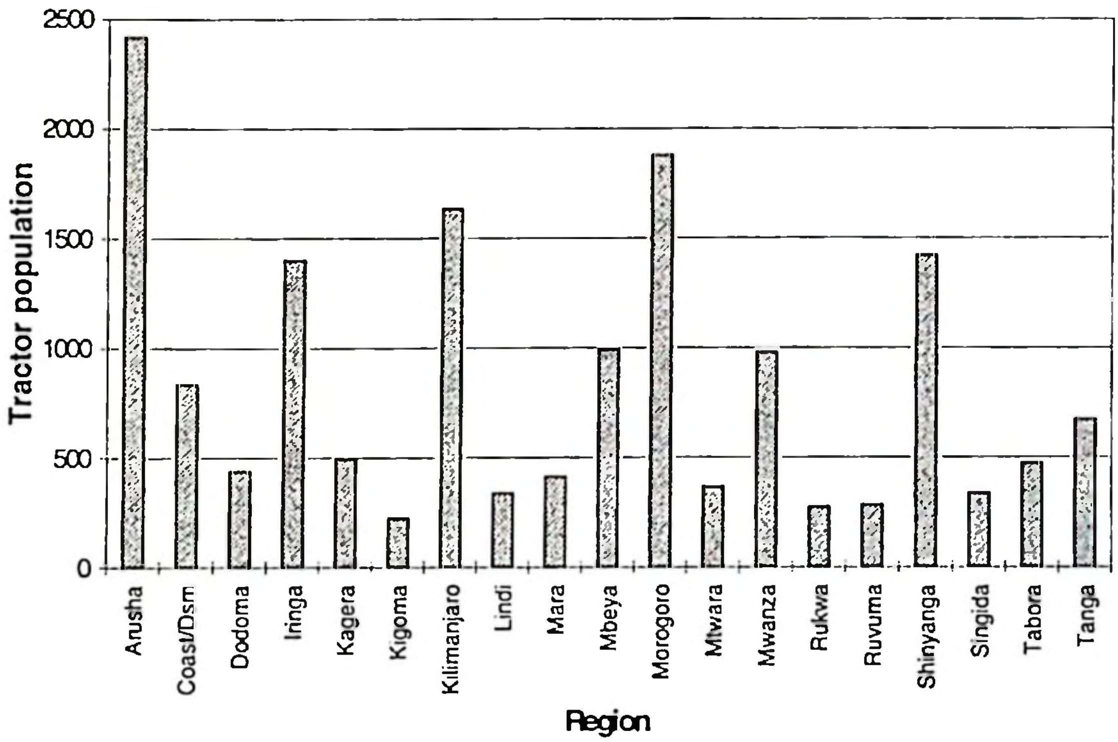

Figure 13: Tractor population by region in Tanzania (December 1989)
Source: MALDC (1991) [55]

Figure 14: Map of Tanzania for identification of regions

The number of large scale farms and small-to-medium scale farmers were then selected within the mentioned regions.

4.1.1.1 Large scale farms

The following criteria were used for selection of large scale farms:

1. The farm must be reachable by the team of researchers during the study period.
2. The farm must have relative good past records of tractors that were/are on use at the farm.
3. The farm management must be willing to offer the records to the researchers.

According to these criteria, Shinyanga region was left out for tractor data collection because the farms that intensively use tractors for agricultural activities were too far to be reached during the period of study. Shinyanga region was instead replaced by Tanga region.

Generally reliable and detailed farm machinery data was found to be scarce in Tanzania. Nevertheless relative good data were obtained from 12 large scale farms. The farm include Arusha Seed Foundation, six NAFCO farms, Mtibwa Sugar Estate, and Mwera Sisal Estate. Other farms were Mringa Estate, Tanganyika Planting Company and Tanganyika Wattle Company. The summary of the information from these farms is presented in table 4. However the records were not obtained for all tractors at the farms instead only few tractors with relative good records were chosen for the study. The number of these tractors from each farm is shown in appendix 3.

1. Arusha Seed Foundation (ASF)

Arusha Seed Foundation farm is in Arusha region about 15 km from Arusha town. The government of Tanzania is the owner of the farm. The farm deals mainly with production of improved varieties of seeds such as maize, beans and wheat on 600 ha of land. The farm used to own 11 tractors purchased between 1974 and 1992. To date however only 8 tractors are in good working condition and other 3 tractors are on the process of being auctioned. There are 41 permanent employees, whereas the numbers of temporary workers range from 30 to 110 depending on the season.

Table 4: Summary of the information of the large scale farms

Farm	Owner	Area (ha)	Production activity	Tractor types	Units	Power (hp)	Employee Perm.	Temp.
ASF	Government	640	Seeds	Case Inter.	6	66-108	41	30 -110
				Fiat	3	45-100		
				Ford	2	60		
Basuto	NAFCO	4000	Wheat	Versatile	8	210-280	49	20 - 150
				Case Int.	10	84-148		
Gawal	NAFCO	4020	Wheat	Versatile	3	280	53	20 -100
				Case Int.	14	88 - 150		
Gidagamowd	NAFCO	4000	Wheat	Versatile	3	280	57	20 - 120
				Case Int.	14	88 - 150		
Mringa	Private	400	Coffee	M. Ferguson	12	45 - 70	100	200
				Fiat	2	40		
				Valmet	2	125 - 140		
Mtibwa	Government - Private	4747	Sugarcane	Ford	49	78 - 195	1000	350
Mulbadaw	NAFCO	4000	Wheat	Versatile	3	280	47	5 - 100
				Case Int.	13	88 - 150		
Murjanda	NAFCO	40000	Wheat	Versatile	3	280	47	8 - 50
				Case Int.	14	88 - 150		
				Ford	2	60 - 70		
				MF	1	150		
Mwera	Private	7000	Sisal	Same	15	60 - 120	444	120
Setchet	NAFCO	4000	Wheat	Versatile	7	210 - 280	52	23 - 100
				Case Int.	3	146		
				MF	1	65		
				Ford	1	70		
TPC	Government	4700	Sugarcane	MF	70	72 - 86	4700	
TANWAT	Private	17806	Wattle	Bell	8	250	2576	1200
			Tea	Ford	27	70 - 82		
			Forest					

2. Mringa Estates

Mringa Estates Limited is a privately owned farm. It is located in Arusha region about 12 km from Arusha town. The farm deals mainly with coffee plantations on 400 ha of land. It employs 100 permanent and 200 temporary workers. The farm owns 16 tractors of three different makes (MF, Valmet and Fiat), purchased between 1986 and 1998.

The Arusha Seed Foundation and Mringa Estate receive about 800 mm of rainfall annually, mainly from February to May and October to November.

3. National Food Corporation Farms (NAFCO)

In total six NAFCO farms were chosen for the study. These include the Setchet Wheat farm, Murjanda Wheat Company, and Gidagamowd Wheat Farm. Other farms are Gawal Wheat Farm, Mulbadaw Wheat Farm, and Basotu plantation. All these farms are located in the Hanang district about 350 km from Arusha town and they are part of the large seven farms owned by the government through an organisation called National Agricultural and Food Corporation (NAFCO) in Hanang area. Each farm comprises of at least 4000 ha of land. The farms are used for wheat production. The climate in this area is characterised by a distinct rain season followed by the dry period of approximately five to six months. The rain begins in mid November and end in mid May. The annual rainfall ranges from 500 to 1200 mm. Each farm employs between 45 and 57 permanent workers. The number of temporary employees in each farm ranges from 5 to 150 depending on the season. The peak season is during the harvest period in July to September.

4. Mtibwa Sugar Estate

Mtibwa Sugar Estate is located in Morogoro region about 160 km from Morogoro town. The area receives 800 mm average annual rainfall. The government of Tanzania was the owner of the farm until 1998 but now the farm has been privatised and therefore it is owned by a private company. The farm occupies a land area of 4747 ha, out of which 3672 ha are under sugarcane plantation. The farm employs

1000 permanent and 350 temporary workers. The farm owns also a sugar processing factory, 49 Ford tractors of different power rating, 14 Caterpillars, 7 grab loaders and 6 water pumps.

5. Mwera Sisal Estate

Mwera Sisal Estate is owned by a private company called Amboni Limited. The farm is located in Tanga region about 65 km from Tanga town. It occupies a total area of 7000 ha, out of which 4815 ha are under cultivation. Sisal is the major crop grown on the farm. The area receives about 1200 mm average annual rainfall.

Mwera Estate owns 2 decorticating factories, 10 Same tractors, 4 Caterpillars, 4 Locomotive, 1 water pump and 1 press. There are 444 permanent workers and 120 temporary employee.

6. Tanganyika Planting Company Limited (TPC)

Tanganyika Planting Company Limited (TPC) is located in Kilimanjaro region, about 20 km from Moshi town. The farm is owned by the government of Tanzania. It occupies 6000 ha of land, all being under sugarcane plantation. The farm has 4700 permanent workers and owns 70 tractors mainly Massey Ferguson bought between 1989 and 1996. Other types of agricultural machinery include 5 Caterpillars, 6 Cameco, 1 Combine harvester and a sugar processing factory. The average annual rainfall received in the area is about 500 mm. The rain season is from March to May and October to November.

7. Tanganyika Wattle Company Limited. (TANWAT)

Tanganyika Wattle Company Limited is a private owned farm in Iringa region. The farm is located about 17 km from Njombe town and owns 17,806 ha of land, whereas 14,500 ha are under cultivation. The major crops grown to-date include wattle trees that cover 9190 ha, tea (687 ha) and forest (4623 ha). However, up to the year 1992 they used to cultivate wheat and maize. Maize was mainly produced for seed supply in the country.

TANWAT Company owns 8 Bell tractors with 250 hp each, 27 Ford tractors of different power rating, 8 water pumps, 5 Caterpillars, a factory for wattle extraction and a factory for tea processing. The average annual rainfall received in the area is 1100 mm. The farm employs 2576 permanent and around 1200 temporary workers.

4.1.1.2 Small-to-medium scale farmers

Selection of small-to-medium scale farmers for this study was based on tractor ownership. Only farmers who own at least one tractor were selected for the study. The information of farmers owning tractors was obtained from the district agricultural mechanisation officers. The final selection of farmers however was carried-out randomly. The summary of the information of the interviewed farmers in the two regions is shown in table 5.

Table 5: General information of the small-to-medium scale farmers

Location	Farmers	Area (ha)	Production	Types of tractor	units	Power
Morogoro rural	8	100 - 395	Maize	Fiat	7	70
				Massey Ferguson	2	70
				Valmet	3	70
Kilosa	6	80 - 450	Maize	Fiat	5	70
			Rice	Valmet	1	70
			Sunflower	Massey Ferguson	1	70
Hanang	5	50 - 350	Wheat	Ford	4	60
			Maize	Massey Ferguson	2	72

Data in Morogoro region were obtained in two districts, namely Morogoro rural and Kilosa districts. The number of small-to-medium scale farmers interviewed in Morogoro region were 14. It was found out that the majority of the farmers in Morogoro region own Fiat tractors, which were bought between 1985 and 1988 under the Food and Agricultural Organisation (FAO) Tractorization Credit Programme. Tractors in Morogoro rural district are mainly used for maize production, whereas in Kilosa district are used for maize, sunflower and rice production.

In Arusha region five small-to-medium scale farmers were interviewed and these were in Hanang district. Farmers in these areas use mainly Ford and Massey Ferguson tractors for wheat and maize production. Most of the tractors are second hands.

4.1.2 Data collection

Data collected in this study can be classified into two major groups, namely primary and secondary data. The classification is based on the source of that data.

4.1.2 .1 Primary data

Primary data is the information (data) collected direct from the field. This includes data obtained from large scale farms and data obtained from small-to-medium scale farmers. A set of questions listed in appendix 1 were used as a guide while collecting primary data.

4.1.2.1.1 Large scale farms

Data from large scale farms were obtained from the companies records and files. The records and files are stored as tools for the companies' accounting and management systems, listing expenses for individual machines. The summary of data collected include tractor type, model, power and the initial purchase price. Other information composed include operator's education background, experience and whether training in tractor operation has been undertaken. Additionally data consisting tractor use in terms of hours, main use, tractor repair costs, insurance costs and fuel and oil consumption were collected.

Data at Tanganyika Planting Company was obtained from three departments of the farm, namely the field, workshop and financial department. All data interrelated with the use of tractors such as types of work, hours of use, quantities of fuel and oil consumption were obtained from the field department. Information concerning tractor repair works was obtained from the workshop department and data related to tractor costs were extracted from the financial department.

Data collected at Mringa Estates was obtained from the individual tractor history card. The card contained all information required. These include the date of purchase, purchase price, repair work, fuel and oil quantities, etc.

The information on tractors at the NAFCO (six) farms were extracted from store departments because they are responsible for keeping all monthly reports of the farms, including that of tractors.

Data at Mtibwa Sugar Estate was collected from the tractor history cards. However the farm does not maintain complete farm machinery repair records, as a result relative good data were obtained only for 7 tractors out of 49 tractors which were available.

Tractor data at Mwera Sisal Estate and Arusha Seed Foundation farms were extracted from tractor monthly reports. The monthly reports contained data of total cumulative tractor hours and quantities of fuel and oil consumed. Other information was the detail repair and maintenance works which were carried out in that month. The cost of spares used during the repair work was obtained from the store department.

Data obtained from TANWAT farm was extracted from individual tractor files. The files had documents of fuel and oil issue notes, repair and service records. The files had also some information on total hours for jobs which were carried out in a month. The repair costs were summarised at the rear of the log-sheet for each tractor, whereas the repair costs incurred were obtained from the financial department of the company.

Generally all large scale farms have well-established workshop that undertakes repair work for their tractors and other available machines. In that case the repair costs data collected were for the repair works performed in the workshop. These indicate that the costs of daily routine maintenance of tractors were not recorded because they were not carried out in the workshops. Also data for tractors with more than 200 hp (Bell and Versatile tractors) were not recorded because these kinds of tractors are not popular in the country.

Data on tractor purchase prices were obtained from sales records of the farms. Data on insurance costs were obtained from the financial departments of the farms. In all farms except at Mtibwa and TANWAT farms tractors were covered by the third part insurance policy. Tractors at Mtibwa and TANWAT farms were covered with the comprehensive insurance policy. However for the matter of simplicity the insurance costs for all tractors in the analysis of annual costs were determined according to WITNEY AND SAADOUN (1989) [107]. That is, the insurance costs were considered to be equal to 1% of the remaining value of the tractor at the end of the preceding year. The values were almost equal to the amount paid by most of the farms under the third part insurance policy.

The information of operators at all farms was obtained by interviewing the tractor operators, but sometimes the persons in charges of the agricultural machinery operators were consulted to countercheck for the correctness of the given information. The operators were asked questions related to their education background, training undergone before and after being employed and the total acquired experience since employed. Then the information on education was ranked into grades ranging from 1 to 5. The grade 1 was representing excellent, 2 - very good, 3 - good, 4 - fair and 5 was representing poor.

Information on operation and management of the tractors was obtained by personal observation and interviews with the managers, supervisory staff, tractor operators and sometimes by checking management and organisation records.

4.1.2.1.2 Small-to-medium scale farmers

Data from small-to-medium scale farmers were obtained by using both informal and structured methods. The structured method was based on a set of questionnaires attached in appendix 1. The information from small-to-medium scale farmers was mainly from memory recalling because none of them kept farm machinery records. This had a serious implication because in the case of repair costs only major events were able to be remembered but minor repairs tended to be forgotten. In order to counteract this problem some estimations were made during the course of analysis, for example the unspecified costs were estimated to be equal to 5% of the other assembly group component costs.

The information on type, model and tractor power was easily collected by observing the available tractors. The purchase price of Fiat tractors in Morogoro region was obtained from FAO regional office which issued tractor credits to the farmers. Otherwise the purchase price was gathered from the farmers themselves. The annual utilisation hours of tractors could not be directly obtained from farmers instead they were estimated based on the total areas covered per year. The quantities of fuel used per year were estimated basing on the specifications established by manufacturers. A method used for estimating the insurance costs for large scale farms was applied for this group as well because most of the farmers could not remember exactly the amount they pay for different years of tractor ownership. However most of them revealed that they insure their tractors under third part insurance policy, which is the same policy used by most of the large scale farms. The operator information was obtained by interviewing the operators themselves. The results were then treated the same way as in the case of large scale farms.

4.1.2.2 Secondary data

Secondary data in this study referred to the information collected from other sources apart from those collected from the field. The data include bank interest rates, inflation rates, and the price of the fuel and oil. The prices of the fuel and oil were collected because most of the visited farms were able to provide the annual quantities of fuel and oil consumed but not the costs incurred.

4.1.2.2.1 Bank interest rates

The Bank interest rates for saving deposit and lending money were extracted from the Bank of Tanzania report [15]. The report shows that there are 14 banks operating in Tanzania (Table 6). The banks are free to set their interest rates but these depend much on the market forces prevailing. The interest rates offered by the National

Bank of Commerce are 9% and 29% for depositing and borrowing respectively, whereas the interest rates of CRDB are 10% for deposit and 22% for borrowing.

Table 6: Banks interest rates (per year) in Tanzania.
Source: BOT (1998) [15]

Name of the Bank	Saving Deposit		Borrowing
	Minimum deposit (Tshs)	Interest rate	Lending rate
National Bank of Commerce	20000	9%	29%
Stanbic	-	-	20%
Green Bank	10000	8%	-
1st Adili Bank	100000	10%	-
Stanchart Bank	100000	5%	24%
Eurafrican Bank	-	-	-
Citibank	-	-	-
CRDB	10000	10%	22%
Saving & Finance	100000	12%	-
Exim Bank	1000000	10%	21%
Diamond Trust	100000	10%	-
Furaha Finance	50000	12%	on request
Akiba Commerce	100000	8%	25%
Inter. Bank Malaysia	150000	10.5%	22%

4.1.2.2.2 Inflation rates

Inflation rates spanning from 1986 to 1999 were obtained from the National Bureau of Statistics [96]. Figure 15 shows the trend of the inflation rate from 1986 to 1999. The highest inflation rate occurred in 1990. The trend also shows that the inflation rate dropped from 33% in 1994 to 9% in 1999.

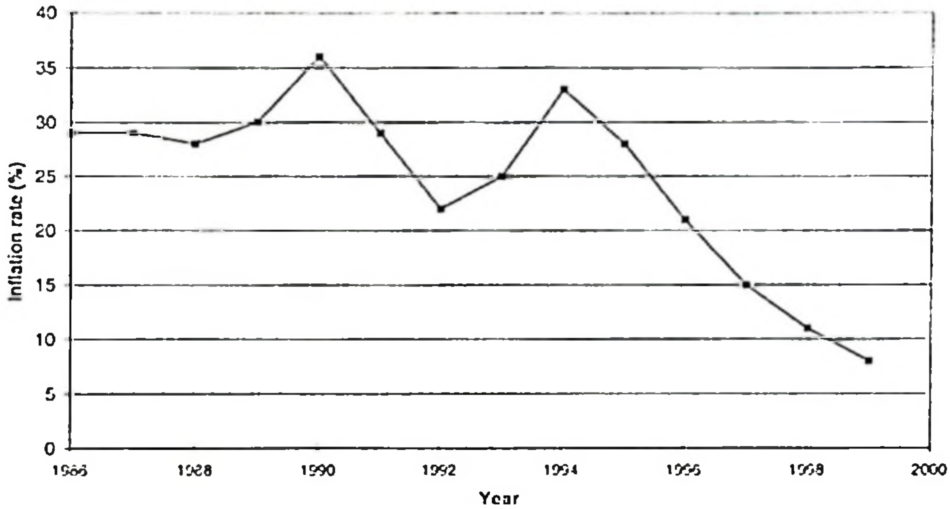

Figure 15: The average yearly inflation rates from 1986 - 1999
Source: URT (1999) [96]

4.1.2.2.3 Prices of fuel and oil

The prices of petrol products per litre or per kg from 1986 to 1996 were obtained from the company which deals with selling of petroleum products (table 7). In that case the quantities of fuel and oil were converted to cost by multiplying the quantities consumed with the respective price per unit.

Table 7: The unit cost of diesel and lubricants
Source: Morogoro Agip Filling Station (1997)

Year	Diesel (Tsh/litre)	Oil (Tsh/litre)	Grease (Tsh/kg)
1986	14.00	150.00	90.00
1987	19.50	250.00	170.00
1988	19.50	300.00	350.00
1989	21.55	350.00	350.00
1990	64.00	400.00	400.00
1991	92.00	420.00	420.00
1992	113.75	450.00	450.00
1993	155.00	500.00	500.00
1994	209.00	600.00	600.00
1995	255.25	650.00	650.00
1996	306.00	750.00	750.00

4.1.3 Data processing

The collected data for each tractor were processed by using a computer. The Excel spread sheet package from Microsoft for windows 95 version 7.0 was used for that purpose. Also the statistical analyses were conducted using the same software package.

The annual tractor use was recorded as the performance of the tractor in hours. The annual performance was obtained by adding the recorded monthly tractor hours for each year under the study. In case the level of performance was not recorded the estimation method was used for determination of the values. The method used was either by dividing the total quantity of diesel consumed in that year with the standard amount of diesel consumption of the tractor or by considering the average use of the tractors in the same group. It was difficult to get the exact hours of use for each separate activity carried out by the tractor because the available recorded data were for all activities done by tractors in a month.

All costs involved in the analysis were adjusted to the base year of 1996 in order to take care of the effect of the inflation [13, 36, 60]. The real Tanzanian shillings were converted to actual Tanzanian shillings by multiplying by the factor $(1+j_1)(1+j_2)........(1+j_n)$ for all costs before 1996 and by a deflation factor $1/(1+j_1)(1+j_2).......(1+j_n)$ for cost obtained after 1996. The values $j_1, j_2, j_3, ..., j_n$ represented the respective inflation factors for the year before 1996 and those after 1996. The year 1996 was chosen as a base year because this research work was initiated in that year.

The collected data were categorised based on the tractor drives, namely the two wheel drive (2WD) and four wheel drive (4WD). The data of the two wheel drive tractors collected from large scale farms were classified further according to their tractor types because most of the data collected belonged to this group. The classification of 2WD tractors gave mainly 4 groups of tractor types, which include Massey Ferguson, Ford, Same and Case International. The group of 4WD tractors owned by large scale farms and 2WD tractors owned by small-to-medium scale farmers were not classified into tractor types because the size and distribution of the data were too small for a meaningful statistical analysis.

4.1.3.1 Repair costs

Better understanding of repair pattern is very crucial for a farmer owning agricultural machinery such as tractor because it can be easier for that farmer to budget before hand and even schedule repair operation to reduce the time taken out of field. BOHM (1993) [14] reported that large saving of machinery costs can be made in repair costs than in costs of fuel and lubricants if unnecessary break down will be avoided or if the extent of breakdowns will be reduced by repairing primary damage at an early age.

Repair operations for agricultural tractors are carried out when failures occurs. There are numerous different reasons which results to failure. Some of the factors include:

1. Type of operation and machine loading
2. Hours of use
3. Age of the machine
4. Badly matched machine in terms of make and power
5. Operator error
6. Accidents
7. Environments, etc.

In this analysis however not all factors influencing repair costs were studied. The reason for that is due to time and financial limits set for the study. In attempt to provide the repair costs information to Tanzanian farmers, this study concentrated mainly on the effect of age and level of utilisation.

In chapter 3.2.1.2.1 repair cost was defined as a combination of the costs of spare parts and labour costs involved in repair works. The data collected during field survey was for the spare parts costs but not for labour costs because data on labour costs was not available. However labour costs during data collection were estimated by most of the farms to be equal to about 6% of costs of spare parts. This value was reasonably equal to the value of 4% established in Burkina [41].

In most of the literature reviewed, the total accumulated repair costs curves which consider the tractor as a unit have been frequently used in developing prediction models. This method however ignores the reality of the situation that tractor is made of a combination of different components. Examples of the components include tyres, reams, pistons, cylinder head, alternator, etc.

If the tractor could be divided into a number of components and then the components be analysed and studied separately, the combination of separate repair cost functions of the components could predict the total repair costs of the tractor better than the combined models. This is because some of the repair cost functions of the components are cyclic in characteristics, hence can be easily predicted. For example one of the cycle can be that of replacing tractor tyres which occur for example after every 2000 to 2500 hours of use. The repair costs function of replacing tyres will be made up by the cost of buying tyres and the labour cost that will be used for installation of the tyres. The disadvantage with this method is that a lot of time will be required to break the tractor into number of components and also to study each component separately. In certain cases specialised tools will be required in order to study and understand the natural cycles of some of the components.

In this study however to use the limited time set for research work, the tractor as a unit was divided into five major assembly groups. The assembly groups include the engine, transmission and hydraulic system. Other groups are electrical system and the group for unspecified components.

1. The engine assembly group includes all components which make the tractor engine. An examples of the engine components are filters (oil, fuel, air), cylinder head, pistons, crankshaft, and valves. Others are injector pump, nozzles, sump, engine gaskets, water pump, radiator, oil pump, bearing, etc.

2. The transmission assembly group includes all components which are involved in transmission of power from the engines to the tyres and to the Power Take Off

(PTO). It includes clutch plate, pressure plate, gears in main gear box. Others are tyres, tubes, speed shift, PTO, differential, etc.

3. The hydraulic system group involves all components which make the hydraulic circuits in a tractor. Example of the components are the hydraulic pump, directional control valves, pressure control valves, hydraulic cylinder, hydraulic filters, hydraulic drives, etc.

4. The electrical system group includes all components responsible for generation and distribution of electricity in the tractor. Examples of the components in the electrical system group are battery, alternator, wires, relay, bulbs, etc.

5. Other assembly group of components include all unspecified components, which can not be categorised in the above mentioned groups. Examples of the these are sheet metals, tractor seat, etc.

The classification of the repaired components into the mentioned assembly groups was done with the help of the maintenance technician at the farms and whenever necessary the tractor repair manuals were referred.

Repair cost functions of tractors could be best calculated by studying each tractor over a period of time. However using such a method it would require a minimum of 10 years to observe each tractor in order to obtain historical repair data before the repair cost functions are established. Since the repair cost functions of tractors were to be determined within a time limit, the method used by WARD *et al.*, (1985) [98] and WENDL (1991) [102] was used in the data processing. This method has an advantage of establishing the repair cost functions within a short time span. It considers repair cost's data for a group of tractors of the same types, which are then classified into different age groups. In each age group the average repair costs of each assembly group, total repair costs, mean utilisation level and their respective coefficient of variations ($c.v$) can be calculated.

The coefficient of variation $c.v$ is calculated as,

$$c.v = \frac{\sigma}{\bar{x}} \qquad \text{.................................} \qquad (4.0)$$

where: σ = standard deviation

$\bar{x}$ = mean value

The flow chart shown in figure 16 summarises the process involved in the establishment of the relationship between the average annual repair costs of the assembly groups with the tractor age and also in developing repair cost functions.

The process involved classification of tractors into different groups as mentioned before. Then, in each group, data were arranged based on tractor age. Thereby the average annual hours of use and average repair costs of the different assembly groups for each age group was calculated. Thereafter the total average accumulated hours of usage for different tractor categories was calculated. The same technique was used to obtain the average accumulated repair costs for each assembly group of components and for the total repair costs. Thus the relationship between the average annual repair costs against the tractor age and the functions based on accumulated average repair costs as the percentage of the initial price versus the average cumulated hours were developed.

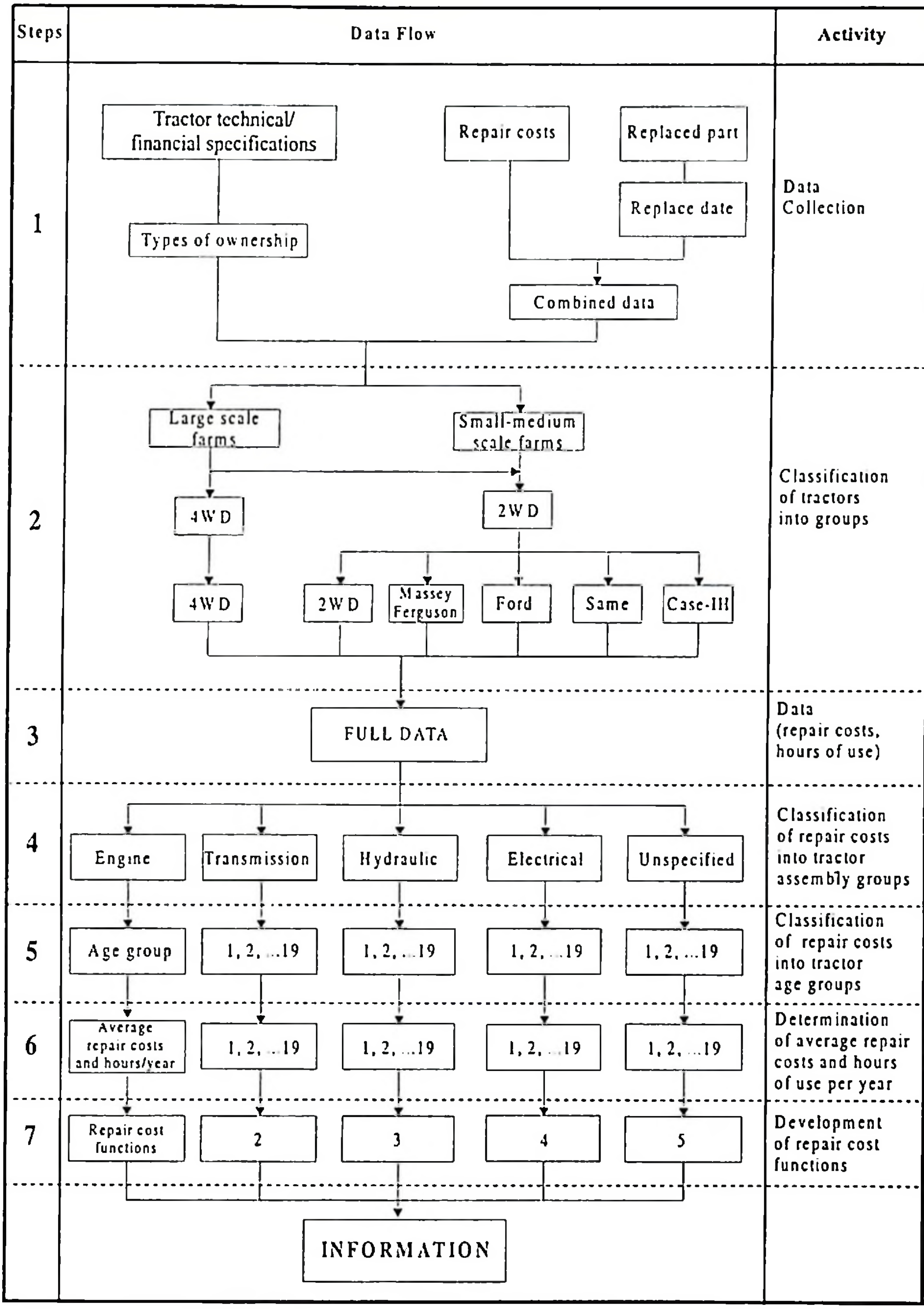

Figure 16: Flow chart for determination of repair cost functions

4.1.3.2 Calculation of tractor annual ownership costs

In order to select one of the two methods to be used for calculation of an annual cost of a tractor, it is important to know exactly what kind of annual cost is being referred in this study. The annual cost of owning and using a tractor is the cost which is comparable to other annual returns and costs. For example the profitability of a farm enterprise is usually determined on an annual basis as the difference between the returns from crops harvested less the cost of production. Therefore to consider machinery on annual basis the notion of depreciation is confusing (depreciation for tax purposes, the reduction in resale value of a machine or the depreciation average over the life of the machine). All these depreciation values do not give an accurate picture of the annual cost of a tractor that the owner had incurred.

Additionally an annual cost of a tractor can be defined as an annual income which exactly balances the machine cost so that over its life the change in farm bank balance is the same with the tractor as without it. In that case the method to be used in the calculation has to take into account the effects of the inflation rate together with the loan and interest rates.

That being the definition of an annual cost in this study, the method based on the actual cash flows established by WITNEY AND SAADOUN (1989) [108] was selected for the purpose of calculation of the tractor annual ownership cost. This is because the method considers the actual annual operating costs (such as mortgage) and it accounts for the changing value of money over the period of ownership. The average annual costs method was not used because it considers the depreciation costs which is not the direct cost and it does not account for the effect of inflation.

The equation developed by WITNEY AND SAADOUN (1989) [108] was however modified by including the annual costs of labour, fuel and oil. The tax component was eliminated from the equation because in Tanzania as mentioned before tractors are not directly charged tax. Thus the final form of the equation used for determination of annual ownership costs is expressed as:

$$A_t = NPV_m + NPV_r - NPV_s + F_c + C_o + C_L \quad \text{...... (4.1)}$$

where: A_t = Annual ownership cost.

NPV_m = Annual repayment of loan capital and interest.

NPV_r = Annual repair and insurance charges.

NPV_s = Income from selling the tractor.

F_c = Annual fuel cost.

C_o = Annual oil cost.

C_L = Annual labour cost.

To simplify the calculation of tractor annual costs, a computer software programme was developed. The programme was written using a quick basic language (Q-basic). The Q-basic language was selected because it is easily available to most of the computer users in Tanzania and can be easily converted with the other software language programmes, such as visual basic.

The written programme is shown in appendix 4. The input data for the programme are:

- The tractor type
- The tractor code
- The purchase price.
- The investment interest rate.
- The loan interest rate.
- The inflation rate.
- The expected tractor annual usage (hours).
- Monthly salary of tractor operator (Tshs)
- Tractor fuel consumption rate (l/h)
- Price of fuel per litre (Tshs/l)
- Price of lubricants per litre (Tshs/l)

The tractors were coded as shown in table 8. The first number represented the type of tractor drive, whereas the second number was just an arbitrary number.

Table 8: Tractor codes

Tractor types	Power (kW)	Fuel consumption (l/h)	Code
Massey Ferguson	62	8.0	21
Case International	64	8.5	22
Ford	58	7.5	23
Same	52	7.0	24
4WD	91	12.5	40
2WD - SMSF	52	7.0	25

The price of fuel and oil in Tanzania are Tshs 350 and Tshs 800 per litre respectively. The monthly salaries of tractor operators are Tshs 40,000 for operators of 2WD tractors and about Tshs 43,000 for drivers of 4WD tractors. The Co-operative Rural Development Bank (CRDB) investment and loan interest rates were used in this study because the CRDB is the main lending institution to the agricultural sector in Tanzania [57].

The repair costs functions developed by this study were used for determination of repair costs in the programme. The resale function developed by WITNEY AND SAADOUN (1986) [107] was used for determination of salvage values because the function was developed more recently as compared to others.

4.1.4 Determination of tractor optimum replacement time

The tractor optimum replacement time was determined basing on the model used by most of the previous studies. The age at which the total annual cost per hour reaches a minimum was considered to be the optimum period for replacement [25, 36, 51]. The model developed by O'CALLAGHAN (1988) [65] was not used because of lack of sets of replacement alternatives (Challengers). The sensitivity analyses to check the effects of change of inflation rates and bank interest rates to the optimum replacement period were also carried-out.

4.2 Determination of annual costs of draft animals

Just like for the case of determination of the annual costs of tractor technology in Tanzania, determination of annual costs of draft animals was made possible after collecting data in some areas in Tanzania and processing.

4.2.1 Study area

Draft animal data were collected in Shinyanga and Morogoro regions. Shinyanga region is one of the area in the country with many farmers having the tradition of cattle keeping. Whereas Morogoro is a region which borders with tsetse-fly infested area, therefore the indigenous people have little or no tradition in cattle keeping. However, nowadays animal draft technology is being promoted by the government and non-government organisations in the region to assist farmers in alleviating the shortage of farm power. Kilosa district is one of the areas that is being favoured by most of the organisations.

The field study in Shinyanga region was carried out in Kahama, Shinyanga rural, Bukombe and Maswa districts. The regional and district agricultural extension officers played a key role in choosing the respective study villages. In Morogoro region data was collected only in Kilosa district. In Kilosa district the study areas were decided also with the help of the district extension officers. Two villages were chosen, namely Lubeho and Kwipipa.

4.2.1.2 Shinyanga region

Shinyanga region lies in the northern part of Tanzania and south of lake Victoria. The region is divided into five administrative districts. The districts include Bariadi, Bukombe, Maswa, Shinyanga and Kahama. The region covers a total area of about 50,000 km^2 out of which 40% is covered with natural forest. According to 1988 population census the population of the region was 2 million (about 7% of Tanzanian population) with a population growth rate of 2.8%.

Shinyanga region can be divided into two agro-climatic zones, namely the eastern and the western zone. The eastern part of the region receives 600 - 800 mm of rainfall annually whereas the western part receives between 800 and 1000 mm per year. The rain season is mainly from March to April, but sometimes some showers are received between November and December.

The major activities carried out in the region include both agriculture and livestock keeping. Agriculture is dominated by cotton production in terms of the area under-cultivation. Cotton is the major cash crop of the region and maize is the major food crop grown followed by millet. Other food crops grown include groundnuts, sweet potatoes and rice. Sunflower and tobacco are produced but in small quantities mainly for cash generation. Livestock sector in Shinyanga is dominated by cattle keeping. However the region has about 1 million goats and sheep [56]. Livestock in Shinyanga is kept as a security (bank) and therefore selling of animals is mainly done to buy food in bad years. However farmers obtain milk, meat and manure in addition to other benefits from livestock.

4.2.1.3 Morogoro region

Kilosa district is one of the four districts forming Morogoro region. Other districts are Morogoro rural, Ifakara, and Ulanga. The region has an area of 73,039 km^2. Based on the population census of 1988 Morogoro has a population of about 2 million. The use of animal power in Morogoro region is negligible due to tsetse infestation.

Morogoro region experiences *orographic* rainfall, which is generally reliable and influences most of the area. The average annual rainfall is about 1000 mm. The region has two distinct seasons, a phenomenon only enjoyed by six regions in the country. Therefore two crops can be grown from November to December/January for the short rains and from February to May for the long rains.

The major crops are grown during the long rains season, these include maize, rice, and sorghum. Usually maize and sorghum are rain-fed whereas rice is irrigated by flooding. The three crops (maize, rice and sorghum) form the major food staples for the region. During the short rains green gram, cowpeas and early maturing maize

(*Katumani* variety) are grown. Other crops such as plantain, fruits and vegetable can be raised at either season. Sugarcane and cotton are the major cash crops grown in the region. Sugarcane is mainly grown on estates.

4.2.2 Animal data collection

In order to speed up the process of field survey, research assistants were trained to assist in data collection. The research assistants played a key role in collecting most of the draft animals data because they were able to carry out the interviews in almost all selected villages.

Both formal and informal methods were used in gathering of information. The formal method was based on a set of questionnaires shown in appendix 2. The informal method was based on a wide range of farm, off farm and family activities carried by the interviewed farmers in the selected households. The key informants in all villages visited were the family members with draft animals.

The information collected was then fed into the computer for analysis. The analysis was carried out by the use of a Microsoft Excel software package for windows 95, version 7, similar to the one used for analysis of tractor data.

4.2.3 Animal data processing

The analysis of the annual costs of draft animals in this study was carried out for oxen only because these are the common animals used as draft animals in many places of the country as compared to other work animals (such as donkeys, horses, cows, etc.). The average annual costs method was applied in determination of annual costs because the animal costs are considered not to vary much with the age. The major cost components considered in the method were the purchase price of draft animals, interest, and insurance costs. Other costs components were the labour, tax, shelter, health and compensation costs.

The cost of feed was not considered in the calculation because during data collection the majority of the households indicated that they were not supplementing their draft animals with other feeds apart from practising free range grazing. The few households which carried-out feed supplementation were found to use only crop residues and by-products from their farms which they obtain mainly freely.

In the calculation, the oxen (draft animals) were assumed to start working with an average live weight of about 200 kg [58]. The oxen were also assumed to work for an average of 6 years before being sold [11, 31, 66]. By the end of this time the draft animals were assumed to attain weight of about 340 kg [11, 22].

The purchase price of the draft animals was considered to be 10% more than the purchase price of a non working oxen listed by the farmers during the survey period. The 10% increase in cost is due to the animal training costs. The animal training period takes normally between one to three months.

On the total area worked by a pair of oxen per year, literature has indicated that on average draft animals in Tanzania work for about five hours a day [19, 84]. The starting working time depends much on daily weather. If the day has a moonlight, the draft animal starts to work as early as 0300 hours. According to SIMALENGA AND HATIBU (1994) [78] the length of the annual working period varies widely. In some areas draft animals are used for one growing season while in other areas they are worked for two growing seasons. However for the matter of uniformity, the experience from other countries was adopted in this study. Thereby a pair of oxen was assumed to have a potential of working 4 hectares per season [30, 82]. In that case 3 pairs of oxen will be able to work 12 hectares per season. In other word the area to be worked out per season was assumed to be directly proportional to the number of pair of oxen.

The labour costs were assumed to be charged only during the working season, which is equivalent to three working months per year. At this particular time three labourers will be hired to control a pair of oxen [67]. The wage for each labourer in a village of Tanzania was found to be about Tshs 3000 per month for cultivating 4 ha but additionally the labourers are provided with food. However increasing the number of pair of draft animals will require to increase the number of labourers. Increasing number of labourers will increase the demand of the labourers and this will cause the owner of draft animals to increase the labour costs accordingly so as to attract the number of labourer required. The estimated costs for such increase are shown in appendix 10.3. During the off season the labour cost was assumed to equal to zero because then the draft animals will be taken care by the family labour and for matter of simplicity the family labour in this study is regarded to be free during off season.

Mathematically the minimum annual costs C_a of draft animals were calculated using the following function:

$$C_a = f_1(n_{pa}) + f_2(n_{pa}) + f_3(n_{pa}) + f_4(n_{pa}) + f_5(n_{pa}) + f_6(n_{pa}) + f_7(n_{pa}) + f_8(n_{pa}) \ldots\ldots \quad (4.2)$$

where: n_{pa} = number of pair of draft animals

$f_1(n_{pa}) = 2n_{pa}\left(\frac{P_{ad} - S_a}{L_a}\right)$ .... annual depreciation value

$P_{ad} = 1.1P_a$, $S_a = \frac{340}{200}P_a$

P_{ad} = total purchase cost of trained draft animal

P_a = purchase cost of untrained draft animal

S_a = salvage value

$f_2(n_{pa}) = 2n_{pa}\left[\frac{P_{ad}(1+i_l)^{L_a} - S_a}{L_a}\right]$ .... annual interest cost

L_a = economic life of draft animal

i_l = loan interest rate

$f_3(n_{pa}) = 2n_{pa}k_h$ .... annual housing cost

k_h = housing cost per draft animal

$f_4(n_{pa}) = 2n_{pa} \times 0.08P_{ad}$ .... annual insurance cost

$f_5(n_{pa}) = 2k_t n_{pa}$ .... annual tax cost

k_t = annual tax cost per draft animal

$f_6(n_{pa}) = 2(c_v + c_d + c_m)n_{pa}$ .... annual health cost

c_v = annual cost per draft animal for vaccination

c_d = annual cost per draft animal for dipping and spraying

c_m = annual cost per draft animal for medication

$f_7(n_{pa}) = (3k_w)3n_{pa} = 9k_w n_{pa}$ .... annual labour cost

k_w = annual labour charge per labourer

$f_8(n_{pa}) = 1400n_{pa}$ .... annual compensation cost

5. Results and Discussion

The results obtained in this study, as mentioned before emerged from data collected from three main sources, namely large scale farms, small-to-medium scale farmers and from farmers owning draft animals.

Records of 121 tractors were collected from large scale farms and 25 tractors from small-to-medium scale farmers. The records obtained from large scale farms were available for 96 two wheel drive (2WD) and 25 four wheel drive tractors (4WD). The classifications of the 2WD tractors include 42 Massey Ferguson, 19 Case International, 22 Ford and 13 Same tractors. Data from small-to-medium scale farmers were only for two wheel drive tractors. Most likely because in Tanzania it is not common for small-to-medium scale farmers to own four wheel drive tractors. The mean power rating of the 2WD tractors owned by small-to-medium scale farmers was 52 kW, whereas the power ratings of the 2WD tractors owned by large scale farms were 62 kW for Massey Ferguson, 64 kW for Case International, 58 kW for Ford and 52 kW for Same tractors. The average power rating of the 4WD tractors was 91 kW.

The animal drafts data were collected from 30 households. The household as a unit was used because in the majority of the villages, the household is the primary unit of production, consumption and social interaction. The members of the household mainly farm together and supply themselves from a common granary. The household comprises of members of the nucleus family, members of the extended family, and other members of the family, who for one reason or another have to live outside the village (such as pupils) but are still being supported partly or fully by the family.

5.1 Tractor operator skills

Tractor operators are the most important people as far as controlling and management of tractors is concern. In other word, these are the people trusted to manage an investment worth more than twenty million Tanzanian Shillings. One of their key responsibility is to carry out normal routine maintenance that prevents tractors from frequent breakdowns and major repairs. Therefore investing into tractor business requires to employ a competent tractor driver. The word competent driver in this context means an operator, who is well built in terms of education and skills in operation and maintenance of tractors. Employing a competent operator can make the owner of the tractor to expect some returns out the investment.

In Tanzania however the situation is different because the majority of the employed tractor operators have never undergone any training in tractor operations and maintenance. The result in figure 17 revealed that only 15% of the interviewed operators in Tanzania had the opportunity to attend a training course of not more than 2 weeks in tractor operations. The trained operators were mainly for the four wheel drive tractors. One of the training courses was organised by the Canadian experts for the operation of 4WD tractors in Hanang wheat belt.

The result of the education attained by the operators (figure 18) shows that the majority of the tractor operators (74%) have the basic education. The basic education in Tanzania means that one has obtained a primary education. Therefore it is possible for the person to read and write in Swahili language without any problem. However it was found out that 23% of the operators did not have the basic education and out of these about 10% were not able to read and write. The results also shows that 3% of the interviewed operators had completed secondary education but all of them indicated that they had very little command in English both in writing and reading.

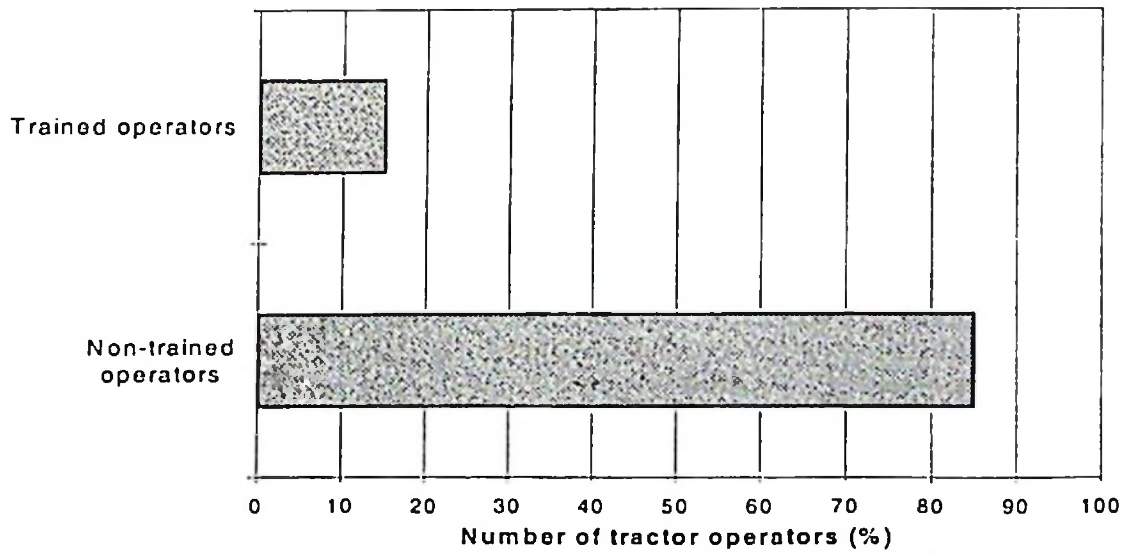

Figure 17: Trained and non-trained tractor operators

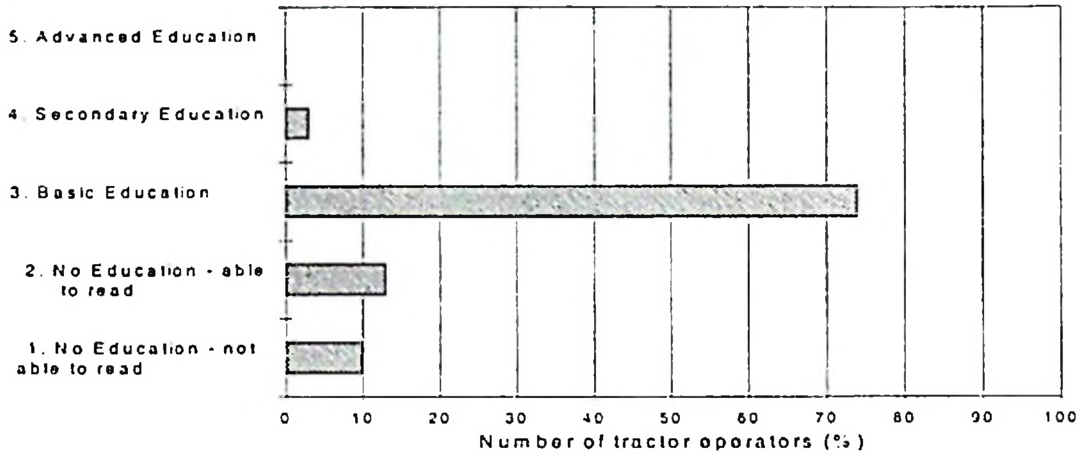

Figure 18: Education information of tractor operators

This study did not establish whether the use of untrained operators result into higher repair costs. However there is no doubt about poor performance from untrained operators as compared to well educated and trained operators. Having such low percentage of trained operators is showing that investment into tractors in Tanzania lacks adequate information on the role played by trained operators in the success of the investment. If operators do not have adequate training in operations and maintenance then at least one should expect that the operators will be able to use the available instruction manuals. Nevertheless, all instruction manuals available on tractor operations and maintenance in Tanzania are written in English language and as established, English is not the commanding language for most of the operators.

5.2 Tractor utilisation

Tractor utilisation may be defined in terms of the number of hours spent by the tractor on various tasks. The agricultural tasks could be ploughing, harrowing, planting, transportation, inter row cultivation or spraying operation. The utilisation can therefore be stated as the accumulated quantity of work accomplished by the tractor within a given time interval or can be represented by the accumulated hours within a specified interval of period.

There are several methods used to represent the magnitude of utilisation. HUNT (1983) [36] expressed tractor utilisation as accumulated hours of the use. ADELHELM (1976) [1] and SINGH AND TANDOM (1987) [79] presented tractor utilisation data as total annual hours of use for various tasks including leisure trips. PARK (1990) [68] presented his work using working days and accumulated area worked. Also SINGH, K.N., (1975) [81] presented hour of utilisation by considering tractor utilisation hours for productive and non-productive hours. Productive hours are those in which the tractor is engaged in useful work. It does not include preparation time nor the travel time from base to the fields. This kind of distinction may be important in precise revenue analysis but is of no useful consequence in the calculation of tractor operating costs.

In this study, tractor utilisation was expressed in terms of annual hours for different groups of tractors. However in developing the repair cost functions tractor utilisation was expressed in terms of accumulated hours of use, similar to the method used by HUNT (1983) [36]. The utilisation level however did not distinguish the different annual hours spent for the different tasks performed by tractors because such information was not available during data collection. Nevertheless most of the activities carried out by tractors in the studied areas are ploughing, harrowing, planting and transportation of agricultural products. The agricultural products include sugarcanes, sisal cuts, coffee, wheat, maize, etc.

Table 9 shows the result of the mean annual tractor utilisation levels in Tanzania. These are found to be in the range from 600 to 1100 hours per year per tractor. The coefficients of variations for the result were found to be between 16% and 52%. The level of utilisation in Tanzania does not differ much when compared to the level of utilisation in other African countries. In Nigeria for example, KOLAWOLE (1974) [46] reported that the annual utilisation of government tractors (hire services) was about 500 h, while annual use of privately owned tractors was about 786 h.

Table 9: Mean annual utilisation levels of tractors in Tanzania

Tractor Make/Group	No. of units	Age	Annual use (h)
2WD Massey Ferguson	42	19	920
2WD Case International	19	19	730
2WD Ford	22	17	860
2WD - Same	13	9	1020
2WD - Small holder	25	17	660
Four wheel drive	25	18	640

The mean annual level of utilisation of two wheel drive tractors used on large scale farms is about 880 hours per tractor. The average annual use of four wheel drive tractors under the same scale of ownership is 640 hours. This shows that 2WD tractors are utilised more than 4WD tractors under large scale farm ownership in Tanzania. This could be attributed by the fact that 2WD tractors under large scale ownership are regarded as multipurpose tractors therefore they are assigned frequently into a range of activities, namely ploughing, spraying, planting, and transportation. Whereas four wheel drive tractors are regarded as special tractors. In that case 4WD tractors are restricted only for heavy duty tasks, such as uprooting, sub soiling, ploughing, furrowing, etc. On the other hand, 4WD tractors are bigger machines than 2WD tractors, therefore they tend to accomplish their tasks at a faster rate than their counterpart 2WD drive tractors. This idea is also supported by the trend of agriculture in Europe and USA, where farmers tend nowadays to own bigger farms than before and use bigger 4WD tractors to complete all agricultural activities in time.

The level of utilisation of 2WD tractors owned by small-to-medium scale farmers is lower when compared to 2WD tractors under large scale farms most likely because of the sizes of farms they own. The small-to-medium scale farmers own farms of about 50 to 150 ha, whereas large scale farms own big farms with the size ranging between 600 ha and 4000 ha.

Same tractors in Tanzania are observed to have the highest average annual utilisation when compared to other tractor makes. However this should not always be taken to be the case because the utilisation value of Same tractors was obtained by taking an average of 9 years of use. Perhaps within this period Same tractors had not started developing serious problems. The average values of other tractors were obtained by considering at least 17 years of use. If Same tractors could have been used for that period, perhaps the average annual use could have been less than the value currently obtained. In that case substantial conclusion can not be drawn at the time being.

5.3 Tractor repair costs

The analysis of the results of repair costs obtained in this study are presented in appendix 5.1 to 5.6. The results show an extreme range of coefficient of variations for both repair costs of the assembly groups of components and of the total repair costs. This observation indicates the variations that one could expect in repair costs from one tractor to another. The same kinds of variations have been reported even with other researchers in a number of previous studies. For example, the standard deviations equal to mean was reported in the investigation of repair cost's data in USA [4] and in Germany [102]. Likewise, WARD *et al.*, (1985) [98] reported extreme range of coefficient of variations of between 45% and 283% while investigating repair costs of tractors in Ireland

In this study however, higher coefficient of variations was observed within the different repair costs of the individual assembly groups rather than within the total repair costs. This could be elaborated by taking an example in table 10, which shows the coefficient of variations of Massey Ferguson tractors for the total repair costs and the individual assembly groups. The result in this table indicates that the coefficient of variations of the repair costs within the individual assembly groups ranges from 0% to 283% whilst the coefficient of variations of the total repair costs is in the range between 40% and 96%. This suggests that the model functions of the total repair costs are much more reliable than the functions of the individual assembly groups in this study.

Table 10: Coefficient of variations from the mean values of repair costs of Massey Ferguson tractors

	Engine	Transmission	Hydraulic	Electrical	other	Total
Minimum	45%	54%	0%	74%	0%	40%
Maximum	133%	162%	283%	168%	239%	96%

5.3.1 Average annual repair costs of tractors

The result of the average annual repair costs against the years of use of Massey Ferguson tractors is shown in appendix 5.1 and summarised in figure 19. The result shows that the annual average total repair cost per tractor vary widely with tractor age.

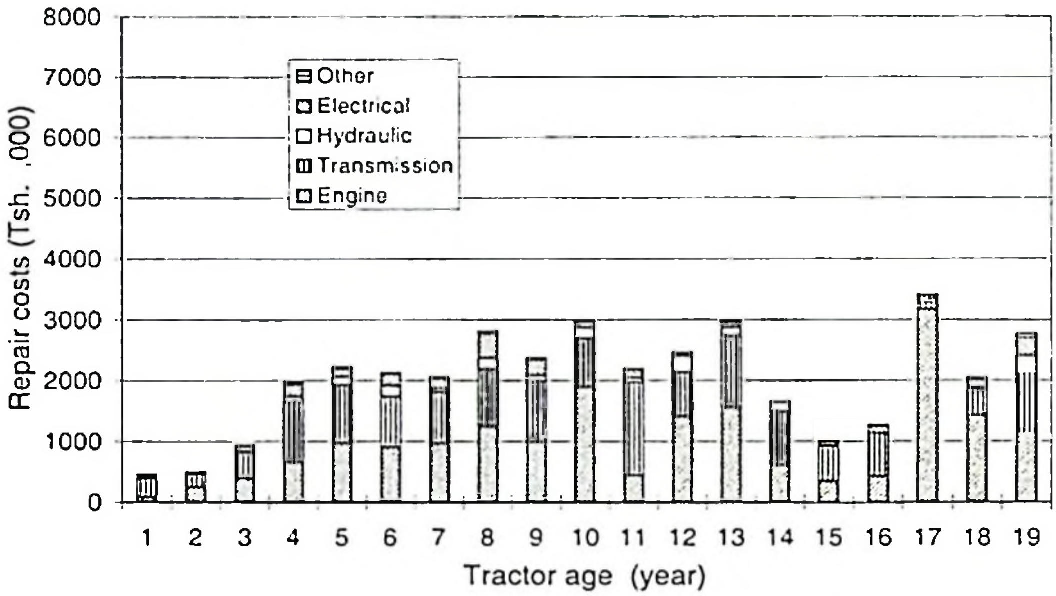

Figure 19: Variation of average annual repair costs per tractor with ages of Massey Ferguson tractors

The minimum and maximum average annual total repair costs for the total ownership period of 19 years of Massey Ferguson tractors are about Tshs 490,000 and Tshs 3,600,000 per tractor respectively. The overall average annual total repair cost of Massey Ferguson tractors is about Tshs 2,000,000 per tractor. When considering the annual use of 920 h (as per section 5.1.2), then the average annual repair costs translate to about Tshs 2200 per hour per tractor. According to figure 19, the overall minimum annual repair costs occur in the first three years. Whilst the highest repair costs are experienced when the tractors are over 7 years old. The drop in repair costs in year 14 to 15 could be explained by the considerable attention paid for the tractors in year 12 and 13.

The result of the repair costs of the assembly groups of Massey Ferguson tractors shows that the engine and transmission failures dominate in terms of the average annual repair costs undertaken through out the tractor's life. Extremely high engine repair costs in Massey Ferguson tractors occur in year 10, 13 and 17. The transmission repair costs are almost uniformly distributed starting when the tractors are 4 years old. Also the hydraulic repair costs start to develop when the tractors have reached 4 years old. The electrical repair costs in Massey Ferguson tractors are seriously high at the age of 8 and 19 years but otherwise they do occur starting from the beginning of ownership.

The result in appendix 5.2 shows that the overall annual average total repair cost of Case International tractors is about Tshs 2,900,000 per tractor. That is equivalent to about Tshs 4000 per hour per year per tractor when the average annual use of 730 h is considered. The average minimum annual repair cost value of Case International tractors is about Tshs 600,000 and the maximum is about Tshs 6,400,000 per tractor. The average annual total repair costs of Case International tractors during the first 9 years are found to be below the overall annual average cost. The explanation for the fall of annual repair costs in year 11 could be clarified by the major repair works that were undertaken to restore the tractors performance in year 10.

Likewise, the result for Case International tractors (figure 20) shows that the engine and the transmission repair costs dominate throughout the life of these tractors. However extremely high engine repair costs occur when the tractors are 9, 10 and from 12 years old and above. Similarly, the owners of Case International tractors spent a lot of money in repairing transmission system in year 10, 11, 13 and 14. The drop of transmission cost observed from year 15 and onwards was related to the change of tractor tasks. Most of the farm management revealed that old tractors are assigned to less demanding job than the relative new tractors. That is shifting from ploughing activities to less demanding jobs such as transportation. Even though hydraulic repair costs of Case International tractors are minimum, high hydraulic repair costs occur in year 6, 10 to 14 and 17. Whereas the electrical repair costs transpire uniformly throughout the life of Case International tractors.

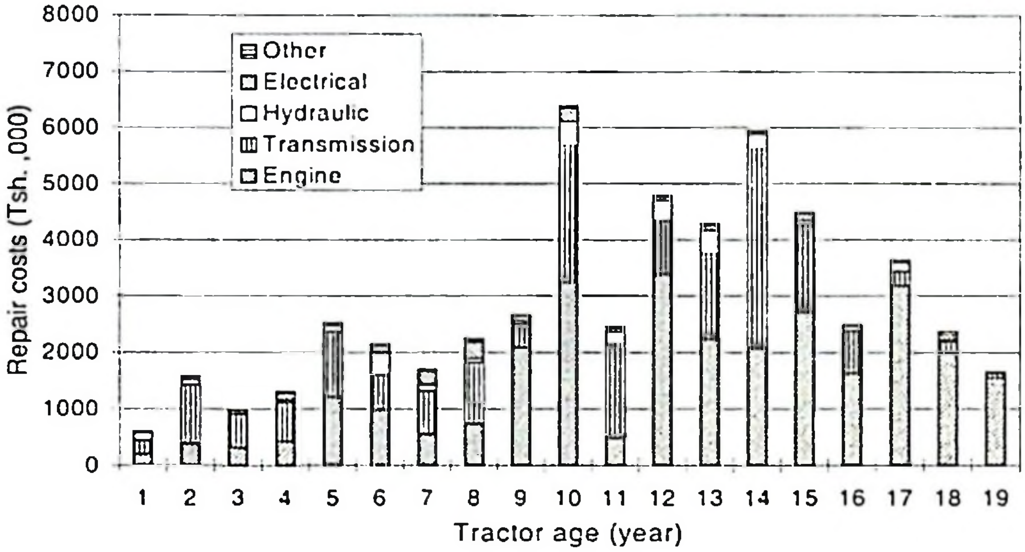

Figure 20: Variation of average annual repair costs per tractor with ages of Case International tractors

The results in appendix 5.3 indicate that the minimum average annual total repair cost of Ford tractors is about Tshs 720,000 per tractor. The maximum average annual total repair cost is about Tshs 5,200,000 per tractor. The overall annual average total repair cost for 17 years of ownership is about Tshs 2,800,000 per tractor. In other word the average annual repair cost is Tshs 3300 per hour per tractor, when the annual use of 860 h is considered.

The result of Ford tractors presented in figure 21 indicates that the owners of these tractors incur high engine repair costs in year 5, 6, 9, 10 and thereafter from year 12 and above. Transmission repair costs in Ford tractors are experienced regularly, starting in year 2, but extremely high transmission repair costs occur in year 11 and 14. Hydraulic repair costs in these type of tractors are minimum, although they tend to build up mainly in year 6 and from year 10 and ahead. The electrical problem in Ford tractors occur almost constantly throughout the life of the tractors, but their impact to the total repair costs is minimal.

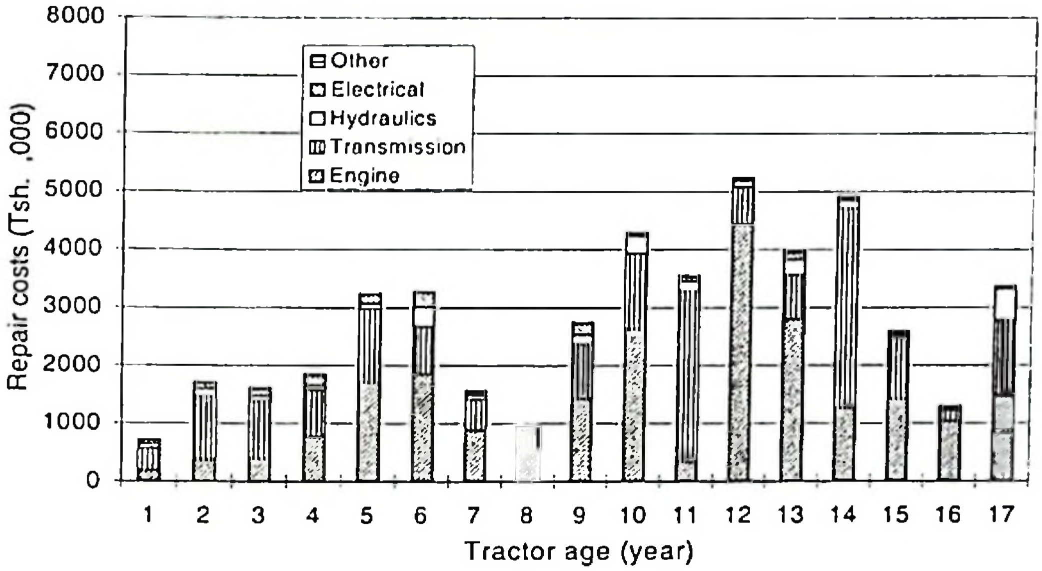

Figure 21: Variation of average annual repair costs per tractor with the ages of Ford tractors

Although Same tractors are increasingly used on the Tanzanian agriculture, they are relative new on the market. This is also illustrated by the summary of the results in appendix 5.4. Same tractors had been owned for at least 9 years as compared to at least 17 years for other tractors. The overall mean annual total repair cost of Same tractors is about Tshs 2,900,000 per tractor (Tshs 2800 per hour per tractor for 1020 h of annual utilisation level). The minimum and maximum average annual repair costs are Tshs 890,000 and Tshs 7,300,000 per tractor respectively. The first four years are characterised by having minimal repair costs, but when Same tractors are 5 years old and above they start to experience high repair costs.

The result plotted in figure 22 shows also that engine failures are the leading factor in the total repair cost in Same tractors. Engine repair costs increase with the increase of the tractor age. Higher engine costs occur in year 9 as compared to the early life. Whereas high transmission repair costs occur in year 2 and 5. On the other hand Same tractors experience high hydraulic repair costs in year 6 and 8. The electrical problems appear mainly in year 5.

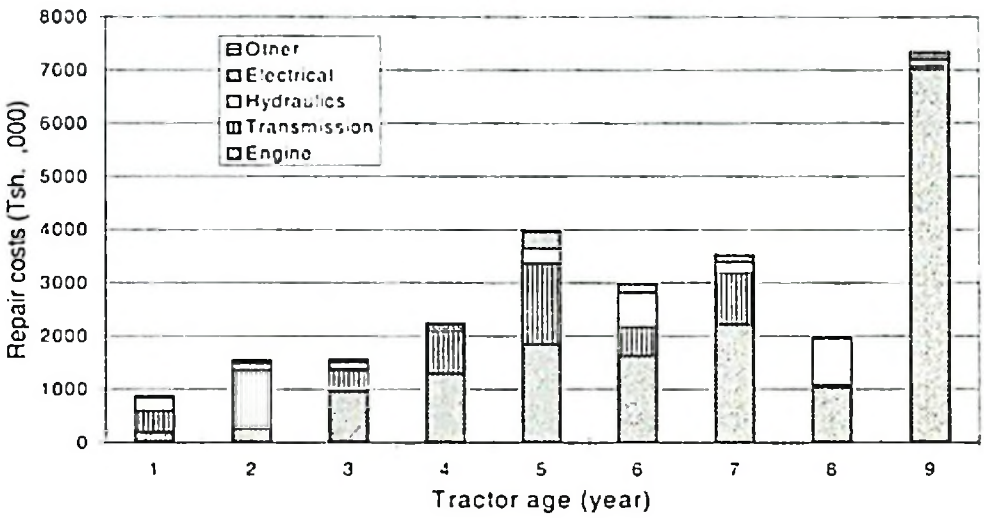

Figure 22: Variation of average annual repair costs per tractor with ages of Same tractors

The results of the average annual repair costs of 4WD tractors are shown in appendix 5.5. The results show that the average annual total repair costs of four wheel drive tractors in Tanzania alter widely from one year to another. The minimum repair cost of these tractors is about Tshs 1,100,000 per year per tractor, whilst the maximum total repair cost is about Tshs 6,800,000 per year per tractor. The mean annual repair cost is about Tshs 2,900,000 per tractor. This is equivalent to the mean annual repair cost of about Tshs 4500 per hour per tractor when the mean annual utilisation of 640 h is considered.

The result plotted in figure 23 shows that 4WD tractors in Tanzania start to experience high engine repair costs when the tractors are 4 and 5 years old. When engine problems are rectified at this period it takes again about 9 to 10 years to develop. This is the time when 4WD tractors are about 14 and 15 years old. Transmission repair costs become a serious burden when these tractors have reached 12 years. Although funds are also spend to repair other assembly groups, their effects to the total repair cost are not so notable.

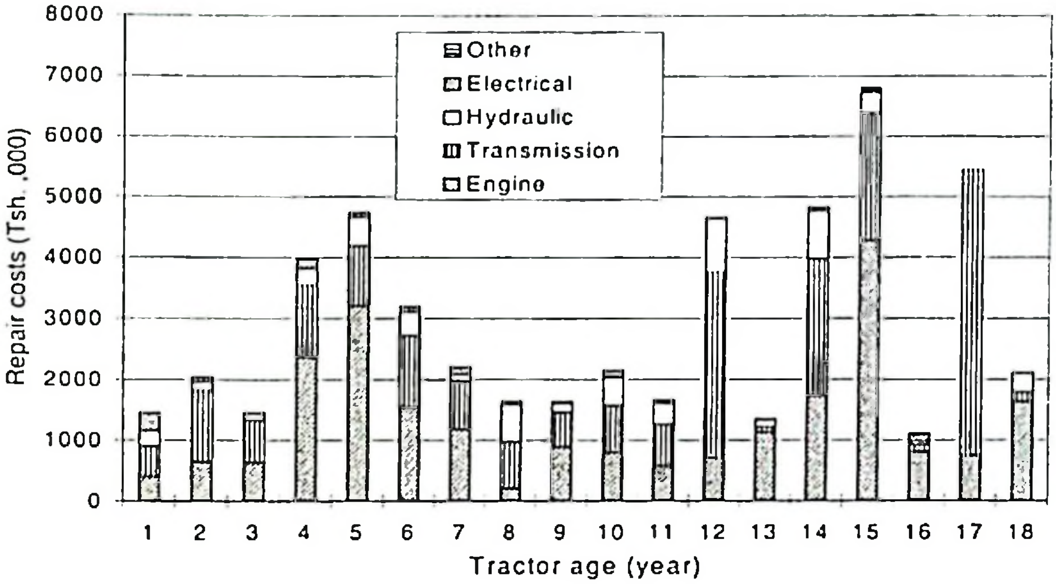

Figure 23: Variation of average annual repair costs per tractor with ages of 4WD tractors

The analysis of the results of tractors owned by small-to-medium scale farmers are shown in appendix 5.6. The result shows that the minimum average annual total repair cost of these tractors is about Tshs 240,000 per tractor. The maximum annual average total repair cost is about Tshs 4,800,000 per tractor. The overall average annual total repair cost is found to be about Tshs 1,900,000 per tractor.

The results in figure 24 show that tractors owned by small-to-medium scale farmers experience engine problems throughout the period of ownership. However high engine repair costs occur when the tractors are 6, 8 and 10 years old. Transmission repair costs are found to occur in cyclic nature, mainly after every five years. This was due to the problems of lack of proper data keeping on repair costs as a result most of the tractor owners tended to present their results in cyclic form. For example it was reported by most of the tractor owners that tyres are changed after every five years. This was contrary to the information obtained from the large scale farms which gave the proper period at which the tyres were changed. Hydraulic system in this group of ownership was found to be repaired almost throughout the period of ownership. Nevertheless high repair costs in this system are spent in year 7 to 10. The electrical repair costs are also found to occur periodically mainly after every five years from year 5 and 6. The unspecified repair costs according to tractor owners occur throughout the period of ownership but their magnitudes are minimum. During data collection these were estimated to be around 5% of the total repair costs of the other assembly groups.

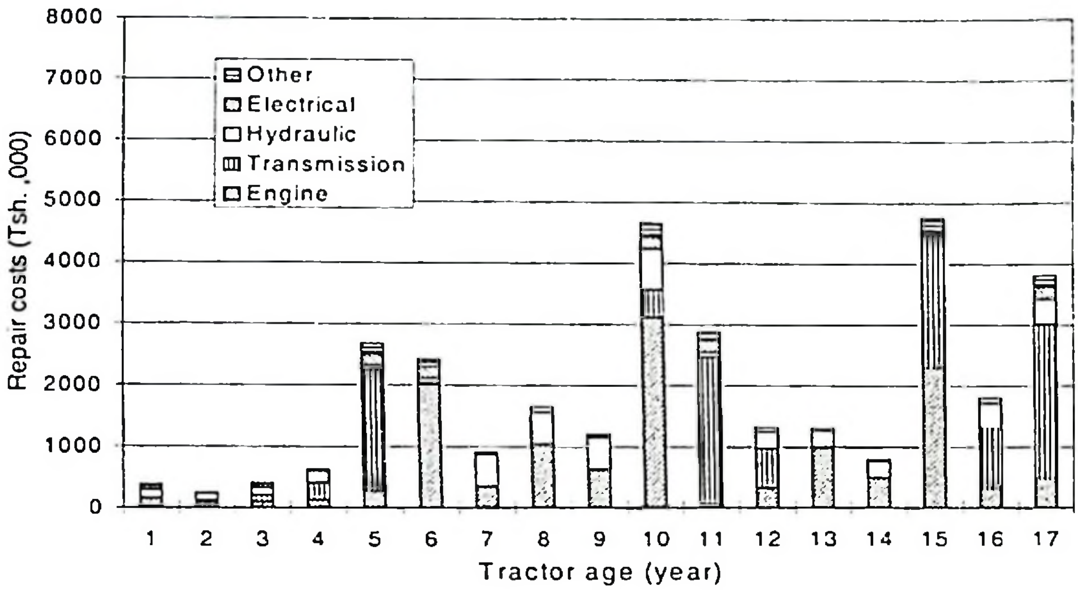

Figure 24: Variation of average annual repair costs per tractor with ages of 2WD tractors owned by small-to-medium scale farmers (SMSF)

A comparison of the annual average total repair costs of these six tractor groups was carried out by using the analysis of variance. The result confirmed the fact that there is significant variation of the annual average total repair costs between the different tractor groups at 95% confidence level. However most of the tractors regardless of their types or group have minimum repair costs at the early stage of their life and they tend to have high repair costs at the age of five years old (Same and 2WD tractors owned by small-to-medium scale farmers) or when they are above 8 years old for the other tractor groups.

In the case of tractors owned by large scale farms, Massey Ferguson tractors are observed to have minimum overall annual average total repair costs per tractor per hour. This could be perhaps the reason why the population of Massey Ferguson tractors for agricultural activities in Tanzania is higher than other tractor makes. These are followed by Same, Ford, Case International and last but not least the 4WD tractors. 4WD tractors are expensive to repair because their corresponding repair parts are in most cases more expensive than the parts of 2WD tractors.

However according to MORRIS (1988) [60] the method which considers the annual repair costs per hour is not the best method for comparing the annual repair costs of different tractors because it is does not reflect the variations in the levels of tractors use.

5.3.2 Distribution of repair costs into assembly groups

Table 11 shows the distribution of breakdowns among assembly groups of the Massey Ferguson tractors. The distributions include the highest, lowest and the mean percentage of the total accumulated repair costs. The engine and the transmission are found to be the sources of high repair costs in Massey Ferguson tractors. Each group contributes 43% of the total accumulated costs spend in repairing Massey Ferguson tractors for the 19 years studied. The hydraulic system contributes to 8% while the electrical and unspecified failures endow 5% and 1% respectively.

Table 11: Distribution of the repair costs into assembly groups of Massey Ferguson tractors

	Engine	Transmission	Hydraulic	Electrical	unspecified
Maximum	52%	63%	7%	10%	1%
Minimum	20%	36%	3%	7%	0%
Mean	43%	43%	5%	8%	1%

Table 12 shows the result of the distribution of repair costs into assembly groups of the Case International tractors over number of years. The transmission failures have shown to be the foremost root cause in the total accumulated repair costs for 19 years studied. The engine breakdowns are the next high contributor to the total repair costs of the Case International tractors over years. The mean contribution of the transmission group is 45% whilst 42% is for the engine. The hydraulic system, electrical and unspecified problems together contribute to 14% only.

Table 12: Distribution of repair costs into assembly groups of Case IH tractors

	Engine	Transmission	Hydraulic	Electrical	Other
Maximum	54%	59%	23%	8%	1%
Minimum	27%	36%	5%	2%	0%
Mean	42%	45%	8%	5%	1%

Table 13 presents the results of the distribution of repair costs of assembly groups of Ford tractors. Ford tractors seem also to suffer more breakdowns in the transmission group than other group components over years because the transmission group is the leading contributor, with 45% of the total accumulated repair costs. The engine group is the second with the contribution of 42%. The electrical and hydraulic system group contributes each 6% whilst the unspecified group is the most inferior contributor, with only 1% of total accumulated repair costs.

Table 13: Distribution of repair costs into assembly groups of Ford tractors

	Engine	Transmission	Hydraulic	Electrical	unspecified
Maximum	53%	60%	9%	10%	1%
Minimum	24%	37%	5%	4%	0%
Mean	42%	45%	6%	6%	1%

The results of the distribution of the accumulated repair costs in terms of assembly groups of Same tractors are shown in table 14. The engine repair costs contribute most, with a mean value of 42% of the total accumulated repair costs. The transmission group is the second, it is found to contribute 40% of the total accumulated repair costs. The hydraulic system group of Same tractors contributes substantially when compared to other tractor types, with the mean share of 13%. The remaining groups of components (electrical and unspecified) have the mean value of 5%.

Table 14: Distribution of repair costs into assembly groups of Same tractors

	Engine	Transmission	Hydraulic	Electrical	Unspecified
Maximum	63%	61%	27%	5%	3%
Minimum	19%	22%	8%	2%	0%
Mean	42%	40%	13%	4%	1%

In the case of four wheel drive tractors (table 15), the engine group takes the largest share of the accumulated repair costs (46%) when compared to other groups. The transmission assembly group procure about 37%, followed by the hydraulic system group which accounts to 12% of the total accumulated annual repair costs. The electrical and unspecified groups account for the remaining 5% of the total repair costs.

Table 15: Distribution of repair costs into assembly groups of 4WD tractors

	Engine	Transmission	Hydraulic	Electrical	Unspecified
Maximum	84%	86%	37%	20%	1%
Minimum	13%	6%	0%	0%	0%
Mean	46%	37%	12%	4%	1%

Table 16 presents the results of the distribution of the accumulated repair costs of two wheel tractors owned by small-to-medium scale farmers. The result indicates that the engine group component accounts for most of the accumulated repair costs. The mean contribution of this group is 41%. The transmission and the hydraulic system groups are the next, contributing to 26% and 21% of the total accumulated repair costs respectively. The electrical group components accounts for 7%, while as mentioned before the unspecified group takes the remaining 5%.

Table 16: Distribution of repair costs into assembly groups of 2WD tractors (SMSF)

	Engine	Transmission	Hydraulic	Electrical	Unspecified
Highest	52%	55%	36%	17%	5%
Lowest	17%	0%	15%	3%	5%
Mean	41%	26%	21%	7%	5%

The findings of the distribution of the accumulated repair costs can be summarised that most of farmers owning tractors in Tanzania spend more than 70% of the total accumulated repair costs in restoring the performance of the engine and the transmission groups. The reason for that could be due to the considerable work required to expose the damaged part of the engine and transmission groups, as compared to other groups. For example it is easier to identify and correct an electrical problem than changing a damaged gear in the tractor gearbox. The implication of these finding is that when one needs to reduce the repair costs of tractors in Tanzania should be prepared to pay much more attention to these two groups than other groups. If primary failures of these groups can be discovered and rectified early then there is a potential of serving substantial amount of money. The same findings as the these have been reported by BOHM (1993) [14].

5.3.3 Repair cost functions

In this study repair cost prediction functions were based on the relationship between the accumulated repair costs as percentage of the initial purchase price against the cumulated hours of use - just like most of the previous studies.

The total accumulated repair cost functions developed in this study for different tractor types are obtained from the curves plotted in appendix 6.1 to 6.6. These prediction functions are presented in table 17. Whereas the prediction functions for assembly groups of different tractors are shown in appendix 7.

Table 17: Repair cost functions for different groups of tractors

Tractor make/group	Repair cost function	R^2
Massey Ferguson	$TAR = 2.6517\left(\frac{X}{1000}\right)^{1.4574}$	0.988
Case International	$TAR = 3.0536\left(\frac{X}{1000}\right)^{1.6694}$	0.9969
Ford	$TAR = 3.9613\left(\frac{X}{1000}\right)^{1.4353}$	0.9957
Same	$TAR = 5.0813\left(\frac{X}{1000}\right)^{1.4206}$	0.9911
Four Wheel Drive	$TAR = 0.157\left(\frac{X}{1000}\right)^{3.049}$	0.8078
Two wheel drive (SMSF)	$TAR = 0.4639\left(\frac{X}{1000}\right)^{2.3775}$	0.9297

where: TAR = total accumulated repair costs as % of initial price (I.P)
X = cumulated hours of usage

The result in table 17 shows that the power functions are the best prediction models of the total accumulated repair costs against the cumulative hours of use because the coefficients of determination (R^2) for all tractor groups except for the Four Wheel

Drive tractors indicate more than 90% of the accumulated repair costs are attributed to variation in cumulative tractor hours. The coefficients of determination for the 4WD tractors was found to be around 81%. The low value of the coefficient of determination of the 4WD tractors in comparison to other groups shows that the power function is not the best curve of fit for the data points of this group. But due to the fact that repair costs are best predicted by power function, it was then necessary also to represent the repair costs of this group in that form.

The functions derived from this study however cannot be generalised to all tractors in Tanzania because as observed at the beginning of this chapter, large variations in repair costs occur from one tractor to another. The variation is acknowledge due to difference in other factors that are not included in the modelled functions. These factors include maintenance practice, inherent tractor defects, environmental, operator skill and altitude, accounting procedure, etc. Nevertheless the developed functions provide an important analytical model which indicates the nature and magnitude of the repair costs. In that case they are appropriate to be used in determining the expected repair costs for a given tractor type.

5.3.4 Comparative repair cost curves

Comparison of the repair costs of 2WD tractors under large and small-to-medium scale ownership is presented in figure 25. The result shows that the 2WD tractors owned by small-to-medium scale farmers have lower repair costs at early life up to cumulated use of about 6,500 hours than tractors owned by large scale farms. This fact could be partially explained by the fact that tractors owned by large scale farms are operated sometimes by different operators and therefore make them more disposed to abuse at the early life than those owned by small-to-medium scale farmers which have the advantage of being strictly operated by one person. However above 6,500 hours the repair costs of these tractors increase at a higher rate than the 2WD tractors owned by large scale farms. This could be partially explained by the fact that at high accumulated usage the 2WD tractors owned by the small-medium scale farmers are too old in comparison to those owned by large scale farms at the same accumulated hours. This being attributed by low level of annual usage. In that case they have higher failure rates than their counterparts.

Massey Ferguson tractors under large scale farms are characterised with the low repair costs when compared to other tractor makes. The reason for this could be due to the fact that Massey Ferguson tractors experience less frequency of failures as compared to other tractor makes. This is because the costs of spare parts for different 2WD tractors do not differ much from one make to another. Same, Case International, and Ford tractors have high accumulated repair costs. One possible explanation for Same tractors to have high repair cost is because of its lower initial purchase price when compared to other tractor makes owned by large scale farms.

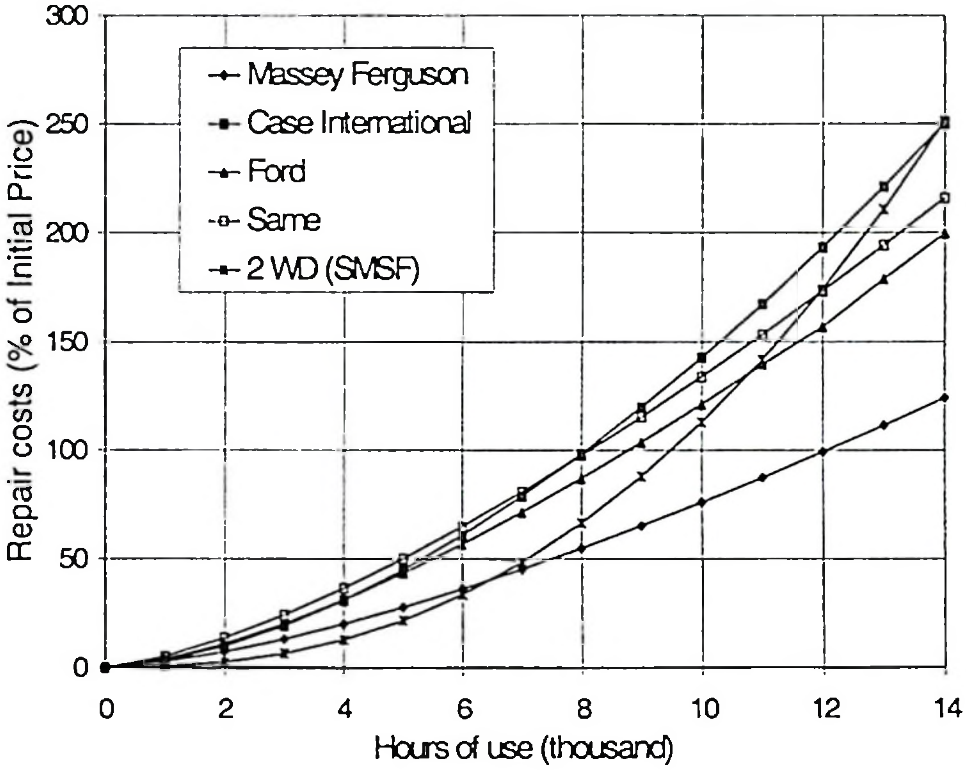

Figure 25: Comparison of repair costs of 2WD tractors (this study)

The results of 2WD tractors obtained in this study shows consistency with the findings in other countries obtained in earlier studies [4, 41, 60]. However the overall average magnitudes of the accumulated repair costs function of the 2WD tractors in Tanzania (figure 26) are higher than those published in Europe and America. On the other hand the magnitudes of repair costs of 2WD tractors in Tanzania are almost equal to the result of repair costs documented in another African country, Burkina Faso for that matter [41].

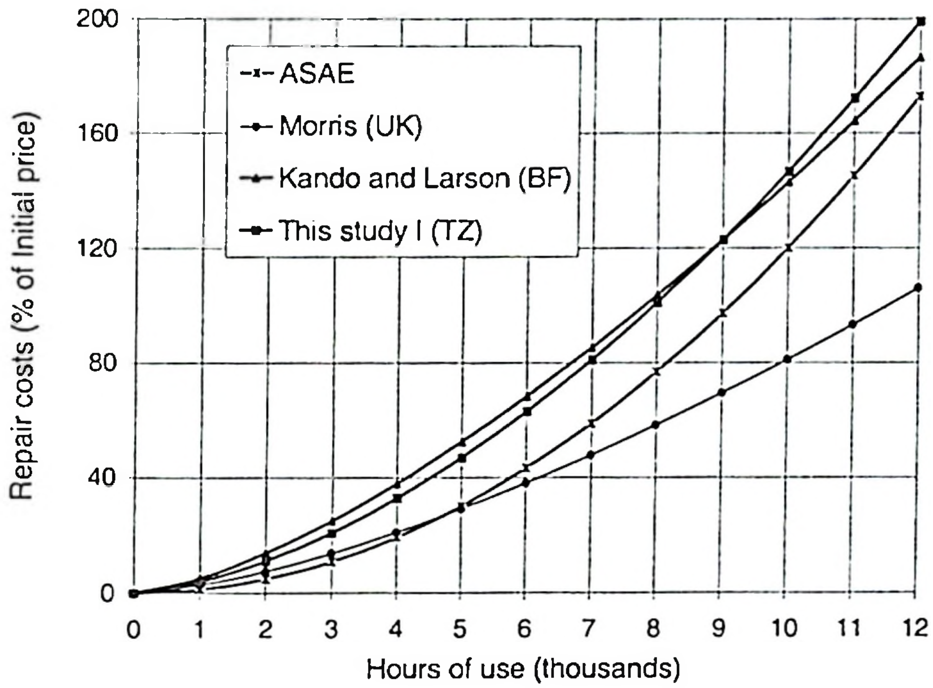

Figure 26: Comparison of repair costs of the 2WD tractors with other sources

The results of the 4WD tractors of this study were compared in figure 27 to the functions model developed in Germany [99, 102]. Repair costs of this study were lower during tractor early life than the predicted repair costs in Germany, but at higher usage of above 7000 h the repair costs in Tanzania were higher than that of Germany. This may be explained by fact that at early life less attention was taken to repair the 4WD tractors in Tanzania, in that case tractor owners had to suffer higher repair costs at the later ages.

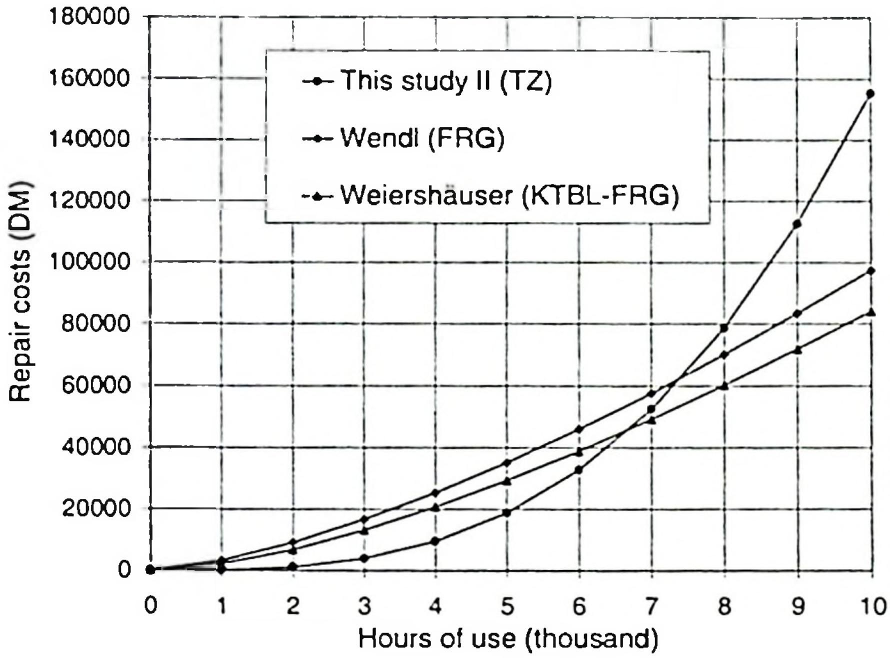

Figure 27: Comparison of repair costs of 4WD tractors with other sources

These findings could therefore be confirming the hypothesis speculated by BEPPLER AND HUMMEIDA (1985) [12], which states that repair costs in Africa may be greater than the corresponding repair costs in Europe or America.

The reason for high repair costs in Tanzania could either be explained by the high costs of the imported spare parts because labour cost in Tanzania is lower than that of Europe and America [98, 102] or due to the fact that most of the tractor operators have never undergone any training in tractors operation. Therefore they do not carry-out the routine maintenance of their tractors as specified by manufacturers. The resulting effects are higher frequencies of breakdowns and therefore higher repair costs. During data collection however almost all tractor operators indicated that they do perform routine maintenance as scheduled in tractor service manuals but the truth of it remains questionable. On the other hand, if the operators do really perform the maintenance as scheduled in tractor manuals then the problem lies on the specifications provided by tractor manufacturers. Probably the repair and maintenance specifications provided by the manufacturers are not very appropriate to some of the operating conditions in which tractors are used. However the service manuals provided for tractors to be used in Europe and Africa are the same.

5.4 Annual costs of tractors

The results of annual costs of different tractors in this study were obtained for three different levels of utilisation, namely the annual use of 500, 1000 and 1200 hours. These levels were chosen because tractors in Tanzania are found to operate within these ranges. As mentioned in chapter 4, equation 4.1 was used to determine the annual cost of the tractors. The loan for investment was assumed to be obtained from CRDB bank.

The current averages initial price for the different tractor types used in the calculations are shown in table 18. The price is much more influenced by the average power of the tractors rather than by the tractor makes.

Table 18: Current initial price of tractors in Tanzania

Tractor type	Average tractor power (kW)	Initial price (Tshs)
Massey Ferguson	62	22,400,000
Case International	64	24,000,000
Ford	58	22,000,000
Same	52	18,700,000
4WD	91	35,340,000
2WD (SMSF)	52	18,000,000

The ownership period of tractors used in the programme was taken to be 19 years. The choice of the period was based on the information obtained from the field survey, for example it was found out during data collection that some of tractors (Massey Ferguson, Case International, and 4WD) in Tanzania were operational for at least 19 years. The bank rates used in the calculation programme were 10% for the investment interest rate and 22% for the loan interest rate. The 9% inflation rate was used because this was the average current inflation rate in Tanzania [96].

Appendix 8.1 to 8.6 show the summarised results of the annual ownership cost per hour at different ownership periods. The results of which are presented in figure 28 to 33 respectively. All figures demonstrate that the annual ownership costs of different tractors decline rapidly in the first few years but after sometimes the annual cost curves become flatter. When the ownership period is extended further the total cost curves increase with the increase of tractor age. This kind of trend is a typical result of the annual ownership costs one can expect [33, 108]. In the early life the machines (tractors) are usually experiencing a decrease in capital costs. Whereas in later stages when the curve is on the increase, tractors are usually suffering from the increase in repair costs due high rate of wear and tear.

The results of the annual costs at different levels of utilisation indicate that 2WD tractors with annual use of 500 hours have higher annual cost than 2WD tractors performing about 1000 or 1200 hours annually. However in the case of 4WD tractors the result in figure 32 shows that the annual cost of tractors used for 500 h per year is higher within the first 10 years of ownership than that of tractors used for 1000 or 1200 hours. Above 10 years of ownership 4WD tractors with annual usage of 1200 hours are found to have high annual costs followed by tractors used for 1000 hours.

The increase of annual use from 1000 hours to 1200 hours for most of the tractors in the first few years of ownership decrease the annual costs. However the decrease in cost is minimum (maximum being about 16% decrease at most). At later stages of tractor ownership the annual costs of tractors operated for 1200 hours per year tend to increase more than tractors with annual usage of 1000 hours. This fact could be elaborated with an example of the 2WD tractors owned by small-to-medium scale farmers (figure 33). The figure shows that the annual costs of 2WD tractors used for 1200 hours per year are higher than the annual cost of the same type of tractors used for 1000 hours per year for the period above 10 years.

Therefore these results suggest that it is more economical for most of the 2WD tractors to be used for an average of 1000 hours per year than to be operated below or above that figure. Whereas in the case of 4WD tractors it is more economical to be operated at an average annual use of about 500 hours than 1000 hours. This is because 4WD tractors need first to be replaced after a long period of use than 2WD tractors due to their high initial purchase prices. Secondly although the 500 hours seems to be few hours but the fact is 4WD tractors can perform a lot of activities within such time span because they are bigger machines and therefore their performance is higher than that of 2WD tractors.

The result of the annual costs of Massey Ferguson tractors (figure 28) indicates that the minimum annual cost of these tractors will be about Tshs 9,800 per hour if these tractors will be used for 1000 hours per year. The minimum annual ownership cost of Case International tractors (figure 29) will be about Tshs 11,500 per hour. Whereas figure 30 shows that the minimum ownership cost of Ford tractors will be about Tshs 10,800 per hour. The result in figure 31 shows that the minimum annual cost of Same tractors will be about Tshs 9,200 per hour. The minimum annual cost of 4WD tractors will about Tshs 18,000 per hour (figure 32), if these tractors will be used for 500 hours per year. The results of 2WD tractor owned by small-to-medium scale farmers are presented in figure 33. The minimum annual operating cost of these tractors will be about Tshs 8,200 per hour for annual usage of 1000 hours. The explanation for the difference in annual cost per hour between different tractors could be due to the difference in the initial purchase prices of the tractors and in repair costs.

The comparison of the minimum values of annual ownership costs established in this study with the annual costs of owning tractors in Germany (table 19) shows that the annual costs of using tractors in Tanzania are high by almost 1.1 to 1.5 times the annual costs of owning tractors in Germany. The reason for this is attributed more to higher operational costs in Tanzania than in Germany.

Table 19: The annual ownership costs of Tractors in Germany
Source: KTBL, 1998/99 [48]

Tractor type	Annual cost (DM/h)	Annual cost (Tshs/h)
2 WD (49 - 59 kW)	17.82	6772
2 WD (60 - 74 kW)	20.64	7843
4 WD (75 - 92 kW)	43.17	16405

Note: DM 1 = Tshs 380

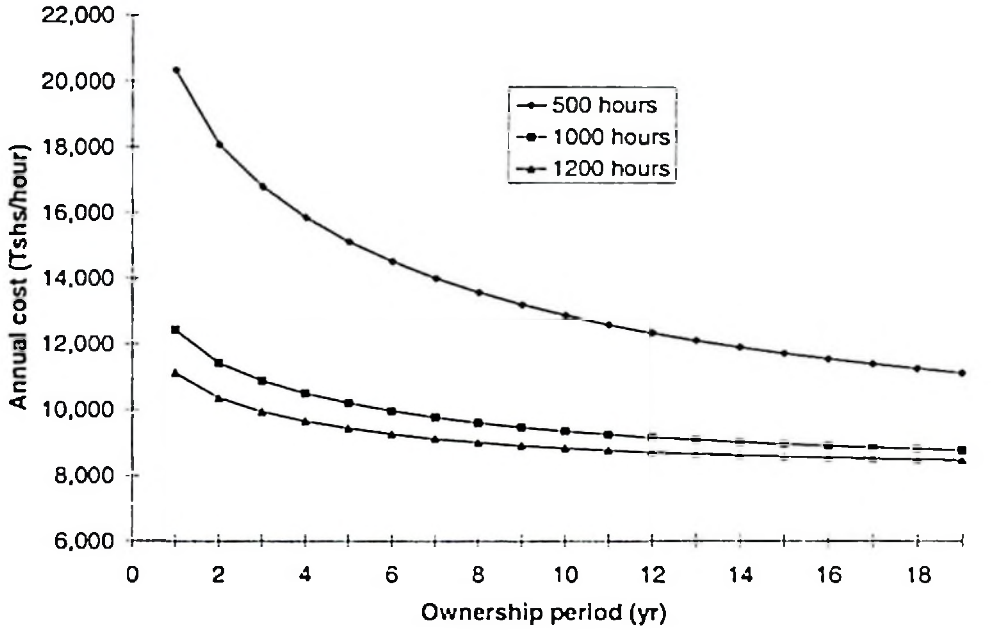

Figure 28: Annual ownership costs of Massey Ferguson tractors at different period

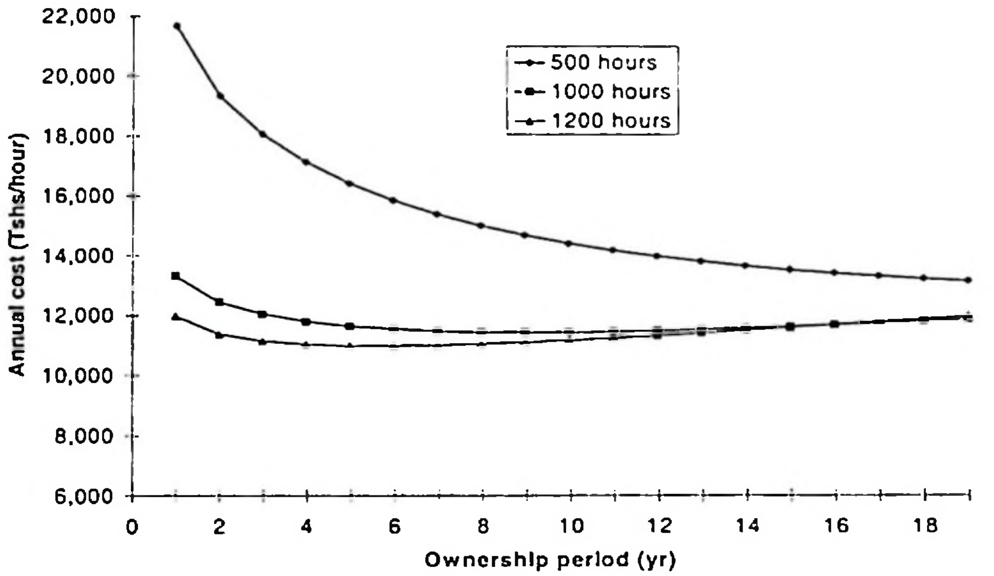

Figure 29: Annual ownership costs of Case International tractors at different periods

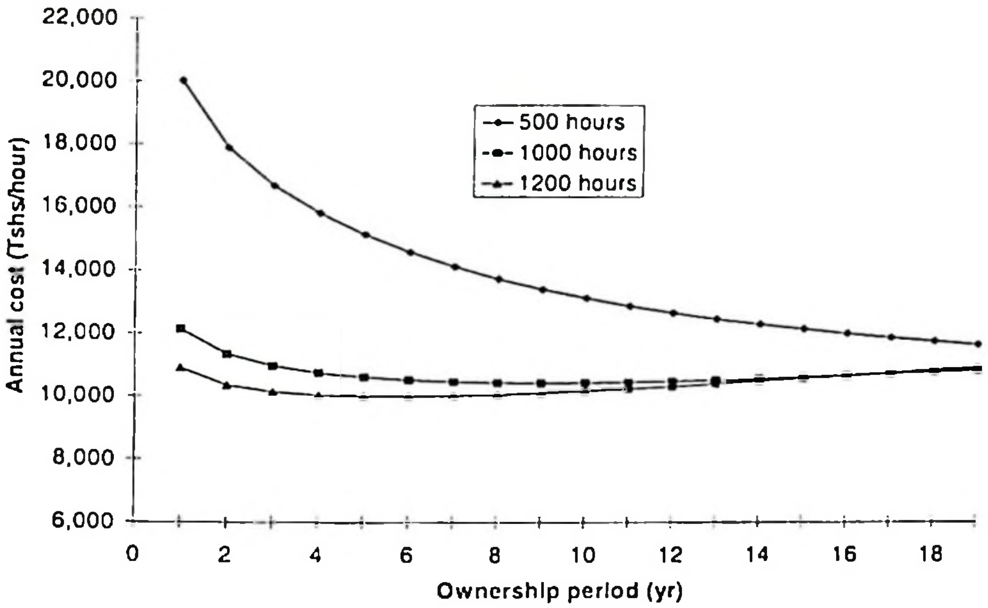

Figure 30: Annual ownership costs of Ford tractors at different periods

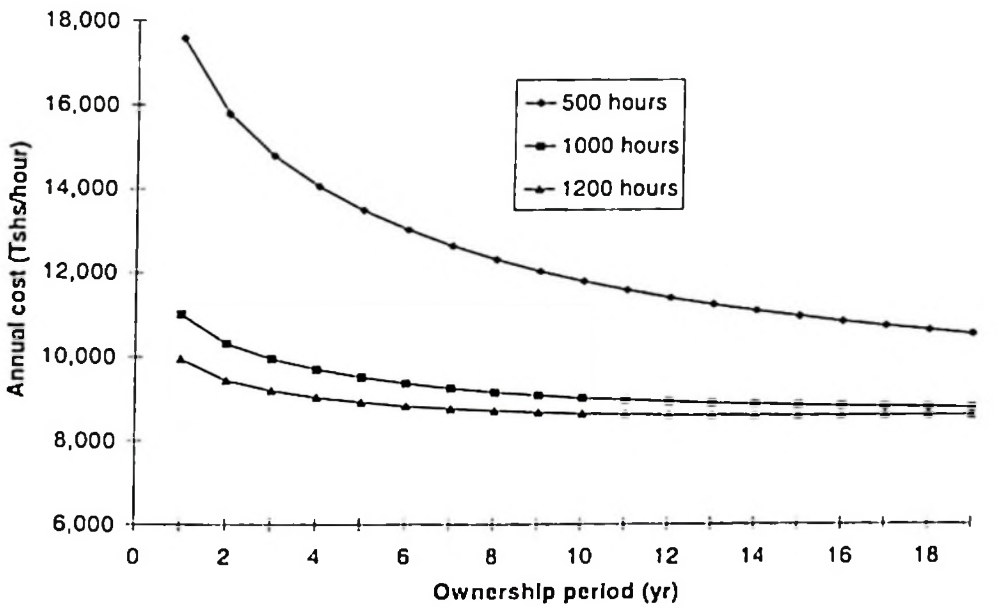

Figure 31: Annual ownership costs of Same tractors at different periods

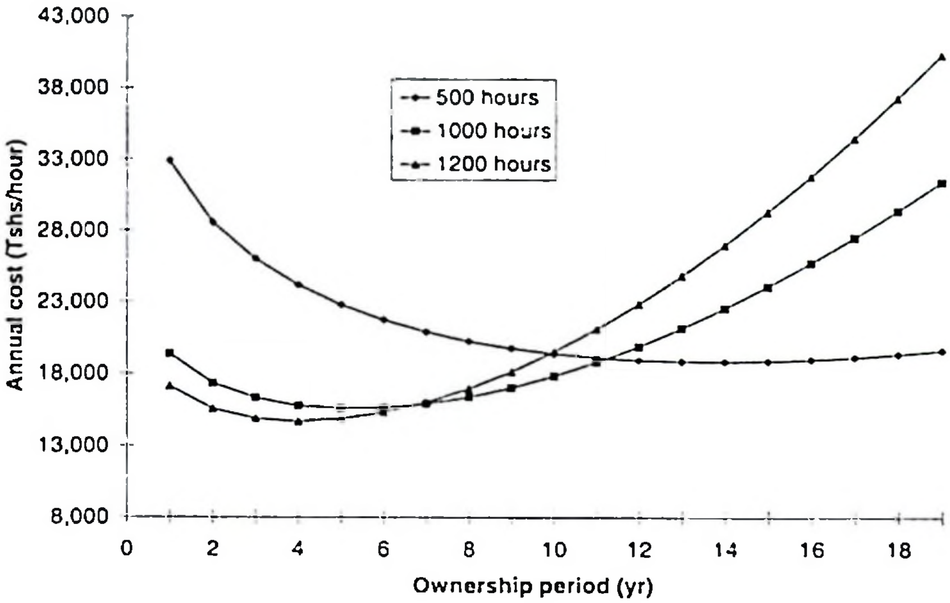

Figure 32: Annual ownership costs of 4WD tractors at different periods of ownership

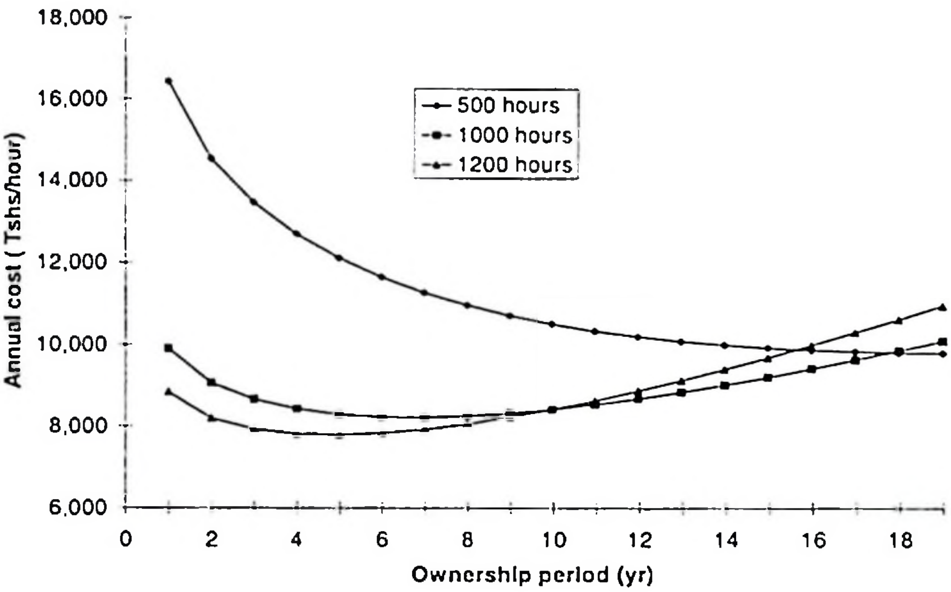

Figure 33: Annual ownership costs of 2WD tractors (Small-to-medium scale farmers) at different periods

It is however possible to reduce the annual costs of tractors in Tanzania if some measures will be taken. Some of the measures that can be used apart from using the tractors optimally are the possibility of using tractors with low initial price or by reducing repair costs of the tractors.

The initial price of the tractor has a significant effect to the annual cost. If this can be reduced then the annual ownership cost of tractor can also be substantially decreased. In Tanzania this can be achieved by the use of imported second hand tractors. In Morocco for example, where the mechanisation degree is still low like that of Tanzania, a considerable number of second hand tractors are used for agricultural activities [16]. More than 50% of the estimated 43,000 tractor units in Morocco are imported second hand tractors. Their experience shows that even though modifications on the imported second hand tractors are carried-out at the beginning, once the tractors are bought, the final initial costs of second hand tractors are far below the initial price of the new tractors. Generally the second hand tractors in Morocco have given a good response for farmers needs despite the problems of high repair costs. WARD (1990) [97] also suggested that second hand tractors of less than 4 years are the best option for farmers with annual use of about 400 to 900 h.

On the other hand, reducing repair costs of the tractors could be another feasible measure to decrease the annual costs of ownership. Actual repair costs can be reduced by maintaining tractors carefully. This could be achieved by employing well educated and trained tractor drivers in the field of tractor operations, service and maintenance. In the case of tractor operators who are employed but do not have quality in tractors operation, short training courses need to be arranged for them. In Tanzania training courses can be arranged through the government extension services system in collaboration with tractor dealers, or vocational training centres. Additionally it is high time now for the tractor operation programme to be incorporated in the daily extension services system offered by the government of Tanzania to farmers. The tractor programme can be addressing activities like the importance of tractor record keeping, routine maintenance on tractors, minimum area to be cultivated per year when using a certain size of tractor, etc. Just like how other activities are addressed to farmers, for example how better a farmer can conserve soil, the importance of using improved seed and fertiliser, etc.

Other important method which can be used to reduce the ownership costs is to replace tractors within the optimum period. Every farmer or machinery manager has to consider from the very beginning replacement of tractor once that tractor is bought.

5.5 Recommended tractor optimum replacement age

Tractors like all other machines have definite life span. Economic life of a tractor is defined as the number of years over which the annual ownership cost is minimum [36, 51, 65, 71]. There is a point at which it is more economical to replace a tractor than to accept increasing repair costs. Operating tractor above this point results in unnecessarily additional costs that make agricultural mechanisation unattractive.

During data collection it was found out that some of the tractors owned by large scale farms in Tanzania were operated for at least 19 years. This indicate that the tractor replacement policy of the farms was not dictated by the rule of lowest cost per utilisation hours as suggested by a number of researchers. Instead it was revealed that replacement of tractors in most cases was decided by top management based on the availability of funds for investment from other sources. This finding agrees with the study of MWOMBEKI (1992) [64]. In his study MWOMBEKI found out that most of the National Agriculture and Food Corporation farms in Tanzania ceased operation due to lack of replacement of machinery because the farm management did not have funds for replacement. Similarly a personal conversation with small-to-medium scale farmers with tractors revealed that most of the money obtained by these farmers especially from hire service jobs is regarded as a profit. In other words there is no money set aside for depreciation and later for replacement purpose. The little money saved by most of the farmers is only for repair works.

The recommended optimum replacement ages of various tractor makes included in this study are shown in table 20. The results were obtained by considering the periods in figure 28 to 33 at which the annual ownership costs of tractors are minimum. However in case where the minimum point could not be established, the importance of technological advancement was considered. In that case the replacement periods were taken at the year where the decrease in annual cost with time was so minimum from the adjacent years.

The results presented in table 20 for 2WD tractors are for the annual use of 1000 hours, whereas the results for 4WD tractors are for the annual usage of 500 h because in chapter 5.4 it was recommended that this two groups of tractors should be used at that annual levels. The useful life of Massey Ferguson and Same tractors is recommended to be about 10 years. Case International and Ford tractors are recommended to be replaced at the age of 8 years. The table also shows that the 4WD tractors have to be replaced at the age of 14 years, while the 2WD tractors owned by small scale farmers are recommended to be replaced at the age of 7 years. The recommended replacement ages are equivalent to an average total use of between 7000 and 12000 hours.

The comparison of the these results agree very well with the findings of the other previous researchers. Particularly WARD *et al.*, (1985) [98] proposed 8000 h as the best period for replacement of tractors. While BOWER AND HUNT (1970) [17] were of the opinion that 12000 h is a more realistic period for replacement. Other findings documented in different data books show that 10000 h is the best time for tractor replacement [48]. However all findings agreed that the actual replacement ages of tractors are significantly affected by annual usage levels and changes in repair and reliability costs over time.

Table 20: Optimum recommended replacement age for different tractor groups

Tractor	Annual use	Recommended replacement age
Massey Ferguson	1000	10 years or 10000 hours
Case International	1000	8 years or 8000 hours
Ford	1000	8 years or 8000 hours
Same	1000	10 years or 10000 hours
4WD	500	14 years or 7000 hours
2WD (SMSF)	1000	7 years or 7000 hours

The results of the tractor replacement age established above as mentioned before were based only on levels of tractor usage. Yet it is not clear how other factors in the function used for determination of the annual costs can affect the replacement age. These factors include the bank interests and the inflation rates. Inflation rate in Tanzania for example dropped from 33% in 1994 to 9% in 1999 and still the prediction indicates that the inflation rate will drop to about 6% in 2002 [96]. Changing inflation rate will also affect the bank interest rates. In that case a sensitivity analysis was conducted in order to determine the effect of these factors on the replacement age of tractors and to broaden the applicability of the results to other situations.

To simplify the analysis the investment interest rate was assumed to be constant while varying the inflation rates and the loan interest rates. The inflation rates were varied by decreasing the values from 0% to 40% of the investment interest rate, while the loan interest rates were changed by increasing the values from 0% to 140% of the investment interest rate. In the analysis however the investment interest rate was considered to be 10%. In that case the inflation rates used in the analysis were varied from 10% to 6% and the loan interest rates were changed from 10% to 24%.

The sensitivity analysis was carried out using data of 2WD (SMSF) tractors only at two levels of annual usage, namely 500 h and 1000 h because of avoiding repetition. As the effect of bank interest rates and inflation rates to the optimum replacement age are considered to be the same on both 2WD and 4WD tractors due to the fact that the determining functions used in calculation are the same.

The results of this findings are plotted in figure 34. At high annual use the effect of inflation rates and bank interest rates are insignificant on the optimum replacement age, but at low annual usage the result shows that as the inflation rates decrease while increasing the loan interest rate the replacement age of the tractors increases.

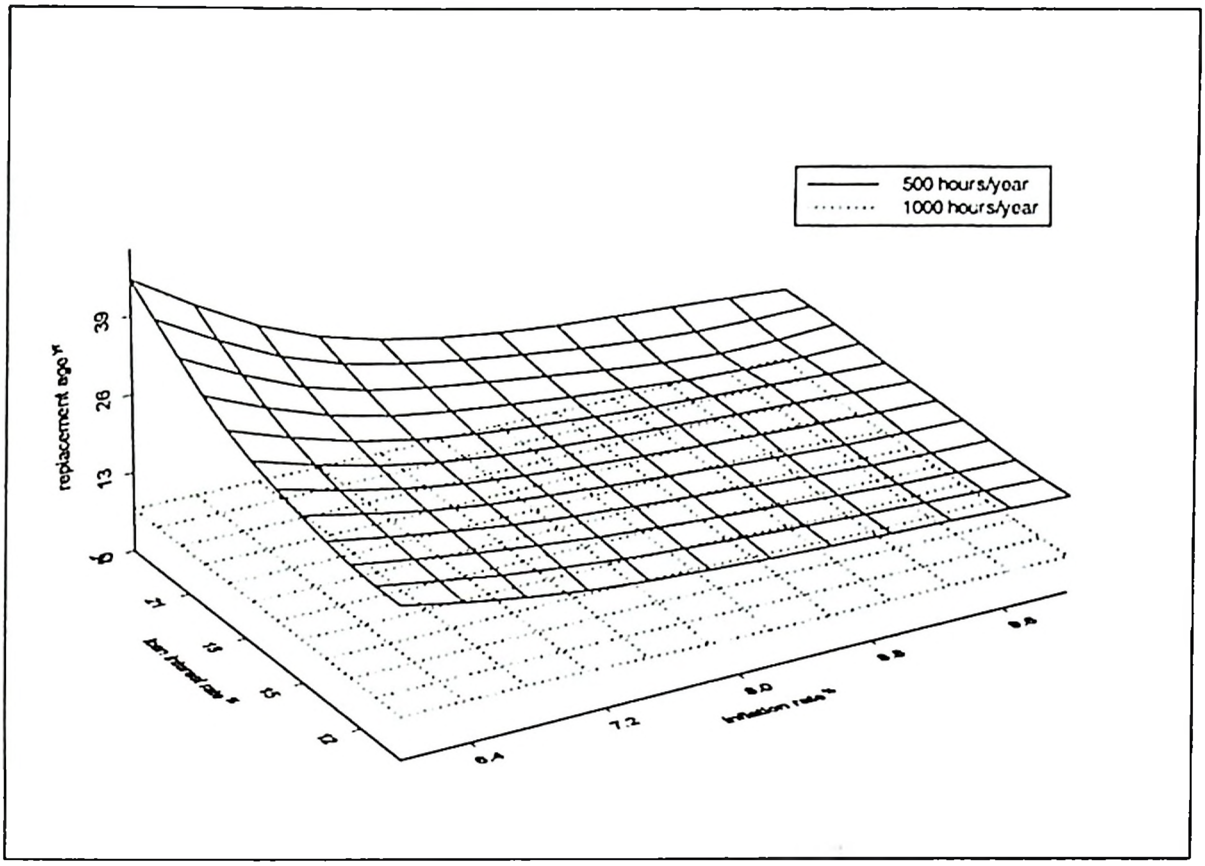

Figure 34: The effect of bank interest and inflation rates on optimum replacement age

However in order to establish the reason for the effects shown in figure 34 another analysis was done by varying inflation rates from 9%, 8%, 7% to 6% while the loan interest rates were varied from 22%, 18%, 14% to 12%. Four different usage levels (500, 600, 800 and 1000 hours/year) were considered in each scenario using the same data of 2WD tractors owned by the small-to-medium scale farmers.

The results of this analysis (appendix 9.1 and 9.2 and plotted in figure 35 to 38) show that when investment rate and loan rate are kept constant while varying the inflation rates, the replacement age decrease with the increase of inflation rate at low annual usage of 500 and 600 h. However at high levels of annual usage the replacement age is almost unaffected (figures 35 and 38). This could be partially explained by the justification raised by PERRY AND NIXON (1991) [71]. At low annual usage, the capital cost required the tractor be kept for longer period to spread the cost over more years. Whereas at high usage the great benefits accrued from the investment encourages more rapid replacement. Similarly when loan and investment interest rates are kept constant, the low inflation rate will encourage to deposit money into the bank rather than taking a loan and in so doing the investor will be encouraged to keep the tractor at a longer period. But if the inflation rate is increased, these discourage depositing money into the bank rather the situation encourages to take a loan, in that case the environment is good for more rapid replacement. At high annual levels of usage the benefits will be playing the key role as a result the change in inflation rates will have very little impact to replacement age. This finding however is somehow in line by the statement made with YULE *et al.*, (1988) [111] that the replacement age of tractors is affected by inflation. With low inflation they suggested that it is better to keep a machine longer, while in times of high inflation it is better to change machinery more rapidly.

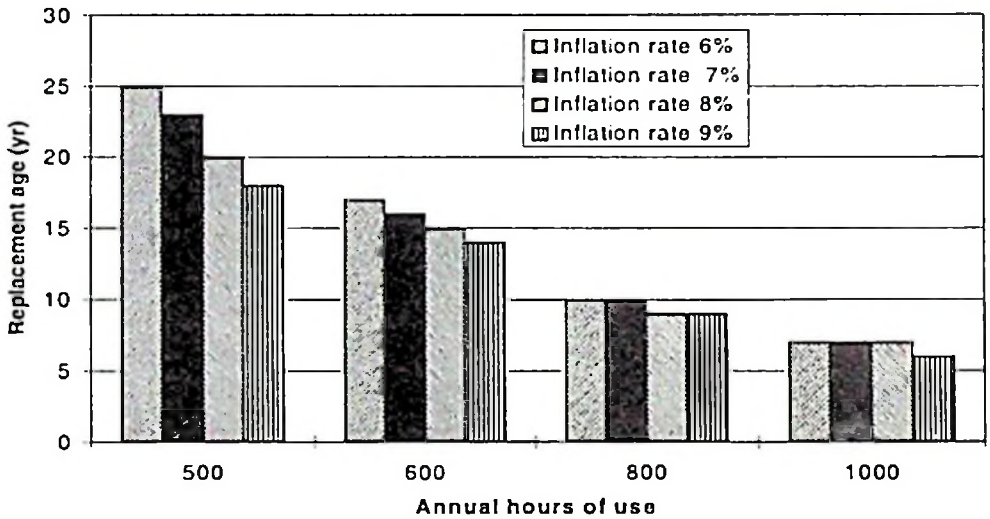

Figure 35: The effect of inflation rates on the optimal tractor replacement ages for different levels of annual usage (Loan interest rate 18%, investment interest rate 10%)

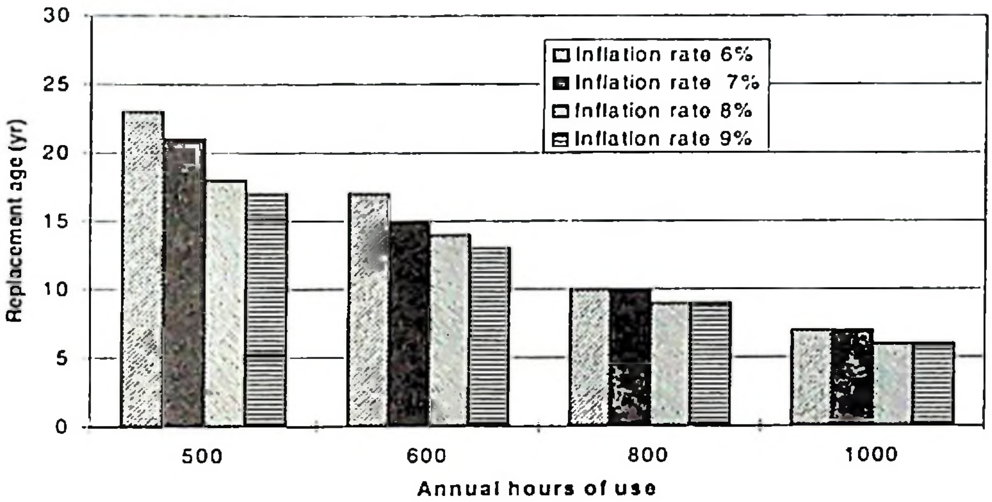

Figure 36: The effect of inflation rates on the optimal tractor replacement ages for different levels of annual usage (loan interest rate 12%, investment interest rate 10%)

On the other hand, when investment interest rate and inflation rate are kept constant while loan interest rates are changed, the replacement age of the tractors increases with the increase of the loan rates at low annual usage (500 h and 600 h). At annual use of about 800 to 1000 h, loan rates had almost no effect on the optimal replacement age (figure 37 and 38). This could again be partially explained by the fact that the increase of loan rates increases the capital expenses of the tractors. Therefore at lower annual usage the period to keep the tractor is extended to spread the costs over more years.

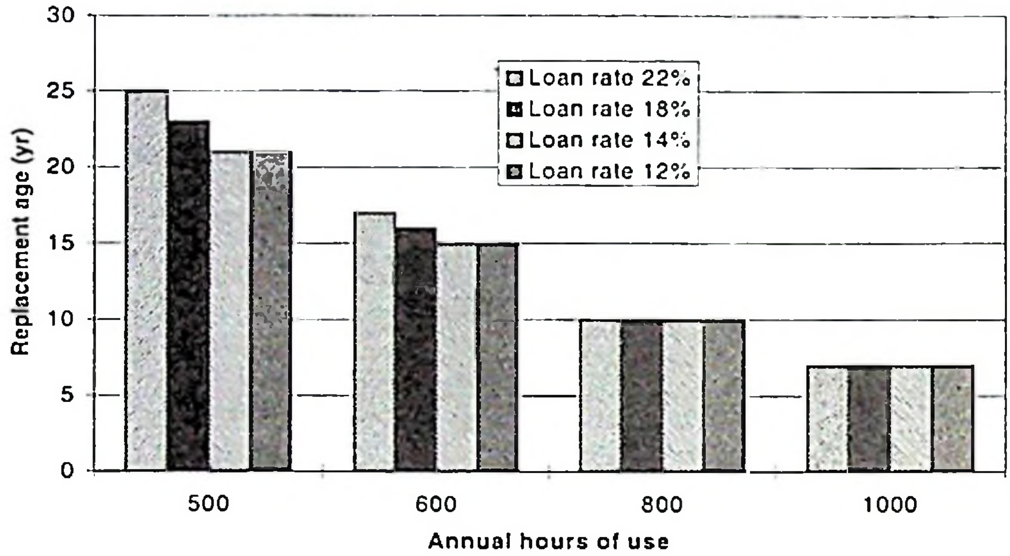

Figure 37: The effect of loan interest rates on optimum tractor replacement ages for different levels of annual usage (inflation rate 7%, investment interest rate 10%)

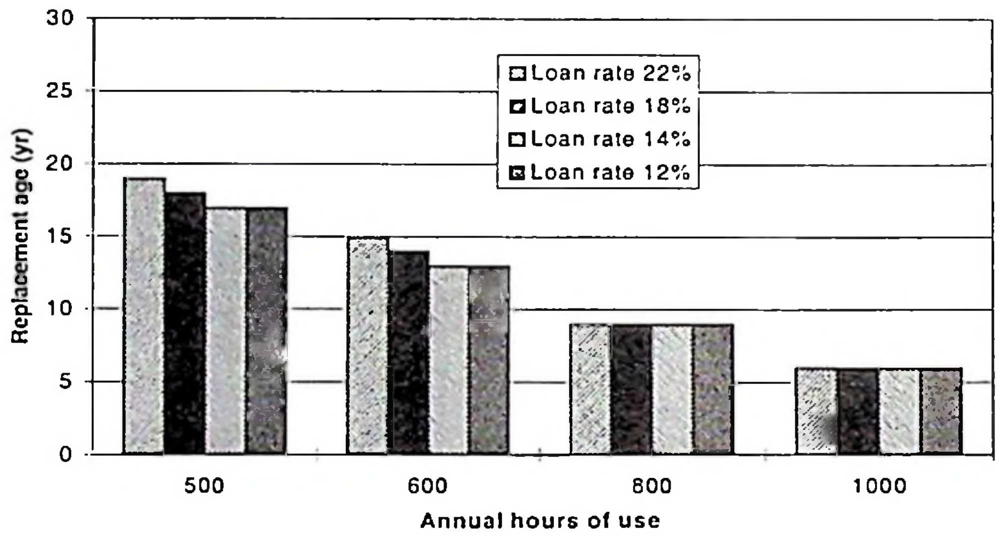

Figure 38: The effect of loan interest rates on optimum tractor replacement ages for different levels of annual usage (inflation rate 9%, investment interest rate 10%)

5.6 Annual costs of draft animals

The annual costs of using draft animals (oxen) in Tanzania were determined by considering the results of the analysis of data collected from the field and by considering some few assumptions. The assumptions were based on information obtained from secondary sources such as literature.

In accordance to material and methods (4.2.3) a replacement period of six years was used in the calculations presented in this work. Other assumption was on the acquisition of draft animals, just like in the case of tractor technologies, the importance of financial support was also considered in the analysis. It was assumed that farmers using draft animals for agricultural activities have equal access to financial institutions operating in the country as farmers using tractors. This means the purchase of draft animals was considered to be financed by the bank loan (CRDB bank in Tanzania). An interest rate of 22% is charged on the loan given to the farmers. The loan repayment is spread over the economical life of the draft animals.

The summary of the result of costs obtained from field survey are presented in table 21. The table shows that the purchasing price of a non trained draft animal (ox) in Shinyanga region is lower than that of Morogoro region. According to t - statistic the variation difference of the mean purchase price of ox is significant at 99% confidence level. This is not a surprise because as mentioned before Shinyanga region has a tradition in animal keeping while Morogoro region does not. The traditional keeping of cattle result into higher population of oxen in Shinyanga region than in Morogoro region. In that case the supply of oxen to the local markets in Shinyanga is higher, thereby resulting to lower price of ox than in their counterpart Morogoro region.

Table 21: Result of costs(Tshs) of draft animal (ox) in Shinyanga and Morogoro regions

	Shinyanga	Morogoro	t - value
Average purchasing price per ox	75,340	166,470	-6.6***
	(36%)	(36%)	
Annual tax per ox	500	400	-
Mean annual vaccination cost per ox	5,019	3,633	1.93
	(54%)	(24%)	
Mean annual dipping cost per ox	9,519	5,547	3.42***
	(46%)	(26%)	
Mean annual treatment costs per ox	10,981	11,067	-0.05
	(40%)	(58%)	
Average annual housing costs per ox	1,300	3,850	

Note: Values in brackets are coefficient of variations

*** Significant at 99% confidence interval

- Not applicable

The annual tax rates per cattle in both areas are set by the local government of the respective areas. The results of the tax rate revealed that there is no much difference in values in the two regions.

It is a common trend for farmers in Shinyanga and Morogoro regions to vaccinate their cattle (including draft animals) against a number of diseases which tend to erupt in their areas. Farmers in both areas mentioned *black quarter*, *foot and mouth* rot, *rinderpest*, *pleuropneumonia* and *East Coast Fever* as the major diseases which erupt in their areas. The average annual vaccination cost per draft animal in both areas is shown in table 21. Farmers in Shinyanga region spent more cost on vaccination than in Morogoro. However the statistical t - value shows that there is no significant mean cost difference between the areas at 95% confidence level.

Dipping is another measure taken by farmers of both areas to protect the draft animals and other animals against diseases caused by protozoa, transmitted by ticks (*anplasmosis*, *babesiosis* and *theileriosis*) and other external parasites. In most cases the dipping wells are owned by the respective local governments of the areas. Farmers pay the local government a fee per animal every time they take animals for dipping. The fee paid for dipping is around Tshs 100 per animal per dip in both areas. Nevertheless, the mean total annual dipping cost per draft animal incurred by farmers in Shinyanga region is higher than in Morogoro region. The statistic also confirms the mean cost difference at 99% confidence level. The reason for the difference could be partially explained by the fact that in Shinyanga, most of farmers keep large number of cattle because they regard cattle as their only wealth (banks). Therefore in order to protect the animals from loss caused by tick borne diseases they take their animals frequently for dipping to keep them clean and health. However, in Morogoro region farmers do not consider cattle as their only wealth and thus the level of care of the animals is not so high and this is reflected in the low dipping frequency.

The treatment costs of draft animals are the costs that farmers incur to cure sick animals. It includes diagnostic charges and the cost of buying drugs. The result of t-statistic indicates that there is no significant mean difference in the annual treatment costs between Shinyanga and Morogoro regions. Nevertheless, the result in table 21 shows that farmers in Morogoro region have higher cost in treatment of ox than in Shinyanga region. This is perhaps due to the problem of the *trypanosomiasis* disease caused by tsetse-fly in Morogoro region.

Other important cost component of the draft animals is the housing costs. The housing costs in Morogoro are relative higher than in Shinyanga region. This could be explained by the fact that in Shinyanga region farmers accommodate many cattle in one housing than in Morogoro. In Morogoro region most of the farmers keep a small number of cattle in a house, in most cases a pair of draft oxen. As a result, when the housing costs are distributed to the total number of cattle accommodated in a housing, the result is low housing costs per animal in Shinyanga.

The results of the minimum total annual costs of owning and using a pair of draft animals in Shinyanga and Morogoro regions are shown in table 22. The total costs are regarded to be minimum because the costs do not include the feeding costs and labour costs during off season. The feeding costs was not considered because the feeding management practised by majority of farmers in both areas depend on free range grazing, while family labour is used for taking care of the animals during grazing. The family labour in these areas is regarded as free because no monthly salary is paid.

Table 22: Annual costs of using a pair of draft animals (oxen) in Shinyanga and Morogoro regions

Parameters	Shinyanga	Morogoro
P_{ad} - purchase price of trained ox	82,874.00	183,117.00
S_a - salvage value of ox	128,078.00	282,999.00
L_a - economical life of oxen	6 years	6 years
$f_1(1)$ - annual depreciation cost for a pair of oxen	- 15,068.00	- 33,294.00
$f_2(1)$ - annual interest cost for a pair of oxen	48,394.00	106,931.00
$f_3(1)$ - annual housing cost for a pair of oxen	2,600.00	7,700.00
$f_4(1)$ - annual insurance cost for a pair of oxen	13,260.00	29,299.00
$f_5(1)$ - annual tax cost for a pair of oxen	1,000.00	800.00
$f_6(1)$ - annual health cost for a pair of oxen	51,038.00	40,494.00
$f_7(1)$ - annual labour cost for controlling a pair of oxen	27,000.00	27,000.00
$f_8(1)$ - annual compensation due to a pair of oxen	1,400.00	1,400.00
TOTAL	129,624.00	180,330.00

The overall minimum total annual cost of using a pair of oxen in Shinyanga region is Tshs 129,624 and in Morogoro region is found to be Tshs 180,330. Considering this finding it can be concluded that the cost of using draft animals in Tanzania varies from one area to another. Areas with tradition in cattle keeping have advantage of low annual costs of using draft oxen as compared with areas of little or no tradition in cattle keeping. This finding is somehow proving the hypothesis speculated by MREMA AND MREMA (1993) [62] that animal traction technology is more suitable (socially and economically) for farmers with tradition in animal keeping than those without tradition.

5.7 Comparison of annual costs of tractors and draft animals

Comparisons of the annual costs of using tractors and draft animals were carried out in order to determine how expensive are the two power technologies in relation to each other. Moreover to establish the optimum sizes of the farms that are suitable to be cultivated by either of the power sources. To achieve this, the analysis was carried out by comparing the annual cost per unit output power and then by comparing the annual cost per unit area for different farm sizes.

The average power outputs shown in table 8 were used for determination of the annual cost per output power (kW) of tractors. In the case of the draft animals the output power extracted from literature was used in the calculation because during data collection the output power of draft animals was not measured. However, STOUT (1979) [84] reported that the power outputs of draft animals working under tropical conditions vary from 0.44 kW for a pair of *Zebu* bullock to 0.97 kW for a pair of *Indian Brahman* oxen. Similarly KWILIGWA *et al.*, (1991) [49] found out that a pair of the *East African zebu* cattle provide power output of about 0.56 kW for six hours per day. Therefore in accordance to these the annual cost per output power of using draft animals in Shinyanga and Morogoro regions was based on the output power of 0.56 kW. The results of this analysis are shown in appendix 10.1 and in figure 39.

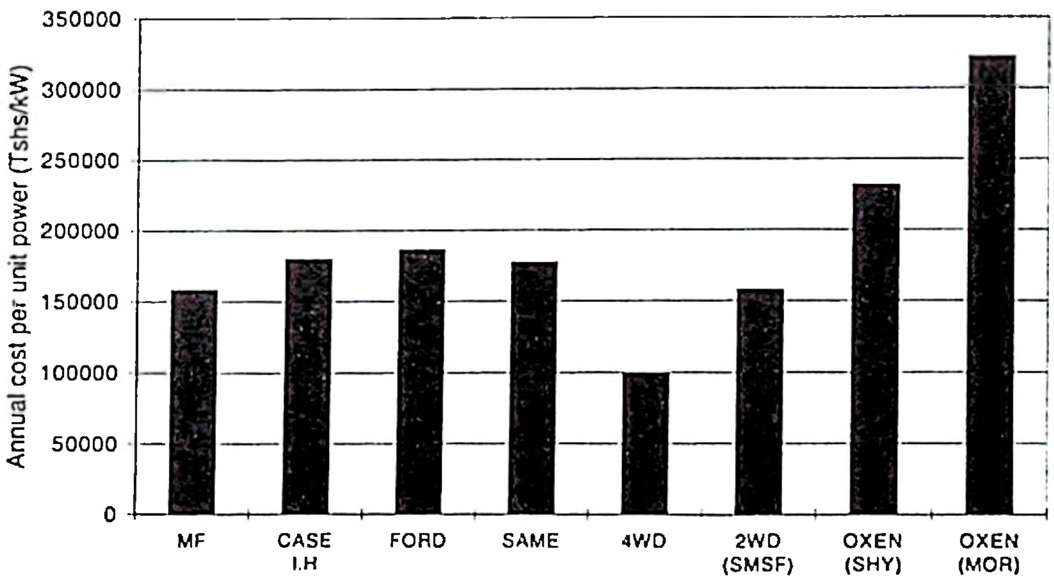

Figure 39: Comparison of annual costs per unit output power of tractors and draft animals

The results show that a unit output power obtained from draft animals is more expensive than the same output power procured from tractors. As an example, the annual cost per output power of using a pair of draft animals in Shinyanga is about Tshs 230,000. The annual cost per unit output power of using 2WD tractors owned by small-to-medium scale farmers is around Tshs 158,000. The reason for high annual cost per output power of a pair of draft animals is attributed by the small magnitude of output power generated by this technology.

The comparison of the annual costs per output power of draft animals show that the unit output power acquired in Morogoro region is 39% more expensive than that secured in Shinyanga region. The comparison of the annual costs per output power of different tractors show that the output power obtained from Ford tractors is the most expensive. Whereas the output power obtained from 4WD tractors is the least expensive. The output power from Ford tractors is about 50% more expensive than the output power obtained from 4WD tractors. The annual cost per output power of Case International and Same tractors is almost equal. Similarly the annual cost per output power of Massey Ferguson and 2WD tractors owned by small-to-medium scale farmers is almost equal.

The analysis for determination of the annual costs per unit area of animal drafts is shown in appendix 10.4 and the procedure used for determination of the annual costs per area of tractors is shown in appendix 10.5. The results of the findings of the annual costs per unit area of animal drafts and tractors (appendix 10.4 and 10.5.3 respectively) are compared in figure 40.

The annual costs per unit area (ha) of draft animals increase as the farm size is increased. This is due to the assumption made in the study that a pair of oxen in Tanzania is capable of cultivating a maximum area of about 4 ha. When a farmer (using draft animals) intends to increase the farm area then the pair of oxen need to be increased as well. This in turn increases the demand of labourers required to control the animals, leading to an increase in the wage paid to labourers (appendix 10.3). Without increasing the wage it is impossible to get the required number of labourers. In that case the up-rise in annual costs per area of draft animals shown in figure 40 are attributed to the increase of labour costs. All other cost components such as initial price, insurance, medication per unit area remains constant with the increase of area because these costs are directly proportional to the number of animals available.

The results of the annual costs of tractors per unit area decrease with the increase of farm areas. A very high cost is incurred when the farm size is small. The costs decrease sharply as the farm size is increased to about 50 ha. Then the curves decrease slowly and later flattens out as the farm size increases more than 150 ha for all tractors. This could be explained by the fact that large farm area needs more annual hours of use than small farms. Therefore when the fixed costs are spread over larger number of hours (large farm area) the cost decrease with the increase of the hours of use. The trend of the annual costs per hectare of tractors obtained in this study are consistence with the studies conducted with other previous researchers [47, 97].

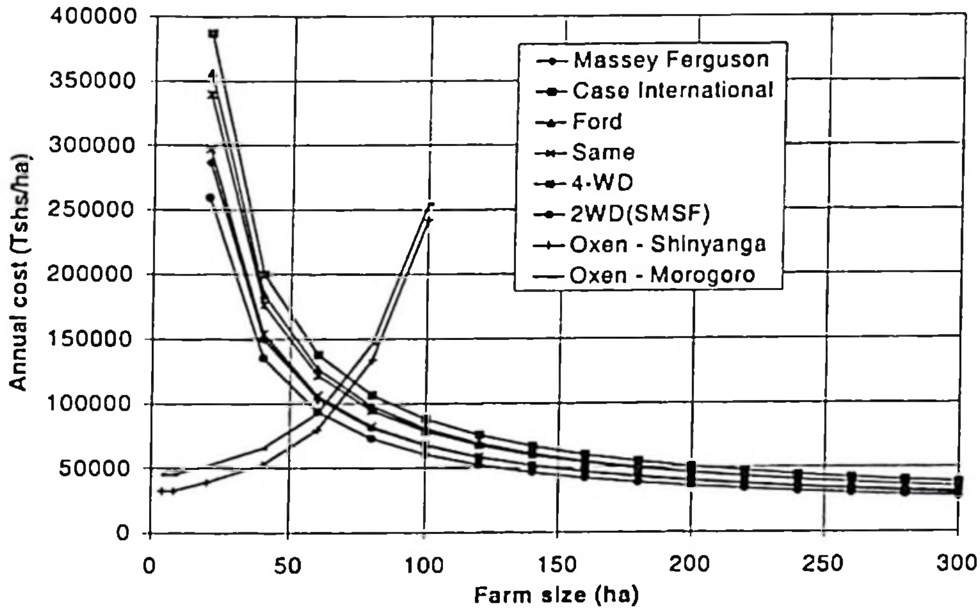

Figure 40: Comparison of annual costs per hectare for different farm sizes

The results in figure 40 imply therefore that farmers with small farm sizes of about 4 to 10 ha are advised to own and use draft animals for agricultural production. Annual cost per hectare of owning draft animals for small farm sizes is much lower than that of owning a tractor for same number of hectare as can be seen from the graph.

Farmers with farm areas of more than 100 ha can be advised to own tractor for their agricultural activities because the annual costs of tractors per unit area at these sizes are shown to be less than that of using draft animals. However farmers having between 50 ha and 80 ha of land can own tractor on the condition that they should be prepared to offer contract services to other farmers so that the minimum area to justify ownership of tractor of more than 100 ha per year is reached.

Whereas for farmers with farm areas of between 20 ha to 40 ha could not be advised to own tractors or draft animals instead they can be advised to hire tractors from other farmers or else increase their farm sizes.

Similar findings have been reported in different studies such as that of HENDERSON AND FANASH (1984) [33] in Jordan, RAHMOO (1979) [72] in Pakistan and HUNT (1983) [36] in USA. HENDERSON AND FANASH reported that to justify owning a tractor in Jordan the area of the farm should not be less than 100 ha. Whereas RAHMOO stated that to justify owning a 2WD tractor in Pakistan the area of the farm should be between 100 and 200 ha. Other finding is that of HUNT, who stated that to own a 75 kW tractor the farmers need to have the optimum farm of about 240 ha. Therefore the results obtained from this study and the standard mentioned above show that the relationship between farm area and tractor cost per unit farm area is positive.

6. THE IMPLICATION OF THE FINDINGS

Tractor as a power unit is an essential farm power input in medium or large scale agricultural production system. The cost of owning and using tractors in Tanzania is found to be slightly higher than that in developed countries. The problem of high cost is not due to the fact that the technology is not appropriate for Tanzanian condition as it was noted in the government second five year plan [91]. Instead it is due to improper farm practice and inability for farmers to perform farm operations like business enterprise. Lack of tangible decision making factors associated with limiting management requirement for optimisation of agricultural production costs could perhaps be the source of the problem. However according to this study there is a possibility to minimise annual costs of tractors and thereby increase the opportunity to maximise profit for the whole agricultural production system in Tanzania. In that case agricultural productivity in Tanzania could be stimulated and increased more fold than at present.

6.1 Tractor operation and management data

In any management system proper data keeping is a very fundamental resource for making and effecting decisions for prediction of the future of the business. Record keeping as reported in Tanzania is not practised at all by the small-to-medium scale farmers. The record keeping exercise by the large scale farms was seen to be a useless formality because it was very difficulty to obtain a well-kept complete record for each tractor at every farm visited. The recorded data in most cases was not used to influence any decision for making cost/return budget for farm production system. Also the recorded data was not used at all to influence the optimum replacement period of the tractors.

It is therefore very beneficial to increase awareness on the importance of record keeping in Tanzania to all agricultural machinery owners. This could be achieved by addressing the issue through seminars and short courses. The participants could be all personnel involved in tractor management including tractor owners, operators, and in the case of large scale farms also management personnel and entry clerks could also be involved. It will be also interesting to open up a special project unit at the department of agricultural engineering of the Sokoine University of Agriculture in Tanzania. The project unit will be responsible in collecting this data, analysing and sending some feed back to tractor owners. The proposed project unit could establish links with similar institution elsewhere, such as KTBL in Germany to benefit from their experience.

The study also revealed that within large scale farms there was no standard format of keeping tractor records. This was reflected by the various sources of records in different farms. The recorded data was extracted from all sorts of forms, including files, exercise books, ledgers, loose sheets and all differing in features and content. If at all the project unit will be established then one of its task will be to standardise the format of data keeping. However according to this study, it is proposed that the data should be kept in log books. The log books should be issued to all farmers with tractors through the available government extension offices in Tanzania. The log books have to be kept by the tractor operators and should contain sufficient space for one month entries only. The log books should be exchanged for a new one each month. The extension officers could be used to check for the collect methods of data entry and then forward them to the project unit.

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 period of occurrence. It is recommended that any standard tractor record keeping should include this item. This would in course of time reveal inherent design defects common in different tractor types, makes or models.

6.2 Applicability of repair costs prediction functions

The empirical findings of the repair cost prediction functions agree fairly closely with the results of earlier studies developed elsewhere [4, 41, 60, 99, 102]. Therefore the developed functions in this study can be used to estimate the expected magnitude of repair costs of tractors at different period of ownership. However, it should be noted that large variations between the predicted and the actual repair costs should be anticipated to occur because the prediction functions do not include all factors responsible for tractor failures.

Generally these findings provide an important information which was lacking in the scope of agricultural mechanisation in Tanzania. Previously, functions established for tractors in developed countries were used for prediction of repair costs of tractors at different ownership period in Tanzania [12]. Unfortunately the estimated magnitudes of repair costs in this study have shown to be different from those established in USA or Europe.

The developed prediction functions however will have to be reviewed from time to time as more data will be collected for the existing machines or as other new machines will be introduced to Tanzania market. This is also the case for developed countries. For example ROTZ AND BOWER (1991) [73] reported that in the USA studies on repair costs of machinery have gone through several revisions. The first finding on repair costs was reported in 1941 but they continue to be changed as the new machines are developed or machines are redesigned.

6.3 Importance of the annual cost findings

The findings of annual costs of tractors and draft animals provide also an important information that was lacking from agricultural extension materials in Tanzania. It is therefore presumed that agricultural planners in Tanzania will change their views as far as mechanisation with tractors in Tanzania is concern because the results of the annual costs have shown that with a certain size of the farms the use of tractors is justified than the use of draft animals. Nevertheless, it is important to observe management factors when using tractors for agricultural production so as to minimise the annual costs and thereby increase the overall profit.

On the other hand, these results have a clear message to policy change in Tanzania. That is instead of relying on the current small peasant farmers to increase agricultural production the policy should be changed toward depending on small-to-medium scale farmers.

For the past 30 years the policy of Tanzania has been geared to increase the agricultural production by use of peasant farmers. But experience has shown that peasant farmers have failed to increase agricultural production in Tanzania. Simply because most of peasant farmers in Tanzania have failed or indicated low adoption rate of new technologies such as from hand tools to draft animal implements. The animal draft technology seems to be more complicated than the use of hand tools. Although most of the requirements for draft animals are within the reach of the peasant farmers mainly concerning technical and managerial skills.

If the government will encourage small-to-medium scale farmers then it will be encouraging the use of tractors in agricultural production. Small-to-medium scale farmers can operate commercial agricultural production by observing the economics of scale, to include the increase of farm sizes. The major groups of people who can be part of the small-to-medium scale farmers will include the businesspersons and the young educated people who as of to-date are busy migrating from rural to urban areas to liberate themselves from back breaking job associated with hand tools.

In practising such a policy, the role of the government will be to initiate the availability of credit to farmers for necessary farm inputs. Only farmers capable of engaging themselves in agricultural activities and producing should be availed to such credit facilities. This is because the loans offered by the banks tend to be given to the people with fixed asset in Tanzania. This perhaps could be a problem for the young educated people who intend to establish themselves in farming enterprises. It is also important to note that the credit to be offered should be strictly on commercial principles. Other important role of the government should be to advise these farmers to practise good agricultural mechanisation. The work of advising farmers should continue through the use of extension services.

The government should remove all unnecessary policies that discourage investment in agricultural production, such as those of not allowing farmers to own large pieces of land. The government should encourage open trade policy, whereby farmers can be allowed to sell their produce even to the neighbouring countries. Especially when the prices of produce in the neighbouring countries are more attractive than that of within the country. It has been the policy of the government to encourage and assists industries to sell their products to other countries but the same government discourages farmers to sell their produce (food crops) to neighbouring countries. The author of this report remembers one case where farmers were held by police because they were transporting their maize to sell in the neighbouring country where the price was much higher than inland. If the government does not want farmers to export their produce then it should be prepared to buy those produce at a price equal or more than that offered outside the country. Otherwise hindering farmers in the free trade market system will paralyse even the commercial oriented farmers.

7. Summary and Conclusions

The use of tractors in Tanzania has been for the past 30 years considered to be inappropriate. This has resulted to the population of tractors in the country to drop. Moreover the overall agricultural production has stagnated. But when observing the green revolution of other developing countries, such as those of far east, countries like India, Malaysia, etc. have recorded greater economic growth in the 20th century as a result of improved means of production in agriculture through increase use of tractors. All countries which have realised this potential, and which have properly employed tractor technology in agricultural production have made considerable advancement in economic development.

In order to stimulate the use of tractors in Tanzania, this study was initiated. With the aim of determining the costs of owning and using tractors under Tanzanian conditions which could act as a support in advising farmers to use the technology profitably. Currently such information is not available.

The analysis of this work was based on the hypotheses that the output power generated from tractors is cheaper than the output power generated from draft animals. Also if tractors are used properly based on the technical and economic factors, then the annual costs per unit area of the cultivated land are lower than that of draft animals. It should be noted here that the animal draft technology is being favoured by the government policy since in 1969.

The work started with determination of repair costs of tractors because tractorization in Tanzania has been observed to be limited with number of problems, among these repairs is one of the major sources. The software programme for calculating the annual costs of tractors was developed and the recommended optimum periods for replacement of tractors for different levels of utilisation were also ascertained. Similarly, the annual costs of using draft animals in a place with and without tradition of cattle keeping were determined. Then a direct comparison of the annual costs of tractors and draft animals was carried-out.

Data for the study was collected in Tanzania for a total period of 8 months in six regions, namely Arusha, Iringa, Kilimanjaro, Morogoro, Shinyanga and Tanga. Tractor data was collected from 12 large scale farms and 19 small-to-medium scale farmers. The recorded tractor data from large scale farms were collected from the past records, whilst data from small-to-medium scale farmers were collected by interviewing the respondents, who relied mainly from recalling. Animal draft data was obtained from 30 households by the use of questionnaire.

Data of 121 tractors were collected from large scale farms. Out of these 96 were two-wheel drive tractors and the rest were four-wheel drive tractors. Data of 25 tractors were collected from small-to-medium scale farmers. The results of the 2WD tractors owned by large scale farms were classified based on tractor makes, to include Massey Ferguson, Case International, Ford and Same. Other tractor groups were not classified into tractor makes because the number of tractors in the group were too small to permit a meaningful statistical analysis. In the analysis of repair costs, the actual repairs were classified into 5 major assembly groups, namely engine, transmission, hydraulic system, electrical and the other group for unspecified components.

Data for draft animals was collected in Shinyanga and Morogoro regions. Shinyanga region represented the area with tradition in cattle keeping. While Morogoro region represented areas with no tradition in cattle keeping but draft animal technology is being introduced to reduce the problem associated with shortage of farm power.

The major findings of the results are summarily presented as follows:

1. The survey data indicate that most of the tractor operators in Tanzania (85%) have never undergone any training in operating and caring of the tractors. About 10% of the operators are not able to read and write. However about 70% of tractor operators has the basic education, thus they can read and write in Swahili. It was the opinion of this work that training course for operators is very important because the training programme will expose the drivers on the facts regarding caring of tractors. Otherwise it is very difficult for operators to carry out for example tractor routine maintenance by relying on tractor manuals that are

written in English language. Whereas English language is not a commanding language for the most of the operators. The repair costs of tractors can possibly be reduced if trained operators will be used.

2. The mean utilisation levels of tractors vary between 600 and 1100 hours per year per tractor. The utilisation levels of 2WD tractors owned by large scale farms are higher than 2WD tractors owned by the small-to-medium scale farmers. The reason could be due to the fact that large scale farms own large areas of land that are found to be in one area. While small scale farmers own small farms which are scatted from one place to another. The 4WD tractors owned by large scale farms were found to have few annual hours of use because they are regarded as special tractors. In that case they are restricted to heavy assignments only.

3. The repair costs analysis have shown an extreme range of coefficient of variations for the total repair costs and for the repair costs of the different assembly groups from one tractor to another in the same group. Also the results have shown that the annual repair costs of tractors vary widely with the increase of tractor's age. The Massey Ferguson tractors owned by large scale farms were found to have minimum average annual repair cost per hour. While 2WD-Case International and 4WD tractors were found to have the highest average annual repair cost per hour.

4. The results of repair costs according to assembly groups revealed that more than 70% of the costs are used to restore the performance of the engine and transmission groups for all tractor groups. The reason could be partially explained by the considerable work required to expose the damaged part in the engine and transmission than in other assembly groups. In that case these are areas which offer a potential for repair costs saving, if attention is taken to prevent primary damages.

5. The repair cost prediction models were best represented as a power functions of the accumulated hours of use similar to the results of the previous researches. The results of 2WD tractors owned by both large and small-to-medium scale farmers were found to be consistent in magnitude with the result of Burkina Faso [41]. The result of 4WD tractors were consistent with the results published in

Germany [99, 102]. However, at higher accumulated usage above 7000 hours they predict extremely higher repair costs than that of Germany. Generally the applicability of the established prediction functions is recommended, besides the fact that the variations in the magnitude between the predicted values and the actual values are expected. This is attributed to the fact that the functions do not include all factors that affect repairs, namely operators skill and altitude, inherited tractor design defects, maintenance regime, etc.

6. The curves which represented the results of the annual cost per hour indicate that as the period of tractor ownership is increased the annual costs decreases rapidly in the first few years, then the curves become flat. However if the ownership period is increased further the annual costs per hour increase rapidly. The overall annual costs of tractors in Tanzania depends very much on the amount of annual usage. The 2WD tractors used annually for 1000 hours have the minimum annual costs ranging between Tshs 9,800 and Tshs 11,500 per hour. Whereas 4WD tractors used for 500 hours per year have the minimum annual cost of about Tshs 18,000 per hour.

7. Comparison of the annual costs of tractors established in Tanzania with that appearing in Germany's agricultural machinery standards book [48] shows that the annual costs in Tanzania are high by almost 1.1 to 1.5 times the values reported in Germany. Nevertheless, in the report important measures were discussed on how these costs could be reduced. The measures include increasing annual utilisation and reducing repair costs by using trained operators. Other measures include that of reducing initial costs by using second hand tractors, a case of Morocco was cited as an example.

8. The survey data provided an evidence that the replacement period of tractors in Tanzania for both small-to-medium and large scale farmers is not guided by the economical principles. Tractor owners do not set aside funds which could be used later for replacement of tractors. To reverse the situation requires the need to address the issue in order to impart the importance of optimum replacement period to tractor owners. The analysis of data collected shows that the optimum replacement ages in Tanzania range from 7000 h to 12000 h. The comparison of

these findings agrees with the results published elsewhere [17, 98]. Additionally, It was found out that low inflation rates and high bank loan interest rates at low tractor annual usage increases the optimum replacement period of tractors because the rates increase the capital costs. But at high annual usage the effect of inflation and loan interest rates on the optimum replacement are insignificant.

9. In the analysis of the annual costs of using draft animals (oxen) for agricultural activities, the results showed that the purchasing price of oxen in Shinyanga region is lower than in Morogoro region. The mean different was significant at 99% confidence level. The costs spent by farmers for vaccination was higher in Shinyanga than in Morogoro, however the mean difference was insignificant. The dipping costs were higher in Shinyanga than Morogoro and the mean difference was found to be significant at 99% confidence level. The treatment costs which include diagnostic and purchase of medicine were higher in Morogoro than Shinyanga, although statistically the mean difference was not significant. The overall minimum annual cost of using draft animals in Shinyanga region was found to be Tshs 129,624, whereas the minimum annual cost in Morogoro region was established to be Tshs 180,330. That means the area with traditional in cattle keeping has lower annual costs of using oxen than areas without the tradition.

10. The result of the comparison of the annual costs per output power shows that the output power obtained from draft animals is expensive when compared to output power obtained from tractors. The costs of output power from draft animals range between Tshs 220,000 and Tshs 320,000 per kW while that of tractors range between Tshs 100,000 and Tshs 180,000 per kW.

11.The result of the comparison of annual costs of tractors and draft animals based on the size of the farm revealed that the annual costs per ha of the draft animals were found to increase as the farm size increases. However the annual costs of tractors per unit area were found to decrease as the farm size increases. These implied that farmers with small sizes of the farm (less than 10 ha) have to own and use draft animals for agricultural production. The ownership of tractors in Tanzania is justified for farmers owning or capable of cultivating more than 100 ha per year. Farmers having 20 ha to 40 ha are recommended to hire tractors for agricultural production. The comparison of these results with standards established elsewhere were found to be positive [33, 36, 72].

Generally the findings of this study confirm the validity of the study hypothesis. Tractor technology offers a clear solution to the problem of low productivity in the country because tractors can put more land under-cultivation and as it has been found the usage of tractors for large areas of land reduces the annual costs to a level below that of using draft animals for cultivating small sizes of farms.

Since the increase of agricultural productivity is absolute essential in Tanzania due to among other reasons to increase production of food for the increasing population, and cash crops for export to obtain foreign currency for importing essential goods for development and social services. The increment in production is unlikely to be realised through the peasant farmers. This is mainly because peasant farmers are ageing and the young and educated bodies are migrating to urban areas.

Then government intervention to promote the use of tractors in terms of policy change is very essential. The different group of farmers with the ability to manage tractors technically and economically need to be promoted. The farmers to be developed should run agriculture as a commercial enterprise, such that they produce substantial surpluses from their farming operations. Also apart from using tractors for farming practice these farmers have to use modern technologies as a necessary input for increasing production. This group of farmers can no longer be the peasant farmers who are currently depended on by the government. Coupled with policy change, provision of credit and good mechanisation advice through adequate extension services are very important factors for the development of this group.

Future work in this area should be geared in collecting more data under long term and controlled conditions. This could be achieved if the awareness to keep complete tractor records is imparted to tractor owners and operators. Then the data could be used for developing expert system software to assist farmers in selection, utilisation and replacement of tractors. The impact evaluation study could also be carried out by comparing the socio-economics of tractor users with farmers who use other power sources.

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Appendix 1: Questions used in collection of Tractors data

1. Name of the Farm or owner..
   Address ....

2. Location from major town...
   Types of soil in the area...
   Average annual rainfall..

3. Total number of permanent employee at the farm...
   Average number of temporary employee...

4. Total area of the farm...
   Types of crops grown...

5. Types of agricultural machinery available at the farm......................................
   Types of tractors available..
   Types of implements available..

6. General remarks regarding the farm...

7. Tractor technical data
   Tractor type .... Model .... Power ....
   Purchasing price .... Year of purchase ....

8. Name of tractor operator..
   Experience in tractor operation..
   Operator education (according to five ranks) ....
   Any training in tractor operation? .... Where and for how long......................

9. Tractor annual performance history (hours or area cultivated)...........................
   Annual quantities of fuel and oil if available..

10. Types of insurance policy used..
    Historical annual insurance costs...

11. Housing costs if any ....

12. Is routine maintenance carried out?..

13. Tractor repair history: Date and types of repair carried out ....

Appendix 2: Questions used for collection of draft animals data

1. Name of the owner ....
   Address..

2. Location: name of the village ....
   Distance from the major town...

3. Types of draft animals used ....
   Number of draft animals...
   Types of implements available..

4. How big is the farm cultivated using draft animals..
   Crops grown...

5. Purchase price of draft animals..
   Training cost of draft animal...
   Annual housing cost...
   Annual insurance cost..
   Annual tax cost..

6. Types of basic feed used..
   Types of supplementary feed...
   Cost involved in providing basic feed...
   Cost involved in providing supplementary feed...

7. Types of diseases common in the place...
   Annual vaccination cost per draft animal..
   Annual dipping cost per draft animal..
   Annual treatment costs..
   Other annual health cost if any..

8. How many labourers are used to control draft animals.......................................
   What is the labour charge...
   For how long do you pay labourers...

9. Any other comment ....

Appendix 3: Types and number of tractors data collected from large scale farms

Farm	Type of tractor	No. of units
Arusha Seed Foundation	2WD - Case International	1
	4WD - Case International	3
	2WD - Ford	2
Basuto Plantation	2WD - Case International	1
	4WD - Case International	2
Gawal Wheat Farm	2WD - Case International	5
	4WD - Case International	4
Gidagamowd Wheat Farm	2WD - Case International	5
	4WD - Case International	2
Mringa Estate	2WD - Massey Ferguson	3
	4WD - Valmet	2
Mtibwa Sugar Estate	2WD - Ford	5
	4WD - Ford	2
Mulbadaw Wheat Farm	2WD - Case International	3
	4WD - Case International	3
Murjanda Wheat Company	2WD - Case International	4
	4WD - Case International	3
	2WD - Ford	2
Mwera Sisal Estate	2WD - Same	13
	4WD - Same	1
Setchet Wheat Farm	2WD - Ford	1
	4WD - Case International	3
Tanganyika Planting Company	2WD - Massey Ferguson	39
Tanganyika Wattle Company	2WD - Ford	12

Appendix 4: Programme for calculating annual costs of tractors

```
CLS
REM Programme for Calculating Annual Ownership Costs of tractors
INPUT "Enter tractor types"; A$
INPUT "Enter tractor code"; T
INPUT "Enter Purchase price in Tshs."; P
INPUT "Enter Investment interest rate"; r
INPUT "Enter Loan interest rate"; i
INPUT "Enter Inflation rate"; g
INPUT "Enter Annual use in hours"; h
INPUT "Enter monthly salary of tractor operator"; Lm
INPUT "Enter fuel consumption"; Uc
INPUT "Enter fuel price"; fp
INPUT "Enter oil price"; fo
PRINT
PRINT "OUTPUT FILE"
PRINT
PRINT "The Purchase Price of tractor is Tshs "; P
PRINT "Investment interest rate is "; 100 * r; "%"
PRINT "Loan interest rate is "; 100 * i; "%"
PRINT "Inflation rate is "; 100 * g; "%"
PRINT "Monthly salary of tractor operator is Tshs  "; Lm
PRINT "Price of fuel per litre is Tshs  "; fp
PRINT "Price of Lubricant per kg is Tshs  "; fo
SLEEP
PRINT
PRINT "ANNUAL COSTS OF "; A$; " TRACTOR FOR ANNUAL USE OF "; h; "
HOURS"
PRINT
PRINT "Years", "Annual costs (Tshs.)"
FOR N = 1 TO 19
S1 = 0
S2 = 0
```

```
FOR j = 1 TO N
    wn = (1 + g) ^ j / (1 + r) ^ j
    IF T = 40 THEN In = .01 * P * EXP(-.28 * (j - 1) + .007 * (j - 1) ^ 2)
    IF T < 40 THEN In = .01 * P * EXP(-.24 * (j - 1) + .005 * (j - 1) ^ 2)
    S1 = S1 + wn
    S2 = S2 + (In * wn)
    NEXT j
IF T = 40 THEN Sn = P * EXP(-.28 * N + .007 * N ^ 2)
IF T < 40 THEN Sn = P * EXP(-.24 * N + .005 * N ^ 2)
Dn = Sn * ((1 + g) ^ N / (1 + r) ^ N)
REM Rn is Accumulated Repair costs for annual use equal to h hours
IF T = 40 THEN Rn = P * .00157 * (.001 * h * N) ^ 3.049
IF T = 21 THEN Rn = P * .026517 * (.001 * h * N) ^ 1.4574
IF T = 22 THEN Rn = P * .030536 * (.001 * h * N) ^ 1.6694
IF T = 23 THEN Rn = P * .039613 * (.001 * h * N) ^ 1.4853
IF T = 24 THEN Rn = P * .050813 * (.001 * h * N) ^ 1.4206
IF T = 25 THEN Rn = P * .004639 * (.001 * h * N) ^ 2.3775
Z = Rn * (1 + g) ^ N / (1 + r) ^ N
Po = P * i * (1 + i) ^ N * ((1 + r) ^ N - 1) / (r * (1 + r) ^ N * ((1 + i) ^ N - 1))
REM Cl is annual labour cost
Cl = 12 * Lm
REM Fc is annual fuel cost
Fc = fp * Uc * h
REM Co is annual cost of oil
Co = .15 * Uc * h * fo
An = ((Po + Z + S2 - Dn) / S1 + (Cl + Fc + Co)) / h
PRINT N, An
NEXT N
END
```

Appendix 5.1: Analysis of repair costs (Tshs ,000) of 2WD Massey Ferguson tractors

Age	No. of tractors	Usage (hr)	Engine	Transmission	Hydraulic	Electrical	Other	Total
1	15	662	91,67	295,19	33,71	43,10	1,52	465,19
	c.v (%)	45	71	106	184	127	239	69
2	18	983	254,03	213,04	9,90	25,47	2,43	504,88
	c.v (%)	29	113	133	246	106	185	80
3	36	1212	391,88	425,15	17,46	89,57	13,37	937,44
	c.v (%)	24	133	160	187	125	204	92
4	41	1036	661,62	982,08	87,72	205,84	36,61	1973,87
	c.v (%)	35	93	72	209	93	92	57
5	25	932	981,58	945,44	131,78	138,43	28,25	2225,47
	c.v (%)	39	92	99	198	168	148	63
6	19	1081	907,37	836,71	168,61	200,29	16,92	2129,90
	c.v (%)	41	117	90	170	108	130	75
7	30	1320	974,92	836,40	61,24	166,70	19,86	2059,12
	c.v (%)	22	95	91	263	103	151	61
8	35	1147	1251,03	937,78	182,35	394,43	47,39	2812,99
	c.v (%)	35	95	87	172	92	126	74
9	21	970	1002,47	992,14	83,61	262,32	31,94	2372,48
	c.v (%)	31	128	103	192	109	107	96
10	15	705	1903,18	787,25	178,59	106,33	13,16	2988,52
	c.v (%)	6	77	74	161	143	87	59
11	13	813	471,94	1623,50	65,96	138,24	28,00	2327,65
	c.v (%)	26	52	78	124	136	72	58
12	10	708	1412,82	726,99	263,50	52,77	6,75	2462,82
	c.v (%)	20	101	100	171	93	114	69
13	10	790	1566,90	1168,68	139,38	92,11	14,54	2981,60
	c.v (%)	13	95	81	97	113	122	68
14	4	909	617,03	875,26	152,91	8,57	0,00	1653,78
	c.v (%)	15	111	124	148	105	0	96
15	8	857	360,01	564,19	22,52	59,37	8,50	1075,47
	c.v (%)	19	91	98	283	112	109	72
16	7	768	435,96	695,42	0,00	120,42	26,37	1278,16
	c.v (%)	50	90	88	0	96	103	52
17	4	737	3173,11	108,72	53,55	72,87	3,06	3411,32
	c.v (%)	28	45	162	200	74	200	40
18	8	954	1429,27	449,23	2,13	137,78	27,74	2046,15
	c.v (%)	31	89	138	283	116	148	56
19	6	710	1184,75	922,72	296,14	301,12	67,72	2772,45
	c.v (%)	46	84	54	128	93	106	59

Appendix 5.2: Analysis of repair costs (Tshs ,000) of 2WD - Case International tractors

Age	No.of tractors		Usage (hr)	Engine	Transmission	Hyraulic	Electrical	Other	Total
1	8		950	204,40	239,47	139,00	11,13	8,27	638,40
		c.v (%)	23	85	102	139	224	218	77
2	7		886	390,24	1040,47	82,05	73,33	5,86	1591,96
		c.v (%)	29	80	81	103	200	138	33
3	7		384	323,48	581,63	15,60	62,21	0,00	982,92
		c.v (%)	9	86	127	178	138	0	120
4	7		933	431,48	676,93	54,29	118,69	26,91	1308,31
		c.v (%)	41	90	68	133	152	153	50
5	7		683	1215,48	1155,13	90,29	41,71	20,66	2523,26
		c.v (%)	59	68	82	128	253	188	54
6	7		767	987,46	612,89	396,70	136,01	9,67	2142,72
		c.v (%)	51	71	81	100	116	132	46
7	7		571	554,63	764,84	105,83	262,38	7,00	1694,68
		c.v (%)	103	107	88	127	113	265	62
8	5		497	739,37	1085,21	65,34	287,99	66,50	2244,41
		c.v (%)	69	112	51	173	70	138	63
9	7		764	2083,80	425,83	45,93	108,29	0,00	2663,85
		c.v (%)	57	100	115	143	151	0	64
10	13		779	3245,67	2442,18	411,73	248,81	44,61	6393,01
		c.v (%)	52	110	80	136	111	161	69
11	13		869	484,96	1660,44	214,12	68,19	30,44	2458,13
		c.v (%)	24	94	86	159	89	89	60
12	14		756	3384,96	945,17	366,55	78,03	15,62	4790,32
		c.v (%)	28	96	115	199	146	261	65
13	14		879	2238,30	1518,77	407,68	95,35	30,55	4290,65
		c.v (%)	25	116	71	162	107	104	80
14	11		831	2079,58	3531,38	269,67	20,79	44,96	5946,38
		c.v (%)	27	115	113	92	212	164	79
15	8		822	2710,34	1550,75	76,52	139,10	9,19	4485,90
		c.v (%)	37	65	120	62	218	151	72
16	8		785	1637,61	744,27	87,59	13,07	3,13	2485,67
		c.v (%)	35	120	150	141	125	262	117
17	7		662	3188,85	250,88	157,07	45,49	2,23	3644,53
		c.v (%)	47	76	189	116	218	265	62
18	6		659	1989,45	195,62	41,90	85,21	56,86	2369,04
		c.v (%)	42	143	121	140	156	117	113
19	2		419	1553,07	76,71	23,24	0,00	0,00	1653,02
		c.v (%)	43	91	115	115	0	0	88

Appendix 5.3: Analysis of repair costs (Tshs ,000) of 2WD - Ford tractors

Age	No.of tractors	Usage (hr)	Engine	Transmission	Hydraulic	Electrical	Other	Total
1	8	858	189,61	386,99	65,72	73,10	5,09	720,51
	c.v (%)	34	131	101	155	133	254	68
2	10	962	390,47	1078,21	127,32	113,36	6,04	1715,40
	c.v (%)	21	49	125	141	123	105	78
3	15	1170	397,65	995,05	82,58	114,57	27,78	1617,63
	c.v (%)	24	83	162	177	102	168	108
4	17	901	779,03	805,51	70,96	176,70	26,01	1858,21
	c.v (%)	34	92	77	217	113	162	58
5	20	970	1714,75	1271,70	77,64	166,41	22,66	3253,16
	c.v (%)	26	95	92	187	133	145	71
6	18	1056	1855,84	820,94	331,92	262,55	12,80	3284,06
	c.v (%)	27	96	95	105	89	154	67
7	17	849	890,52	535,60	63,72	69,29	10,92	1570,06
	c.v (%)	36	112	89	219	101	189	81
8	6	534	519,35	295,15	32,39	79,12	4,77	933,26
	c.v (%)	80	96	138	200	143	245	78
9	11	853	1433,76	942,27	149,86	204,12	23,83	2753,84
	c.v (%)	10	68	75	105	112	143	36
10	12	810	2638,52	1300,05	294,28	45,82	14,63	4293,30
	c.v (%)	12	64	105	107	162	119	36
11	9	877	337,72	2954,62	158,72	82,57	29,17	3562,81
	c.v (%)	16	83	76	56	107	104	63
12	11	761	4435,18	643,57	104,87	46,27	16,87	5246,77
	c.v (%)	22	71	97	114	105	171	65
13	11	751	2803,77	766,21	256,00	117,39	21,53	3964,90
	c.v (%)	10	61	82	221	98	118	51
14	9	890	1259,95	3451,27	134,89	25,34	38,69	4910,14
	c.v (%)	16	67	67	104	123	105	32
15	4	752	1428,24	1090,69	37,19	39,06	3,20	2598,39
	c.v (%)	12	95	84	144	83	75	74
16	4	863	1039,61	185,64	56,43	17,42	0,09	1299,20
	c.v (%)	19	23	73	105	71	200	20
17	5	814	1476,86	1303,00	543,44	32,56	17,85	3373,70
	c.v (%)	15	54	44	70	102	96	22

Appendix 5.4: Analysis of repair costs (Tshs ,000) of 2WD - Same tractors

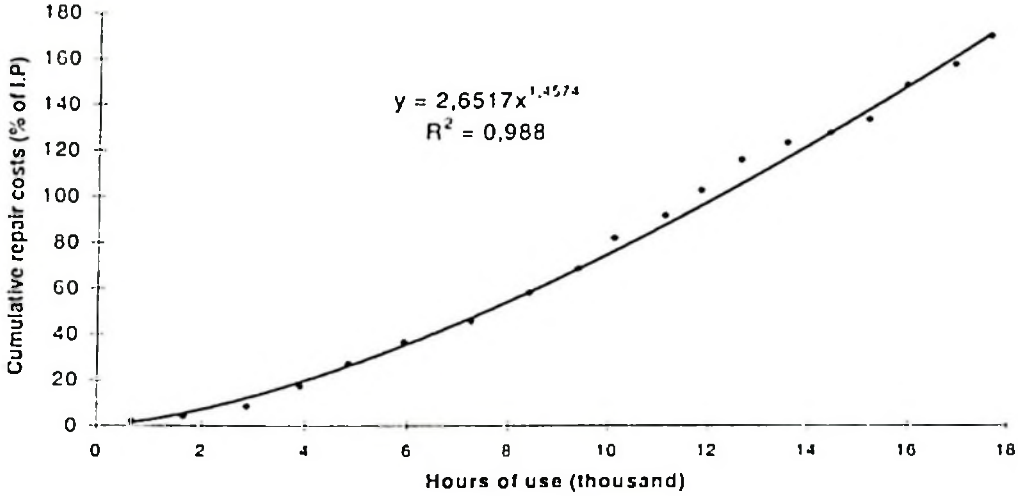
Age	No. of tractors	Usage (hr)	Engine	Transmission	Hydraulic	Electrical	Other	Total
1	10	898	200,60	399,59	242,64	20,57	23,20	886,60
	c.v (%)	53	83	118	157	202	276	57
2	12	997	270,74	1086,06	129,62	66,29	3,55	1556,26
	c.v (%)	39	168	89	204	183	162	57
3	13	1202	966,91	407,17	136,58	43,58	9,01	1563,25
	c.v (%)	35	81	139	180	164	186	65
4	13	1036	1297,09	787,29	57,97	77,51	20,79	2375,09
	c.v (%)	30	168	134	200	102	177	118
5	11	1030	1852,10	1509,40	276,69	323,57	14,81	3976,57
	c.v (%)	36	138	106	126	269	224	59
6	13	1115	1626,91	541,95	642,71	167,61	9,45	2988,61
	c.v (%)	27	109	139	181	90	185	66
7	12	1115	2216,07	969,03	198,84	128,77	10,66	3734,77
	c.v (%)	25	133	109	194	88	223	86
8	2	1162	1036,49	45,60	875,82	0,00	0,00	1957,91
	c.v (%)	23	141	141	141			8
9	2	664	7016,74	67,22	110,05	132,47	21,38	7347,86
	c.v (%)	40	66	141	99	141	141	60

Appendix 5.5: Analysis of repair costs (Tshs ,000) of Four wheel drive tractors

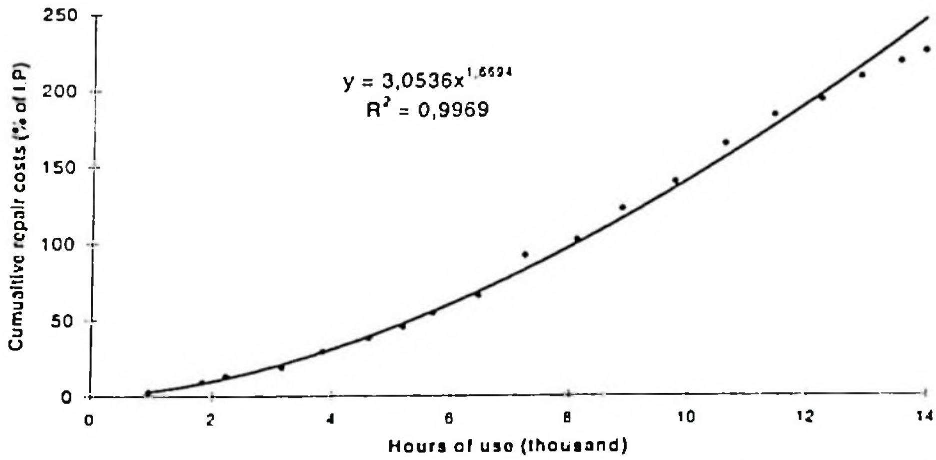
Age	No.of Tractors	Usage (hr)	Engine	Transmission	Hydraulic	Electrical	Other	Total
1	16	919	399,76	502,01	255,88	295,40	1,73	1454,77
	c.v(%)	33	40	126	106	120	220	50
2	20	1029	649,18	1172,51	145,49	72,95	1,84	2041,97
	c.v(%)	37	68	104	138	177	266	61
3	20	1037	636,60	702,04	98,28	20,39	2,36	1459,67
	c.v(%)	27	79	135	129	202	275	65
4	21	818	2363,16	1186,34	272,94	149,87	5,34	3977,65
	c.v(%)	47	99	110	121	126	260	66
5	19	1057	3217,70	979,99	467,83	72,01	1,54	4739,08
	c.v(%)	37	74	98	112	136	208	56
6	19	775	1548,03	1173,93	384,30	78,59	22,53	3207,38
	c.v(%)	51	109	81	90	149	192	53
7	18	684	1180,34	798,81	109,19	115,67	1,49	2205,50
	c.v(%)	46	97	88	159	152	212	50
8	16	512	209,73	765,56	613,98	52,31	1,23	1642,81
	c.v(%)	57	93	84	117	159	248	56
9	17	308	891,96	573,12	132,62	39,25	1,44	1638,39
	c.v(%)	95	96	79	157	153	254	62
10	14	479	806,04	769,65	458,04	114,31	1,90	2149,95
	c.v(%)	30	100	95	129	91	183	65
11	14	397	584,45	673,08	349,03	60,53	1,95	1669,04
	c.v(%)	67	58	66	74	135	237	26
12	14	172	709,89	3057,72	876,55	15,24	2,89	4662,29
	c.v(%)	29	61	53	90	326	253	41
13	14	639	1135,80	81,01	114,32	16,24	0,00	1347,38
	c.v(%)	40	71	160	155	374		56
14	10	639	1731,98	2249,24	788,68	56,54	0,00	4826,44
	c.v(%)	40	69	60	89	139		40
15	8	469	4285,74	2103,99	346,00	57,03	11,87	6804,63
	c.v(%)	17	58	91	81	185	152	53
16	6	583	807,47	119,17	51,95	119,15	3,89	1101,64
	c.v(%)	17	76	123	179	114	164	64
17	2	450	745,41	4708,34	0,00	0,00	0,00	5453,75
	c.v(%)	12	124	141				139
18	2	539	1636,66	155,90	311,79	0,00	0,00	2104,35
	c.v(%)	48	113	141	141			119

Appendix 5.6: Analysis of repair costs (Tshs ,000) of 2WD tractors owned by SMSF

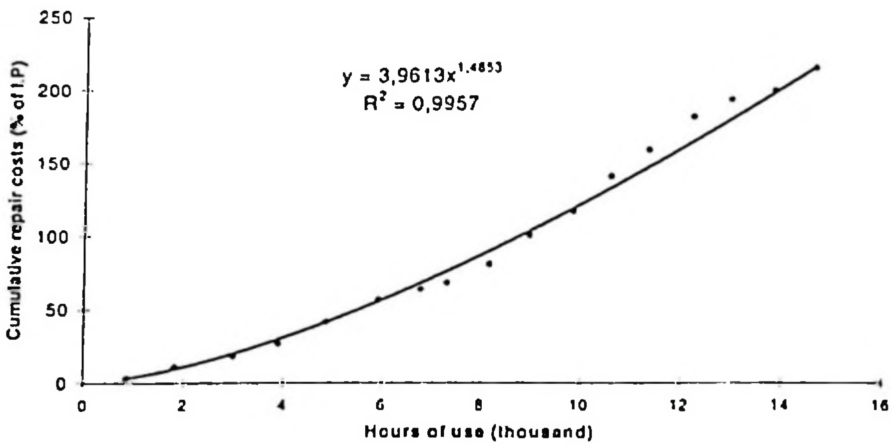
Age	No.of tractors	Usage (hours)	Engine	Transmission	Hydraulic	Electrical	Other	TOTAL
1	10	1307	157,42	0,00	136,59	65,59	17,98	377,58
	c.v (%)		46		316	211		
2	10	1363	87,97	28,94	115,75	0,00	11,63	244,29
	c.v (%)		30	32	32			
3	10	1295	97,23	110,29	115,75	65,59	19,44	408,31
	c.v (%)		57	174		211		
4	10	707	128,61	277,80	187,52	0,00	29,70	623,63
	c.v (%)		72	32	12			
5	10	585	279,64	1968,57	70,60	188,26	178,35	2685,41
	c.v (%)		150			42		
6	8	654	2009,63	33,89	70,60	200,02	115,71	2429,84
	c.v (%)		68	224		45		
7	13	524	348,27	0,00	522,41	0,00	43,53	914,22
	c.v (%)		35					
8	15	457	1044,82	0,00	522,41	0,00	78,36	1645,59
	c.v (%)		64					
9	18	345	626,89	0,00	522,41	0,00	57,47	1206,77
	c.v (%)		105					
10	13	587	3125,05	449,46	658,90	200,02	221,67	4655,10
	c.v (%)		2	58		58		
11	13	695	65,89	2409,68	70,60	200,02	137,31	2883,49
	c.v (%)		65	58		58		
12	8	711	325,89	651,77	271,57	0,00	62,46	1311,69
	c.v (%)		52	50				
13	6	529	999,38	0,00	271,57	0,00	24,44	1295,40
	c.v (%)		84					
14	5	458	499,69	0,00	271,57	0,00	19,01	790,27
	c.v (%)		85					
15	4	367	2307,92	2163,67	53,42	0,00	226,25	4751,26
	c.v (%)		82	50				
16	4	308	327,67	983,00	409,58	0,00	86,01	1806,27
	c.v (%)		45	120				
17	3	323	491,50	2528,50	409,58	209,88	171,48	3810,94
	c.v (%)		62	16				



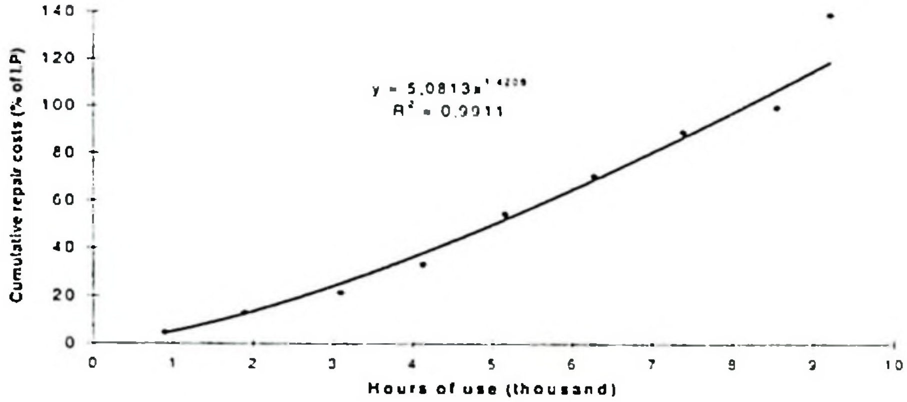
Appendix 6.1: The influence of hours of use on total repair costs of Massey Ferguson tractors



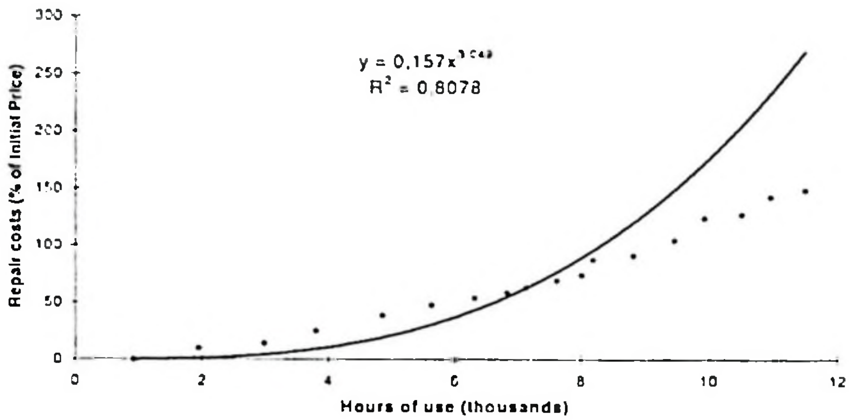
Appendix 6.2: The influence of hours of use on total repair costs of Case International tractors



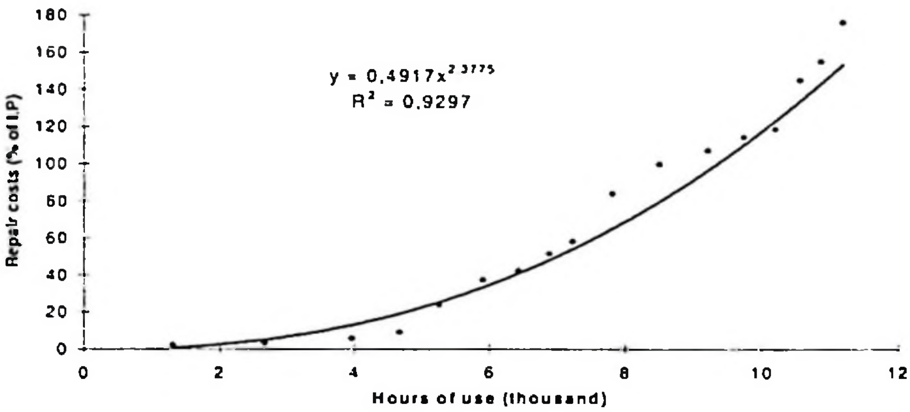
Appendix 6.3: The influence of hours of use on total repair costs of Ford tractors



Appendix 6.4: The influence of hours of use on total repair costs of Same tractors



Appendix 6.5: The influence of hours of use on total repair costs of 4WD tractors



Appendix 6.6: The influence of hours of use on total repair costs of 2WD - SMSF- tractors

Appendix 7: Repair costs functions of the assembly groups (TAR as % of Initial price)

Tractor type	Engine	Transmission	Hydraulic	Electrical	Other
MASSEY FERGUSON	$0.71(x)^{1.67}$	$154(x)^{1.3162}$	$0.13(x)^{1.4653}$	$0.244(x)^{1.3837}$	$0.015(x)^{1.7293}$
CASE I.H	$0.803(x)^{1.921}$	$1.713(x)^{1.5352}$	$0.396(x)^{1.3424}$	$0.118(x)^{1.762}$	$0.028(x)^{1.5961}$
FORD	$0.881(x)^{1.509}$	$2.437(x)^{1.3133}$	$0.333(x)^{1.2622}$	$0.447(x)^{1.1361}$	$0.031(x)^{1.4397}$
SAME	$1.021(x)^{1.8915}$	$2.945(x)^{1.1377}$	$1.044(x)^{1.0616}$	$0.133(x)^{1.673}$	$0.108(x)^{0.7272}$
4WD	$1.128(x)^{1.6523}$	$1.469(x)^{1.4559}$	$0.461(x)^{1.4314}$	$0.673(x)^{0.6596}$	$0.0043(x)^{1.5813}$
2WD - SMSF	$0.153(x)^{2.5086}$	$5.847(x) - 20$	$0.244(x)^{1.8762}$	$0.1268(x)^{1.5926}$	$0.0246(x)^{2.379}$

Note: $x = \frac{X}{1000}$, where X = cumulated hours of use.

Appendix 8.1: Annual ownership costs (Tshs/hour) of Massey Ferguson tractors at different period of ownership

Period of ownership (year)	Annual hours of use		
	500 hours	1000 hours	1200 hours
1	20326	12421	11128
2	18060	11426	10354
3	16776	10886	9945
4	15837	10501	9657
5	15095	10202	9437
6	14487	9961	9262
7	13979	9764	9120
8	13547	9600	9004
9	13175	9462	8908
10	12851	9344	8828
11	12566	9243	8760
12	12314	9156	8703
13	12089	9079	8654
14	11886	9012	8611
15	11702	8953	8574
16	11534	8899	8542
17	11380	8851	8514
18	11237	8808	8489
19	11106	8769	8467

Appendix 8.2: Annual ownership costs (Tshs/hour) of Case International tractors at different period of ownership

Period of ownership (year)	Annual hours of use		
	500 hours	1000 hours	1200 hours
1	21669	13333	11993
2	19340	12461	11393
3	18061	12065	11168
4	17149	11824	11060
5	16445	11667	11014
6	15882	11566	11008
7	15422	11505	11030
8	15041	11473	11073
9	14722	11465	11131
10	14453	11474	11200
11	14223	11496	11278
12	14026	11529	11363
13	13856	11570	11452
14	13708	11618	11544
15	13579	11671	11639
16	13465	11727	11735
17	13364	11787	11832
18	13275	11848	11929
19	13196	11912	12026

Appendix 8.3: Annual ownership costs (Tshs/hour) of Ford tractors at different period of ownership

Period of ownership (year)	Annual hours of use		
	500 hours	1000 hours	1200 hours
1	20030	12148	10913
2	17894	11349	10364
3	16701	10986	10158
4	15836	10765	10059
5	15158	10621	10016
6	14607	10529	10011
7	14149	10473	10031
8	13763	10444	10070
9	13433	10436	10123
10	13148	10444	10187
11	12900	10465	10258
12	12681	10495	10336
13	12488	10533	10417
14	12315	10576	10502
15	12159	10625	10589
16	12019	10676	10677
17	11891	10731	10766
18	11773	10787	10855
19	11665	10845	10944

Appendix 8.4: Annual ownership costs (Tshs/hour) of Same tractors at different period of ownership

Period of ownership (year)	Annual hours of use		
	500 hours	1000 hours	1200 hours
1	17587	11014	9954
2	15799	10318	9452
3	14799	9961	9211
4	14073	9714	9050
5	13502	9526	8932
6	13037	9379	8844
7	12649	9262	8777
8	12322	9168	8725
9	12041	9091	8686
10	11798	9028	8657
11	11586	8977	8635
12	11399	8934	8619
13	11233	8898	8608
14	11083	8868	8600
15	10949	8842	8596
16	10826	8821	8593
17	10715	8802	8593
18	10612	8786	8593
19	10517	8773	8595

Appendix 8.5: Annual ownership costs (Tshs/hour) of 4WD tractors at different period of ownership

Period of ownership (year)	Annual hours of use		
	500 hours	1000 hours	1200 hours
1	32891	19402	17172
2	28556	17387	15600
3	26019	16376	14939
4	24198	15830	14742
5	22816	15611	14891
6	21745	15654	15334
7	20911	15921	16039
8	20265	16387	16984
9	19771	17034	18153
10	19403	17848	19535
11	19143	18818	21119
12	18975	19937	22898
13	18888	21196	24865
14	18872	22590	27016
15	18920	24115	29344
16	19027	25767	31847
17	19186	27541	34520
18	19394	29435	37359
19	19648	31446	40363

Appendix 8.6: Annual ownership costs (Tshs/hour) of 2WD tractors owned by Small to medium scale farmers at different period of ownership

Period of ownership (year)	Annual hours of use		
	500 hours	1000 hours	1200 hours
1	16435	9910	8838
2	14538	9068	8196
3	13473	8665	7932
4	12711	8429	7817
5	12124	8295	7794
6	11658	8232	7837
7	11283	8224	7931
8	10977	8259	8065
9	10727	8330	8234
10	10523	8430	8430
11	10356	8554	8651
12	10219	8700	8892
13	10109	8864	9151
14	10021	9043	9426
15	9952	9236	9714
16	9899	9441	10015
17	9860	9657	10326
18	9834	9883	10648
19	9819	10116	10978

Appendix 9.1: The effect of inflation rates on optimum replacement period (year) at two levels of loan interest rates (18% and 12%) while keeping investment interest rate constant of the 2WD tractors owned by Small-to-medium scale farmers

Annual hours of use	Loan interest rate	18%	18%	18%	18%	18%	18%	18%	18%
	Investment interest rate	10%	10%	10%	10%	10%	10%	10%	10%
	Inflation rate	6%	7%	8%	9%	6%	7%	8%	9%
500		25	23	20	18	23	21	18	17
600		17	16	15	14	17	15	14	13
800		10	10	9	9	10	10	9	9
1000		7	7	7	6	7	6	6	6

Appendix 9.2: The effect of loan interest rates on optimum replacement period (year) at two levels of inflation rates (7% and 8%) while keeping investment interest rate constant of the 2WD tractors owned by Small-to-medium scale farmers

Annual hours of use	Loan interest rate	22%	18%	14%	12%	22%	18%	14%	12%
	Investment interest rate	10%	10%	10%	10%	10%	10%	10%	10%
	Inflation rate	7%	7%	7%	7%	9%	9%	9%	9%
500		25	23	21	21	19	18	17	17
600		17	16	15	15	15	14	13	13
800		10	10	10	10	9	9	9	9
1000		7	7	7	7	6	6	6	6

Appendix 10.1: Analysis of comparison of annual costs per output power (Tshs/kW) of tractors and draft animals

Type	Average output power (kW)	Annual cost per hour (Tshs/hr)	Annual hours of use (hr)	Total annual cost (Tshs)	Annual cost/output (Tshs/kW)
Massey Ferguson	62	9800	1000	9800000	158064.52
Case International	64	11500	1000	11500000	179687.50
Ford	58	10800	1000	10800000	186206.90
Same	52	9200	1000	9200000	176923.08
4WD	91	18000	500	9000000	98901.10
2WD (SMSF)	52	8200	1000	8200000	157692.31
Oxen - Shinyanga	0.56			129624	231471.43
Oxen - Morogoro	0.56			180330	322017.86

Appendix 10.3: Estimated monthly labour costs required to attract the required number of labourers to control draft animals

Farm Area (ha)	Pair of Oxen	No. of Labourer required	Monthly salary per labourer (Tshs)
4	1	3	3000
8	2	6	3000
20	5	15	6000
40	10	30	12000
60	15	45	24000
80	20	60	48000
100	25	75	96000

Appendix 10.4: Determination of annual costs per hectare (Tshs/ha) of draft animals on different farm sizes

Area (ha)	No. of Labourers	labour cost (Tshs)	Labour cost/ha Tshs/ha	Annual cost/ha without labour cost (Tshs/ha)		Total annual cost/ ha (Tshs/ha)	
				Shinyanga	Morogoro	Shinyanga	Morogoro
4	3	27000	6750	25656	38333	32406	45083
8	6	54000	6750	25656	38333	32406	45083
20	15	270000	13500	25656	38333	39156	51833
40	30	1080000	27000	25656	38333	52656	65333
60	45	3240000	54000	25656	38333	79656	92333
80	60	8640000	108000	25656	38333	133656	146333
100	75	21600000	216000	25656	38333	241656	254333

Appendix 10.5: Procedure used for determination of annual costs per hectare (Tshs/ha) of tractors on different farm sizes

In most cases determination of the annual costs per unit area of tractors will involve dividing the annual fixed costs with the total area to be worked per year. Then this will be added with the annual variable costs per unit area. The variable costs per unit area for different sizes of the farms are normally constant.

In this study calculations were based on the actual cash flows method. Whereby the three cash flows were considered separate from labour, fuel and oil costs. In that case the minimum annual costs for every tractor were determined (as per table appendix 10.5.1). Then the minimum annual costs had to be added with the labour costs and the actual costs of fuel and oil depending on the size of the farms presented in appendix 10.5.2. The total sums were then divided by the respect farm sizes. The result of which are presented in table 10.5.3.

Appendix 10.5.1: Annual costs of tractors (Tshs) at the recommended replacement period

Tractor type	Replacement period	Annual costs (Tshs)
Massey Ferguson	10 - 11 years	5003223
Case International	10 - 11 years	6993711
Ford	8 - 9 years	6410902
Same	10 - 11 years	5246555
4WD	14 years	6008608
2WD (SMSF)	7 years	4493594

- The annual labour cost for operators of 2WD tractors is about Tshs 480000
- The annual labour cost for operators of 4WD tractors is around Tshs 520000

Table 10.5.2: The costs of fuel and oil consumption per hectare (Tshs/ha)of land

	Massey Ferguson	Case International	Ford	Same	4WD	2WD
Fuel consumption (l/h)	8.0	8.5	7.5	7.0	12.5	7.0
Oil consumption (l/h)	1.2	1.27	115	1.0	1.8	1.0
Fuel consumption (l/ha)	26.64	28.31	24.98	23.31	28.13	23.31
Oil consumption (l/ha)	4.00	4.23	3.83	3.33	4.05	3.33
Cost of fuel (Tshs/ha)	9324.00	9906.75	8741.25	8158.50	9843.75	8158.50
Cost of oil (Tshs/ha)	3196.80	3383.28	3063.60	2664.00	3240.00	2664.00
Total cost (Tshs/ha)	12520.80	13290.03	11804.85	10822.50	13083.75	10822.50

Note: The average performance of 2WD tractors = 3.33 h/ha
The average performance of 4WD tractors = 2.25 h/ha
Fuel price = Tshs 350/litre
Oil price = Tshs 800/litre

Appendix 10.5.3: Summary of the combined total annual costs per hectare (Tshs/ha) of tractors for different farm sizes

Area (ha)	Massey Ferguson	Case International	Ford	Same	4WD	2WD (SMSF)
20	286681.95	386975.58	356349.95	297150.25	339514.15	259502.20
40	149601.38	200132.81	184077.40	153986.38	176298.95	135162.35
60	103907.85	137851.88	126653.22	106265.08	121893.88	93715.73
80	81061.09	106711.42	97941.13	82404.44	94691.35	72992.43
100	67353.03	88027.14	80713.87	68088.05	78369.83	60558.44
120	58214.33	75570.96	69229.03	58543.79	67488.82	52269.12
140	51686.68	66673.68	61025.58	51726.46	59716.66	46348.17
160	46790.94	60000.72	54872.99	46613.47	53887.55	41907.46
180	42983.15	54810.65	50087.64	42636.69	49353.79	38453.58
200	39936.92	50658.59	46259.36	39455.28	45726.79	35690.47
220	37444.54	47261.44	43127.13	36852.30	42759.24	33429.75
240	35367.56	44430.49	40516.94	34683.15	40286.28	31545.81
260	33610.12	42035.07	38308.32	32847.71	38193.78	29951.71
280	32103.74	39981.86	36415.21	31274.48	36400.21	28585.34
300	30798.21	38202.40	34774.52	29911.02	34845.78	27401.15

Lebenslauf

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