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Tractor repair and maintenance costs and management policies in Burkina Faso

Konda, Issa, M.S.

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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

TRACTOR REPAIR AND MAINTENANCE COSTS AND MANAGEMENT POLICIES IN BURKINA FASO

by

Issa Konda

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STATEMENT BY AUTHOR

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This thesis has been approved on the date shown below:

______________________ 23 Jan. 91

D. L. Larson
Associate Professor of
Agricultural and Biosystems Engineering

Date

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ABSTRACT

Farm machinery management data were collected in Burkina Faso, for the prediction of repair and maintenance costs. Equations were developed to predict repair and maintenance costs of tractors, cane loaders, generators and motopumps. The analysis of data revealed that tractor repair and maintenance appears a greater burden than predicted by the American and Australian data. Tractor trade-in was not prescribed by the rule of minimum total cost per unit tractor use. Farm machinery and power units were operated more than twice as long as in The United States. New machine purchase was discouraged by the current sugar prices on the local market.

INTRODUCTION

Farm machinery plays an important role in agricultural production. Mechanization contributes to an increase in farm size and labor productivity. However, the use of farm machinery may increase farm operational costs. Thus, good farm equipment management is essential to economic success of agricultural enterprises. Awareness of the importance of farm machinery management is part of the solution. However, absence of reliable and classified information is a major handicap to implementation of such a policy. In America and Europe, some farm machinery management data have been gathered, but very little data are available in developing countries. Obviously, when such information is needed, data are taken from the American or European sources. However, extrapolation of data to other geographical areas is unreliable (Beppler and Hummeida, 1985).

Burkina Faso is a landlocked Country which stretches across a peneplain of two hundred seventy four thousand square kilometers in West Africa. It lies between the Sahara Desert and the Gulf of Guinea, south of the loop of the Niger river. Three climatic zones characterize this African region: The Southern Sudanian Zone with an annual rainfall above 1000 mm, the Central North Sudanian Zone where precipitation ranges from 1000 to 650 mm per year, and the Northern Sahelian Zone with average annual rainfall below 650 mm (Sivakumar and Gnoumou, 1987). Arable land represents about half of the total land area, and nearly sixty percent of this potential tillable land is under cultivation. Agriculture accounts for two fifths of the Gross National Product. This relatively low contribution of agriculture to the national economy is explained by a production potential reduced by inadequate farming systems, short rainy season, and erratic rainfall. Although subsistence farming practice using inadequate tools are dominant on most of the cultivated land, farm mechanization is increasing substantially. The SOSUCO sugarcane plantations, the SOFITEX cotton network and the Sourou Project are some examples of mechanized farming in Burkina Faso.

An efficient mechanized agricultural production requires good equipment management. This thesis reports on the collection and analysis of farm machinery management data for the prediction of power unit repair and maintenance costs, and the development of policies for more cost effective machinery management in Burkina Faso.

LITERATURE REVIEW

At first, tools were invented in a rural environment to process natural resources needed for existence. Some simple hand tools were used to hunt, cut wood and till the soil. Because those instruments were single piece tools, they were used until they broke and then were replaced by new ones. This practice was abandoned when the advantage of a separate cutting edge or working part that could be replaced was discovered (Limbrey, 1988).

Today with the increasing complexity of farm equipment, part replacement cannot preclude equipment replacement. At a period when the twin pressures of falling commodity prices and rising production costs produce a severe scrutiny on economic performance of agricultural systems, management decisions are very important (O'Callaghan, 1988).

Fixed or ownership costs account for the largest portion of machine costs during the period following machine purchase. These costs are largely dependant on purchase price, depreciation rate, interest rate, tax structure and insurance costs. However, machine replacement policy can be implemented to minimize variable costs. Variable or operating costs consist primarily of repair and maintenance, labor and energy costs. Equipment repair and maintenance policies and actions can maximize equipment availability and improve performance.

Machinery management research in the United States, Europe, and to a lesser extend in other countries has generated data and developed policies to assist with planning, budgeting and operational management of machinery to maximize economic benefits of farm machines. In the following, farm equipment management research has been categorized as:

1. Repair and Maintenance Costs,
2. Economic Replacement Methods, and
3. Reliability Evaluation.

Repair and Maintenance Cost

Repair and maintenance costs represent a relatively small portion of farm equipment ownership and operating costs. Reported repair and maintenance costs range from 10% to 18% of the total machine cost in America and Europe; somewhat greater in Africa and Asia (Beppler and Hummeida, 1985).

Repair and maintenance cost is highly variable; the coefficient of variation often exceeds the data mean (Ward et al., 1985; ASAE, 1989 a; and Rotz, 1987). However, machinery repair and maintenance cost variability can be reduced by expressing repair and maintenance costs as cumulative costs (ASAE, 1989 a).

Rotz (1987) reported some agricultural machines used in The United States have a relatively constant repair and maintenance cost over their lifetime. This is especially true for equipment like tillage implements which have few moving parts. Uniform repair costs are related to the mode of wear of these implements, which occurs at points of contact with the soil. However, moving parts are associated with aging wear.

Repair and maintenance costs tend to increase with cumulative use due to wear and aging. However, age has a different effect on equipment capital costs which decrease due to depreciation. Thus, repair and maintenance cost predictions could help determine an optimum time for farm machinery replacement.

Efforts to predict tractor repair and maintenance costs in the United States have yielded several models. In early farm machinery management studies, repair and maintenance cost was related to machine age with a power equation, where age was expressed in percent of lifetime hours (ASAE, 1966).

Bowers and Hunt (1970) used data from a survey of nine hundred Midwestern farmers to develop a mathematical relationship which related tractor cumulative repair and maintenance cost to cumulative use and list price.

$$TAR = ILP\ (RC_1)(RC_2)(L)^{RC3}$$

where:

TAR = total cumulative repair cost at "L" in $,

L = cumulative hours in % of lifetime hours,

ILP = initial list price of machine in \$,

RC_1, RC_2, RC_3 = model parameters, functions of machine type.

Hassan and Larson (1978) derived the same type of equation to predict Arizona combine repair and maintenance costs. A similar relationship was developed by Ward et al. (1985) to assess tractor repair and maintenance costs in Ireland.

The ASAE cost prediction later was modified to the following relationship derived from United States data (ASAE, 1986):

$TAR = P[RF_1(L)^{RF2}]$ where

P = purchase price in current dollars,

L = cumulative use in % lifetime hours.

RF_1, RF_2 = repair and maintenance factors, and

TAR = cumulative repair and maintenance cost.

An RF_1 value of 0.012 was suggested for 2 wheel drive tractors and stationary power units, and RF_1 value of 0.010 was proposed for 4 wheel drive and crawler tractors. However, a single value of 2.0 was specified for the RF_2 parameter for stationary power units, two wheel drive, four wheel drive, and crawler tractors.

Rotz (1987) suggested a reformulation of the ASAE model based on a review of models developed from the American data.

$$TAR = LP(RC_1)(USE)^{RC2}$$

where:

TAR = total cumulative repair and maintenance cost, in % of list price.

USE = cumulative use in thousands of hours,

LP = list price of similar new machine, $,

RC_1, RC_2 = repair and maintenance parameters.

For this model, machine age was expressed in thousands of hours instead of percent of lifetime. Cumulative repair and maintenance cost was expressed as a percentage of present list price instead of purchase price in current dollars. The model predicted tractor repair costs analogously to the nationwide model during the first half of tractor life and similarly to the Midwest model during the second half. However, the model predicted combine repair and maintenance costs similarly to the Midwest model. Rotz (1987) suggested the preceding equation should be modified to include travel speed effect on costs when modeling a particular field operation. The modified model is:

$$TAR = ILP(RC_1')(USE*S)^{RC2}$$

where:

S = field speed km/h

$RC1' = RC_1/(AS)^{RC2}$

AS = average or typical field speed km/h.

Kruger and Logan (1980) conducted a pilot study in Australia and developed the following equation to predict tractor repair and maintenance costs:

$TAR = 2.8(X)^{1.06}$

In this equation X represents machine use and repair and maintenance costs expressed as a percentage of the tractor new list price. However, repair and maintenance excluded the costs of tires.

Recent studies of farm machinery costs in Europe also have yielded the development of several prediction equations for tractor repair and maintenance costs as a function of tractor initial list prices (Morris, 1980; Weiershaeuser, 1989).

Replacement

Component replacement business began with the invention of several component tools as a solution to keeping a machine in satisfactory condition reliabilitywise and safetywise. Component replacement is currently used when cleaning, adjusting or calibration of worn parts becomes inadequate. Overhauling is favored when replacing a block or subsystem made of similar mean life components. Part replacement can be a preventive or corrective action. An optimum period between preventive actions can be defined by determining when the corrective maintenance cost is higher than the preventive maintenance cost. If the preventive maintenance cost exceeds corrective maintenance cost, the minimum cost policy is to discontinue preventive maintenance (Kececioglu, 1990).

Several reasons may justify equipment replacement: accidental damage, inadequacy of machine capacity, obsolescence, low reliability or increasing unit cumulative repair and maintenance costs (ASAE,1989). However, research found that other reasons also are involved. Hassan and Larson (1978) studied combine capacity and costs in Arizona, and discovered that machine trade-in policy was strongly affected by tax incentives, prevailing grain prices, machine cost, and reliability. Most economic replacement of machines may occur at a cumulative use corresponding to the time when the minimum total ownership and operating costs are reached (Ward et al., 1985), Figure 1. When rapid inflation produces a low or negative depreciation, replacement is better indicated by comparing unit cumulative cost of a present machine with the projected cost for a potential challenger machine (ASAE, 1989 b).

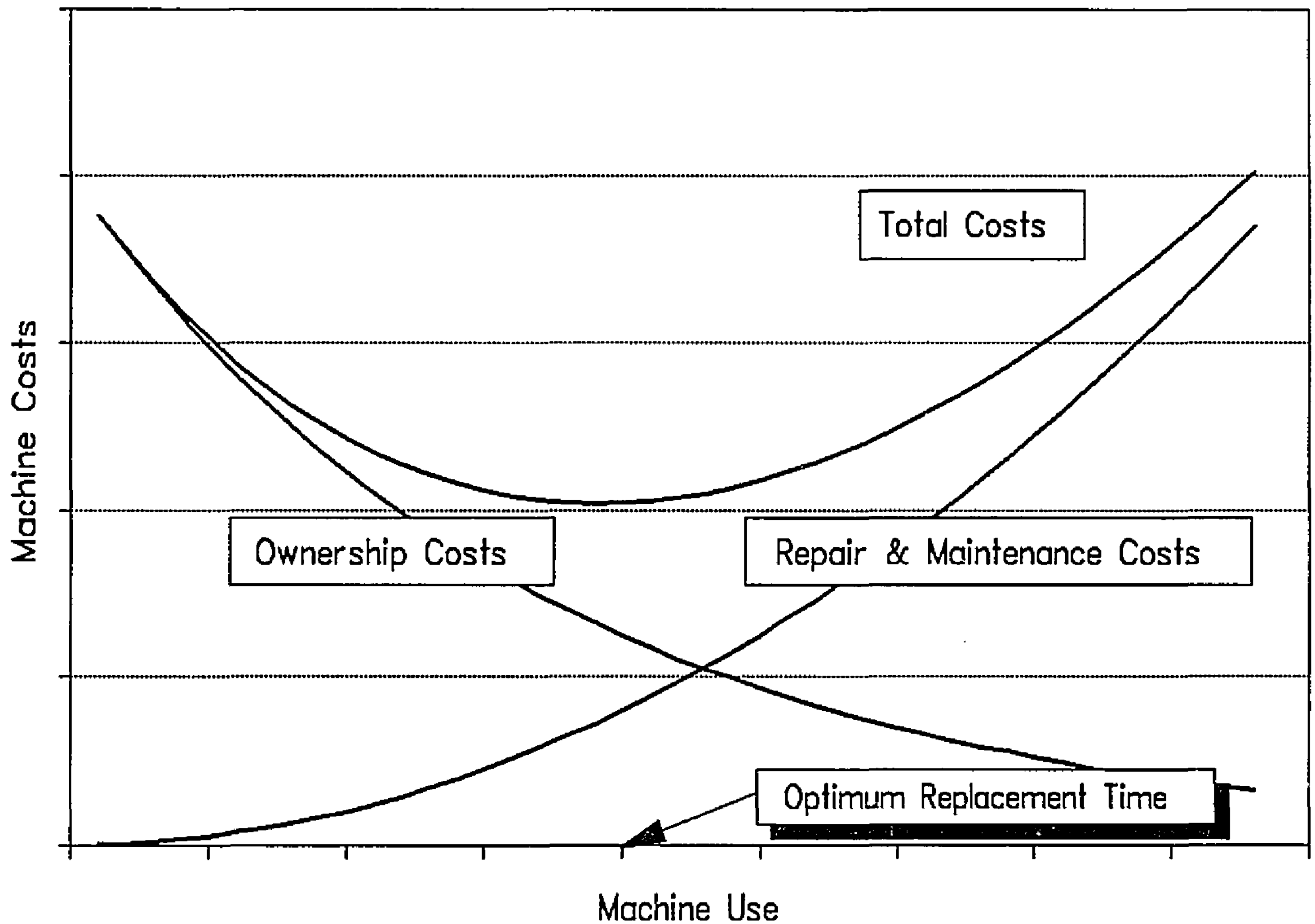

Fig. 1: AN OPTIMUM TIME FOR MACHINE REPLACEMENT

O'Callaghan (1988) showed that an equipment replacement problem could be regarded as searching for an answer to issues of the depreciation rate, repair timing and costs, labor requirements and adopting technological advances. Minimizing the cost of owning and operating machinery could be less important than maximizing the profit of the total production process. Replacement analysis should consider enterprise cash-flow and tax effects.

Inflation may greatly change acquisition prices. In all costing of farm machinery, the effect of inflation must be considered, and all costs should be actualized. In case of capital recovery computation, real interest rate should be used instead of the market interest rate (Bartholomew, 1981; ASAE, 1989 b).

Reliability

Reliability is a conditional probability, at a given confidence level, that a component, equipment or system will perform its intended functions satisfactorily or without failure, within a specified performance limits, at a given age, for a specified mission time, when used in the manner and purpose intended while operating under specified operational environments with their associated stress levels (Kececioglu, 1990).

Failure analysis is an important component of reliability evaluation. Tullberg et al. (1984) concluded that drawbar pull was the most significant factor explaining tractor failure after evaluating two hundred and forty tractors under farm operating conditions. ASAE (1989 c) reported that cumulative hours of downtime were found to be related to cumulative use for spark ignition engine tractors by the following equation:

$$\text{Cumulative downtime} = 0.0000021(\text{USE})^{1.9946}$$

A similar equation was developed for Diesel tractors:

$$\text{Cumulative downtime} = 0.0003234(\text{USE})^{1.4173}$$

Reliability data are used mainly as feedback to management, planning and design. Combine reliability improvements from design based on reliability test data were reported by Remley (1989).

Kececioglu (1990) indicated that the number of critical components in a farm tractor in the United States soared from one thousand two hundred in 1935 to two thousand in 1980. The projected number of components for 1990 was two thousand nine hundred. Complexity as a design trend requires highly reliable components to maintain acceptable tractor reliability.

Tractor operational availability relies on appropriate maintenance. Preventive and corrective maintenance, if properly planned and executed can yield reduced equipment failure rates and increased reliability and availability. Equipment availability is important in agriculture, especially in areas where the weather allows small time periods for execution of farm operations. Timeliness can be critical to maximizing crop yield and profit.

Insufficient preventive maintenance is linked to costly corrective repairs and interruption of operations at undesirable time, while excessive preventive maintenance results in unjustified expenses. For every specific environment, an appropriate part replacement policy can be defined to minimize machinery costs. Different policies are justified by the great variability in operating environments (Kececioglu, 1990).

Available management data are limited to developed countries. Very little data have been reported for developing countries, where the need for mechanized farming has been increasing to help feed the growing populations.

OBJECTIVES

Few studies of farm equipment costing have been conducted in Burkina Faso. To provide suitable data for management and planning, farm machinery repair and maintenance cost data were collected in 1990. The objectives of this study were to obtain data on farm equipment repair and maintenance costs in Burkina Faso, and use this information to:

1. Develop repair and maintenance cost prediction equations for some farm equipment and compare these equations with published relationships,

2. Evaluate the effects of downtime on tractor availability,

3. Determine parameters which play a key role in equipment replacement, and

4. Make suggestions for more cost effective machinery management.

PROCEDURES

The SOSUCO sugarcane plantations were selected for this study since they provide a concentration of farm equipment in a small area under a single manager. The sugarcane plantations and the SOSUCO processing unit are located in Southwest Burkina Faso, where the average yearly rainfall is 1140 mm. It is rainy in this area from May to October, hot and dry the rest of the year. The main soils are luvisols (Sivakumar et al., 1987). Sugarcane is planted in March and harvested from December through February. Sugarcane fields are irrigated except during the most rainy months of the year, June, July and August.

Sugar production in Burkina Faso began in 1965 with the cooperation of Ivory Coast and the French SOMDIAA Corporation for Industrial and Agricultural Supplies. The SOSUCO Sugar Company was created in 1968 from the SESUHV Sugar Study Project, and the SOSUHV Sugar Production Unit which was built in 1968. The Sugar Company has five main objectives:

- grow sugarcane,
- process sugarcane into finished products,
- provide sugar for the local market and for exportation,
- recycle sugarcane residues, and
- screen sugarcane varieties.

The Company utilizes ten thousand hectares of land. The sugarcane plantation occupies half of the land area. Sugar production is about thirty tons per annum. SOSUCO farm equipment includes a fleet of about thirty tractors, eight cane loaders, two bulldozers, two graders, twenty motopumps and thirty gas powered generators. The tractor size ranges from 100 to 210 PTO Hp. The four wheel drive tractors are used for tillage, subsoiling and transportation. The two wheel drive tractors are used for pesticide applications. Motopumps with a power range of 117 to 226 Hp are used for surface water pumping. Gas powered generators with a maximum power range of 20 to 34 Hp power the center-pivot irrigation systems.

Farm operations are scheduled by the Exploitation Department, while equipment services, repairs and maintenance are performed by the Mechanization Department. During the sugarcane harvest, tractors and cane loaders are used on a twenty four hour basis, so timeliness and machine reliability and availability are critical.

Preventive maintenance is scheduled once a year to prevent major breakdowns during the active cropping season. Preventive maintenance consists of disassembling components, cleaning, adjusting, replacing faulty parts, lubricating assembling and testing. Most repairs are done in the SOSUCO repair shop, which is divided in several sections: electricity, hydraulics, fuel injection, engines, cooling systems, tooling, lubrication, welding, general assembly, motopumps and generators. The repair shop is equipped with test equipment for starters and alternators, injection pumps and engines. Repair kits are available. Spare part stocks are stored in a warehouse with computerized control of inventory. The extensive maintenance facility and part warehouse are required because of the lack of local commercial services and specialized nature of sugarcane production equipment. Most repairmen are trained locally. The SOSUCO Company maintains close ties with the SOMDIAA Corporation of Industrial and Agricultural Supplies in Paris for technical assistance in management and spare part supplies. The main manufacturers of farm tractors used by the SOSUCO Company are CAMECO and FIAT.

This study focused on equipment used for agricultural production. Data were obtained from the SOSUCO Company records and files in August 1990. These data had been recorded and filed as tools for the Company accounting and management system listing expenses for individual machines. Records listed costs of tires, other spare parts, fuel, lubricants and labor. Every repair or replacement activity for individual items of equipment was recorded using a computer program which lists the code of the spare part or service, the number of parts, the unit cost and total cost per item. Computer printouts were obtained which listed all equipment repair for each year. This information assists with maintenance of a reliable inventory of spare parts. The data summary included the following information: equipment make, model, size, initial cost, list price, annual use, main use, annual repair and maintenance costs and breakdown history.

Labor costs were not available for all years. Therefore labor costs were estimated to equal four percent of replacement part costs for those years. The percentage was determined from available labor and part costs. Labor cost for a hired tractor operator was 60,000 CFA or $200 per month. Overhead costs were estimated as ten percent of the repair and maintenance costs including labor. Cost data recorded in the local currency, the CFA (Franc de la Communauté Franco Africaine) were converted to dollars with a rate of three hundred CFA per dollar.

Economic indicators of the national economy were obtained from Burkina Faso (1985) and Euromonitor (1966-1989). Published inflation rates were used to adjust all costs to a 1990 value. The 1970's inflation rates were 0.134 for 1979, 0.139 for 1978, 0.207 for 1977, 0.028 for 1976, 0.117 for 1975, 0.086 for 1974 and 0.084 for 1973. The Annual inflation rates for the 1980's were 0.07 for 1989, 0.044 for 1988, -0.021 for 1987, 0.011 for 1986, -0.014 for 1985, -0.012 for 1984, 0.10 for 1983, 0.128 for 1982, 0.139 for 1981, 0.11 for 1980. The 1990 inflation rate was projected from the general trend as 0.08.

Generator cumulative repair and maintenance costs and cumulative use were not available for all years; hence the following method described by Ward et al. (1985) was used to compute cumulative costs. Generators were classified in age groups and the mean annual repair and maintenance cost and use were computed from available data for each group. Costs were adjusted for inflation. Cumulative repair and maintenance costs then were calculated by multiplying the mean annual repair and maintenance costs for each group by the group age. Similar computations were done to derive cumulative use and energy costs.

The Least Squares Method was used to derive the cost equations relating cumulative repair and maintenance costs in percent of list price to cumulative use in thousand of hours. The Quattro Pro spreadsheet (Borland International, Inc. version 2.0) was used for most computations, curve fittings and graphics. The CoStat statistical package (Cohort Software version 3.01) was used for quadratic polynomial fitting. Prior transformations of the data using the natural logarithm were necessary for the power regression analysis.

Relative importance of fixed and operating costs for tractors, cane loaders, motopumps, and generators was determined. Since data were derived from a small population, instead of a random sample from a large population, no statistical inference was made beyond the population under study.

Tractor availability was computed by dividing tractor mean operating time by the sum of the mean to repair time and the mean operating time. For this analysis, it was assumed that: all tractors were operationally ready at the beginning of the cropping season and breakdowns were independent.

RESULTS AND DISCUSSION

Data obtained from the SOSUCO Company in August 1990 were compiled and adjusted for inflation to 1990 values. Repair and maintenance costs included lubrication, repairman wages and overhead costs. Repair and maintenance costs, and energy costs varied substantially depending on equipment type and use.

Four Wheel Drive Tractors

Repair and maintenance cost data for four wheel drive tractors are summarized in Table 1. Tractor age varied from five to seventeen years. Statistical curve fitting attempts included straight line, power and second order polynomial equations. Three equations were derived to predict four wheel drive tractor repair and maintenance costs as a function of cumulative use, Table 2.

Table 2: Four Wheel Drive Tractor Repair and Maintenance Cost Regression Relationships

Relationship	Equation	R2
Linear	$Y=-64+23.2(X)$	0.69
Power	$Y=5.95(X)^{1.40}$	0.81
Quadratic	$Y=97.7+28.3(X) -0.17(X)^2$	0.69

Table 1. Descriptive Data for Four Wheel Drive Tractors

		Max PTO	Purchase	New List	Cumulative		
		Power	Price	Price	R&M Costs	Use	Energy Costs
ID #	Model	(Hp)	(cfa)	(cfa)	(cfa)	(hr)	(cfa)
2102	1973	170	26903304	22000000	18787142	5300	80907818
2103	1973	165	26903304	22000000	22290429	9200	74097452
2104	1973	165	26903304	22000000	42013407	10600	71975348
2105	1973	165	26903304	22000000	59805043	10700	70465126
2106	1973	165	26903304	22000000	53480759	13600	70210020
2107	1973	165	26903304	22000000	84196706	15900	45635527
2108	1974	165	24933553	22000000	72055891	16000	61142900
2109	1974	165	24933553	22000000	79195157	16700	75311174
2111	1974	165	24933553	22000000	1.1e+08	17200	63222508
2112	1976	165	44683702	22000000	57245492	17900	65575610
2113	1976	165	44683702	22000000	46024338	16300	57510268
2116	1977	165	43683584	22000000	43703608	15100	60850288
2117	1978	165	31310388	22000000	102796943	19800	46204617
2151	1980	165	33021236	22000000	106960356	19900	30030763
2152	1980	165	33021236	22000000	1.1e+08	20100	28990021
2153	1980	165	33021236	22000000	100433328	20300	25178188
2251	1973	100	26903304	16000000	1.1e+08	21400	51591265
2252	1974	100	24933553	16000000	93680912	22100	21584210
2301	1985	210	12025726	32000000	1.1e+08	23700	21788294

where

Number of observations = 19

Y = Cumulative repair and maintenance costs, percent of a similar new tractor list price.

X = Cumulative use, hours/1000.

The power relationship provides the best statistical fit to the cost data. Eighty one percent of the variation in repair and maintenance costs was explained by tractor use. Linear and quadratic equations provide less reliable predictions.

Figure 2 shows the four wheel drive tractor repair and maintenance cost versus tractor use. Tractor repair and maintenance costs in Burkina Faso were found to be higher at low amounts of usage than predicted by the ASAE nationwide equation, Figure 3. However at high amounts of usage, the ASAE model predicted higher repair and maintenance costs than does the equation developed in this study. Substandard manufacturing, improper handling during shipment or improper operation and maintenance could explain the higher repair and maintenance costs in tractor early life, raising questions about manufacturers shipment policies and operational training in developing countries. While repairs during tractor early life apparently affected costs later in life, the applicability of the ASAE cost equation with high amounts of usage is uncertain.

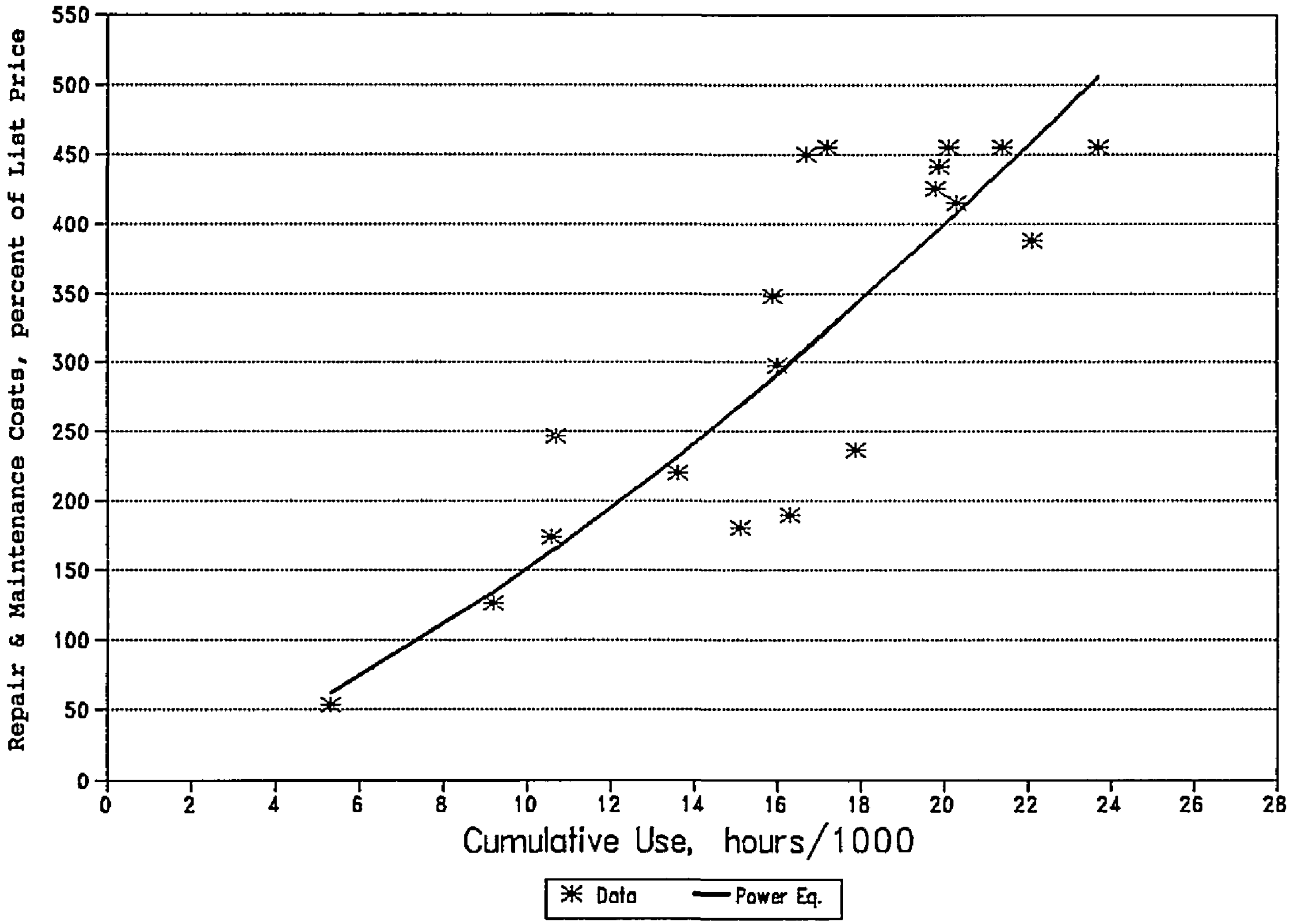

Fig. 2. FOUR WHEEL DRIVE TRACTOR REPAIR AND MAINTENANCE COSTS

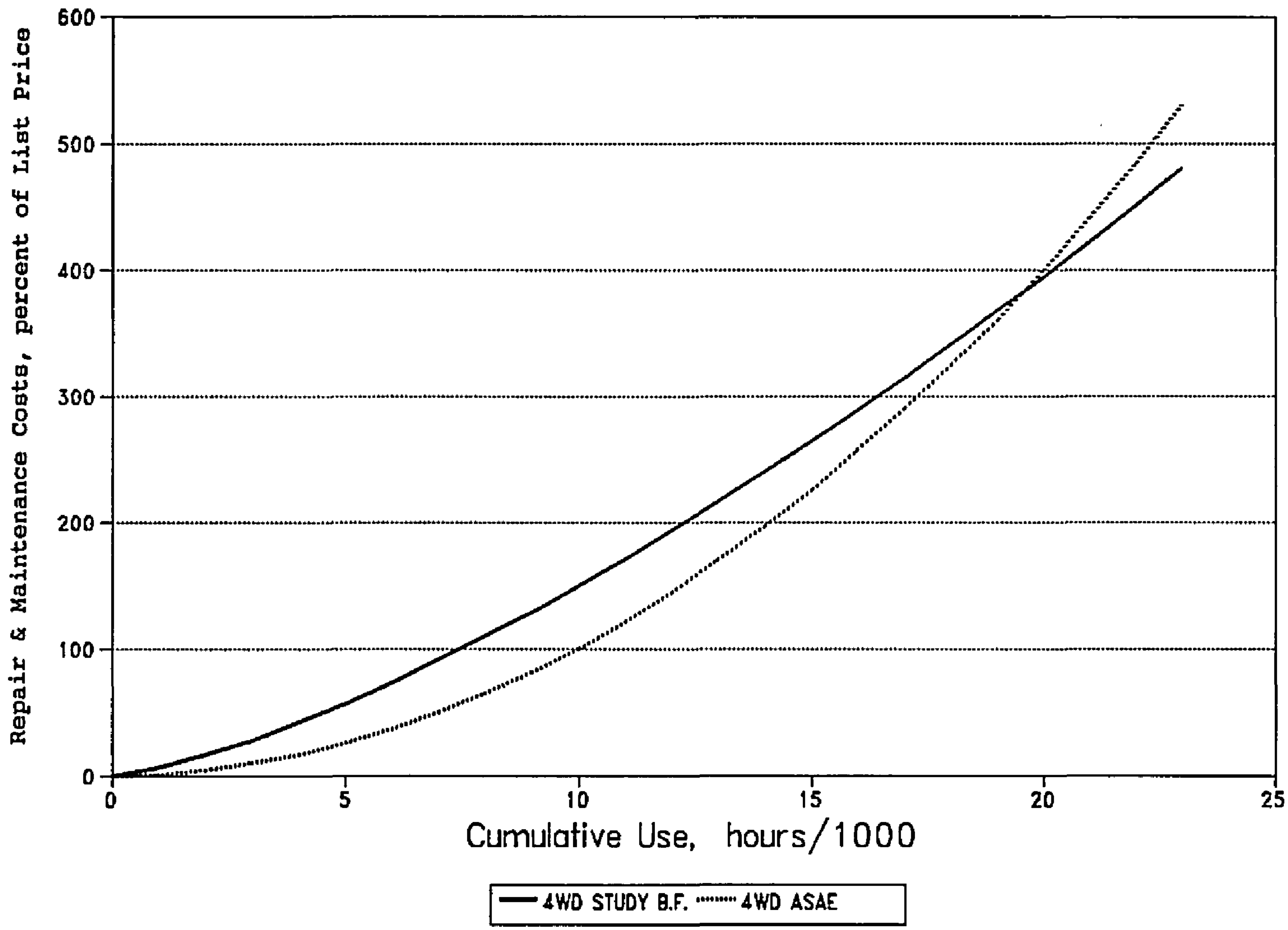

Fig. 3. A COMPARISON OF THE REPAIR AND MAINTENANCE COST RELATIONSHIPS FOR FOUR WHEEL DRIVE TRACTORS

Figure 4 shows the relative importance of four wheel drive tractor cost categories. The largest cost item is related to energy, followed by repair and maintenance costs. Labor is the third largest cost item. Fixed costs, composed of depreciation, interest on investment, and insurance, made up the smallest percentage of the total cost. These findings demonstrate the importance of management to the success of agricultural projects in Burkina Faso. The cost repartition is also linked to the low to average inflation rates. Rapid depreciation was applied to machine investments to reduce ownership costs.

Two Wheel Drive Tractors

Repair and maintenance cost data for two wheel drive tractors are summarized in Table 3. Tractor age varied from five to ten years. Three equations were derived to predict tractor repair and maintenance costs as a function of cumulative use, Table 4.

Table 4: Two Wheel Drive Tractor Repair and Maintenance Cost Regression Relationships

Relationship	Equation	R2
Linear	$Y=-5+15.56(X)$	0.37
Power	$Y=9.3(X)^{1.1}$	0.45
Quadratic	$Y=-60.59+32(X)-1.64(X)^2$	0.38

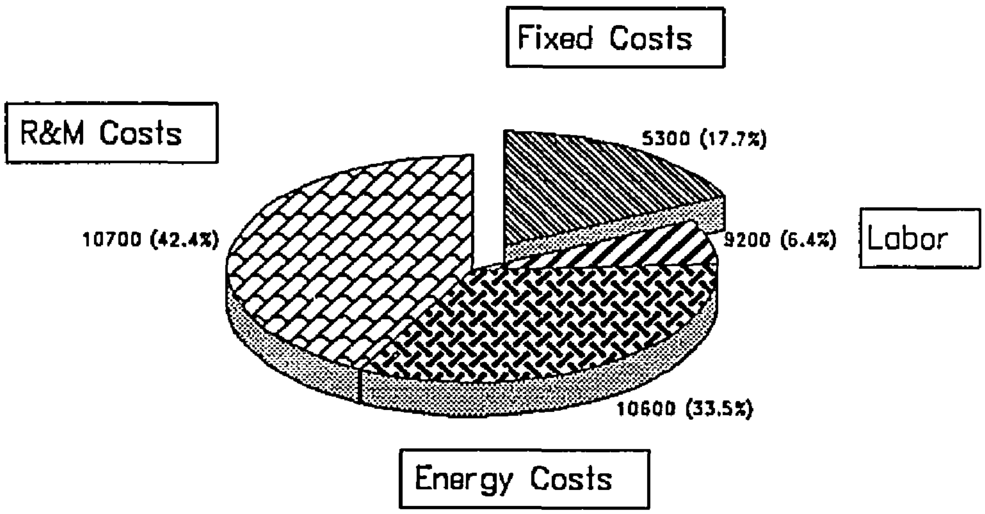

Fig. 4. RELATIVE IMPORTANCE OF COST COMPONENTS FOR FOUR WHEEL DRIVE TRACTORS

		Max PTO	Purchase	New List	Cumulative		
		Power	Price	Price	R&M Costs	Use	Energy Costs
ID #	Model	(Hp)	(cfa)	(cfa)	(cfa)	(hr)	(cfa)
2471	1980	110	13344175	14500000	13721643	7000	18408420
2472	1980	110	13344175	14500000	11408589	7000	16301766
2473	1980	110	13344175	14500000	7124746	5800	13285106
2474	1980	110	13344175	14500000	10721571	5700	11970300
2475	1981	110	14173665	14500000	8053472	6800	15329670
2476	1982	110	12513763	14500000	14245572	8300	20184622
2477	1983	110	13241068	14500000	7952677	7500	14811508
2478	1984	100	11100344	14500000	5172895	3900	10586425
2479	1984	100	11100344	14500000	14301233	6200	19857765
2480	1985	100	11631867	14500000	7783393	4300	9809716
2481	1985	100	10855324	14500000	18407833	7200	16964671

Table 3. Descriptive Data for Two Wheel Drive Tractors

where

Number of observations = 11

Y = Cumulative repair and maintenance costs, % of similar tractor new list price.

X = Cumulative use, hours/1000.

These equations provided inadequate predictions, since cumulative use did not explain much of the variability in cumulative repair and maintenance costs. Only forty five percent of the variation in repair and maintenance costs was explained by tractor use by the best prediction equation, the power relationship. The small sample size and the narrow range of two wheel drive tractor use are possible explanations for poor predictions. The power equation fit is shown in Figure 5.

Cost repartition is illustrated in Figure 6. Repair and maintenance costs represent the major cost item. Twenty five percent of the total costs are due to fuel consumption and lubrication. More than seventy two percent of the total costs are represented by ownership costs. Repair and maintenance costs made up forty percent of costs, leaving thirteen percent to labor charges.

Labor costs in percent of the total costs were less for four wheel drive than for two wheel drive tractors. Energy costs and repair and maintenance costs were relatively higher percentages for four wheel drive than two wheel drive tractors. Costlier components for four wheel drive tractors could justify the difference in repair and maintenance cost

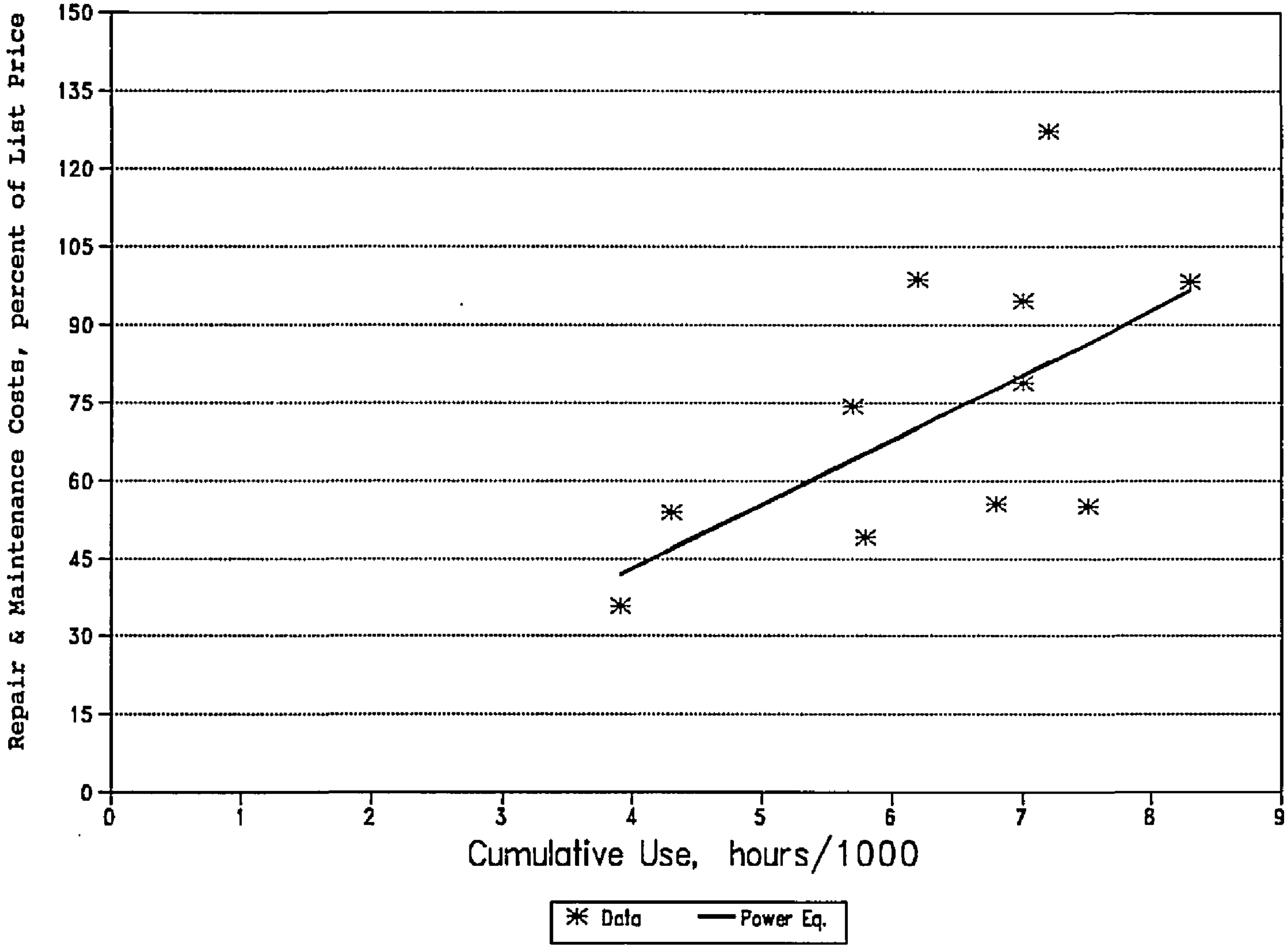

Fig. 5. TWO WHEEL DRIVE TRACTOR REPAIR AND MAINTENANCE COSTS AND PREDICTION EQUATION

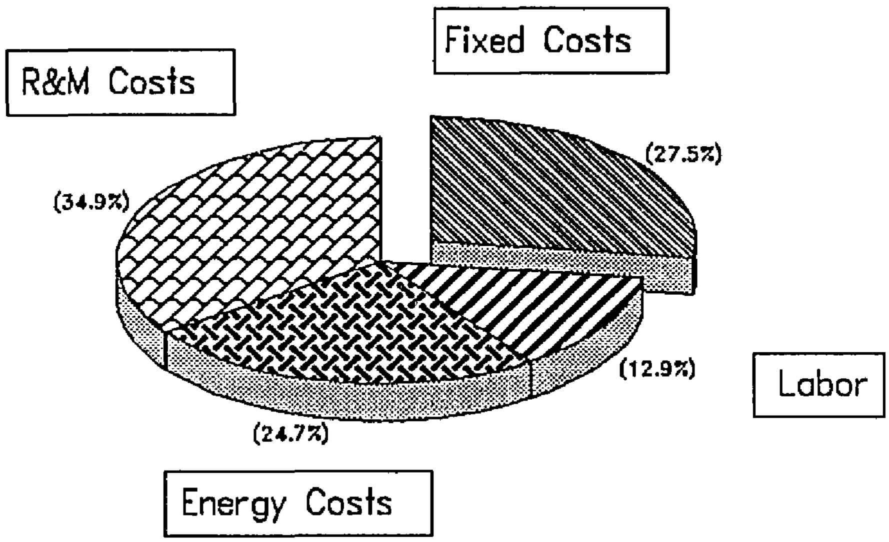

Fig. 6. RELATIVE IMPORTANCE OF TWO WHEEL DRIVE TRACTOR COST COMPONENTS

importance. The difference in energy cost percentages could be explained by the type of use. Four wheel drive tractors were used for tillage and transportation which required more fuel per horsepower-hour than with two wheel drive tractors used for fertilizer and pesticide applications. Fixed costs represented a lesser portion of the total costs for four wheel drive tractors, probably due to higher annual usage.

Two and Four Wheel Drive Tractors

Repair and maintenance cost data for four wheel drive tractors were then combined and analyzed in an attempt to overcome the two wheel drive tractor sample size problem. Prediction equations were derived to predict tractor repair and maintenance costs as a function of cumulative use, Table 5.

Table 5: Two and Four Wheel Drive Tractor Repair and Maintenance Cost Regression Relationships

Relationship	Equation	R2
Linear	$Y=-71.5+24.2(X)$	0.80
Power	$Y=5.08(X)^{1.45}$	0.90
Quadratic	$Y=-103+30.43(X)$ $-0.24(X)^2$	0.80

where

Number of observations = 30

Y = Cumulative repair and maintenance costs, % of a similar new tractor list price.

X = Cumulative use, hours/1000.

The power relationship also provided the best relationship for the combined data. Ninety percent of variation in repair and maintenance costs is explained by tractor use. This prediction has a higher variance estimate than the equation derived for four wheel drive tractors alone probably because of the larger sample size.

Figure 7 shows the combined two and four wheel drive tractor cost data and the power prediction relationship. Figure 8 shows a comparison of relationships developed for two and four wheel drive tractors separately and the one for the combined data. The four wheel drive tractor equation nearly merges with the equation derived from the combined data.

The combined cost relationship is compared to the ASAE model and the relationship developed by Kruger and Logan (1980) from Australian data in Figure 9. Repair and maintenance costs were higher in Burkina Faso during tractor early life than predicted using the American or Australian data. The crossover at high amount of usage for the ASAE equation and the equation developed in Burkina Faso may be explained by the aftermath of SOSUCO repair and maintenance during tractor early life. However, the ASAE and Australian equations were extrapolated beyond tractor life for which they were developed.

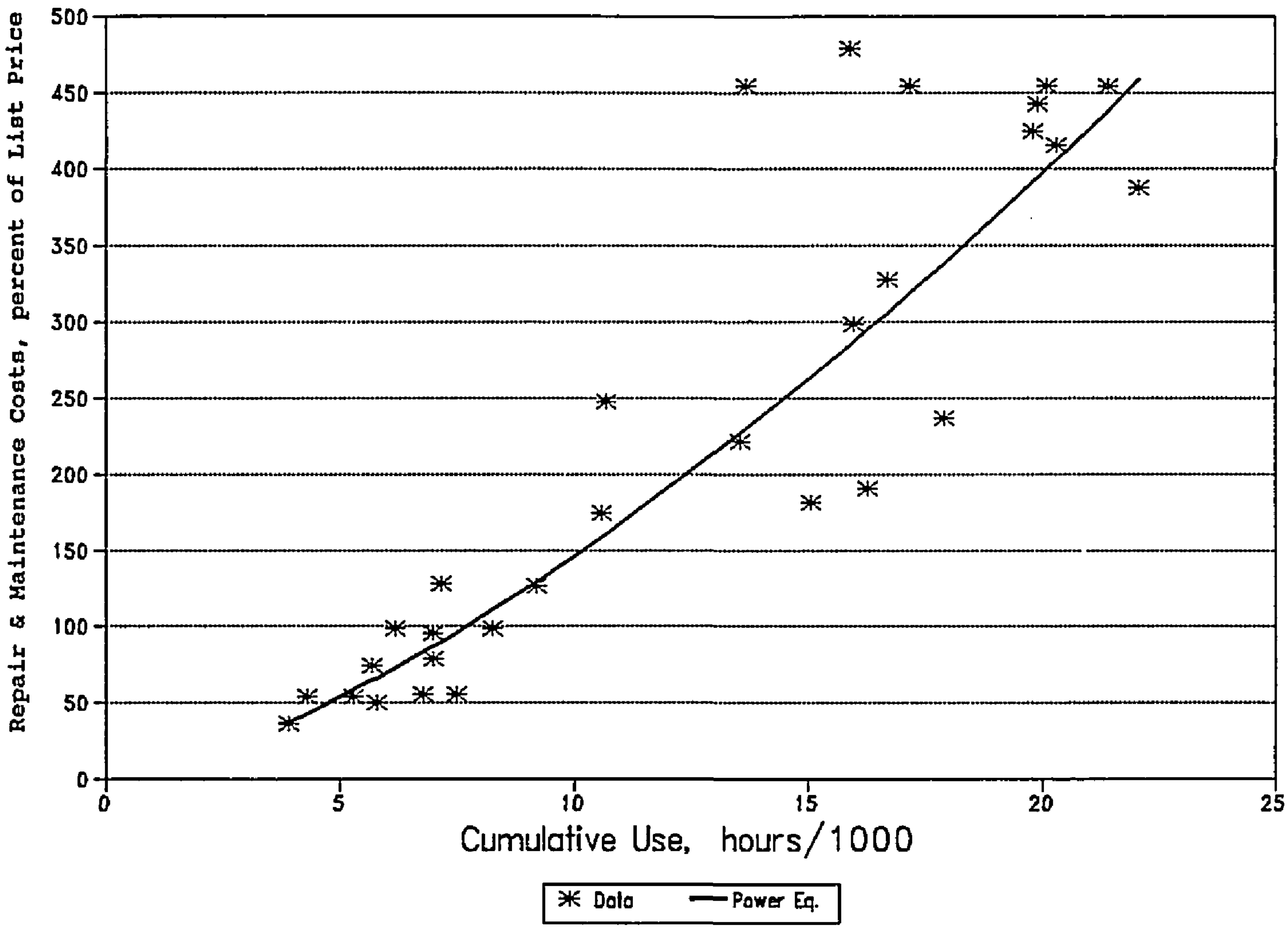

Fig. 7. COMBINED REPAIR AND MAINTENANCE COSTS FOR TWO AND FOUR WHEEL DRIVE TRACTORS

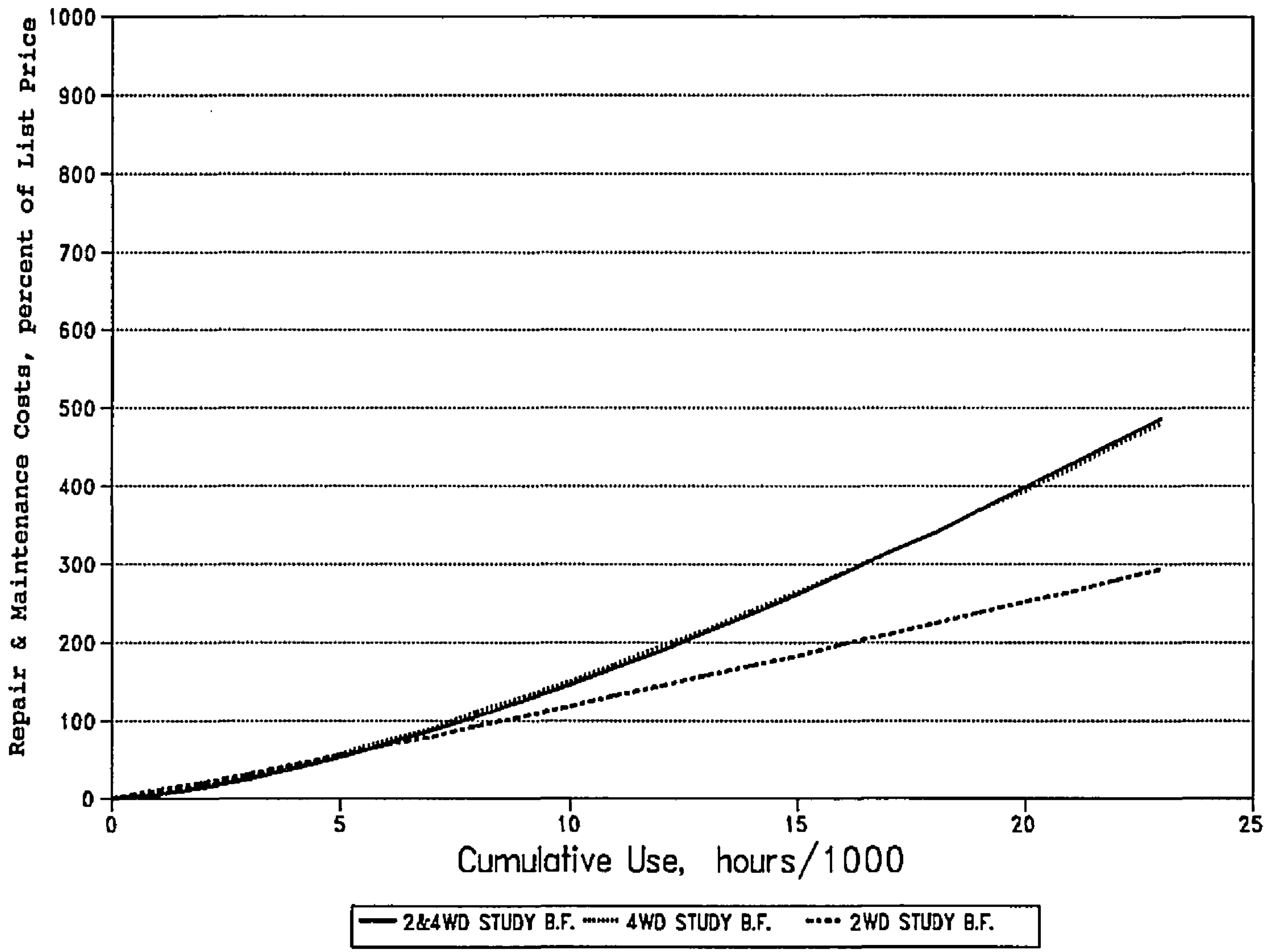

Fig. 8. A COMPARISON OF TWO AND FOUR WHEEL DRIVE TRACTOR REPAIR AND MAINTENANCE COST RELATIONSHIPS

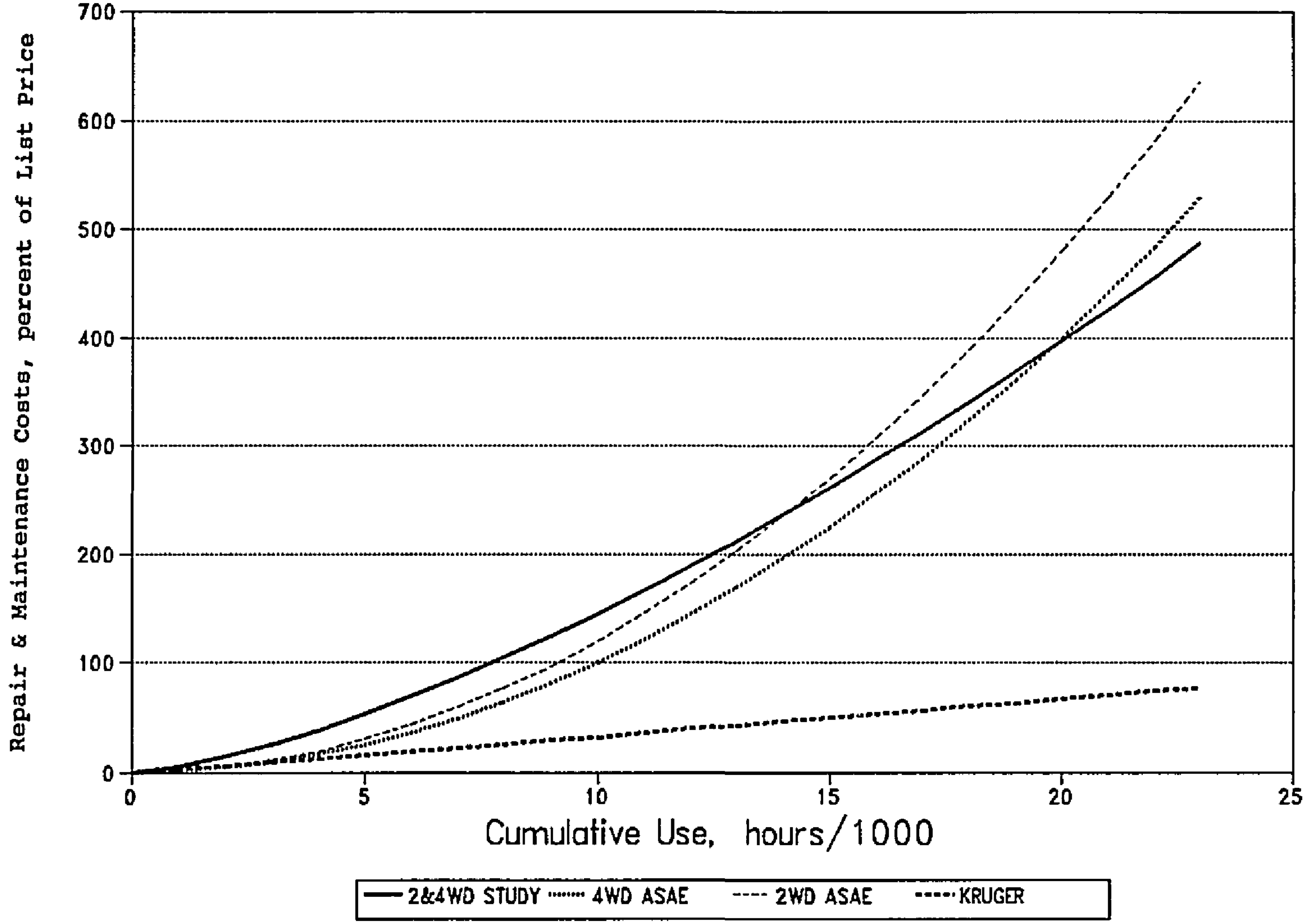

Fig. 9. A COMPARISON OF TRACTOR REPAIR AND MAINTENANCE COST RELATIONSHIPS

Cane Loaders

Repair and maintenance cost data for cane loaders are summarized in Table 6. Equipment age varied from eight to seventeen years. Cane loader cumulative use varied from 9500 to 24600 hours. Three equations were derived to predict repair and maintenance costs as a function of cumulative use, Table 7.

Table 7: Cane Loader Repair and Maintenance Cost Regression Relationships

Relationship	Equation	R2
Linear	$Y=-54.6+13.9(X)$	0.79
Power	$Y=5.98(X)^{1.43}$	0.76
Quadratic	$Y=-33+11.97(X) -0.07(X)^2$	0.79

where

Number of observations = 8

Y = Cumulative repair and maintenance costs, % of a similar new loader list price.

X = Cumulative use, hours/1000.

The quadratic and linear equations provided somewhat better representations of the costs. Seventy nine percent of the variation in repair and maintenance costs is explained by cane loader use. The cane loader cost data and linear relationship are presented in Figure 10.

Table 6. Descriptive Data for Cane Loaders

ID #	Model	Max PTO Power (Hp)	Purchase Price (cfa)	New List Price (cfa)	Cumulative R&M Costs (cfa)	Cumulative Use (hr)	Cumulative Energy Costs (cfa)
2581	1974	100	22134258	26000000	89554000	18400	77780000
2582	1974	100	22134258	26000000	95279000	24000	86772276
2583	1974	100	22134258	26000000	110836000	25600	92506000
2584	1977	100	15965586	26000000	18382000	10800	32463000
2585	1977	100	15965586	26000000	33127000	9500	22339000
2586	1977	100	15965586	26000000	57131000	20900	79529000
2587	1982	100	33578499	26000000	57868000	14200	45095000
2588	1982	100	33578499	26000000	68213000	19900	45541000

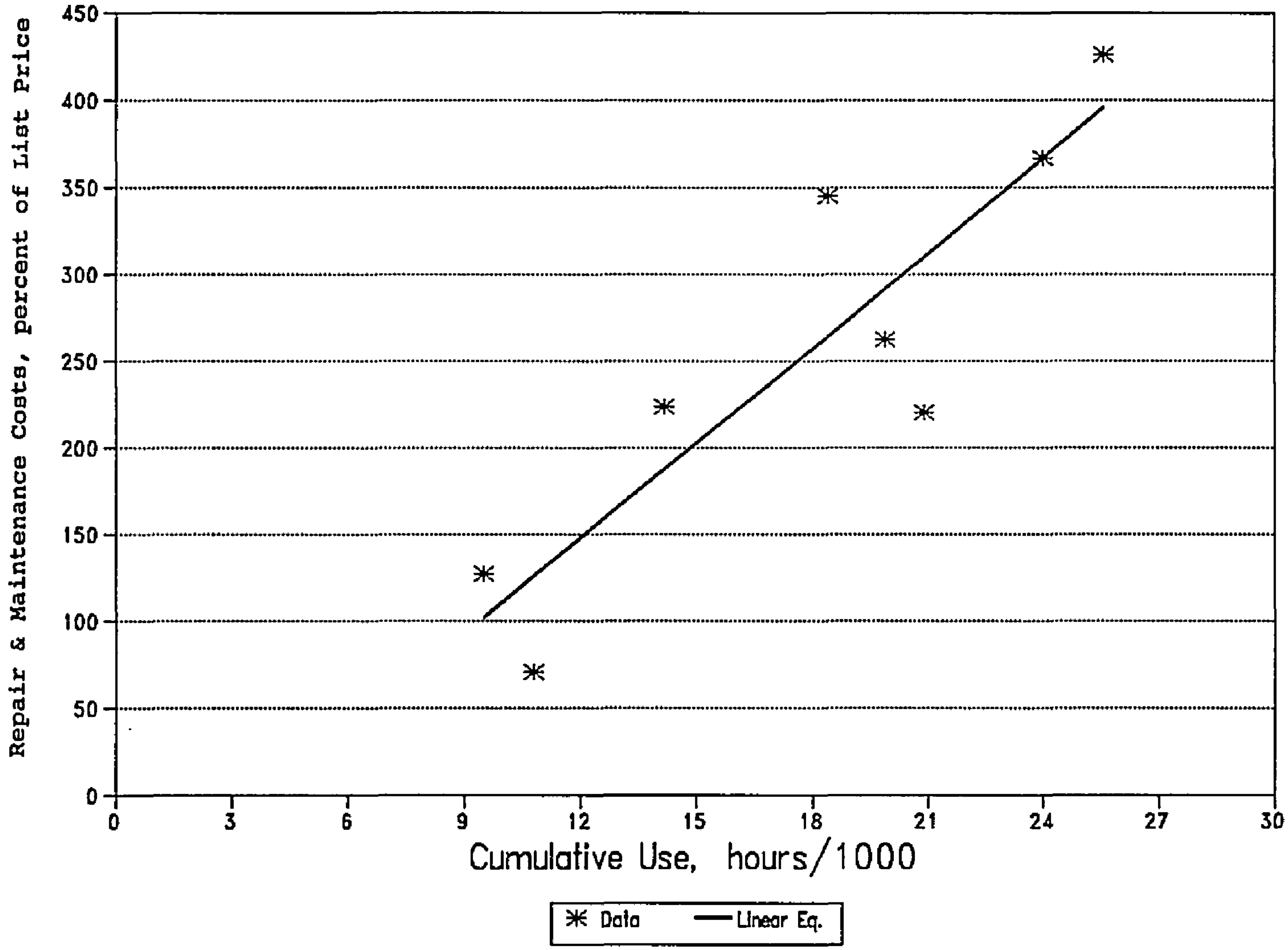

Fig. 10. CANE LOADER REPAIR AND MAINTENANCE COSTS AND PREDICTION RELATIONSHIP

Figure 11 shows the relative importance of cane loader cost items. Repair and maintenance yielded the major cost with forty three percent of the total cane loader costs. Fuel and lubricants made up thirty nine percent. Less than twelve percent of the total costs were ownership costs. Repair and maintenance costs for cane loaders were probably high due to their intensive use during sugarcane harvest. Cane loaders were used on a twenty four basis for loading and unloading sugarcane yielding a high demand for hydraulic parts.

Cane loader cost repartition was similar to the four wheel drive tractor cost repartition except that energy costs were a slightly higher percentage of the total costs, and fixed costs were lower for cane loaders. Cane loader ownership costs were relatively less than with two wheel drive tractors. However, energy, labor and repair costs were a higher percentage of cane loader total costs. A higher operating cost percentage for cane loaders resulted from their intensive use during harvest yielding high demand for repairs on hydraulic components and from higher fuel consumption per horsepower-hour. Two wheel drive tractors were only used for pesticide applications.

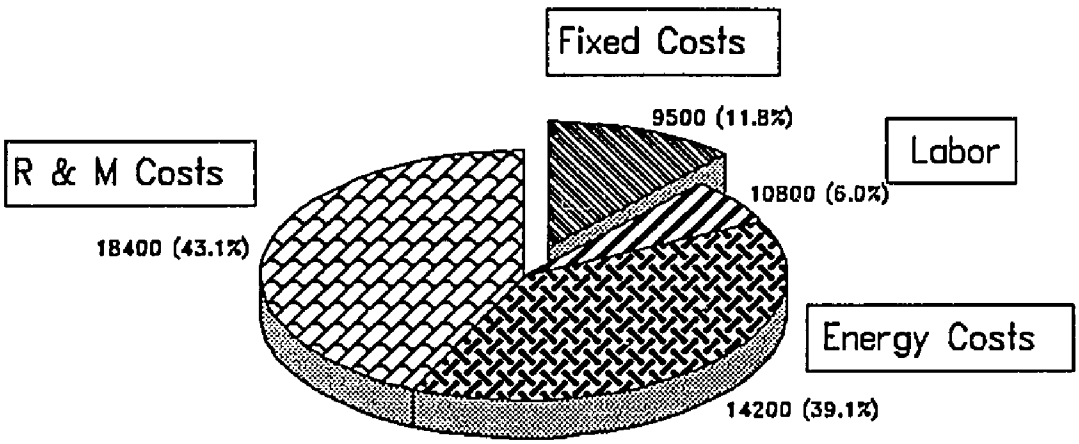

Fig. 11. RELATIVE IMPORTANCE OF CANE LOADER COST COMPONENTS

Generators

Data for generators are presented in Table 8. Generators were purchased only in 1978 and 1989. Repair and maintenance costs were related to usage using linear, power and quadratic equations.

Table 9. Generator Repair and Maintenance Cost Regression Relationships

Relationship	Equation	R2
Linear	$Y=-12.8+12.8(X)$	0.88
Power	$Y=0.50(X)^{2.28}$	0.89
Quadratic	$Y=-2.55+4.55(X)+0.58(X)^2$	0.88

where

Number of observations = 31

Y = Cumulative repair and maintenance costs, % of a similar new generator list price.

X = Cumulative use, hours/1000.

The method developed by Ward et al. (1985 a), previously described, was used to analyze the cost data. The generated relationships show that generator repair and maintenance costs increase rapidly with cumulative use. All equations predict actual costs with high accuracy. However, the power equation has the highest correlation coefficient. No evaluation of generator costs was found in the literature to

Table 8. Descriptive Data for Generators

ID #	Model	Max. Power (Hp)	Purchase Price (cfa)	New List Price (cfa)	Cumulative R&M Costs (cfa)	Cumulative Use (hr)	Cumulative Energy Costs (cfa)
4012	1978	34	1173617	1200000	1572982	12727	5218418
4013	1978	34	1173617	1200000	1572982	12727	5218418
4014	1978	34	1173617	1200000	1572982	12727	5218418
4023	1978	34	1173617	1200000	1572982	12727	5218418
4024	1978	34	1173617	1200000	1572982	12727	5218418
4025	1978	34	1173617	1200000	1572982	12727	5218418
4026	1978	34	1173617	1200000	1572982	12727	5218418
4027	1978	34	1173617	1200000	1572982	12727	5218418
4028	1978	20	1173617	800000	1572982	12727	5218418
4029	1978	20	1173617	800000	1572982	12727	5218418
4030	1978	34	1173617	1200000	1572982	12727	5218418
4031	1978	34	1173617	1200000	1572982	12727	5218418
4032	1978	34	1173617	1200000	1572982	12727	5218418
4033	1978	34	1173617	1200000	1572982	12727	5218418
4034	1978	34	1173617	1200000	1572982	12727	5218418

Table 8. Descriptive Data for Generators (continued)

ID #	Model	Max. Power (Hp)	Purchase Price (cfa)	New List Price (cfa)	Cumulative R&M Costs (cfa)	Cumulative Use (hr)	Cumulative Energy Costs (cfa)
4035	1978	20	1173617	800000	1572982	12727	5218418
4036	1978	20	1173617	800000	1572982	12727	5218418
4037	1978	20	1173617	800000	1572982	12727	5218418
4038	1978	20	1173617	800000	1572982	12727	5218418
4039	1978	34	1173617	1200000	1572982	12727	5218418
4040	1978	34	1173617	1200000	1572982	12727	5218418
4041	1989	34	1173617	1200000	102108	2700	1580125
4042	1989	20	838500	800000	124344	2200	1591475
4043	1989	20	838500	800000	124198	1800	971250
4044	1989	20	838500	800000	58190	1400	898775
4045	1989	20	838500	800000	60828	2000	949725
4046	1989	20	838500	800000	1560	600	237362
4047	1989	20	838500	800000	0	700	231000
4048	1989	20	838500	800000	0	1100	555000
4049	1989	20	838500	800000	0	500	231000
4050	1989	20	838500	800000	16080	1700	845000

allow any comparison. The power equation is plotted in Figure 12.

The importance of generator cost components is shown in Figure 13. The largest cost was related to fuel and lubricant consumption. More than half of the total costs were energy related. Repair and maintenance expenses made up approximately nineteen percent of the total costs. Depreciation, insurance and interest on investments constituted twelve percent of the total costs. Labor costs were not applicable, because no operator was assigned to irrigations pivots. Gas powered generators were used to power the electric motors of center-pivot towers. Ownership costs were the smallest cost item. Minimizing operating costs could help reduce the financial burden of gas powered generator usage.

Motopumps

Repair and maintenance cost data for motopumps are summarized in Table 10. Motopumps were bought in 1976. Maximum power ranges from 20 to 210 Hp. The motopump cost data were analyzed to predict repair and maintenance costs. Three equations were developed from the motopump repair and maintenance cost data, Table 11.

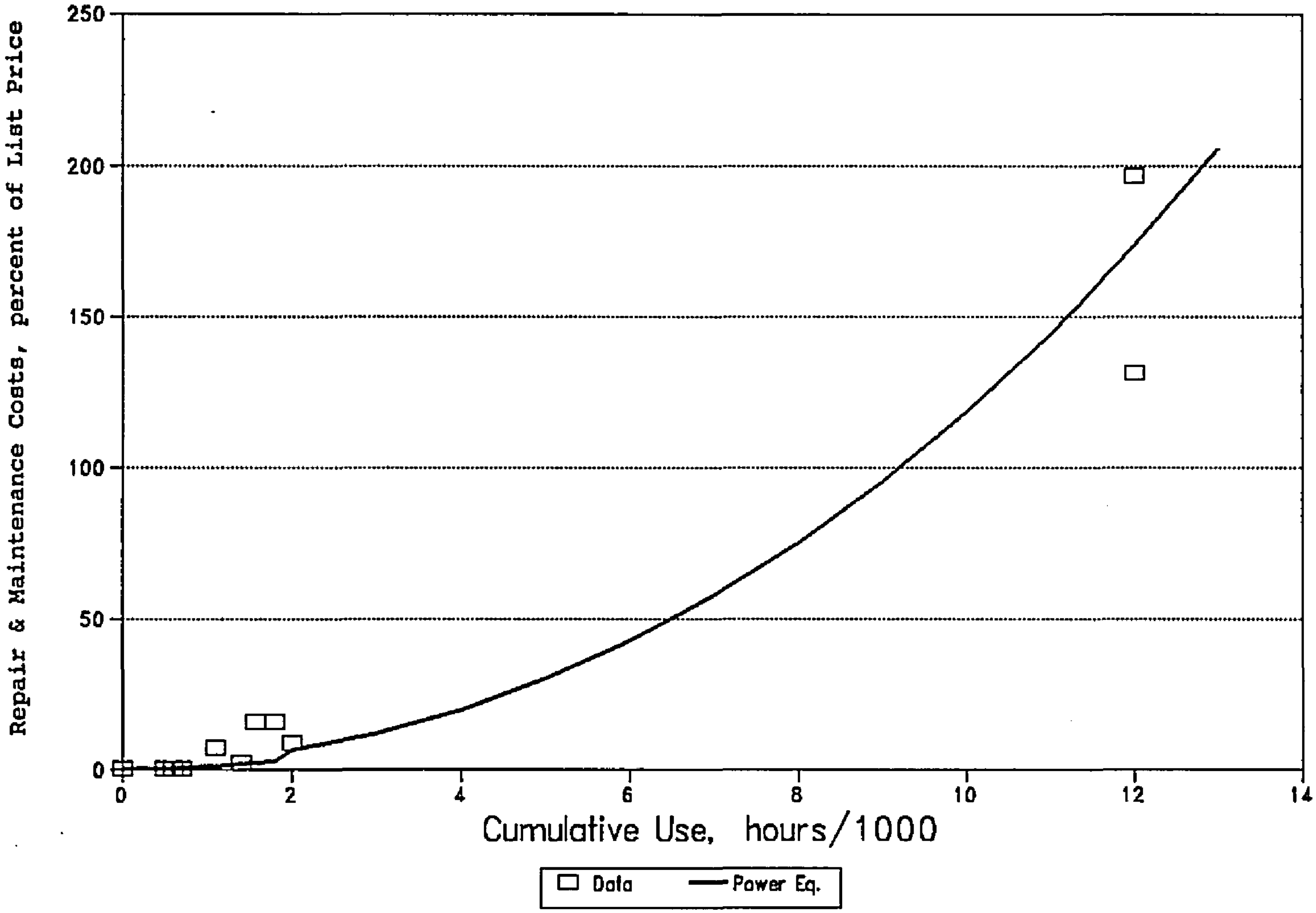

Fig. 12. GASOLINE POWERED GENERATOR REPAIR AND MAINTENANCE COSTS AND PREDICTION RELATIONSHIP

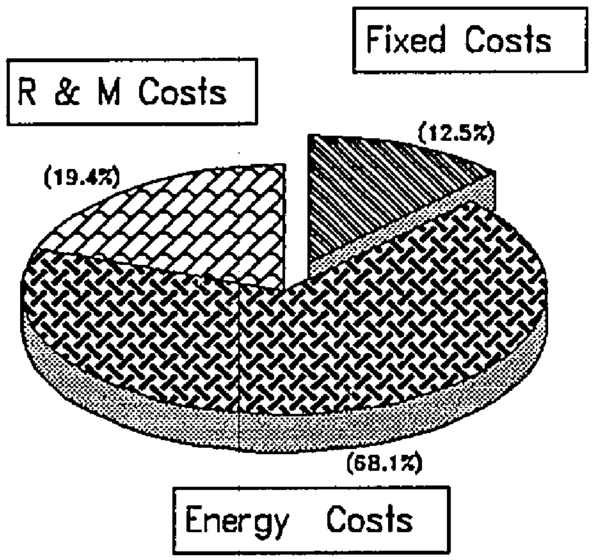

Fig. 13. RELATIVE IMPORTANCE OF GENERATOR COST COMPONENTS

Table 10. Descriptive Data for Motopumps							
		Max.	Purchase	New List	Cumulative		
		Power	Price	Price	R&M Costs	Use	Energy Costs
ID #	Model	(Hp)	(cfa)	(cfa)	(cfa)	(hr)	(cfa)
4803	1976	226	690000	5000000	24544899	12400	6e+07
4804	1976	188	617050	5000000	31105984	19000	99192836
4805	1976	188	650638	5000000	21992280	14700	66220982
4806	1976	188	651744	5000000	20420840	14000	59671934
4807	1976	188	663272	5000000	30518871	14200	99692950
4808	1976	208	730202	5000000	17970730	12800	1.7e+08
4809	1976	208	725998	5000000	12460580	16000	99334845
4810	1976	208	792990	5000000	12818341	14100	92815362
4811	1976	208	888542	5000000	15591034	15700	95531929
4812	1976	117	565805	5000000	2356505	8400	46464835
4813	1976	117	625756	5000000	5608718	7700	42414234

Table 10. Descriptive Data for Motopumps (continued)

ID #	Model	Max. Power (Hp)	Purchase Price (cfa)	New List Price (cfa)	Cumulative R&M Costs (cfa)	Cumulative Use (hr)	Cumulative Energy Costs (cfa)
4831	1976	117	706969	2800000	8487416	9900	54132557
4832	1976	117	802646	2800000	5298399	11700	60420821
4833	1976	117	966740	2800000	8630657	13400	56086267
4834	1976	117	998091	2800000	17696714	16800	83377484
4836	1976	117	1112962	2800000	13577227	9600	30573881
4841	1976	117	1208225	2800000	2481750	5400	235330040
4842	1976	117	1309403	2800000	6669108	8000	28027215
4843	1976	117	357000	2800000	6577427	10800	54238218
4844	1976	117	357000	2800000	714933	3500	15647183
4845	1976	117	357000	2800000	1437124	6700	31947793

Table 11: Motopump Repair and Maintenance Cost Regression Relationships

Relationship	Equation	R2
Linear	$Y=-112.4+36(X)$	0.59
Power	$Y=2.90(X)^{1.84}$	0.72
Quadratic	$Y=120+37.6(X) -0.07(X)^2$	0.59

where

Number of observations = 21

Y = Cumulative repair and maintenance costs, % of a similar new motopump list price.

X = Cumulative use, hours/1000.

The power equation provides a more accurate description of repair and maintenance costs than do the linear and quadratic equations. The cost data and the power prediction equation are plotted in Figure 14. The power equation predicts rapidly increasing costs with high cumulative use. Repair and maintenance costs soared up to six times the unit list price after twenty thousand hours of cumulative use. This observation is justified by motopump intensive use for water pumping and the relatively high sediment content of the surface water.

Cost repartition in Figure 15 reveals that fixed costs were only one percent of the total costs while fourteen percent of the total cost was represented by motopump repair

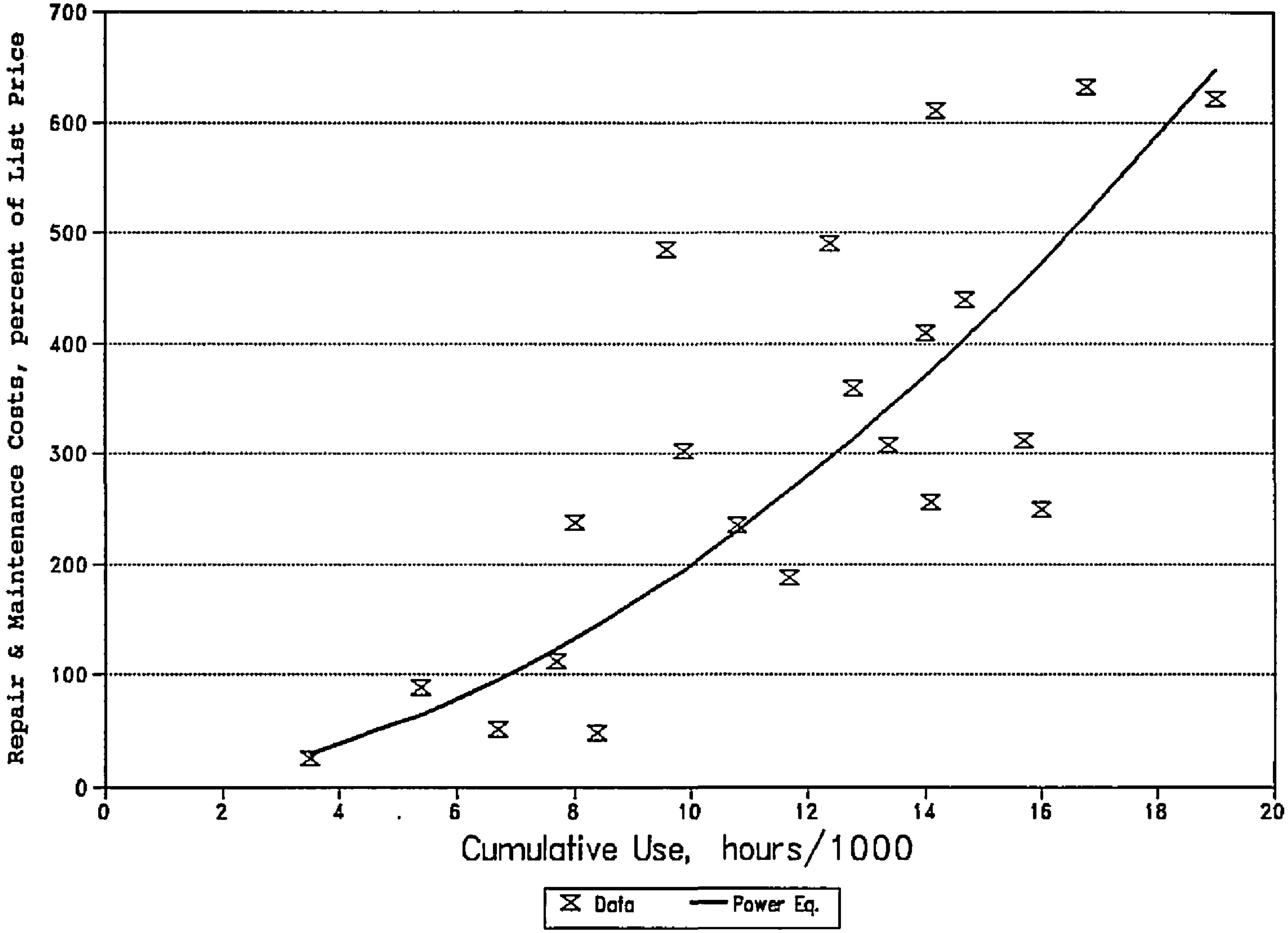

Fig. 14. MOTOPUMP REPAIR AND MAINTENANCE COSTS AND PREDICTION EQUATION

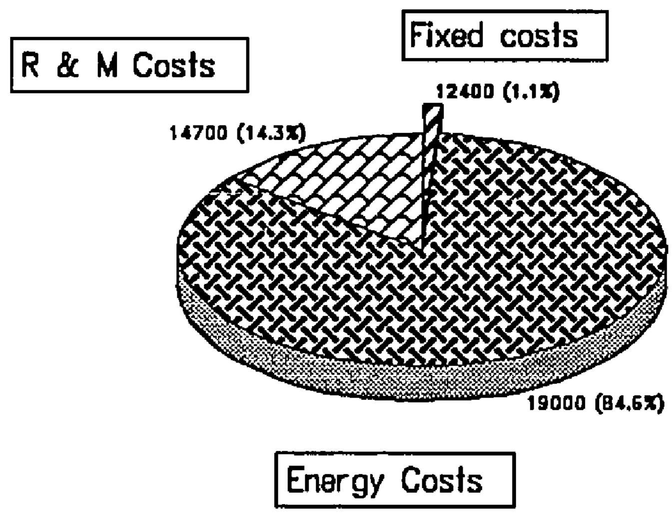

Fig. 15. RELATIVE IMPORTANCE OF MOTOPUMP COST COMPONENTS

and maintenance costs. Energy costs were about eighty four percent of the total costs. Motopump cumulative use revealed that they were intensively used for water pumping and have not been replaced. Significant power losses due the age of the pumping equipment can explain the high energy costs.

Motopump cost repartition was compared to generators. Energy costs represented more than two third of generator and motopump costs. Fixed costs were much higher for generators. Repair and maintenance costs were somewhat more costly for generators. Thus maintenance of better energy efficiency is necessary to reduce generator and motopump costs.

Cost Comparison

A comparison of repair and maintenance cost equations for tractors, cane loaders, generators, and motopumps is shown in Figure 16. The cane loader repair and maintenance cost equation predicts the lowest cost per machine unit list price. Motopumps have the highest repair and maintenance costs per unit list price. Tractor and generator cost predictions are located between the two extremes. Repair and maintenance costs are somewhat higher for tractors than generators at low amounts of use. However, generators exhibit higher repair and maintenance requirements later in lifetime. Differences in power units and applications make comparison difficult. However, motopump intensive use without replacement is one reason for high motopump repair and maintenance costs.

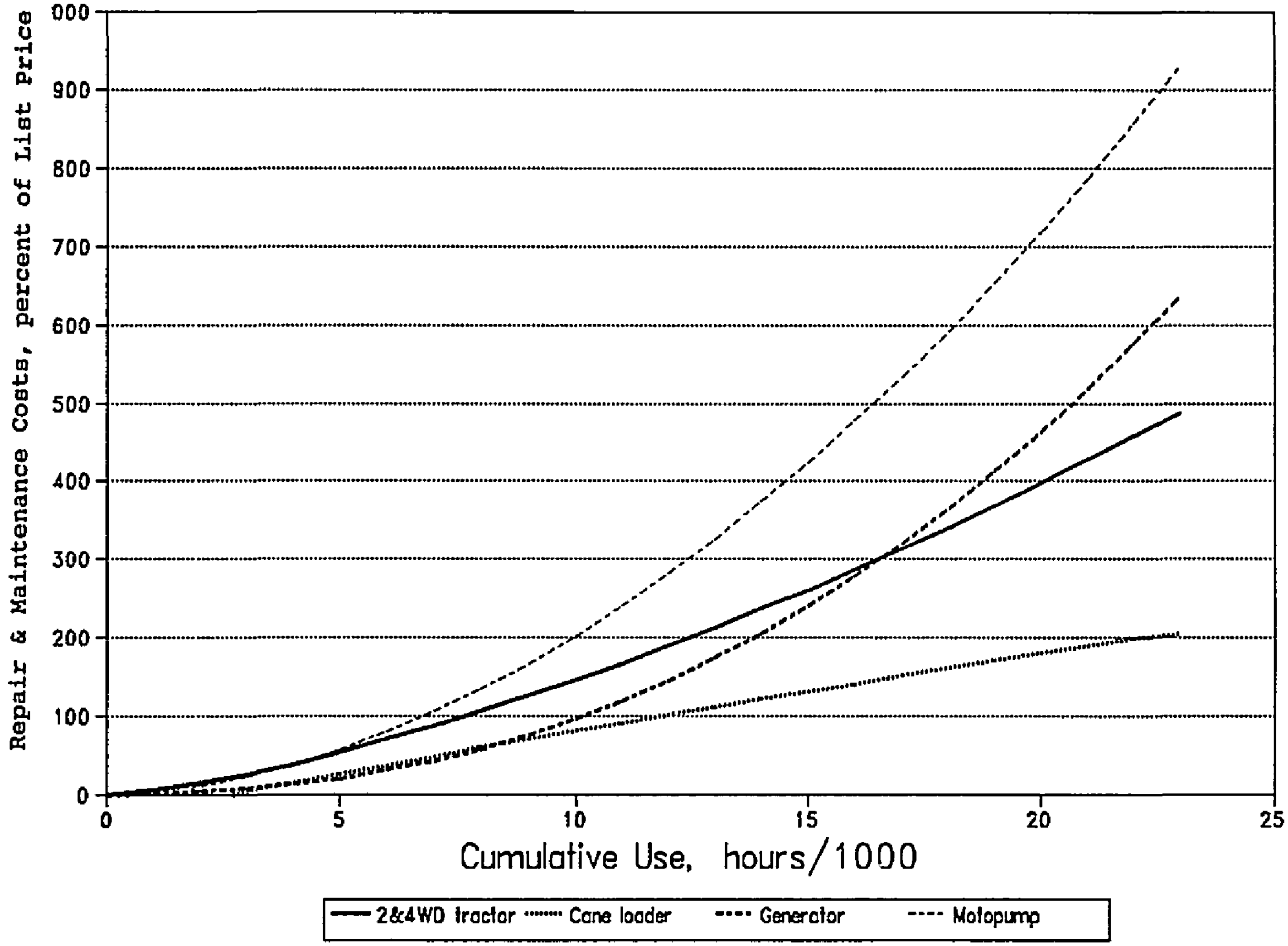

Fig. 16. A COMPARISON OF TRACTOR, CANE LOADER, GENERATOR AND MOTOPUMP REPAIR AND MAINTENANCE COST EQUATIONS

This study revealed some farm equipment used on the sugarcane plantations in Burkina Faso was operated for at least seventeen years. Equipment replacement was not dictated by the rule of lowest cost per unit operating time. Replacements usually were decided by the Director of the Mechanization Service based on equipment past and projected performance. The final decisions were made by company management based on available funds for investments. Other replacements were due to equipment accidental damage which yielded unfeasible repairs.

Decisions on investments usually were made slowly due to administrative procedures. Maximizing the profit of the total production process was weighted more heavily than minimizing the cost of owning and operating farm machinery. Tax incentives on investments did not play a role in SOSUCO decisions. There was no tax pressure, since Burkina Faso did not require any tax, as long as the farm machines or power units were not leased to other users. The most important factor affecting SOSUCO machinery investment decisions is the prevailing sugar price on the local market, a price controlled by the state.

Tractor Availability

Two hundred and forty two tractor breakdowns were reported during the 1989 cropping season. The types of failures and amount of downtime are summarized in Table 12.

Table 12. Tractor Downtime Data for the 1989 Cropping Season

Breakdown code	A	B	C	D	E	F	G	H
Number of breakdowns	32	42	24	19	23	14	20	68
Mean time to repair, hours	12	7	8	12	14	8	16	12
Mean time to breakdown hours	975	743	1300	1642	1357	2229	1560	1835
Availability	0.9878	0.9908	0.9939	0.9927	0.9898	0.9964	0.9898	0.9935

Codes: A = Gear shift, B = Hydraulic system C = Electric system, D = Engine cooling, E = Transmission, F = Brakes, G = Transfer and Gear box, H = Tire.
Availability = Mean operating time/(Mean operating time + Mean time to repair)

Since downtime must be minimized to maintain acceptable timeliness of operations and reduce possible production losses, the data were analyzed to determine average tractor availability during the 1989 cropping season. Downtime includes administrative, logistic, diagnostic and active repair times.

Total operating time for all tractors during the 1989 cropping season was 31200 hours. Component availability was computed by dividing the tractor mean operating time by the sum of the mean time to repair and mean operating time. Tractor availability value was verified by taking the product of component availabilities, assuming components are associated reliability and availabilitywise in series:

$$A_{ss} = \Pi_{i=1}^{n}(A_i)$$

Since tire availability in Table 12 represents the value for each tire, this value was raised to the power of four to conform with each tractor having four tires in this case. Thus, general probability of a tractor being available for use at any time during the 1989 cropping season was ninety one percent, an availability value which indicates that the repair process was effective.

In most cases, tractor downtime was reduced by replacing the failed components by spare parts (new or preventively maintained) or by using several repairmen to accomplish a repair task. Downtime was dependant on the location of the machine on the plantation at the time of the breakdown. It is important to indicate however, that equations of fit to cost data and availability estimations represent the situation under general farming conditions.

Maintenance Policy

Optimizing equipment repair and maintenance costs can be a key to the economic survival of the production system. A practical maintenance policy should rely on accurate failure prediction and spare part ordering to limit stocks of spare parts without sacrificing equipment availability. Large stocks of spare parts are a great financial burden to the production system.

Additional training for tractor operators is required to reduce equipment operating costs. Repair and maintenance was costly due to the age of machines and power units. However, maintenance prevented major breakdowns during the active cropping season, when malfunction of machines could have resulted in production losses.

CONCLUSION

The analysis of farm equipment management data revealed that repair and maintenance costs were higher during tractor early life in Burkina Faso than predicted by the American and Australian data. Farm machine and power unit trade-in was not dictated by the rule of lowest cost per unit operating time. Farm equipment was owned and operated as long as spare parts were available from the dealers. New machine purchase by the SOSUCO Company was discouraged by current low sugar prices on the local market. Curtailing equipment operating costs is essential for Burkina Faso mechanized farming. Additional training of farm equipment operators is required to achieve a reduction of operational costs. An integration of the equipment restoration, maintenance and equipment replacement procedures which consider total production profit optimization can result in more cost effective equipment usage in Burkina Faso.

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