MACHINERY SELECTION BASED ON GROSS-MARGIN COSTING ANALYSIS: A Case Study of Abeokuta Local Government Areas in Nigeria

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ABSTRACT

A survey was conducted in Abeokuta North and South Local Government areas of Ogun State, Nigeria to compare the costs of use of hired tractors with costs of operating privately-owned ones.

The results of the study highlight the factors that affect arable farm machinery selection and how best the factors could be influenced by well-planned selection practices. A Gross-Margin cost analysis was used in the profit evaluation of specific machinery-work combination.

In the work, it was found that the allocation of capital to purchase machinery can be made as effective as possible with machinery being chosen on the basis of which one will give the best financial productivity. The paper also identified poor selection and inefficient operation as factors partly responsible for increase in machinery operation. The study showed that the selection of farm machinery should be area-specific and also be based on the type of farm enterprise.

1.0 INTRODUCTION

Mechanisation pattern is a function of size of the farm holding which is the limiting factor on the choice of different categories of agricultural tools, implements and machinery applied to each farm size. In order to fully utilise the potential power available from agricultural machinery, care must be exercised in the approach to selecting economic, adequate and efficient machinery selection for optimum production. Analysis should go beyond the performance of an individual machine. Quantitative descriptions of the variables affecting the performance of the machinery and their relationships are needed to predict their performance. Their effect on soil compaction as caused by weight of the machinery and ease of operation are all to be considered with the aim of defining a rational system of approach to farm machinery selection. A rational machinery selection consists of four segments, namely system power requirement, tractor-implement combination, field-machine matching and cost analysis. There are two types of ownership of tractors in Nigeria: private and government. The government ownership which has been the dominant source of power for farm operations since the 1930s is administered in the tractor-hiring unit of the Ministry of Agriculture and Natural Resources. The major factor militating against full Mechanisation of Nigerian agriculture is the fact that the costs of owning and operating a tractor are the greatest factors in farm production costs. Thus, by selecting the optimum size tractor and undertaking properly formulated tractor-job matching procedures, a substantial profit can be sustained. Whitson et al (1981) pointed out that a farm operator who operates primarily with owned machinery is faced with the task of selecting the proper size and number of equipment items to perform field operation within a given time frame.

Cervink and Chancellor (1975) were of the opinion that capital costs, operating costs and energy requirements of farm machinery were important budgeting concerns on most commercial farms. They felt that costs were affected by the size of a machine and the way it was used. Murray and De-Beer (1978) viewed it as a costly practice not to fully utilise the potential power available from agricultural machinery. They concluded their report by saying that an effective mechanisation plan needed to take into account the tractor and implements. It should be noted however that tractor and implement cannot be considered

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separately. They must be chosen so that the tractor is fully utilised with respect to the power available and so that the tractor-implement combination is matched to the size of the task in hand.

In mechanisation, many tools and machines are usually available from which farmers could choose, but when deciding on a particular machine, Booysen and De-Beer (1977) stated that it was necessary to consider the rest of the system. For example, a choice between loaders or cutters must take cognisance of factors such as availability and type of labour and implements already on the farm. Also, the need to minimise servicing and maintenance is a factor which should be included in the process of choosing new tractors and equipment (Williams 1992). Aked (1991, 1992), Morgan (1988) and Mabbeth (1992) all studied factors affecting proper choice of machine-implement combinations. These works believed that there was no orthodox approach to selecting farm machinery and that the best basis of choosing suitable tractors was experience and practical trial in the condition in which the machine was to work. Field machinery capacity requirement depends upon the amount of work to be done and time available to complete the job (Singh and Holtman, 1979). In Hughes and Holtman (1979), it was found that selecting the best size machine and implements for a given farm operation helps to avoid yield loss from untimely field work and excessive fixed costs of oversized machines.

It is ironical to realise that mechanisation is often erroneously associated with large-scaled tractorisation in farm operations, moreso as the Nigerian government through her organs like the Ministries of Agriculture, Agricultural Development Project (ADP) with their existing heavy equipment and tractor hiring services and some other related parastatals could fall victim of mechanisation misconception. Hence, there is the present proliferation of brands of tractors in Nigerian market with little or no attention paid to those factors that guarantee efficiency and long service life. The irony of the situation is that the majority of these imported tractors and implements often break down within 1,000 hours of operations and in most cases, the tractors become totally grounded due to non-availability of spare parts for replacement. Through personal experience and information gathered from field officers, it was discovered that in the vast majority of cases, lack of spare parts come directly from wrong choice of machine type and inefficient attention to the manufacturer's recommendations.

It is the objective of this paper to determine all variable factors that affect farm machinery use and selection for effective machine-implement matching that will result in increased productivity and maximum profit.

2.0 MACHINERY CHARACTERISTICS AND METHODOLOGY

2.1 Machine Characteristics

The reduction of labour requirements has been the principal motivating force in agricultural mechanisation. Mechanisation has come to mean the use of machine and other mechanical aids which help the farmers to use his muscles and mind to a better advantage. Farm machines operate over uneven terrain, through dust, sand, mud and stones. It is therefore essential that the machinery to be employed must be ready to face the stress and strain under which it must operate without efficiency loss. The economic applicability of farm machinery is limited since field operations are seasonal. Tractors perform farm jobs effectively only when it is properly matched with its implements. Rating capacity by the number of rows ploughing a tractor can operate is a common and convenient method, but not very accurate since the required power for ploughing varies greatly in different soils. The size of a tractor can be expressed in terms of its weight, horsepower and implement capacity. Adequate matching of implement with tractor is ensured when the tractor power is known with respect to the number of furrows it can normally pull on any particular soil and the width of other standard implements it may be expected to handle.

One of the most difficult problems in selecting farm machinery is to determine before hand, the efficient performance of a particular machine or equipment within a particular environment putting into consideration the prevailing ecological conditions and complexity or hard operation of the machine itself. A qualitative assessment of the performance of an equipment is highly essential and this can be achieved by evaluating its suitability to the ecological condition, ease of operation and how good the quality of job the equipment does under the prevailing condition. The suitability and adaptability of imported equipment to

Nigerian climatic and ecological conditions constitute the problem that should be solved in assessing the effective performance of any agricultural equipment.

3.0 METHODOLOGY

The study reported here was carried out in Ogun State of Nigeria. The state lies within the tropics, bounded in the West by Benin Republic, in the East by Ondo State, in the North by Oyo State and in the South by Lagos State. It covers a land area of about 16,409 sq. km. and has an estimated population of 27.8 million. The state has a tropical climate with two distinct seasons, the rainy season (March-November), followed by the dry season. The annual mean temperature is between 23°C and 30°C and the annual rainfall is between 1,300 - 1,500mm. The topography is undulating, flat and hilly in most parts. Primary and secondary data were used in the study. The primary data was obtained through the use of questionnaires structured to consist of both open and close-ended questions. The open-ended questions allowed the respondents to express their views about a particular phenomena the secondary data was obtained from state tractor hiring centre in Abeokuta Newsletters, Research reports, Journals and Seminar reports. For consistency of records, only farm enterprises in the state and not individual farmers were used in the primary data collection stage. This was because only few individuals could buy tractors and because individual farmers have very small farm areas. Another reason for the restriction was that these individual farmers hardly kept records. The farm enterprises used had a minimum farm area of 10 hectares and most of them had records or documentation departments where records of the previous years were kept.

Within the two local governments under study, 10 farm enterprises were randomly selected from each local government. Twenty questionnaires were distributed in each of the farm enterprises. At the end of the survey, responses were retrieved from eight and seven farm enterprises in Abeokuta South and North Local Government areas respectively. In all, 280 of the farmers from 15 farm enterprises approached responded to the survey.

Gross Margin Analysis (GMA) of each farm enterprise was calculated and the resulting net farm income per hectare was determined for each farm. This was used to determine which enterprise was making more profit than others with regard to the use of farm machineries at their disposal. The following relationship was used to calculate the Gross-Margin:

$$GM = R - TVC \quad \ldots\ldots(1)$$

where,

R = Revenue generated, and
TVC = Total variable cost or operating cost.

Operating costs or total variable costs include the cost of ploughing, harrowing, spraying, planting, harvesting, procurement of inputs, cost of tractor services, maintenance, repairs and spare parts. Fixed costs include depreciation of machines, shelter, insurance and interest on investment. There are no taxes on agricultural machineries in Nigeria.

4.0 RESULTS AND DISCUSSIONS

In the study area covered in this survey, farms less than 5.99 hectares and 9.99 hectares were designated as small and medium farms respectively while those over 10 hectares were classed as large farms based on the level of mechanisation practiced in Nigeria. From this classification, most of the areas covered were in the medium-to-large farm categories. **Table 1** is a compilation of the survey results from the respondents. The level of sophistication and diverse use of tractors on some large farms resulted in less numbers of labour used per unit land area as one multipurpose machine could do the job of many farm workers. The tractor models used on most farms visited were the Massey-Ferguson 165, Styre 768 and Styre 8075.

These makes have the same average power of 53.7kw and the average cost of operating these tractors was M2,000.00 (N82 is equivalent to $1.00) per day. **Table 2** shows the average annual operating cost of privately-owned and government-owned (hired) tractors. The total annual fixed cost with the 53.7kw Styre tractor was M319,000. The table shows the cost advantage of owning farm machineries (tractors). When the tractors and implements belong to the farmer, he does not need to pay for the use of his operations, rather he accounts for the operating costs, cost of labour and all the inputs he needed on the farm. These form his total variable costs (TVC). From the table, the larger the farm size, the higher the TVC and the more the

FARM GROUP	TOTAL AREA CULTIVATED	% FARM AREA	LABOUR SIZE	LABOUR PER HECTARE	NO. OF TRACTORS	HECTARE PER TRACTOR
Small	62	62	62	62	62	62
Medium	110	110	110	110	110	110
Large	179	179	179	179	179	179

Source: Author's Compilation based on Field Survey carried out between October and November, 1994.

Table 1: **Farm Distribution, Labour and Tractor Use of Respondents**

FARM AREA (HECTARES)	NO. OF TRACTORS	HIRING UNIT COST PER HOUR N	PRIVATELY OWNED COST PER HOUR N
10	1	575.56	581.43
10	1	575.56	581.43
12	1	596.98	581.27
15	1	610.40	593.97
15	1	610.40	592.54
18	1	619.97	594.92
20	1	645.56	606.83
22	1	641.52	611.43
25	1	675.00	672.38
25	2	675.00	672.38
26	2	681.37	657.14
30	1	719.52	678.73
30	2	719.52	678.73
45	2	798.33	690.63
48	2	810.27	693.97

Source: Author's Compilation based on Field Survey carried out between October and November, 1994.

Table 2: **Relationship between Farm Size (Under Cultivation) and TotalAverage Cost per Hour for Privately-owned and Government Tractor Hiring Unit (Based on 630 Hours Annual Use)**

and implements, the higher the TVC. It should be noted that the cost of labour or labour size is a function of the number of tractors and different types of jobs the tractor could do.

Table 2 also shows that the higher the farm size and the number of tractors used, the higher the total variable cost. A farmer hiring tractors has the right over the tractor for the period of time he pays for. The tractor will therefore only be available to him despite his hiring power when the owner of the tractor releases it, since farm operations are time-specific and as such the farmer hiring tractors has to beat time and the farmer leasing tractor has to finish his own farm work before leasing out his tractor. This is responsible for the increase or higher number of labour usually found on farms that depend on hiring tractors for their farm operations. This and other reasons contribute to high costs of labour for hiring tractor when compared to

OWNERSHIP	ANNUAL USE (HOURS)	COST PER HOUR (N/HR)
Private	1,047	125.75
Government (Tractor Hiring Unit)	389	250.00

Source: Author's Compilation based on Field Survey carried out between October and November, 1994.

Table 3: **Average Annual Use and Costs of Government (Tractor Hiring Unit) and Privately-owned Tractors**

privately-owned tractor operations. In the tractor-hiring situation, the farmer pays for all farm operations the machines perform while the owner of the machine takes care of the cost of fuelling, repairs and wages of operators. **Table 3** gives the relative annual use and cost of the privately-owned and hired tractors based on the farm area and number of tractors. The annual use of privately-owned tractors is higher than the hired tractors. This was responsible for the difference in their operating costs. The other reasons for the difference in price were that the hired tractors' operators did not give as careful attention to the tractors and these operators are also randomly selected to operate any of the tractor models. These cause frequent hired tractor breakdown and in such cases, the costs of spare parts for hired tractors are excessive. The relative importance of all cost items for the privately-owned and hired tractors is shown in **Figure 1**.

The results of the tractor annual use on costs of operating tractors in the study areas are shown in **Table 4**. These tractors have the same power rating of 53.7Kw, age and operating under similar conditions. The costs were N623.46 and N387.93 per hour for 630 and 1,140 hours annual use respectively. The investigation also revealed that the repair costs are proportional to tractor age (**Table 5**). The regression equation for tractor repair cost in terms of its age is given as:

$$C = 23.64A1.577 \ (R2 = 9998) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where,

C = Repair cost (N), and
A = Age of tractor, Hours

4.1 Profit Determination by Gross-Margin Analysis

Gross margin analysis is an economic procedure used to determine whether an enterprise is operating at profit or loss level. From the survey, it was discovered that a tractor ploughing at the rate of 1.2 hectares per hour and working for an average of 7 hours will plough 8.4 hectares of land per day. It then means that for an area of 20 hectares, it will take one tractor about three days or will cover 25.2 hectares of land for the working period. This is so because the tractor will spend some time out of the 7 hours of each day for loading, fuelling and turning in the field. Hence, the effective operating time will be enough to finish ploughing while the time needed to plough the additional 5.2 hectares during the working period will take care of the idle time. This survey revealed that when the tractors were underutilised, the farmers incurred high TVC, lower profit per hectare per tractor (**Table 6**). As the number of tractors on the farms are reduced, the profit per hectare per tractor will be significantly changed thus reducing the TVC. What this shows is that it is profitable to use the exact optimum number of tractors for a particular farm operation. It was also observed that the higher the number of tractors with regards to the farm size, the lower the profit. **Table 7** shows the profit accruing to farmers adopting mixed cropping operation. The total operating cost in the table includes costs of farm inputs, repairs, labour, fuel, oil and lubrication used for crop production in the local government areas under consideration. The compilation of the results also took cognisance of limitations on land, hours of available field time, machinery size and cropping alternatives found in the survey areas.

5.0 CONCLUSIONS

For effective machinery use, it is necessary to take into account the factors, primarily economic, which affect the choice of tractor and implement. The tractor and implement must be chosen so that the tractor is fully utilised with respect to the power available. This will ensure that the tractor-implement combination is matched to the size of work in hand. From this survey, it was found that it pays to select appropriate numbers of tractors for farm operations as this ensures high profit, minimises the possibility of under-utilising farm resources and thus saves costs. Also, in addition to other

TRACTOR INITIAL COST: N2,000,000.00 53.7Kw (72HP)	SEASONAL USE OF TRACTOR	
	630 HOURS (N)	1,140 HOURS (N)
Fixed Costs		
Depreciation at 10 of New Cost	180,000.00	180,000.00
Interest on Insurance (9%)	99,000.00	99,000.00
Insurance & Shelter at 2%	40,000.00	40,000.00
Total Fixed Cost	319,000.00	319,000.00
Variable Cost		
Fuel Cost	16,200.00	31,387.00
Lubrication at 20% Fuel Cost	3,240.00	7,358.83
Repairing	50,000.00	78,985.70
Interest on Operating Cost	4,336.85	5,506.67
Total Variable Cost	73,776.85	123,238.20
Total Cost	392,776.85	442,238.20
Total Cost per Hour	623.46	387.93

Source: Author's Compilation based on Field Survey carried out between October and November, 1994.

Table 4: **Effect of Tractor Use on Costs**

selection criteria discussed in this work, the use of Gross-Margin (GM) approach to arable farm machinery selection will enhance profitable decision on tractor-implement combination to accomplish a specific farm task. The expected benefits of Gross-Margin approach include reduction in loss of values in terms of quality and quantity of crop and better utilisation of man and machine.

The study showed that the selection of farm machinery should be areas-specific and also be based on the type of farm enterprise. Since timeliness of operation affects yield and hence profitability of using machinery, equipment chosen must be reliable. This will enable timely completion of all tasks. The study also shows that for the use of a privately-owned tractor to be profitable, the annual use should be at least 1,050 hours because this is the least number of hours that gives minimum costs of using the tractors. Also, for cost of operating tractor hiring unit to be minimised, the tractor operators should be trained to acquire the necessary basic skills in tractor use and maintenance. It was also found that substantial profit can be obtained

AGE OF TRACTOR	AVERAGE REPAIR COST PER HOUR
1	23.64
2	70.55
3	133.71
4	210.46
5	299.22
6	398.89
7	508.65
8	627.86
9	756.01
10	892.65
11	1,037.41
12	1,189.98

Source: Author's Compilation based on Field Survey carried out between October and November, 1994.

Table 5: **Relationship between Age of Tractor and Repair Cost**

by selecting the optimum numbers of tractors and undertaking properly formulate tractor-job matching procedures.

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AREA OF LAND (HA)	N. TR.	FIXED COST (FC) (N)	TOTAL VARIABLE COST (TVC) (N)	REVENUE (N)	GROSS MARGIN (N)	PROFIT (GM - FC) (N)	PROFIT PER HECTARE (N)	PROFIT PER HECTARE PER TRACTOR (N)
62	7	346,500	457,510	2,258,605	1,801,095	1,454,595	23,461.21	3,351.60
110	14	693,000	522,800	4,677,225	4,154,345	3,461,345	31,466.77	2,247.63
179	19	940,500	617,640	6,995,984	5,668,994	4,728,494	26,416.17	1,390.32
62	4	198,000	392,125	2,258,605	1,866,480	1,668,480	26,910.97	6,727.74
110	7	346,500	675,480	4,677,225	4,001,745	3,655,245	33,229.50	4,747.07
179	12	594,000	564,387	6,995,984	6,431,597	5,837,597	32,612.27	2,717.69

Source: Author's Compilation based on Field Survey carried out between October and November, 1994.

Table 6: **Effect of Tractor Use on Profit**

LAND AREA	MIXED CROPPING, YIELD, KG/H (LAND ALLOCATION, HA)					REVENUE GENERATED FROM SALES (N/HECTARE)					COST BENEFIT OF CROPPING ALTERNATIVES	
	MAIZE	CASSAVA	MELON	SOYBEAN	COWPEA	MAIZE	CASSAVA	MELON	SOYBEAN	COWPEA	TOC	RAOC
10	69,967	56,087	29,161	-	-	29,992	66,183	21,579	-	-	67,789	49,965
	(7)	(2)	(1)	-	-	-	-	-	-	-	-	-
10	6,096	99,574	12,193	-	-	29,992	117,497	9,023	-	-	89,117	67,395
	(7)	(1)	(2)	-	-	-	35,969	-	-	-	-	-
12	7,620	30,482	-	-	4,064	37,490	-	-	-	79,985	90,628	65,816
	(6)	(3)	-	-	(3)	-	55,951	-	-	-	-	-
15	5,995	47,416	10,161	-	-	29,495	-	7,519	-	-	53,466	39,499
	(10)	(3)	(2)	-	-	-	83,926	-	-	-	-	-
15	6,096	71,124	13,548,	-	-	29,992	-	10,026	-	-	70,909	53,035
	(10)	(2)	(3)	-	-	-	51,954	-	-	-	-	-
18	9,778	44,029	21,845	-	-	48,108	-	16,165	-	-	67,496	48,731
	(13)	(3)	(2)	-	-	-	67,621	-	-	-	-	-
20	9,856	57,306	23,878	-	2,286	48,492	-	17,670	-	44,988	104,381	74,390
	(10)	(5)	(1)	-	(4)	-	51,954	-	-	-	-	-
22	7,112	44,029	3,048	-	4,064	34,991	-	2,256	-	79,985	99,411	69,775
	(10)	(6)	(2)	-	(4)	-	31,773	-	-	-	-	-
25	5,792	26,926	55,477	4,064	-	28,497	-	41,053	99,974	-	119,097	82,200
	(14)	(6)	(1)	(4)	-	-	25,178	-	-	-	-	-
25	7,112	21,337	-	-	-	34,991	-	-	-	-	35,094	25,075
	(15)	(10)	-	-	-	-	14,987	-	-	-	-	-
26	4,064	12,701	-	3,556	4,064	19,995	-	-	87,478	79,985	120,868	81,577
	(12)	(8)	-	(4)	(2)	-	34,170	-	-	-	-	-
30	6,096	28,958	61,167	3,861	5,690	29,992	-	45,264	94,981	111,979	188,012	128,374
	(15)	(7)	(1)	(4)	(3)	-	15,987	-	-	-	-	-
30	7,112	13,548	17,781	-	-	34,991	-	13,158	-	-	37,711	26,425
	(20)	(6)	(4)	-	-	-	10,791	-	-			-
45	-	9,145	-	4,064	4,064	-	-	-	99,974	79,985	114,018	76,732
	-	(30)	-	(5)	(10)	-		-	-	-		-
48	8,230	104,782	13,209	-	-	40,492	123,643	9,775	-	-	99,303	74,607
	(43)	(4)	(1)	-	-		-	-	-	-	-	-

Source: Author's Compilation based on Field Survey carried out between October and November, 1994.

Note: TOC = Total Operating Cost, N/Hectare
RAOC = Return Above Operating Cost, N/Hectare
* Numbers in parenthesis are land allocations to each crop alternative.

Table 7: **Effect of Some Selected Crop Alternatives on Variable Costs, Crop Yields and Sales Prices for Abeokuta North and South Local Government Areas in Nigeria.**

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