FIELD CAPACITIVE PERFORMANCE STUDY OF PLOUGHING OPERATION IN LAFIA L.G.A, NASARAWA STATE, NIGERIA

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ABSTRACT

In field machinery selection, the most pertinent variable is size or capacity of the machine. Size selection of agricultural machinery should be based on anticipated performance. A field capacitive performance study of ploughing operations was carried out on a small field of 0.49ha using a 3 x 1.5m- disc plough pulled by an MF 375 (56kW) tractor. The analysis of the data generated from the time and motion studies yielded a mean field efficiency of about 67%. The average effective width of cut of the ploug was 1.39m as against the theoretical width of plough of 1.5m. Analysis of the man- machine combination performance yielded a maximum man-machine activity of 90% and a minimum of 85.9%. the mean man-machine performance obtained was 0.2ha/hr. an average of 33% of total yield time was spent on non-productive activities while 67% was spent on productive (harrowing) activities. It is concluded that high effective field capacities could be obtained with high speeds. Proper preventive maintenance will minimize the number of field adjustments and also help in increasing implement width of utilization; hence increase in field capacities.

KEYWORDS: Field capacitive performance, operational speed, effective field capacity, field efficiency, total field time.

1. INTRODUCTION

All machines are designed to perform a given task at a specified time. If this design objective is not met, it only means that the machine setting is wrong or the machine of the machine and the power unit is not correct (Kepner et al; 2005). Field machine performance or capacity is the rate at which it can cover a field while performing its intended function or useful work. It is usually measured by the rate of work and the speed of travel with the allowance for are the width of useful work and the speed of travel with the allowance for lost time in turning and servicing the machine (Yohanna and Ifem, 2004).

The theoretical field capacity of an implement is the rate at which it will perform its intended function if it is operated continuously at its rated width. It is the hectare covered per hour or rate of field coverage possible if the machine works all the time at the recorded speed and utilized its entire width of operation. There is no allowance for loss of time or serving. The theoretical field capacity is calculated by multiplying the forward speed in km/hr by the operating width of the implement (Kepner et al; 2005). Culpin (1976) mentioned equation of theoretical field capacity as follows:

$$C_T = \frac{SW}{C}$$

Where, C_T = Theoretical field capacity, ha/hr; S = Speed, km/hr; W = Implement width, m; C = Constant = 10

The effective field capacity of an implement is the average rate at which it covers a field expressed in ha/hr or the actual rate of coverage by the machine. This includes an allowance for loss of time in turning and servicing. The effective field capacity of a machine in ha/hr is determined by multiplying the product of the speed in km/hr and the rated width by the field efficiency expressed in decimal fraction. It can be calculated in area base as follows:

$$C = \frac{Sw\,Ef}{10}$$

Where, C_e = Effective field capacity, ha/hr; S = Field Speed, km/hr; W = Implement working width, m; E_f = Field efficiency, decimal

It was found that effective capacity is affected by the implement size (Moayad et al; 2014). Ahmed and Haffar (1993) reported that heavy disc harrow showed higher effective field capacity than light disc harrow. Field efficiency of a machine is the ratio of the effective field capacity or productivity of a machine under key condition to the theoretical field capacity or theoretical maximum productivity and multiply by 100% (ASAE, 2003), Kumar et al; 2012). The efficiency of machine is always less than 100 and is influence by various factors involved in the effective capacity. Field efficiency account for failure to utilize the theoretical operating width of the machine, time lost because of operator capacity and habits and operating policy and field characteristics. Travel to and fro a field, major repairs, preventive maintenance and daily service activities are not constant for a particular machine but vary with the size and shape of the field, pattern of field operation, crop yield, moisture and crop conditions (ASAE, 2003). The field efficiency of a plough may have a typical range of 74-84 (ASAE, 1988). This value includes all effects of time and width of utilization and might be considered to represent the percentage of time that a machine spends actually doing what it is supposed to be doing. Actual width measurement from field observation of a 3-disc plough is 150cm (1.5m). Doubling the size of a machine does not double the theoretical or effective field capacities; instead it may decrease the field efficiency (Smith, 1965). Field efficiency is expressed by Kumar et al (2012) as;

$$E = \frac{C_e}{C_T} = 100 \quad \text{To} \quad E_f = \frac{X100}{T_e + T_h + T_a}$$

Where, T_o = Theoretical Time per ha; T_e = Effective Operating Time = $\frac{T_o}{k}\,x\,100$; K = The percentage of Implement width actually used; T_h = the time loss per ha due to interruptions and is not proportional to the area

Witney (1988) indicated that the implement might be selected depending on the width for getting sufficient capacity so that work needed to be done within allotted time, and getting the maximum net profit can be estimated as follows:

$$W = \frac{C_e\,x\,C_f}{SE_f}$$

Where, W = optimum width, m; C_e = effective field capacity, ha/hr; CF = Correction factor; S = Field Speed, km/hr; Ef = Field efficiency, decimal

Studies on the field performance of agricultural machinery provide information for machinery design, selection and for the improvement of machinery use. Over the years different types and sizes of agricultural machi9nes have been imported into Nigeria; most often without regards for their adaptability to local needs (Gwarzo, 1991; Onwualu et al; 2006). According to them, some of these machines come without proper information on the design capabilities and the conditions under which they are best utilized. These have posed serious problem to machinery managers especially in the area of optimization of machinery selection for any given situation. It has therefore become necessary for proper performance evaluation to be carried out under different local conditions in order to have the required information on all available machinery and machinery systems.

Morghan and Bolarin (1976) carried out work on disc ploughing, disc harrowing and chiseling operations. The results obtained were respectively 0.13, 0.61 and 0.61ha/hr. in this performance studies of field machinery for crop production, Gwarzo (1991) reported a mean operating speed for ploughing operation of 5.66km/hr using CAT D4E tractor equipped with a 4.32m Rome plough and 9.97km/hr for harrowing using a CASE 2590 tractor equipped with 1 3.7m offset disc harrow. The corresponding values of effective field capacities obtained were 2.34ha/hr and 3.42 ha/hr with field utilization was above 90% during all observations.

The studies conducted during ploughing operations and the information obtained are quantitative values of operation's productive and non-productive times, the field capacity, field efficiency and man-machine performance for the operation.

The main aim of the study was to conduct field performance studies of ploughing operation on small farms. Specific objectives include to: obtain accurate records of ploughing time, turning timer and delay time (idle travel, machine facture and management stops/adjustment) during a ploughing operation; analysis and evaluate the performance of the man-machine combination and obtain the required capacitive performance criteria values of effective field capacity, field efficiency, operating speed and man- machine characteristics.

2. MATERIALS AND METHODS

The machine combination used comprised of Massey Ferguson, MF 375 (56KW) real-wheel driven tractor equipped with a 3-disc furrow 150cm disc plough (or 3 x 1.5m disc plough). The studies were conducted on sandy loan fallow farm lands that have not been under continuous cultivation for more than five (5) years in college of Agriculture, Lafia, Nasarawa State. The time and motion studies were conducted following the procedures in Ullah and Kofoed (1987) and taking into consideration one of the recommendations in Gwarzo (19910, which called for the use of 3 persons equipped with stop watches to record the activity times. The parameters measured included:

1. Ploughing time, support function time or turning time and delay activity times (idle travel, machine failure and management stops (adjustments, repairs etc).
2. Field row length, actual or effective width of cut of plough as well as the ploughing depths. For the measurement of activity times, three stop watches (hever club master 1/5type) were employed. All lengths were measured with a 100m-surveyor type while ploughing depths and widths of cut were measured with crown 3.5m/12FT 16mm pocket steel tape-1k-3H 93W.

During the observations the primary function activity began when the plough was lowered at the starting point and actual ploughing began and ended as soon as the plough was raised at the end of the field now. Time for stoppages (if any) were summed up and deducted from the total times spent on the entire row length. At the end of a filed row just where the plough was raised, the timing activity began. The time spent in making the turn was recorded as the turning activity time. All field adjustments or servicing during operations that exceeds 10 minutes were considered major breakdowns and were therefore excluded from delay activity time following the recommendations of Barnes (1960), Ojha and Michael 2003, 2011). The length of each field row was later measured and the number of passes (trips) made to cover the entire field recorded. Other information collected for each field included soil type and condition and weather condition during every operation. Over the period of study, a total number of ten (10) field outings were made.

3. RESULTS AND DISCUSSION

The results of the activity times for each field row recorded were summed up and the mean values of each field are presented in Table 1. The fields were all rectangular in shape so that all rows in each field were of equal length. The length of field rows varied from 35 to 37. The actual or effective width of cut of plough ranged between 1.36m and 1.41m against a theoretical rated width of 1.5m. Over the entire operations, an average width of plough utilized was 1.39m, which is 93%. This compares favorably with data in Morghan and Bolarin (1976), Gwarzo (1991) and Sahay (2004).

Table 2 shows analysis of data on performance criteria for the tractor plough combination. It can be seen that the size of the field varied between 0.48ha and 0.50ha or a mean ploughed area of 0.49ha, which according to Rahamoo (1983), is about the average plot size in the area. Average ploughing speed varied between a minimum of 6.6 km/hr. this mean value for ploughing operation is well within the ranges recommended in ASAE (1988), Ojha and Michael, (2003) and (2011), Sahay (2004) and Kumar et al, (2012). The turning times recorded were low to mean turning time at row end of 6.3 minutes. The average delay times, due to preventive maintenance (adjustment, minor servicing, greasing etc) during the whole operations was 3.53 minutes.

The theoretical field capacities ranged from 1.29ha/hr to 1.73ha/hr while the effective field capacity of the operations ranged between 0.90ha/hr and 1.12ha/hr with an average of 1.0ha/hr. ideally, the effective field capacity should be the same or as close as possible to the theoretical field capacity; however, in practice this is not because it is not possible to utilize the full width of operation of a machine without any overlap and it is not always possible to work at the speed because of the condition of the field, the judgment and efficiency of the operator and the amount of power available. Considerable time is lost in turning at the ends of rows, in minor breakdown, in lubrication and in adding seed, fertilizer or spraying solution. Thus it is impossible for the machine to be working effectively all the time (Yohanna and Ifem, 2004).

The lowest field efficiency attained was 63% while the highest was 70% as shown in Table 2, with the average being 66.9%. This is within the ranges cited in smith (1965). ASAE (1988) and (2003), Ojha and Michael (2003) and (2011), Sahay, (2004), Onwualu et al, (2006) and Kumar et al, (2012).

Man-machine activity values were very high reaching up to 90%, signifying minimum delay or stoppages during operations. Ordinary, this should be an indication of good operator’s performance and/or machine reliability; however, in this case it is more likely a result of the small sizes of the fields, which made operators stoppages almost unnecessary.

Table 1: Results of Field Studies

Observation	Length (m)	No. of Passes (Trips)	Effective width of cut (m)	Activity Times (Minutes)				Speed (Km/hr)	Area (ha)
1	100	36	1.37	21.4	6.5	4.6	32.5	6.6	0.49
2	98	37	1.36	22.7	5.8	3.7	32.2	6.8	0.49
3	99	35	1.44	18.2	6.2	3.6	28.0	7.4	6.49
4	100	36	1.40	20.8	6.0	3.4	30.2	7.2	0.50
5	10	36	1.38	17.8	6.8	3.6	28.2	7.7	0.50
6	99	36	1.38	22.4	6.4	3.2	32.0	6.7	0.48
7	98	36	1.38	21.0	6.2	3.2	30.2	7.0	0.49
8	98	36	1.40	17.9	6.7	3.4	28.0	7.6	0.49
9	98	36	1.41	17.3	6.2	3.2	26.7	7.9	0.50
10	99	36	1.40	20.3	6.1	3.4	29.8	70	0.50
Total	989	360	13.89	199.8	63	35.3	29.8	721	4.93
Mean	99.0	36.0	1.39	20.0	6.3	3.53	29.8	7.21	0.493

Table 2: Evaluation Values of Various Performance Criteria/Parameters

Observations	A	B	C	D	E	F	G	H	I	J	K	L	M
1	100	36	0.49	6.6	21.4	6.5	4.6	32.5	1.37	0.90	66	0.02	85.9
2	98	37	0.49	6.8	22.7	5.8	3.7	32.2	1.30	0.91	70	0.02	88.5
3	99	35	0.49	7.4	13.2	6.2	3.6	28.0	1.62	1.05	65	0.02	87.1
4	100	36	0.50	7.2	20.8	6.0	3.4	30.2	1.44	0.99	69	0.02	87.7

5	100	36	0.50	7.7	17.8	6.8	3.6	28.2	1.69	1.06	63	0.02	87.2
6	99	36	0.48	6.7	22.4	6.4	3.2	32.0	1.29	0.90	70	0.02	90.0
7	98	36	0.49	70	21.0	6.2	3.2	30.4	1.40	0.97	69	0.02	89.5
8	98	36	0.49	7.6	17.9	6.7	3.4	28.0	1.64	1.05	64	0.02	87.9
9	98	36	0.50	7.9	17.3	6.2	3.2	28.7	1.73	1.12	65	0.02	88.0
10	99	36	0.50	7.2	20.3	6.1	3.4	29.8	1.48	1.01	68	0.02	88.6
Total	989	360	4.93	721	199.8	63	35.3	298	14.96	9.96	669	0.02	880.4
Mean	99	36	0.49	7.2	20	6.3	3.5	29.8	1.50	1.00	67	0.02	88.04

Key/Legend
A = Field row length (m); B = Effective width of cut (m); C = Area ploughed (ha); D = Forward speed (km/hr); E = Ploughing time (minutes); F = Turning time (minutes); G = Delay time (minutes); H = Total Field time (E+F+G); I = Theoretical field (ha/hr) = ($C \times {}^{60}/_{E}$); J = Effective Field capacity (ha/hr) = ($C \times {}^{60}/_{H}$); K = Field efficiency (%) = (${}^{J}/_{I}$); L = Man-Machine productivity M_{mp} [${}^{C}/_{E} + {}_{F}$]; M = Man- Machine activity, Mma (%) = [100 x (E+F)/H]

Man-machines performances mean was about 0.02ha/hr lower than the mean field capacity of 1.0ha/hr. this is due to operator inexperience, capability, habit, operating policy and/or stumps present on the ploughed field as well as the small sizes of the fields. The average time lost in making turns at the ends of the rows was 9.8 minutes.

From the Table 3, it can be seen that the higher the operating speed, the higher the effective field capacity but the lower the field efficiency. This shows that speed and effective field capacity are indirectly proportional to the field efficiency. It can also be deduced that the lower the time loss, the higher the field efficiency showing that the unproductive time is inversely proportional to the field efficiency. This shows that higher field efficiencies could be obtained with lower time loss during field activities.

Table 3: Comparison between Speed of Operation and Effective Field Capacity and between Total Time Lost and Field Efficiency

Observations	Speed (km/hr)	Effective Field Capacity (ha/hr)	Total Time Lost (Mins)	Field Efficiency (%)
1	6.6	0.90	11.1	66
2	6.8	0.91	9.5	70
3	7.4	1.05	9.8	65
4	7.2	0.99	9.4	69
5	7.7	1.06	10.4	63
6	6.7	0.90	9.6	70
7	7.0	0.97	9.4	69
8	7.6	1.05	10.1	64
9	7.9	1.12	9.4	65
10	7.2	1.01	9.5	68
Total	72.1	9.96	98.2	669
Mean	7.21	0.996	9.82	66.9

4. CONCLUSION

Results from these studies show that high effective field capacities could be obtained with high operating speeds. Also as speed is increased, the total field time decreased and the effective field capacity increased while the field efficiency decreased. Proper maintenance and adjustment of machines would also help increasing width utilization and hence increased field capacities. The tractor and implement must be chosen so that the tractor is fully utilized with respect to the power available. This will ensure that the tractor-implement combination is matched to the size of work at hand. Field efficiencies can be increased with proper field time management by the machine operator. These studies showed that it is very necessary to minimize the proportion of the total field spent on non-productive activities. Proper preventive maintenance will minimize the number of field adjustment required during field operation. It is concluded that it is not necessary to have higher efficiency at higher speeds.

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