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Parameters affecting Tractor Fuel Consumption during Primary Tillage Operation in Uyo, Akwa Ibom State, Nigeria

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***Abstract*— Tractor fuel consumption is a vital parameter in management of farm machinery. Parameters affecting tractor fuel consumption in litres per hectare(L/ha) during ploughing operation in Uyo was investigated. The study was conducted at the University of Uyo teaching and research farm, Uyo in Akwa Ibom State, Nigeria. The soil in the study location was characterized as clay loam. Effects of operation parameters on fuel consumption for ploughing operation were investigated using One-Way Repeated Measures Analysis of Variance. The findings of the study indicate that at <0.05 significance level, operation parameters had significant effect on tractor fuel consumption during ploughing operation. The study had identified factors affecting tractor fuel operation during ploughing operation in the study location.*

***Keywords*— Ploughing, parameters, tractor, fuel consumption, clay loam soil**

I. INTRODUCTION

Land preparation is one of the most energy consuming operations in the field. Energy utilized in tillage is governed by such factors as soil type and conditions, depth of cut, operating speed and hitch geometry. Field practices have shown that land development constitutes the major cost of farm operation due to the high level of energy expended during tillage. Fuel consumption plays a significant role in the selection and management of tractors and equipment (Oyelade and Oni, 2018). Two of the common tillage implements in the South-South region of Nigeria are the disc plough and disc harrow. Tillage operations require the most energy and power spent on farms (Al-Suhaibani and Ghaly, 2010).

Soil tilling, according to Oni (1991), is the most intensive of all processes involved in crop production. Tillage of soil is considered to be one of the biggest farm operations (Al-Suhaibani and Ghaly, 2010). There are several tillage implements used by farmers for seedbed preparation. However, the selection of tillage implements to prepare seedbed and weed control depends on soil type and condition, crop residues and weed type (Upadyaya *et al.*, 1984).

The use of tractors plays an important role in agriculture (Mahmood and Gee-Clough, 1989). The application of machines to agricultural production has been one of the outstanding developments in agriculture. Tractors and farm machinery are important sources of modern technology (Singh, 2000., Xinan *et al.*, 2005). According to Panam et al., (2010), tractors are the fastest farm machines used by farmers for tillage operations instead of human tools and animal-drawn implements. Machinery contributes a major capital input cost in most farm businesses.

The objective of this study is to identify parameters that affect fuel consumption in tractors.

II. MATERIALS AND METHODS

Study Location

The study location for this research work was in the University of Uyo in Uyo local government area of Akwa Ibom state, Nigeria.

Tractor and Tillage Implement

The specification of tractor used for the study is presented in Table I. Tillage implement used for evaluating the parameters affecting tractor fuel consumption is 4-buttom disc plough. Its specification is presented in Table 2

Table. I: Specification of Tractor Used

Specification	Eicher 5660
Effective output (hp)	55
Type of engine	3-cylinder
Type of fuel	Diesel
Front tyres (size)	7.50-16
Rear tyres (size)	14.9-28
Fuel tank capacity(L)	60
Country of manufacture	India

Table. 2: Implements Specifications

S/N	Item	Disc plough
1	Type (hitching)	Fully mounted
2	Number of bottoms/discs	4
3	Type of disc blade	Plane concave
4	Disc diameter(cm)	48.7
5	Disc Spacing(cm)	53
6	Tilt Angle (˚)	20
7	Implement width (cm)	129
8	Disc Angle(˚)	45
9	Implement Weight(kg)	386

Soil Sampling and Experimental Procedure

At each of the sampling points, random spots were core sampled and augured at 0-30 cm depth with the aid of a dutch auger and bulked out to give a composite sample. The soil samples from different sampling points were, on each occasion, collected in polyethylene sample bags and labeled accordingly and the samples were taken to the laboratory for analysis. Laboratory methods of analysis were carried out on the soil samples for particle size distribution. The tractor was tested on an area of 0.5 hectare (50 m x 100 m) in a Randomized Complete Block Design (RCBD). Parameters measured during ploughing operation include draft, the width of cut, depth of cut, duration of operation, the speed of operation, field capacity, field efficiency, fuel consumption, wheel slip, soil moisture content, soil bulk density and soil cone index.

Parameters Tested

Implement Draft

The draft of implement was measured according to the tractor technique as described by Oyelade, 2016.

Duration of Operation

According to Oyelade and Oni (2018), the duration of operation measured in hr/ha is the time spent in completing the whole operation and they mathematically expressed it as:

$$X9 = \frac{1}{X5} \quad \text{.....(1)}$$

Where,

X9 = Duration of operation (hr/ha)

X5 = Effective field capacity (ha/hr)

Depth and width of cut

The depth and width of cut during field operation were measured using a steel rule and measuring tape

Speed of operation

The speed of operation for the tillage was determined using the equation below.

$$S = \frac{D}{T} \quad \text{... (2)}$$

Where;

S= speed of operation, km/hr

D =Distance travelled, m

T=Time taken to travel the distance, sec

Theoretical field capacity

Theoretical field capacity measured in ha/hr was expressed mathematically according to Oyelade and Oni (2018) as

$$G = \frac{E(3600)}{Ta} \quad \text{...(3)}$$

Where,

G = Theoretical field capacity ha/hr)

E = Area of field (ha)

Ta = Actual time taken in doing the main tillage work (sec)

Effective field capacity

Effective field capacity measured in ha/hr was expressed mathematically as

$$X5 = \frac{E(3600)}{Tt} \quad \text{... (4)}$$

Where,

X5 = Effective field capacity (ha/hr)

E = Area of field (ha)

Tt = Total time taken in completing the whole tillage operation (sec)

Field efficiency

Field efficiency is the ratio of effective field capacity to theoretical field capacity, expressed in percentage. It was expressed mathematically as

$$H = \frac{X5}{G} \times 100 \qquad \ldots(5)$$

Where,

H = Field efficiency (%)

Fuel consumption

The filling of fuel tank before the operation and then refilling after completing the operation method was used in the study. This method is a common method in the field for determining tractor fuel consumption in liters per hectare. This method was used by Ajav and Adewoyin, 2011., Ikpo and Ifem, 2005; Kudabo and Gbadamosi, 2012; Udo and Akubuo, 2004 and Oyelade and Oni, 2018 in determining tractor fuel consumption in liters per hectare. Fuel consumption measured in either L/ha or L/hr was expressed mathematically as

$$I = \frac{J}{E} \qquad \ldots(6)$$

$$K = X5 \, x \, I \qquad \ldots(7)$$

Where,

I = Fuel consumption (L/ha)

J = Volume of fuel consumed (L)

E = Area of field (ha)

K = Fuel consumption (L/hr)

X5 = Effective field capacity (ha/hr)

Tractive efficiency

Tractive efficiency measured in percentage is the ratio of drawbar power to wheel power and was expressed mathematically as

$$Qt = \frac{Dp}{Qw} \times 100 \qquad \ldots(8)$$

Where,

Qt = Tractive efficiency (5)

Dp = Drawbar power (kW)

Qw = Wheel power (kW), power losses in the transmission from engine to the wheels of, if 10%

is assumed, it can be written as

$$Qt = \frac{Dp}{0.9xQe} \times 100 \qquad \ldots(9)$$

Where,

Qe = Engine power (kW)

Travel reduction (wheel slip)

In determining travel reduction (wheel slip), a mark was made on the tractor drive wheel with coloured tapes. This was used to measure the distance covered by the tractor drive wheel at every 10 revolutions under no load and the same revolution with a load on the same surface. The travel reduction (wheel slip) measured in percentage was expressed mathematically as:

$$L = \frac{M2 - M1}{M2} \times 100 \qquad \ldots(10)$$

Where,

L = Travel reduction (wheel slip, %)

M2 = Distance covered at 10 revolutions of the wheel at no load condition (m)

M1 = Distance covered at 10 revolutions of the wheel at load condition (m)

Soil Parameters

Moisture content of the soil

The research location for the tillage implement was subdivided into twenty-five subplots of 20 m by 10 m measurement. Soil samples were collected during the tillage experiment at three different points of 0 – 30 cm depth choosing randomly on each subplot to determine the average moisture content. The samples were weighed using a weighing balance, and the weight of each sample was recorded. Then the samples were placed in an oven maintained at 110^{0}C for 48 hours. The dried soil samples were reweighed, and the weight was again recorded. The moisture content was calculated on a dry weight basis according to the formula;

$$Moisture\ Content\ (M.C) = \frac{W_w - W_d}{W_d} \times 100 \qquad \ldots(11)$$

Where,

W_w = weight of wet soil sample, g

W_d = weight of oven dry soil sample, g

Bulk density of soil

The procedure for soil sample collection as given for soil moisture content determination was the same for bulk density determination. The bulk density of the soil was determined according to the formula:

$$Bulk\ density\ (g/cm^3) = \frac{4M}{\pi D^2 L} \qquad \ldots(12)$$

Where,

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M = Mass of the soil as contained in the core samples of oven dried soil, g

D = Diameter of cylindrical cone sample, cm

L = Length of the cylindrical cone sample, cm

Soil cone index

The soil cone index (CI) is the soil resistance to penetration and was measured using a cone penetrometer

Statistical Analysis

Results of measured parameters gathered from the experiment on a sandy loam soil during ploughing operation were subjected to Analysis of Variance (ANOVA) in investigating the measured parameters that contributed significantly to tractor fuel consumption in litres per hectare during ploughing operation. Using Version 3.1.1 of the R Software Package according to Oyelade and Oni, 2018 for statistical, computing and graphics, One-way Repeated Measures ANOVA was used to investigate the effects of ploughing operation parameters on tractor fuel consumption. As a result of this, the following hypothesis were drawn.

Hypothesis: Test of significance of ploughing operation parameters

Null hypothesis (H_0): Effects of ploughing operation parameters on tractor fuel consumption in litres per hectare are the same.

Alternative hypothesis (H_1): Effects of the ploughing operation parameters on tractor fuel consumption in litres per hectare are not the same.

Test statistic: ANOVA F-test

Decision rule: Reject H_0 in favour of H_1 at 0.05 level of significance if P-value < 0.05, otherwise do not reject H_0

III. RESULTS AND DISCUSSION

Soil Analysis

The result of the soil analysis test carried out in the study location is presented in Table 3.

Table. 3: Soil Textural Analysis

	Soil Composition			
	Sand (%)	**Clay (%)**	**Silt (%)**	**Classification**
University of Uyo	30	58	12	Clay loam

IV. EXPERIMENTAL TEST RESULTS

Table 4 presents the mean values of measured parameters of the 4-bottom disc ploughing operation. The table was subjected to One-way Repeated Measures ANOVA. The ANOVA result for effects of ploughing operation parameters on tractor fuel consumption is presented in Table 5.

Table. 4: Summary Table of Mean of Measured Parameter During Ploughing Operation

Treatment	**Values**
Width of cut (cm)	176.74
Depth of cut (c)	15.89
Draft (N)	4.97
Effective field capacity (ha/hr)	1.009
Tractive efficiency (%)	20.84
Field efficiency (%)	72.35
Travel reduction (Wheel slip) (%)	11.62
Duration of operation (hr/ha)	1.086
Speed of operation (km/hr)	7.50
Average moisture content (%)	9.29
Average bulk density(g/cm^3)	1.40
Average cone index(N/cm^2)	24.13
TOTAL	**346.825**

Table. 5: ANOVA Table for Effects of Ploughing Operation Parameters on Tractor Fuel Consumption

Source	Sum of Square	df	Mean Square	F-Value	P-Value
Parameters	89916.198	11	7165.113	156.94	< 2e-14
Residuals	1253.017	24	52.209		

Decision: Since P-value is < 2e-14 which is < 0.05, H_0 is rejected

Based on the ANOVA results presented in Table 5, one can comfortably deduce that the effects of the twelve ploughing operation parameters on tractor fuel consumption in litres per hectare in Uyo are not the same. In connection with this , therefore, it is important to conduct multiple comparison test using a Pair-wise test to ascertain which ploughing operation parameters are actually significantly different in terms of their effects on tractor fuel consumption. The result of the Pair-wise test is presented in Table 6

Table. 6: Pair-wise Comparison Result of Ploughing Operation Parameters

	X11	X12	X10	X8	X2	X3	X4	X6	X9	X5	X7
X12	0.72	-	-	-	-	-	-	-	-	-	-
X10	**0.00***	0.68	-	-	-	-	-	-	-	-	-
X8	0.18	0.72	**0.002***	-	-	-	-	-	-	-	-
X2	**0.046***	1.00	0.158	0.060	-	-	-	-	-	-	-
X3	0.14	0.73	0.053	0.132	**0.04***	-	-	-	-	-	-
X4	0.74	0.72	0.012	1.000	**0.04***	**0.03***	-	-	-	-	-
X6	**0.00***	0.13	0.006	**0.004***	**0.00***	**0.00***	**0.004***	-	-	-	-
X9	0.13	0.68	0.755	0.131	0.15	0.25	0.131	**0.011***	0.760	-	-
X5	0.74	0.86	0.865	0,760	1.00	0.75	0.750	0.151	0.865	0.86	-
X7	0.42	0.88	1.001	0.332	0.75	0.76	0.144	**0.034***	0.760	0.86	0.86
X1	0.13	0.32	0.129	0.136	0.21	0.13	0.321	0.623	0.142	0.14	0.197

*Significant at P < 0.05

Key: X1 = Width of cut (cm), X2 = Depth of cut (cm), X3 = Draft (N), X4 = Effective field capacity (ha/hr), X5 = Tractive efficiency (%), X6 = Field efficiency (%), X7 = Travel reduction (Wheel slip) (%), X8 = Duration of operation (hr/ha), X9 = Speed of operation (km/hr), X10 = Average moisture content (%), X11 = Average soil bulk density (g/cm^3), X12 = Average soil cone index (N/cm^2)

V. CONCLUSION

This study was carried out to investigate the factors affecting tractor fuel consumption during polughing (primary tillage) operation in Uyo, Akwa Ibom State, Nigeria. One-way Repeated Measures ANOVA was used to study the influence of ploughing operation parameters on tractor fuel consumption. The results obtained from the One-way Repeated Measures ANOVA indicate that ploughing operation parameters had significant effect on tractor fuel consumption.

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