APPLICATION OF BUCKINGHAM PI THEOREM IN DEVELOPMENT OF TRACTOR FUEL CONSUMPTION MODEL FOR PLOUGHING OPERATION

Ekemube, Raymond Alex[1] and Atta, Adekunle Temidayo[2]

[1]Value Addition Research Division, Cocoa Research Institute of Nigeria, Ibadan, Nigeria
[2]Kenaf and Jute Improvement Programme, Institute of Agricultural Research and Training, Obafemi Awolowo University, Moore Plantation, Ibadan, Nigeria

ABSTRACT

The estimation of tractor fuel consumption during ploughing operation has been consistently receiving attention as a result of diverse nature, varieties and development in prime movers and dynamic response of soil to tillage operation treatment. The need to use selected soil-implement-machine parameters as factors affecting fuel consumption is necessary. Fuel consumption model for estimating tractor fuel consumption per working area for ploughing operation has been developed using Buckingham's pi theorem. Generalized reduced gradient (GRG), a nonlinear method of Excel solver was used for the establishment of the model's constant. The model was validated by simulating the experimental results into the equation, coefficient determination (r^2), graphical comparison, root mean square error, and paired t-Test. The field experiment was performed at Rivers Institute of Agricultural Research and Training (RIART) Farm in Rivers State University, Port Harcourt. Port Harcourt lies on the latitude of 4° 49' 27" N, and longitude of 7° 2' 1" E; with an altitude of 274mm above mean sea level; and average annual rainfall depth of 2310.9 mm The experimental land area was 138 m by 50 m (6900 m^2) which was divided into three blocks of 9 plots each. Each plot was marked out 50 m by 2 m each along with the paths dimension of 1 m between each plot was provided for different treatment options and with a space of 2 m between each block and 1 m at the sides of the of the outer blocks. The group balanced block design (GBBD) was adopted. The design consisted of 9 experimental treatments with three replicates. The experimental fuel consumption per working area was determined by quantity of fuel used per working area with the aid of fuel flow meter. The field test parameters (speed, depth, forward speed, cone index, bulk density) were measured accordingly with their specific standards procedures. The field test parameters (speed, depth, forward speed, cone index, bulk density) results were simulated with fuel consumption to obtain the constants in the estimation model. The developed model displayed good agreement between measured and estimated results with high coefficient of determination (r^2) of 0.9974, and low root mean square error of 0.74. The paired t-Test results also showed no significant difference at 95 and 99 % confidence levels. It is as a result, recommended that the model be used for estimating tractor fuel consumption during ploughing operation.

Keywords: Buckingham Pi Theorem, fuel consumption, model, soil-machine-implement parameters

1. INTRODUCTION

Ploughing is a primary tillage operation that involves the use of implement such as plough for physical and mechanical soil disturbance for preparing seedbed conducive for crop production. This can be done at sufficient soil moisture content and strength to permit ploughing and provide sufficient and well-organized traction. Ikpo and Ifem (2005) reported that tractor used more energy at the lowest work rate during ploughing operation. Tractor's fuel consumption is affected by many parameters during tillage operation, these include type and structure of soil, climate, tractor type, tractor size and tractor-implement relationship

(Fathollahzadeh *et al*., 2010; Ajav and Adewoyin, 2012; Adewoyin, 2013; Adewoyin and Ajav, 2013). Other fundamental factors that affect fuel consumption in ploughing operation include power consumption increment by increasing the working speed, actual width of cut, soil strength, moisture content and the working depth (Cortez *et al*., 2008; Kichler *et al*., 2011; Silveira *et al*., 2013; Moitzi *et al*., 2014; Leghari, *et al*., 2016; Nasr, 2016). It has been reported by Ekemube *et al*. (2021a, 2021b, 2022a) that the variability in tractor hourly and tiled area fuel consumption during ploughing, harrowing, and ridging operations are influenced by differences in the soil-implement-machine parameters and hence become the decisive factors for the management of fuel consumption during ridging. These soil-implement-machine parameters were the variables to be used in predicting tractor fuel consumption during tillage operations

The prediction of tractor fuel consumption during ploughing operation has been determined by different approaches. These approaches are usually focused on supplies of power and individual engines, which call for extensive engine testing to validate the amount of fuel consumed (Grisso *et al*., 2004; 2010; 2011). Different models have been developed by various researcher to predicted tractor fuel consumption per working area during ploughing operation. Series of linear regression model were used by Serrano *et al.* (2005); Moitzi *et al*. (2014); Ajav and Adewoyin (2012); Adewoyin (2013); Adewoyin and Ajav (2013); and Ranjbarian *et al.* (2015) to develop tractor fuel consumption model for ploughing operation that can express the equation reasonably. Kumar and Pandy (2015) used a visual basic programme for predicting gear and throttle position for best fuel economy with multiple linear regression analysis were used and the collected data in excel spread sheet was fitted to the model structure formulae to determine the coefficients. Similarly, Almaliki *et al.* (2016a); and Lee *et al.* (2016) developed tractor fuel consumption model for predicting fuel consumption during ploughing. Furthermore, Rahimi-Ajdadi and Abbaspour-Gilandeh (2011); Almaliki *et al.* (2016b), development models based on artificial neural network and stepwise multiple range regression for prediction of tractor fuel consumption. Fuel consumption was assumed to be a function of engine speed, throttle and load conditions, chassis. Finally, Shafaei *et al.* (2018); Karparvarfard and Rahmanian-Koushkaki (2015); Nkakini *et al.* (2019a) used dimensional amalysis to develop tractor fuel consumption model during ploughing operation. Igoni *et al*. (2019); and Nkakini *et al.* (2019b) also use dimensional analysis to predict fuel consumption during ridging operation. Further studies were carried out by Ekemube *et al*. (2022b, 2022c) using dimensional analysis to predict fuel consumption per working area during harrowing and ridging operations. The following variables, speed, height, forward speed, cone index, bulk density were used as dependent variables. But, in literature there is a dearth of information on tractor fuel consumption model for predicting fuel consumption per working area for ploughing operation. Therefore, there is need to develop a fuel consumption model in terms of working area using dimensional analysis. The aim of this study is to develop a predictive model for estimating tractor fuel consumption per working area for ploughing operation.

2. MATERIAL AND METHODS

2.1 Model Derivation

The significance of accurate prediction in any field of engineering cannot be puffed up. Therefore, the mathematical tool that was employed in this work is dimensional analysis using the Buckingham pi theorem. Hence, in this research fuel consumption model development was done using the method of fuel consumption per working area (FCwa, L/ha). Some of the factors affecting tractor fuel consumption were presented in Table 1 and the dimensional matrix in Table 2.

Table 1. Dimensions of Some Variables Influencing Fuel Consumption

Variables	Symbol	Unit	Dimensions
Dependent Variable			
Fuel consumption	FCw_a	L/ha	L^3 L^{-2} (L)
Independent Variables			
Forward speed	V	Km/h	LT^{-1}
Ploughing depth	d	m	L
Cone index	CI	N/cm^2	$ML^{-1}T^{-2}$
Bulk density	P	g/cm^3	ML^{-3}
Width of cut	W	m	L

Table 2. Dimensional Matrix of the Variables

Dimensions	Parameters					
	FC_{wa}	**V**	**d**	**CI**	**ρ_b**	**W**
M	0	0	0	1	1	0
L	1	1	1	-1	-3	1
T	0	-1	0	-2	0	0

Fuel consumption, FC_{wa} is a function of (d, W, V, CI, ρ_b)
Mathematically;

$$\mathrm{FC}_{ta} = f(d, W, V, CI, \rho_b) \tag{1}$$

The dependent variable = FC_{wa}
Total number of variables, n = 6
Total number of fundamental dimensions, m = 3
Therefore, number of dimensionless groups (π- terms) to be formed = n – m = 6 – 3 = 3
Equation 2 can be written as:

$$f(\pi_{1,}\pi_2, \pi_3) \tag{2}$$

Each π- term contains (m + 1) variables, where m = 3 and is also equal to repeating variable choosing from ρ_b, W, S as repeating variables, we get five π- terms as:

$$\pi_1 = \rho_{b,}{}^{a_1}.W^{b_1}.V^{c_1}.\mathrm{FC}_{ta} \tag{3}$$

$$\pi_2 = \rho_{b,}{}^{a_2}.W^{b_2}V^{c_2}.d \tag{4}$$

$$\pi_3 = \rho_{b,}{}^{a_4}.W^{b_4}V^{c_4}.CI \tag{5}$$

2.1.1 Transformation to dimensionless parameters

A new set of pi terms can be generated by multiplying or dividing present pi terms with each other. In addition, the present pi terms can be reversed to make a new pi term. This is to ensure simplicity in the experimentation process. The present pi terms($\pi_{1,}\pi_2, and\ \pi_3$) can be adjusted to generate a new pi term (Langhaar, 1980; Tarham and Carman, 2004; Nkakini *et al*., 2019a, 2019b; Igoni *et al*., 2019).

π_1 Terms

$$\pi_1 = \frac{\mathrm{FC}_{tw}}{W} \tag{6}$$

π_2 – Terms

$$\pi_2 = \frac{d}{W} \tag{7}$$

π_3 – Terms

$$\pi_3 = \frac{CI}{\rho_b S^2} \tag{8}$$

Substituting the values of $\pi_{1,}\pi_2, \pi_{3,}\pi_4 and \pi_5$ in equation (2), we get;

$$f\left(\frac{\mathrm{FC}_{wa}}{\mathrm{W}},\ \frac{d}{W,}\frac{CI}{\rho_b V^2}\right) = 0 \tag{9}$$

2.1.2 Formulation of the fuel consumption model

The method of product and quotient component functions of pi terms were adopted for development of the fuel consumption model. This prognostic model was developed by simple multiplication and division of the component equations. The validity of combining the equation components by multiplication and division were tested by assuming that the general prediction model is obtained by simple multiplication and division of the pi terms (equations 10 and 11).

Let establish π_1^1 by dividing equation 7 by equation 8, we get;

$$\pi_1^1 = \frac{\pi_2}{\pi_3} = \frac{\frac{d}{\mathrm{W}}}{\frac{CI}{\rho_b V^2}} \tag{10}$$

$$\pi_1^1 = \frac{\rho_b s^2 d}{CIW} \tag{11}$$

Hence, the relationship becomes

$$\pi_1 = K_{FC} f(\pi_1^1) \tag{12}$$

$$\frac{\pi_1}{\pi_1^1} = K_{FC} \tag{13}$$

Substituting the values of π_1 and π_1^1 into equation (123.69), we get:

$$\frac{\mathrm{FC}_{wa}}{\mathrm{W}} = K_{FC}\left[\frac{\rho_b V^2 d}{CIW}\right] \tag{14}$$

K_{FC} can be calculated using method of GRG in excel solver and the constant obtained becomes the K_{FC} value

$$\therefore K_{FC} = \frac{\mathrm{FC}_{wa} CI}{\rho_b V^2 d} \tag{15}$$

Rearranging equation (143.71), it becomes:

$$FC_{ta} = K_{FC}\left[\frac{\rho_b V^2 d}{CI}\right] \tag{16}$$

The equation (16) expresses the tractor fuel consumption per working area during ploughing operation.

where,

- FC_{wa} = Fuel consumption per working area (L/ha),
- K_{FC} = Fuel consumption constants
- CI = Cone Index (N/cm^2),
- V = Tractor forward speed (Km/h)
- d = ploughing depth (m)

2.1.3 Model validation

The developed model was validated by simulating the experimental data in to the model and then compare the experimental with the prediction data. Under the varying factors of treatment parameters (ploughing depth, forward speed, cone index and bulk density) that were used for ploughing operation. These parameters were determined experimentally and substitute into the formulated model to compute the predicted fuel consumption per working area. Also, the root mean square error (RMSE) was used to check the error difference as represented in equation (17).

$$RMSE = \sqrt{\frac{\sum_{i-1}^{i-N}\left(FC_{wa(m)} - FC_{wa(E)}\right)^2}{N}} \qquad (17)$$

where,

N = number of samples,

$FC_{wa(m)}$ = measured fuel consumption (L/ha)

$FC_{wa(E)}$ = estimated fuel consumption (L/ha).

Furthermore, the developed model was validated with regression curve and coefficient of determination (r^2) to check if the measured and predicted results have good agreement and graphical comparison of measured and predicted results as well the paired t- test as presented in equation (18) was considered as significant at $t_{computed} > t_{table}$ (95 and 99 % confidence) levels.

$$t = \frac{\sum D/N}{\sqrt{\frac{\sum D^2 - \left(\frac{(\sum D)^2}{N}\right)}{(N-1)(N)}}} \qquad (18)$$

where,

$\sum D$ = summation of the differences.

$\sum D^2$ = summation of the squared differences,

$(\sum D)^2$ = summation of the differences squared.

N = number of samples

2.2 Experimental Site Description

This experiment was performed at the Rivers Institute of Agricultural Research and Training (RIART) farm at Rivers State University, Port Harcourt. In Port Harcourt, agriculture is well practiced and the agricultural products are namely food crop, cash crop, fish and animal. Port Harcourt lies on the latitude of 4° 49′ 27″ N, and longitude of 7° 2′ 1″ E; with an altitude of 274mm above mean sea level; and average annual rainfall depth of 2310.9 mm. The ambient environment (i.e., Port Harcourt metropolis) having a mean monthly relative humidity of 85%, a daily minimum temperature about 23^0C and a mean daily maximum temperature of 32^0C.

2.3 Experimental Design

The experimental design used in this study is group balanced block design (GBBD). A farm size of 138 m by 50 m (6900 m^2) was divided into three plots of 9 sub-plots each. Each sub-plot of 50m by 2m was marked with a 1m alley. The sub-plot was provided for different treatment options and with a space of 2 m between each block and 1 m at the sides of the outer blocks (Figure 1).

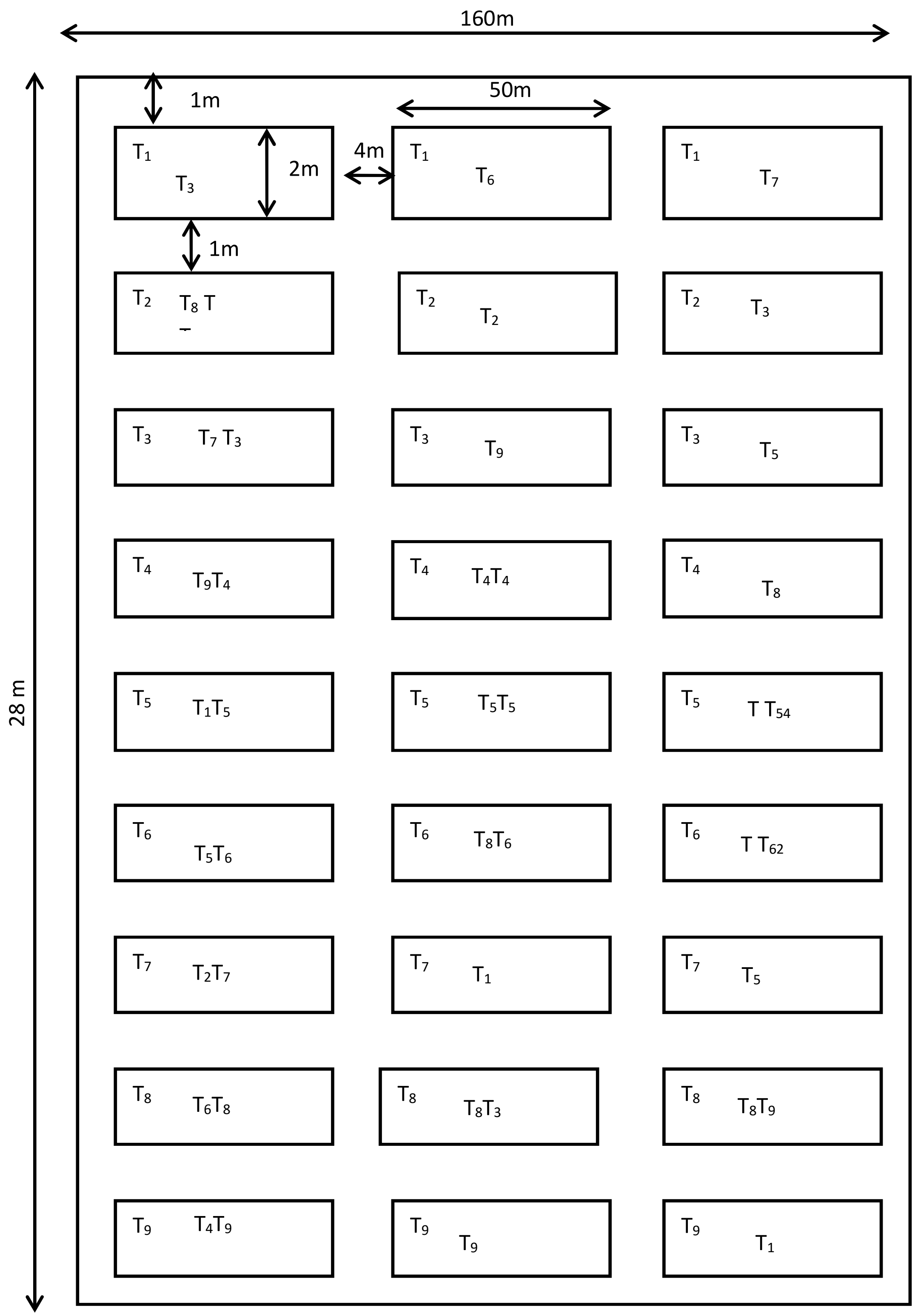

Figure 1. Layout of nine treatment randomized with three replications (note: the diagram is not to scale)

T_1: Ploughing with depth of 0.10 m at speed of 5 Kmh^{-1}

T_2: Ploughing with depth of 0.10 m at speed of 7 Kmh^{-1}

T_3: Ploughing with depth of 0.10 m at speed of 9 Kmh^{-1}

T_4: Ploughing with depth of 0.20 m at speed of 5 Kmh^{-1}

T_5: Ploughing with depth of 0.20 m at speed of 7 Kmh^{-1}

T_6: Ploughing with depth of 0.20 m at speed of 9 Kmh^{-1}

T_7: Ploughing with depth of 0.30 m at speed of 5 Kmh^{-1}

T_8: Ploughing with depth of 0.30 m at speed of 7 Kmh^{-1}

T_9: Ploughing with depth of 0.30 m at speed of 9 Kmh^{-1}

2.4 Tractor and Implement Specifications

The tractor used to perform the ploughing operation was A two-wheel drive tractor Swaraj 978 FE (Swaraj, India) was used for this study (Plate 1). The tractor has a total weight of 3015kg, engine horsepower of 72 hp and lifting power of 2200 kg. Front and the rear tyres were 7.5–16, 8 ply and 16.9 – 28, 12 radial respectively. A 1180 mm frame width mounted-type disc plough with disc diameter of 300 mm of disc plough (Baldan Implementos Agricolas, Brazil) with 3-disc bottom mounted on a gauge wheel was used for the experiments (Plate 2). Also, a DFM 100CD fuel flow meter (Technoton Engineering, Belarus) has nominal fuel pressure 0.2 MPa, maximum fuel pressure 2.5 MPa, minimum kinematic viscosity 1.5mm^2/s, maximum kinematic viscosity 6.0 mm^2/s, minimum supply voltage 10 V and maximum supply voltage 45 V (Plate 3).

Plate 1. The Swaraj 978 FE Tractor (Swaraj, India)

Plate 2. The disc plough (Baldan Implementos Agricolas, Brazil) used in this study

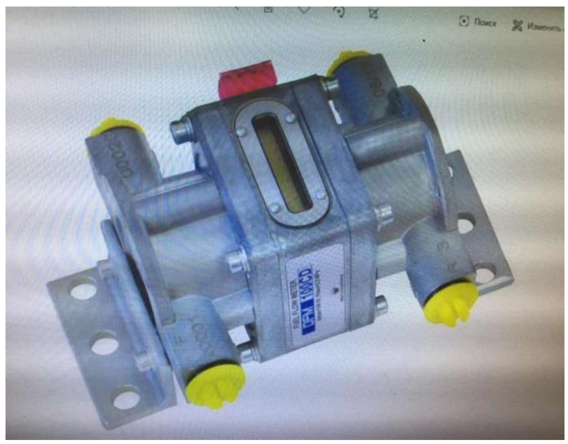

Plate 3. DFM 100CD fuel flow meter (Technoton Engineering, Belarus) used in thisstudy

2.5 Methods

Preceding ploughing operation, soil core was used for obtaining the soil sample from the depth of 0 – 10, 10 – 20 and 20 - 30 cm respectively at random in the field to determined textural classification of the soil and the bulk density. The collected soil samples were taken to the laboratory for analysis. The parameters such as textural classification of the soil was determined by hydrometer method and the bulk density was determined using core method (Walter *et al.*, 2016).

The disc plough was attached to the tractor and levelled using the top links of the tractor in order to reduce parasitic forces. Then, harrowing depths were determined by setting the level control of the lifting mechanism (three-point linkage height) to lower the disc plough to the desired ploughing depth. Tractor forward speeds were determined by selecting a particular gear that gave the desired speed. This was done in a practice area in advance for each test plot to maintain the desired treatment. The ploughing depth measurement was done by placing the meter rule from furrow bottom to the surface of the ploughed land, while the width of cut was measured by placing a steel tape from one side of the furrow wall to the other end. These were done after each operation. Time was determined with a stopwatch set at zero before each operation. The cone index was also determined using a cone penetrometer.

The digital method of measuring the quantity of fuel used was adopted to determine tractor fuel consumption. During this process, the use of DFM fuel flow meter was employed to measure fuel consumption. The metre was mounted on the fuel line between the tractor's fuel tank and the pump. At the end of each test operation the data was taken from the fuel flow meter as display information, switching is performed by light touch to the top cover of fuel flow meter by iButton key. Mathematically, fuel consumption per working area was calculated by expression in equation 19:

$$FC_{wa} = \frac{10 \times T_{fc}}{V \times W \times E \times h} \tag{19}$$

where,

FCwa = Tilled area fuel consumption, L/ha;
T_{fc}= Tractor fuel consumption, L;
V = Forward speed, Km/h;
W = Implement width, m
E = Implement field efficiency, %;
h = Working hour h

3. RESULTS AND DISCUSSION

3.1 Establishment of constant(K_{FC}) for Fuel Consumption per working Area

From equation 16, $K_{FC}$was constants for the fuel consumption model developed using Buckingham pi theorem. The generalized reduced gradient (GRG) method of excel solver was used to compute the constants by simulating measured field test results d, V, CI, ρ_b, measured FCwa, predicted FCwa, and error sum of squared. Therefore, the values for the constants (K_{FC}) was established for tractor fuel consumption model for ploughing operation (Table 3). It is represented as:

$K_{FC} = 113.2993$

The computed constant (K_{FC}) of the model developed was fitted into the fuel consumption model established. Thus, from the model constants of 113.2993 has been established. The results showed acceptable agreement with minimum error ranging from 0.00169 to 0.253165, revealing the reliability and acceptability of the model applied. Therefore, fuel consumption per working area model established for ploughing operation attractor forward speed of 1.39, 1.94 and 2.50 m/s; ploughing depths of 0.10, 0.20 and 0.30 m; cone index of 195.31, 234.38 and 273.44 N/cm^2 respectively is:

$$FC_{ta} = 113.2993 \left[\frac{\rho_b s^2 d}{CI}\right] \tag{20}$$

This model is similar Ekemube *et al*. (2022b, 2022c) that used generalized reduced gradient (GRG) method of excel solver was used to compute the constants by simulating measured field test results d, V, CI, ρ_b, measured FCwa, predicted FCwa, and error sum of squared.

Table 3. Fuel Consumption per working area and operating conditions for ploughing

Treatment	ρ_b (g/cm^3)	V Km/h	CI (N/cm^2)	d (m)	Measured FCwa, L/ha	Estimated FCwa, L/ha	(Error)^2
1	1.55	5.00	195.31	0.10	2.08	2.2479	0.028186
2	1.55	7.00	195.31	0.10	4.59	4.4059	0.033908
3	1.55	9.00	195.31	0.10	6.78	7.2832	0.253165
4	1.69	5.00	234.38	0.20	4.15	4.0847	0.00426
5	1.69	7.00	234.38	0.20	8.49	8.0061	0.234185
6	1.69	9.00	234.38	0.20	13.21	13.2345	0.000602
7	1.85	5.00	273.44	0.30	5.68	5.7491	0.004772
8	1.85	7.00	273.44	0.30	11.23	11.2682	0.001459
9	1.85	9.00	273.44	0.30	18.64	18.6270	0.000169

K_{FC} = 113.2993 and SS_E = 0.560705, d = depth of cut, V = forward speed, CI = cone index, ρ_b = bulk density, measured FCwa = measured fuel consumption per working area, and predicted FCwa = predicted fuel consumption per working area

3.2 Validation of Mathematical Models for Estimating Tractor Fuel Consumption per Working Area

The representativeness of a developed model for solving a particular problem depends on its estimates and validation. Results of the developed fuel consumption model for ploughing operation was by substitution of the results of a number of measured data which is being compared with the measured tilled fuel consumption per working area as shown Table 3. Figures 2 and 3 showed the graphical comparison between measured and estimated fuel consumption per working area values. It was observed that the model has a high relationship with measured data from the ploughing operation with coefficient of determination (r^2) value of 0.9974. This showed that the model can expressed the experimental data 99.74 %. Also, comparing the means of estimated and measured data statistically, it was revealed that the root mean square error (RMSE) analysis which illustrated the error differences between the measured and estimated results is 0.74. In addition, the paired t-Test was used to determine the level of significance between the means of measured and estimated tilled area fuel consumption at 0.05 and 0.01 significance levels. The value of the paired t-Test is $t_{calculated}$ (0.13) that is less than t_{table} values (2.306 and 3.355) (i.e., $t_{cal} < t_{tab}$). This pointed out that there is no significant difference between the measured and the estimated data. This was comparable to the findings Ekemube *et al.* (2022b, 2022c) that developed fuel consumption model of a tractor during harrowing and ridging using dimensional analysis. Also, Nkakini *et al.* (2019a, 2019b) used dimensional analysis in Buckingham pi theorem to develop fuel consumption model for ploughing and harrowing operations. As well, Igoni *et al.* (2019) used dimensional analysis to modelled fuel consumption for ridging operation.

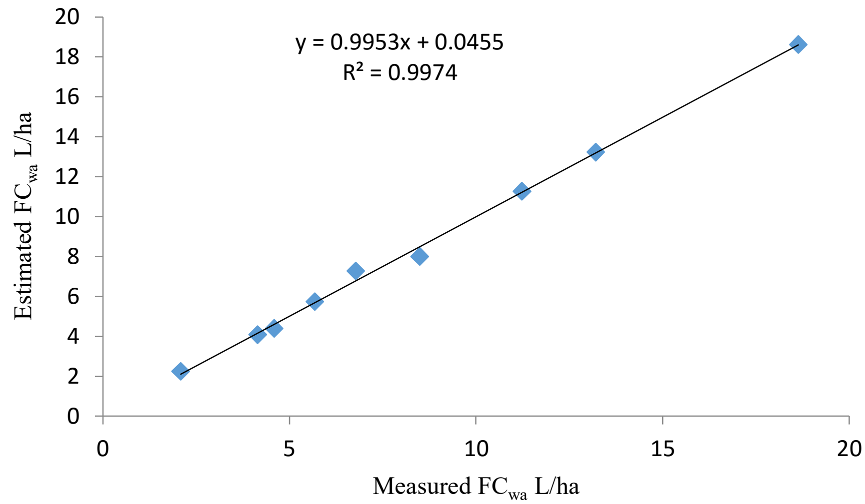

Figure 2. Estimated Vs measured fuel consumption per working hour for ploughing

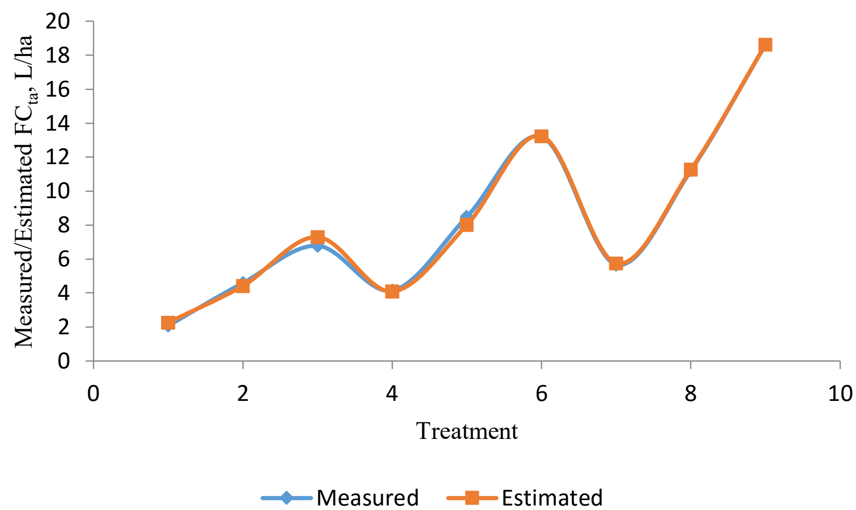

Figure 3. Measured and estimated fuel consumption per working area Vs treatment for ploughing

4. CONCLUSION

This study had developed a tractor fuel consumption model for ploughing operation to ensure estimation of fuel consumption per working area usage. The following conclusions were drawn from the obtained results:

i. A model for estimating tractor fuel consumption per working area in course of ploughing operation has been developed.

ii. The developed model constant (K_{FC}) for ploughing operation with respect to the equipment used was obtained as 113.2993.

iii. Model estimation achieved in this study can be categorized as almost good for high coefficient of determination (r^2), low root mean square error, and paired t Test calculated was less than the table value.

iv. Therefore, these results showed acceptable agreement with measured and estimated model results. These proved that the model can estimate experimental data precisely.

REFERENCES

Adewoyin, A. O. (2013). Fuel Consumption Evaluation of Some Commonly Used Farm Tractors for Ploughing Operations on the Sandy-Loam Soil of Oyo state, Nigeria. *Research Journal of Applied Sciences, Engineering and Technology, 6*(15), 2865-2871.

Adewoyin, A. O. and Ajav E. A. (2013) Fuel Consumption of Some Tractor Models for Ploughing Operations in the Sandy-Loam Soil of Nigeria at Various Speeds and Ploughing Depths. *International Commission for Agricultural Engineering Journal, 15*(3), 67-74.

Ajav, E.A. and Adewoyin, A. O. (2012). Effect of Ploughing Depth and Speed on Tractor Fuel Consumption in a Sandy-Loam Soil of Oyo State, Nigeria. *Journal of Agricultural Engineering and Technology, 20(*2), 1-10.

Almaliki, S., Alimardani, R. and Omid, M. (2016a). Fuel Consumption Models of MF285 tractor Under Various Field Conditions. *International Commission for Agricultural Engineering Journal, 18*(3), 147-158.

Almaliki, S., Alimardani, R. and Omid, M. (2016b). Artificial Neural Network Based Modeling of Tractor Performance at Different Field Conditions. *International Commission for Agricultural Engineering Journal, 18*(4), 262 - 274.

Cortez, J. W., Furlani, C. E. A., Silva, R. P. and Grotta, D. C. C. (2008). Residual Effect of Soil Preparation and Speed of Displacement in the Sowing Operation of Crotalaria. *Juncea Scientia Agraria, Curitiba 9*(3), 357-362.

Ekemube, R. A., Atta, A. T., Nkakini, S. O. and Amgbara, T. O. (2022b). Mathematical Modeling of Tractor Fuel Consumption for Ridging Operation in Sandy Loamy Soil. *Nigerian Research Journal of Engineering and Environmental Sciences, 7*(1), 309 – 318.

Ekemube, R. A., Atta, A. T., and Okogbule-Wonodi, A. (2022c). The Use of Dimensional Analysisfor Modeling Tractor Fuel Consumption for Harrowing Operation. *Nigerian Journal of Technology (NIJOTECH), 41*(5), 913 – 919.

Ekemube, R. A. Nkakini, S. O., Igoni, A. H., and Akpa, J. G. (2021a). Determination of Variabilityin Hourly and Tilled Area Tractor Fuel Consumption during Harrowing Operations. *Journal of Newviews in Engineering and Technology (JNET), 3*(4), 43 – 52.

Ekemube, R. A. Nkakini, S. O., Igoni, A. H., and Akpa, J. G. (2021b). Evaluation of Tractor Fuel Efficiency Parameters Variability during Ploughing Operations. *Journal of New views in Engineering and Technology (JNET), 3*(4), 88 – 98.

Ekemube, R. A., Nkakini, S. O., and Tom, C. N. (2022a). Assessment of Tractor Hourly and Tilled Area Fuel Consumption during Ridging Operations. *International Journal of Academic Multidisciplinary Research (IJAMR), 6*(2), 11 – 18.

Fathollahzadeh, H., Mobli, H., Rajabipour, A., Minaee, S., Jafari, A. and Tabatabaie S.M.H. (2010). Average and Instantaneous Fuel Consumption of Iranian Conventional Tractor with Moldboard plow in tillage. *Asian Research Publishing Network, Journal of Engineering and Applied Sciences, 5*(2), 30-35.

Grisso, R. D., Kocher, M. F. and Vaughan, D. H. (2004). Predicting Tractor Fuel Consumption. *Applied Engineering in Agriculture, 20*(5), 553-561.

Grisso, R. B., Perumpral, J. V. and Vaughan, D., Roberson, G. T., and Pitman, R (2010). Predicting Tractor Diesel Fuel Consumption. Virginia Cooperative Extension

Publication VCE publication 442-073. http://pubs.ext.vt.edu.edu/442-073 (accessed on December 5th, 2016).

Grisso, R. B., Perumpral, J. V., Roberson, G. T. and Pitman, R (2011). Predicting Tractor Diesel Fuel Consumption. Virginia Cooperative Extension Publication VCE publication 442-073. http://pubs.ext.vt.edu.edu/442-073 (accessed on September 5th, 2016).

Igoni, A. H., Ekemube, R. A. and Nkakini, S. O. (2019). Predicting Tractor Fuel Consumption during Ridging on a Sandy Loam Soil in a Humid Tropical Climate. *Journal of Engineering and Technology Research, 11*(3), 29-40.

Ikpo, I. and Ifem, J. L. C. (2005). Fuel Consumption of Tractors – Steyr 768 and 8075 during Tillage Operations in Makurdi, Benue State. *Proceedings of the Nigerian Institution of Agricultural Engineers, 27*, 60 – 63.

Karparvarfard, S. H. and Rahmanian-Koushkaki, H. (2015). Development of a fuel consumption equation: Test case for a tractor chisel-ploughing in a clay loam soil. *Biosystems Engineering, 130*, 23 – 33. DOI: 10.1016/j.Biosystemseng.2014.11.015.

Kichler, C. M., Fulton, J. P., Raper, R. L., McDonald, T. P. and Zech, W. C. (2011). Effects of Transmission Gear Selection on Tractor Performance and Fuel Costs during Deep Tillage Operations. *Soil and Tillage and Research, 113*(2011), 105-111.

Kumar, N. and Pandey, K. P. (2015). A Visual Basic Programme for Predicting Optimum Gear and Throttle Position for Best Fuel Economy for 32 Kw Tractor. *Computer and Electronic in Agriculture, 119*(2015), 217-257.

Langhaar, H. L. (1980). Dimensional Analysis and Theory of Models. New York: Wiley.

Lee, J. W., Kim, J. S. and Kim, J. U. (2016). Simulations to Maximise Fuel Efficiency and Work Performance of Agricultural Tractors in Rotovating and Ploughing Operations. *Biosystem Engineering, 142*(2016), 1 - 11.

Leghari, N., Oad, V. K., Shaikh, A. A. and Soomro, A. A. (2016). Analysis of Different Tillage Implements With Respect to Reduced Fuel Consumption, Tractor Operating Speed and its Wheel Slippage. *Sindh University Resources Journal, (Science Series) 48*(1), 37 - 40.

Moitzi, G., Wagentrist, H., Refenner, K., Weingartmann, H., Piringer, G., Boxberger, J. and Gronauer, A. (2014), Effects of Working Depth and wheel Slip on Fuel Consumption of Selected Tillage Implements. *International Commission for Agricultural Engineering Journal, 16*(1), 282-290.

Nasr, G. E., Tayel, M. Y., Abdelhay, Y. B., Sabreen, K. P. and Dina, S. S. (2016). Technical Evaluation of a New Combined Implement for Seedbed Preparation. *International Journal of Chemical Technology Research, 9*(05), 193-199.

Nkakini, S. O., Ekemube, R. A. and Igoni, A. H. (2019a). Development of Predictive Model for Fuel Consumption during Ploughing Operation in Agricultural Soil. *European Journal of Engineering and Technology, 7*(1), 16 – 30.

Nkakini, S. O., Ekemube, R. A. and Igoni, A. H. (2019b). Modeling Fuel Consumption Rate for Harrowing Operations in Loamy Sand Soil. *European Journal of Agriculture and Forestry Research, 7*(2), 1 – 12.

Rahimi-Ajdadi, F. and Abbaspour-Gilandeh, Y. (2011). Artificial Neural Network and step wise multiple range regression methods for prediction of tractor fuel consumption. *Journal of Measurement*, (2011), 1 – 8. doi:10.1016/j.measurement.2011.08.006.

Ranjbarian, S., Askari, M. and Jannatkhah, J. (2015). Performance of Tractor and Tillage Implements in Clay Soil. *Journal of the Saudi Society of Agricultural Sciences, 16*, 154–162. http://dx.doi.org/10.1016/j.jssas.2015.05.003.

Serrano, J. M., Peça, J. O. and Santos, F. (2005). Draft and Fuel Requirements in Tillage Operations: Modelling for Optimizing Tractor Implement Systems. EFITA/WCCA joint Congress in Agriculture, VILA Real, Portugal, 831–836.

Shafaei, S. M., Loghari, M. S. and Kamgar, S. (2018). On the Neurocomputing Based Intelligent Simulation of Tractor Fuel Efficiency Parameters. *Information Processing in Agriculture, 5*(2018), 205 – 223. (Accessed on July 6th, 2018) (Available at www.sciencedirect.com).

Silveira, J. C. M., Fernandes, H. C., Modolo, A. J., Silva, S. L. and Trogello, E. (2013). Energy Needs of a Planter at Different Travel and Engine Speeds. *Revista Ciência Agronômica, 44*(1), 44-52.

Tarham, S. and Carman, K. (2004). Modeling the Torque and Power Requirement of Traction Tires of Horticultural Tractors using Dimensional Analysis. *Mathematical and Computational Applications, 9*(3), 427 - 434.

Walter K., Don, A., Tiermeyer, B. and Freibauer, A. (2016). Determining Soil Bulk Density for Carbon Stock Calculations: A Systemic Method Comparison. *Soil Science Society American Journal*, 80: 579-591.

AUTHOR'S GUIDE

Manuscript: Manuscript should be submitted typed double space on A4 paper, one side only. Four copies each not exceeding 12 pages including figures and tables should be submitted. Manuscripts can also be attached as files and MS word. The paper should be typed in 12 font size using Times New Roman.

Organization of Manuscript: Manuscript should be arranged as follows: Title; Introduction; Materials and Methods; Results and Discussion; Notations (if any); Acknowledgement; References. The headings listed above should be in capital letters and left justified. Sub-headings should be in lower case but left justified and the first letter capitalized. Sub-sub headings should be in italics. All headings should be in bold font. Headings with sub-headings should be identified with numbers.

Title: It should not be more than 15 words but preferable shorter and in words usable for indexing. Multiple authors should be identified with superscripted numbers with the addresses listed according to these numbers.

Abstract: The abstract should give a brief outline of the problem, methods, results and conclusions in not more than 350 words.

Keywords: A maximum of 5 word fit for indexing is allowed as keywords.

Introduction: This should give the background of the problem both recent and past with reference to previous work done on them. It should be concluded with the objective and contribution of the work done.

Materials and Methods: In this section, papers involving experiments should present methods, experimental design and procedures. Reference to standard procedures should be presented rather than the standard procedure. This section should contain machine or equipment description, and statistical analysis if available. For theoretical analysis, the theory of the work should be presented.

Results and Discussion: Here, the results achieved should be presented in descriptive, graphical or tabular form. The ways data and these results illustrated in any of these forms describe problem areas or proffer solutions should also be discussed.

Conclusion: The summary of the solutions should be given here. The nature of the study, major results whether conclusive and recommendations for further studies should as well be briefly stated.

Notation: A list of the abbreviations and symbols used should be presented despite explaining them wherever used.

Equations: Any formula or equation used must be presented in equation editor style and numbered.

References: Only the name-date style in the text will be accepted. All cited references should be listed in alphabetical order with same authors of two or more papers published in the same year distinguished by appending alphabets to the year.