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SIMPLE REGRESSION RELATIONSHIPS FOR ASSESSING THE PERFORMANCES OF SELECTED TILLAGE IMPLEMENTS IN SOUTH-EAST, NIGERIA

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Abstract: Research was conducted on the three dominant agricultural soils of south-east Nigeria to develop some empirical regression relationships for predicting the performances of some selected tractor-hitched tillage implements from the experimental results obtained in the field. Results of the experiments revealed that the optimum speed of plough in clay-loam and loamy – sandy soil was 6km/h with corresponding field efficiencies of 88.11% and 87.55% respectively, while in sandy – clay soil, the plough recorded its optimum speed of 7km/h with field efficiency of 87.78%. The optimum speed of harrow in clay-loam soil was 8km/h with field efficiency of 87.98%. In loamy – sandy soil, its optimum speed was 8km/h with field efficiency of 87.19%; while in sandy – clay soil; it recorded optimum speed of 9km/h with field efficiency of 98.54%. The optimum speed of ridger was 9km/h for all the soils with corresponding field efficiencies of 87.96%, 87.95%, and 89.09% respectively, for clay-loam, loamy-sandy and sandy – clay soil.

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The optimum speed of rotovator was also 9km/hr in all the soils with corresponding field efficiencies of 89.81%, 87.11%, and 89.40% in clay-loam, loamy-sandy and sandy-clay soil, respectively.

These field efficiencies experimentally obtained in the field were compared with the efficiencies obtained from the regression equations using percentage error and the accuracy of the predictions were tested using error root mean square.

The comparison of the predicted results with the experimental results revealed that the regression equations broadly did not over or under- predict the experimental results, thus, the prediction errors were within allowable range of $\pm 5\%$. The coefficient of determination, R^2 for the regression equations developed for predicting the various performance indicators of the tractor – hitched implements vary from 0.7 to 0.9 which show that the variables tested were highly correlated and also an indication that the regression equations were adequate for predicting the performance of the implements.

Key words: Empirical, equation, performance, regression, tillage implement.

INTRODUCTION

Performance efficiencies/capabilities of farm machinery can generally be evaluated by the rate at which they carry out their field operations and the quality and quantity of production. [1] state that machine field capacity is the rate at which the machine can cover a given field operation within the limit of time. [2] noted that effective capacity is evaluated by the rate of working of implement measured in hectares per hour, and that the indicators involved are the implement operation width and the working speed with the allowance for time loss, in turning at the end of the field, adjustment and servicing of the machines. The efficiency of machines/implements indicates how good the machine can perform its functions. According to [3], an experienced farmer is usually conscious of the effective and efficient operation of his/her farm machinery because poor operation or improper utilization of the equipment may lead to great operating loss and minimizes production or result to total loss of money/productivity.

Differences exist among various agro ecological areas; and performance data from various tractor - hitched implements are essential document that guides farm machinery users and managers in proper selection of machinery for a given field operation under different soil types/conditions. Selection and utilization of farm machinery are better done with the aid of detailed performance information of such machinery taking into account the variations in agro ecological soil types/conditions. [4] noted that, due to some differences in the agro-ecological soil conditions, performance data of the field capacities of machines under varying soil type/conditions is very essential for machinery selection; the performance data are the essential parameters for assessing the performances of farm machinery. But regrettably this information are not provided to farmers or farm managers in Nigeria by the producers of the machines to guide the farmers in assessing and making proper selection of the machine/implement before buying them. [5] studied the performance efficiencies of chisel and disc plough and the impact they have on some physical properties of soil in Sudan. They came out with the performance data of these implements. However, their study was only on plough tested on only one soil type, other tillage implements and their power requirements were not

considered in their study; thereafter, they recommended that more investigations are needed to verify the impact of the ploughs under study on the physical properties of different types of soils in the area.

[6] evaluated the performance of some selected tillage implements in Samaru, Zaria. The study only considered one soil type; and because of variations among soil types in an ecological area, results of such study cannot provide enough information that may guide farmers in selecting machines for their agricultural field operations.

[7] investigated the performance efficiency of tractor – hitched tillage tools in clay soil in Urmia, Iran. This study was also based on only one soil type and because of the same reason, the results may not guide farmers properly in machine selection to be used in other soil types; furthermore, Iran and South-east Nigeria may not have the same soil type with same properties/conditions; there must be differences; in which case, farmers in Nigeria may not use data from such study area to select their farm machinery.

[8] evaluated disc plough performance on sandy- loam soil at different moisture levels in Ilorin. In this study, he used dimensional analysis to develop model expressions relating the cutting depth, disc plough weight and draught force on sandy-loam soil. Despite the detailed study, did not consider the energy requirements of the implement for operation; and the study was conducted on only one soil type with only one tillage implement. These may not be enough to guide machine users in implement selection because of variations in soil type and conditions as emphasized earlier.

Development of empirical model is an essential and simple way of assisting the farmers, farm managers and other users of agricultural machinery both at subsistence and commercial level in assessing and predicting the possible performance capabilities of farm machinery in order to make proper selection of the equipment based on soil type/conditions and season of operation before purchasing and/or engaging any machine to work. This will go a long way to reduce failures, unnecessary break down, mismatching of implement to prime movers, minimize fuel consumption (energy loss), reduce cost and generally maximize production and profit [9]. The objective of this work is to develop empirical regression equations/relationships that will be used to predict the field performances of tractor hitched tillage implement in South-east agro- ecological region of Nigeria.

MATERIALS AND METHOD

Description of the experimental site

The experimental sites have average area of 8100 m² (0.81ha) each. The land area was divided into four units of 45 x 45m² each for random observations. Each unit was separated by a distance of 2.5m from the other to avoid interaction between the plot borders and to be equally used as head lands for the commencement of the experimental operations.

The tests were conducted in May, through June, July, August, September and October, 2016. These months coincide with planting season of the year; and will also offer the tractor and the hitched implements an exposure to wide range of soil conditions.

Description of Machine used and its operation

A Massey Ferguson tractor with 3- point hitch systems and age of 5 months from date of first hand purchase was hired with the hitched implements and used for the study. The same operator was used to operate the machine throughout the test to ensure minimal variation in the operation skill and style throughout the study.

Each field operation (test) starts in the morning (9 am) and lasts for 2,5 h to ensure that the operator did not get weary during the operation and the machines are properly checked for faults before being engaged to work. This is to minimize delays or unnecessary failures and to ensure optimum production time during operation.

Determination of soil physical properties

Some soil physical and mechanical properties such as moisture contents, bulk density, soil structure, texture, porosity, cone index, penetration resistance and shear resistance which affect implement performances were examined before conducting the test, using the method adopted by [9].

Field Performance Characteristics Test

The field operations were generally performed longitudinally at selected forward speeds, the distance travelled and the corresponding time taken to complete the working distance were noted; and the total productive and delay time were evaluated and recorded [10]. The speed selections were made within the speed range recommended by [11] for tillage. The implement performance indicators such as field efficiency, effective field capacity, theoretical field capacity and material efficiency were evaluated.

Measurement of Productive and Delay (Idle) Time

The total time spent on the entire row length operation and the delay or idle time encountered in the operation which include, time for refilling the tank, time for repair of breakdown/adjustments, turning time, and any other idle time observed was noted and the actual time (productive time) used in the operation was evaluated from the relationship [3];

$$T_e = T_t - T_d \quad (1)$$

Where:

T_e = actual (productive) time, (h)

T_t = total time spent on the entire row length operation, (h)

T_d = delay (idle) time, (h)

Measurement of turning time commences immediately the implement is raised on the completion of a row length, to initiate a turn until it turns completely to continue the operation.

Determination Field Efficiency

The field efficiency was determined from the expression suggested by [12]

$$\mathcal{E} = \frac{100T_e}{T_t} \tag{2}$$

Where:

\mathcal{E} = field efficiency, %

T_e = actual working (productive) time, (h)

T_t = total working time = ($T_e + T_d$), (h)

T_d = delay or idle time

Determination of the Effective Field Capacity

The effective field capacity was determined by noting the speed of operation, implements working width and the field efficiency of the machine; and then was evaluated from the expression suggested by [11]

$$C_e = \frac{Swe}{c} \tag{3}$$

Where:

C_e = effective field capacity, ha/h [a/h]

S = speed, km/h, [mi/h]

W = rated width of implement, m [ft]

e = field efficiency as a decimal

c = constant, 10 [8.25]

Determination of Theoretical Field Capacity

The Theoretical Field Capacity was determined by rearranging the expression suggested by [1] for field efficiency as follows

$$\mathcal{E} = \frac{C_e}{C_t} \tag{4}$$

By rearrangement,

$$C_t = \frac{C_e}{\mathcal{E}} \tag{5}$$

Where:

C_t = theoretical field capacity, ha/h

C_e = effective field capacity, ha/h

\mathcal{E} = field efficiency, decimal

Determination of the Material Capacity

The machine material capacity was determined by noting the speed of operation, implement working width, the field efficiency of the machine and the weight of soil scooped (for tillage implements), but for the planter, the quantity/weight of seeds loaded in the hopper; and then was obtained from the expression.

$$M = \frac{Swey}{c} \quad (6) [11]$$

Where:

M = material capacity, kg/h

y = yield/mass of material handled, kg/m²

s = implement/machine speed, km/h

w = implement working width, cm

e = implement field efficiency, %

c = constant = 10

Development of Empirical Regression Equation

The data obtained from the study were subjected to regression analysis and empirical regression equations for predicting the implement performances at different operation speeds were developed.

Determination of the adequacy of the equations

The adequacy of the equations developed from the study were determined by comparing the results obtained from the experiment with the regression results using percentage error (eqn. 7) suggested by [13]

$$\text{Error} = \frac{\text{Regression Result} - \text{Experimental Result}}{\text{Experimental Result}} \times 100 \quad (7)$$

Thereafter, the root mean square (RMS) of the error were evaluated to determine the accuracy of the predicted results. The predictions are considered accurate if the RMS errors of the prediction are within the tolerable limit of $\pm 5\%$.

More so, the coefficient of determination, R^2 will also indicate the adequacy of the model if it is within limit of 0 and 1 [14].

RESULTS AND DISCUSSION

Results of this research work are presented in Table 1-9

Table 1. Optimum speeds and efficiencies of tractor-hitched implements under different soil type/conditions

Soil type/M.C. % (wb)	Speed range, km/h	Range and optimum values of field efficiency, (%)			
		Plough	Harrow	Ridger	Rotovator
Clay-loam M.c, % (wb)	5-10	85.74- 88.11	82.59 – 87.98	83.65– 87.96	85.81– 89.81
	Optimum speed	6 km/h (15.5- 17.2)	8 km/h (14.8 – 16.2)	9 km/h (14.0-14.4)	9km/h (13.0 -14.2)
Loamy-sandy M.c, % (wb)	5-10	85.31- 87.55	83.41 – 87.19	85.54 – 87.95	81.10 - 87.11
	Optimum speed	6 km/h (15.2-16.2)	8 km/h (13.3 – 15.4)	9 km/h (13.2 -14.5)	9 km/h (13.1-13.6)
Sandy-clay M.c, % (wb)	5-10	85.90- 87.98	87.05-98.54	86.26-89.09	87.05-89.40
	Optimum speed	7 km/h (14.8-18.6)	9 km/h (13.0-19.3)	9 km/h (13.0-17.1)	9 km/h (13.3-16.3)

Table 2. Regression equations for predicting ploughing efficiencies of the implement in different soil types in south-east Nigeria

Soil type	Efficiencies (performance indicators)	Regression equations	Coefficient of determination, R ²
Clay-loam	Field efficiency (E)	$Y = 0.067x^2 - 0.7733x + 89.283$	0.9838
	Effective capacity (Ce)	$Y = 0.0864x^2 - 1.4406x + 6.8173$	0.8081
	Theoretical field capacity(Te)	$Y = 0.0026x^2 - 0.0877x + 1.7641$	0.909
	Material efficiency (Me)	$Y = 0.0888x^2 - 1.6513x + 49.11$	0.71
Loamy-sand	Field efficiency (E)	$Y = - 0.089x^2 + 0.8208x + 85.801$	0.9615
	Effective capacity (Ce)	$Y = - 0.0036x^2 + 0.0318x + 0.9189$	0.9524
	Theoretical field capacity(Te)	$Y = 0.0019x^2 - 0.033x + 1.2483$	0.8473
	Material efficiency (Me)	$Y = - 0.2184x^2 + 2.911x + 32.207$	0.9501
Sandy-clay	Field efficiency (E)	$Y = 0.0198x^2 + 0.0847x + 84.957$	0.9258
	Effective capacity (Ce)	$Y = 0.0672x^2 - 1.1748x + 6.0411$	0.8427
	Theoretical field capacity(Te)	$Y = - 0.0209x^2 + 0.3103x + 0.1481$	0.9625
	Material efficiency (Me)	$Y = - 0.9018x^2 + 13.699x - 4.9457$	0.9515

Note: Y = Performance indicators; X = Operational speeds

Table 3. Regression equations for predicting the harrowing efficiencies of the implement in different types in south-east zone.

Soil type	Efficiencies (performance indicators)	Regression Equations	Coefficient of determination, R ²
Clay-loam	Field efficiency (E)	$Y = - 0.3745x^2 + 7.4659x + 50.757$	0.9149
	Effective capacity (Ce)	$Y = - 0.0056x^2 + 0.1486x + 0.3631$	0.9007
	Theoretical field capacity(Te)	$Y = 0.0041x^2 + 0.0885x + 0.9156$	0.8894
	Material efficiency (Me)	$Y = 0.1952x^2 - 0.6095x + 84.343$	0.9144
Loamy-sand	Field efficiency (E)	$Y = - 0.3423x^2 + 5.2326x + 67.303$	0.9549
	Effective capacity (Ce)	$Y = - 0.0301x^2 + 0.550x - 1.0181$	0.9752
	Theoretical field capacity(Te)	$Y = 0.0085x^2 + 0.186x + 0.6977$	0.9475
	Material efficiency (Me)	$Y = - 1.512x^2 + 30.058x - 26.412$	0.9443
Sandy-clay	Field efficiency (E)	$Y = 0.3945x^2 - 4.2087x + 97.777$	0.8652
	Effective capacity (Ce)	$Y = - 0.0044x^2 + 0.1375x + 0.4436$	0.9105
	Theoretical field capacity(Te)	$Y = - 0.01x^2 + 0.194x + 0.5459$	0.9607
	Material efficiency (Me)	$Y = - 0.3586x^2 + 11.229x + 36.297$	0.9105

Note: Y = Performance indicators; X = Operational speeds

Table 4. Regression equations for predicting the ridging efficiencies of the implement in different soil types in south-east zone.

Soil type	Efficiencies (performance indicators)	Regression equations	Coefficient of determination, R ²
Clay-loam	Field efficiency (E)	$Y = -0.1873x^2 + 3.9156x + 67.166$	0.933
	Effective capacity (Ce)	$Y = -0.0329x^2 + 0.9125x - 4.1054$	0.9112
	Theoretical field capacity (Te)	$Y = 0.027x^2 - 0.3873x + 2.5757$	0.8603
	Material efficiency (Me)	$Y = 1.3063x^2 - 17.514x + 115.46$	0.9276
Loamy-sand	Field efficiency (E)	$Y = -0.1861x^2 + 3.5461 + 70.901$	0.9637
	Effective capacity (Ce)	$Y = -0.0061x^2 + 0.114x + 0.6533$	0.859
	Theoretical field capacity (Te)	$Y = -0.0217x^2 + 0.3893x - 0.3754$	0.8117
	Material efficiency (Me)	$Y = -1.1914x^2 + 21.493x - 28.259$	0.899
Sandy-clay	Field efficiency (E)	$Y = 0.2082x^2 - 3.1954x + 98.731$	0.9425
	Effective capacity (Ce)	$Y = -0.0126x^2 + 0.1867x + 0.6991$	0.9591
	Theoretical field capacity (Te)	$Y = 0.0019x^2 + 0.0375x + 1.191$	0.9118
	Material efficiency (Me)	$Y = 0.8154x^2 - 11.968x + 109.01$	0.9233

Note: Y = Performance indicators; X = Operational speeds

Table 5. Regression equations for predicting the pulverizing efficiencies of the implement in different soil types in south-east zone.

Soil type	Efficiencies (performance indicators)	Regression equations	Coefficient of determination, R ²
Clay-loam	Field efficiency (E)	$Y = -0.1741x^2 + 4.531x + 59.272$	0.9672
	Effective capacity (Ce)	$Y = 0.0033x^2 - 0.0715x + 1.1462$	0.9501
	Theoretical field capacity (Te)	$Y = -0.0769x^2 + 2.0311x - 11.388$	0.8773
	Material efficiency (Me)	$Y = -0.2234x^2 + 5.8529x - 13.643$	0.9775
Loamy-sand	Field efficiency (E)	$Y = -0.7563x^2 + 18.097x - 19.798$	0.9122
	Effective capacity (Ce)	$Y = -0.0006x^2 + 0.0113x + 0.7612$	0.9614
	Theoretical field capacity (Te)	$Y = -0.0812x^2 + 1.668x - 6.5609$	0.9396
	Material efficiency (Me)	$Y = -0.868x^2 + 20.363x - 90.59$	0.8995
Sandy-clay	Field efficiency (E)	$Y = -0.0825x^2 + 1.9006x + 76.649$	0.9235
	Effective capacity (Ce)	$Y = -0.0053x^2 + 0.1441x - 0.1535$	0.9162
	Theoretical field capacity (Te)	$Y = -0.0426x^2 + 0.7346x - 1.1896$	0.7867
	Material efficiency (Me)	$Y = 0.0977x^2 - 2.0643x + 32.16$	0.8545

Note: Y = Performance indicators; X = Operational speeds

Table 6. Comparison of the field experiment and regression equation results for ploughing operation

Soil type	speed km/h	Field efficiency, %			Effective field capacity, ha/h			Theoretical field capacity, ha/h			Material efficiency, kg/h		
		Exp.	Regr.	Er %	Exp.	Regr.	Er %	Exp.	Regr.	Er %	Exp.	Regr.	Er %
Clay-loam	5	87.08	87.47	4.48	1.031	1.016	-1.45	1.844	1.162	-1.86	43.46	42.82	-1.46
	6	88.11	87.26	-0.96	0.99	1.002	1.21	1.123	1.147	2.14	41.73	42.18	1.08
	7	87.05	87.08	0.03	1.978	0.988	-0.01	1.124	1.132	0.71	41.22	40.53	-1.67
	8	86.45	86.84	-4.51	1.019	0.974	-4.42	1.179	1.117	-5.3	42.95	40.89	-4.8
	9	85.74	77.18	-9.77	0.847	0.960	13.5	0.981	0.912	-7.6	35.67	40.24	12.8
	10	87.24	86.42	-0.94	1.002	0.946	-5.6	1.149	1.059	-7.83	42.23	38.35	-9.19
	RMS			4.48		6.32		5.01		6.81		6.81	
Loamy-sandy	5	86.79	88.99	2.52	0.981	0.976	-0.51	1.130	1.120	-0.88	41.35	40.76	-1.42
	6	88.55	88.79	1.40	0.991	0.958	-3.33	1.119	1.104	-1.34	41.77	40.50	-3.04
	7	87.07	88.59	1.75	0.875	0.955	9.14	1.005	1.088	8.26	36.88	40.24	9.11
	8	85.13	88.40	3.84	0.932	0.922	-1.07	1.102	1.072	-2.72	40.30	39.26	-2.58
	9	86.02	88.21	2.55	0.911	0.904	-0.77	1.111	1.056	-4.95	41.09	39.73	-3.31
	10	82.31	88.02	6.94	0.885	0.886	0.11	1.003	1.040	3.69	39.32	39.47	-0.38
	RMS			3.71		4.00		4.42		4.31		4.31	
Sandy-clay	5	85.90	84.71	-1.39	0.974	1.061	8.93	1.134	1.199	5.73	41.05	45.20	9.21
	6	83.23	85.72	2.69	1.062	1.045	-1.60	1.275	1.171	-8.16	44.76	44.53	-0.51
	7	86.23	86.22	-0.13	1.113	1.029	-7.55	1.282	1.143	-10.8	46.91	43.86	-6.50
	8	88.23	86.97	-1.43	1.143	1.013	-11.4	1.296	1.115	-14.0	48.18	43.19	-10.4
	9	88.22	87.73	-0.56	0.848	0.997	17.6	0.961	1.087	13.1	35.74	42.52	19.0
	10	87.78	88.48	0.80	0.985	0.981	-0.41	1.122	1.059	-5.61	41.52	41.85	0.79
	RMS			1.42		4.75		5.08		4.99		4.99	

Table 7. Comparison of the field experiment and regression equation results for harrowing operation

Soil type	Speed km/h	Field efficiency, %			Effective field capacity, ha/h			Theoretical field capacity, ha/h			Material efficiency, kg/h		
		Exp.	Regr	Er %	Exp.	Regr	Er %	Exp.	Regr	Er %	Exp	Regr	Er %
Clay-loam	5	82.59	83.68	1.32	1.063	1.076	1.22	1.287	1.329	3.26	86,8992.04	88.01	1.29
	6	83.42	85.04	1.94	1.126	1.113	-1.15	1.350	1.347	-0.22	89.67	91.01	-1.12
	7	80.17	86.40	7.77	1.097	1.150	4.83	1.368	1.365	-0.22	105.8	94.00	4.83
	8	87.98	87.76	-0.25	1.289	1.187	-7.91	1.465	1.387	-5.60	97.76	97.00	-8.28
	9	86.70	89.12	2.79	1.196	1.224	2.34	1.379	1.401	1.60	101.3	99.99	2.28
	10	88.56	90.48	2.17	1.239	1.261	2.73	1.399	1.419	1.43		102.9	1.68
	RMS		3.60			4.10			2.81			4.11	
Loamy-sandy	5	83.58	85.68	2.51	1.192	1.302	9.23	1.426	1.517	6.38	97.43	108.7	11.5
	6	86.82	85.41	-1.62	1.389	1.327	-4.46	1.600	1.542	-3.63	113.5	106.6	-6.14
	7	87.08	85.17	-2.19	1.436	1.352	-5.85	1.649	1.567	-4.97	117.4	104.5	-11.0
	8	84.19	84.92	0.87	1.399	1.377	-1.57	1.589	1.592	-0.19	98.32	102.4	4.13
	9	55.22	84.24	-1.15	1.386	1.402	1.15	1.603	1.617	0.89	97.18	100.3	3.20
	10	83.41	84.44	1.23	1.394	1.427	2.37	1.611	1.642	1.92	96.74	98.20	1.51
	RMS		4.23			5.03			3.72			6.19	
Sandy-clay	5	87.55	87.15	-0.46	1.095	1.116	-1.92	1.251	1.291	3.20	89.51	92.09	2.88
	6	86.05	87.48	1.66	1.204	1.182	-1.83	1.400	1.357	-3.07	98.41	97.17	-1.26
	7	86.95	87.82	-0.99	1.281	1.248	-2.58	1.473	1.423	-3.39	104.7	102.3	-2.35
	8	91.38	88.15	-3.53	1.343	1.314	-2.16	1.470	1.489	1.29	109.8	107.3	-2.23
	9	88.54	88.49	-0.11	1.311	1.380	5.26	1.480	1.555	5.07	107.2	112.4	4.90
	10	87.45	88.82	1.57	1.458	1.446	-0.82	1.667	1.621	-2.76	119.2	117.5	-1.41
	RMS		1.82			2.83			3.35			2.84	

Table 8. Comparison of the field experiment and regression equation results for ridging operation

Soil type	Speed, km/h	Field efficiency, %			Effective field capacity, ha/h			Theoretical field capacity, ha/h			Material efficiency, kg/h		
		Exp.	Regr	Er %	Exp.	Regr	Er %	Exp.	Regr	Er%	Exp	Regr	Er %
Clay-loam	5	83.65	83.68	0.04	1.065	1.117	4.88	1.273	1.152	-9.51	59.85	62.57	4.55
	6	85.68	84.56	-1.31	0.932	1.113	19.4	1.088	1.200	10.3	52.38	62.12	18.6
	7	83.90	85.43	1.83	1.457	1.109	-23.9	1.260	1.248	-0.95	79.40	61.67	-22.3
	8	86.00	86.31	0.36	1.152	1.105	-4.08	1.340	1.296	-3.28	64.74	61.22	-5.44
	9	88.06	87.18	-0.10	0.945	1.101	16.5	1.073	1.344	25.3	53.11	60.77	14.4
	10	87.92	88.05	0.15	1.089	1.100	0.73	1.603	1.392	-13.2	59.19	60.32	1.91
	RMS		0.91			5.81			4.63			4.33	
Loamy-sandy	5	87.54	87.59	5.37	1.007	1.087	7.94	1.150	1.249	8.61	56.59	61.07	7.92
	6	87.45	87.50	0.06	1.175	1.109	-5.62	1.344	1.265	-5.88	66.04	61.20	-6.12
	7	87.54	87.42	-1.37	1.166	1.131	-3.00	1.332	1.281	-3.83	65.55	62.92	-4.01
	8	87.48	87.39	-0.10	1.170	1.153	-1.45	1.290	1.297	0.54	63.18	63.85	1.05
	9	86.95	87.26	0.36	1.165	1.175	0.86	1.318	1.313	-0.38	64.39	64.77	0.59
	10	87.32	87.17	-12.8	1.169	1.195	3.27	1.301	1.329	2.15	64.52	65.69	1.82
	RMS		2.61			3.42			2.71			2.52	
Sandy-clay	5	87.07	86.63	-0.51	1.170	1.175	0.44	1.344	1.359	1.12	65.75	64.43	-2.00
	6	86.60	86.91	0.36	1.182	1.168	-1.18	1.365	1.345	-1.47	66.43	65.25	-1.78
	7	86.26	87.20	1.08	1.165	1.162	-0.26	1.351	1.331	-1.48	65.47	66.06	0.90
	8	89.19	87.48	-1.92	1.206	1.155	-4.23	1.352	1.317	-2.59	67.78	66.87	-1.34
	9	86.09	87.77	1.95	1.009	1.148	13.8	1.164	1.303	11.9	56.31	67.69	20.2
	10	88.82	88.05	-0.87	1.218	1.141	-6.32	1.371	1.289	5.98	77.05	68.50	-11.1
	RMS		0.64			3.12			4.12			4.22	

Table 9. Comparison of the field experiment and regression equation results for pulverizing operation

Soil type	Speed km/h	Field efficiency,%			Effective field capacity,ha/h			Theoretical field capacity,ha/h			Material efficiency, kg/hr		
		Exp.	Regr	Er%	Exp.	Regr	Er%	Exp.	Regr	Er%	Exp	Regr	Er%
Clay-loam	5												
	6	85.81	85.81	0.00	0.775	0.789	2.97	0.903	0.916	1.39	20.93	18.20	-13.0
	7	87.38	85.55	-0.95	0.759	0.797	5.01	0.869	0.911	4.83	20.49	19.17	-6.42
	8	88.20	87.30	-1.02	0.962	0.795	-17.4	1.091	0.906	-17.0	25.97	20.15	-22.4
	9	88.24	88.05	-0.22	0.669	0.794	18.7	0.758	0.902	19.0	18.06	21.12	16.9
	10	89.81	88.89	-1.13	0.811	0.793	-2.22	0.903	0.898	-0.55	21.90	22.09	0.89
	RMS	86.63	89.54	3.36	0.795	0.792	-0.38	0.918	0.893	-2.72	21.47	23.06	7.41
Loamy-sandy				1.22			3.16			5.02			4.18
	5	81.10	83.80	3.33	0.804	0.804	0.00	0.913	0.917	0.48	21.71	22.51	3.70
	6	86.76	84.45	-2.67	0.803	0.805	0.21	0.925	0.924	-0.14	21.68	23.19	6.95
	7	86.83	85.09	-2.00	0.812	0.805	-0.86	0.935	0.930	-0.53	27.94	23.86	-14.6
	8	84.92	85.74	0.97	0.800	0.805	0.63	0.911	0.936	2.78	22.61	24.53	8.89
	9	87.11	86.39	-0.83	0.811	0.806	-0.65	1.002	0.943	-5.92	26.81	25.21	-6.36
	10	85.81	87.04	1.43	0.804	0.806	0.26	0.916	0.949	3.61	24.41	25.89	6.01
	RMS			2.24			0.51			2.21			3.60
Sandy-clay	5	87.05	87.81	0.87	0.800	0.763	-4.61	0.919	0.900	-2.05	21.60	20.75	-3.95
	6	89.40	87.91	-1.67	0.778	0.776	-0.23	0.933	0.910	-2.42	21.01	21.10	0.45
	7	86.88	88.02	1.31	0.685	0.789	15.2	0.788	0.921	15.7	18.50	21.46	16.0
	8	87.51	88.12	0.70	0.902	1.274	41.2	1.031	0.931	-9.72	24.35	21.82	-10.4
	9	88.36	88.23	-0.15	0.812	0.816	0.44	0.919	0.941	2.39	21.92	22.18	11.6
	10	87.43	88.33	1.03	0.825	0.829	0.32	0.950	0.951	0.11	22.36	22.53	0.77
	RMS			1.66			6.14			3.18			4.96

DISCUSSION

Table 1. presents the optimum performances of the implements under different soil types/ conditions. Results of this table revealed that the optimum speed of plough in clay-loam soil was 6km/h. At this speed, the plough recorded the highest field efficiency of 88.11% at a cutting depth of 25cm within soil moisture content range of 15.3 – 17.2% (w.b). In loamy – sandy soil, the optimum speed of the plough was also 6km/hr with corresponding field efficiency of 87.55% at moisture content range of 15.2 – 16.2% (w.b); while in sandy – clay soil, the plough recorded its optimum speed of 7km/hr with field efficiency of 87.78% at moisture content range of 14.8 – 18.6% (w.b).

Furthermore, the optimum speed of operation of harrow in clay-loam soil was 8km/hr with highest field efficiency of 87.98% within soil moisture content range of 14.2 – 16.2% (w.b). In loamy – sandy soil, the optimum speed of the harrow was 8km/hr with highest field efficiency of 87.19% at moisture content range of 13.3 – 15.4% (w.b); while in sandy – clay soil; it recorded its optimum speed of 9km/hr with the field efficiency of 98.54% at moisture content range of 13.0 – 19.3% (w.b). Results of this table also revealed that for all the soils studied, the optimum speed of ridger was 9km/hr with corresponding field efficiencies of 87.96%, 87.95% and 89.09% respectively in clay-loam, loamy-sandy and sandy clay soil at soil moisture content range of 14.0 – 14.4% (w.b) , 13.2 – 14.5% (w.b) and 13.0 – 17.1% (w.b) respectively. More so, the rotovator in recorded the same optimum speed with the ridger (9km/h) for all the soils with field efficiency of 89.81% at soil moisture content range of 13.0 – 14.2% (w.b) in clay-loam soil; 87.11% at moisture content range of 13.1 – 13.6% (w.b) loamy-sandy soil; and 89.40% at moisture content range of 13.3 – 16.3% (w.b) in sandy-clay soil.

Table 2 to 5 showed the regression equations developed from the experimental results obtained during the performance evaluation of the implements under study.

The developed regression equations were validated by comparing its results with the experimental results using percentage error (Table 6 - 9). The comparison of the predicted results with the experimental results of this study revealed that the regression equations broadly did not over or under- predict the experimental results, thus, the prediction errors were within allowable range. More so, from the root mean square error analysis, the errors are within acceptable limit of $\pm 5\%$. However, the little deviations in the prediction of some performance indicators in some operations were attributed to variations in soil conditions/characteristics. The coefficient of determination R^2 for the regression equations developed for predicting the various performance indicators of the tractor – hitched implements vary from 0.7 to 0.9 which indicate that the equations are adequate for predicting the performances of the implements.

CONCLUSION

1. The optimum speed of plough in clay-loam and loamy – sandy soil was 6km/h with corresponding field efficiencies of 88.11% and 87.55% respectively, while in sandy – clay soil, the plough recorded its optimum speed of 7km/h with field efficiency of 87.78%.
2. The optimum speed of harrow in clay-loam soil was 8km/hr with field efficiency of 87.98%. In loamy – sandy soil, its optimum speed was 8km/hr with field efficiency of 87.19%; while in sandy – clay soil; it recorded optimum speed of 9km/hr with field efficiency of 98.54%.
3. The optimum speed of ridger was 9km/hr for all the soils with corresponding field efficiencies of 87.96%, 87.95%, and 89.09% respectively, for clay-loam, loamy-sandy and sandy –clay soil.
4. The optimum speed of rotovator was also 9km/hr in all the soils with corresponding field efficiencies of 89.81%, 87.11%, and 89.40% in clay-loam, loamy-sandy and sandy –clay soil, respectively.
5. The comparison of the predicted results with the experimental results (using percentage error and error root mean square) revealed that the regression equations broadly did not over or under- predict the experimental results, thus, the prediction errors were within allowable range of $\pm 5\%$.
6. The coefficient of determination R^2 for the regression equations developed for predicting the various performance indicators of the tractor – hitched implements vary from 0.7 to 0.9 which indicate that the equations are adequate for predicting the performances of the implements.

RECOMMENDATIONS

Differences exist in soil conditions among different agricultural or ecological areas; it is therefore recommended that more studies should be conducted in every agricultural zone to provide data on machine/ implement performances based on soil conditions for increased production, minimization of production costs, reduce loss/wastage of energy, time and waste of agricultural products.

Finally, this study did not cover all the agricultural field machineries. Researchers are also recommended to make detailed time study in other machineries not covered in this work in order to provide database in their performances as to guide farmers here and other agricultural zones in machine/implement selections.

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JEDNOSTAVNE REGRESIJSKE VEZE ZA PROCENU PERFORMANSI IZABRANIH PRIKLJUČAKA OPREME U JUGOISTOČNOJ NIGERIJ

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Sažetak: Istraživanje je obavljeno na tri dominantna poljoprivredna zemljišta jugoistočne Nigerije da bi se razvio određeni empirijski regresijski odnos za predviđanje performansi nekih odabranih priključaka za obradu zemljišta agregatiranih na traktore na osnovu eksperimentalnih rezultata dobijenih na terenu. Rezultati eksperimenata pokazuju su da optimalna brzina oranja u glinovito -ilovastom i ilovasto - peskovitom zemljištu iznosi 6 km/h, sa odgovarajućom efikasnosti (učinkom) na polju od 88,11%, odnosno 87,55%, dok je u peskovito- glinovito zemljištu za plug registrovana optimalna brzina 7 km/h sa efikasnosti (učinkom) na polju od 87,78%. Optimalna brzina operacije obrade drljanjem na glinovito-ilovastom zemljištu bila je od 8 km/h, a učinak (efikasnost) je 87,98%. Kod ilovasto-peskovitog zemljišta, optimalna brzina bila je 8 km/h, a učinak (efikasnost) bila je 87,19%; dok je u kod peskovito - glinovitog zemljišta registrovana optimalna brzinu od 9 km/h sa učinkom (efikasnost) od 98,54%.

Optimalna brzina traktor-podriivač bila je 9 km/h za sva ispitivana zemljišta sa odgovarajućom efikasnosti (učinkom) na polju 87,96%, 87,95%, odnosno 89,09%, za glinovito-ilovasta, ilovasto-peskovita i peskovito-ilovasta zemljišta. Optimalna brzina rotatofreze bila je takođe 9 km/h na svim zemljištima u ispitivanju, sa odgovarajućom efikasnosti (učinkom) od 89,81%, 87,11%, odnosno 89,40%, u glinovito-ilovastom, ilovasto-peskovitom i peskovito-glinovitom tipu zemljišta.

Ove efikasnosti (učinci) na polju su eksperimentalno dobijene na terenu su upoređene sa efikasnosti dobijenom iz jednačina regresija, koristeći grešku od $\pm 5\%$, a tačnost predviđanja testirana je korišćenjem srednjeg kvadratnog odstupanja R^2 . Upoređivanje predviđenih rezultata sa eksperimentalnim rezultatima otkrilo je da regresione jednačine u velikoj meri nisu premašile ili umanjile eksperimentalne rezultate, tako da su greške predviđanja bile u okviru dozvoljenog raspona od $\pm 5\%$.

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Koeficijent R_2 za regresione jednačine razvijen za predviđanje različitih pokazatelja performansi traktorskih priključaka varira od 0,7 do 0,9 što pokazuje da su testirane varijable bile visoko povezane, a takođe su pokazatelj da su regresione jednačine adekvatne za predviđanje performanse priključaka.

Ključne reči: Empirijski, jednačine, performanse, regresija, primena obrade.

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