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PERFORMANCE CHARACTERISTICS OF AGRICULTURAL FIELD MACHINERIES IN SOUTH- EAST NIGERIA

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ABSTRACT

The field performances of agricultural field machineries in South -East agricultural zone of Nigeria were assessed, to enable farmers and agriculturists select suitable farm machines/implements based on soil conditions/characteristics for their agricultural activities. The various implements studied include; disc plough, 2-gang tandem disc harrow, ridger, rotovator and 6-row combine seed planter. Three different makes and models of tractors namely: New Holland (model-NH5610SE and capacity-55.9kw), Massey Ferguson (model-MF430E and capacity-55.2kw) and Mahindra (model-NH7570E and capacity-55.9kw) with 3- point hitch systems and average age of 1.3 years were used to study the field performances of each of the implements, in five different states that made up the study area. The field performances studied include; implement's working speed, operation time, depth of cut, effective and theoretical field capacities, field efficiency, fuel consumption rate, implement power requirements, and wheel slippage, under different soil conditions. Results obtained revealed that the disc plough had field efficiency range of 85.74% to 88.55%, effective and theoretical field capacities range of 0.846 to 1.164ha/hr and 0.961 to 1.319ha/hr respectively; and the highest field (ploughing) efficiency was obtained in loamy-sandy soil when the plough was operated with the Massey Ferguson tractor. Harrow recorded field efficiency range of 80.17 to 91.38%, effective and theoretical field capacities range of 0.931 to 1.458ha/hr and 1.151 to 1.667 ha/hr respectively; and the highest field (harrowing) efficiency was obtained on sandy-clay soil by New Holland tractor. Ridger recorded 83.65 to 88.82% field efficiency, 0.932 to 1.322ha/hr effective capacity and 1.073 to 1.504ha/hr theoretical field capacity; and sandy-clay gave the highest field (ridging) efficiency when operated with a New Holland tractor. The rotovator had field efficiency range of 81.10 to 89.81%, effective and theoretical field capacities range of 0.759 to 0.902ha/hr and 0.758 to1.039ha/hr respectively; and the highest pulverizing efficiency was achieved on the clay-loam soil with a Massey Ferguson tractor. The planter recorded 80.63 to 89.37 field efficiency,1.012 to1.481ha/hr effective field capacity and theoretical field capacity of 1.22 to 1.716ha/hr. Ploughing gave the highest average fuel consumption rate of 22.72L/ha (8.89L/hr), followed by harrowing with average consumption of 19.57L/ha (8.04L/hr), ridging recorded 19.42L/ha (7.97L/hr), rotovator had 16.79L/ha (7.19L/hr) and least was planter with average consumption rate of 15.10L/ha (6.26L/hr). More so, all implements recorded highest slippage in sandy-clay soil, followed by loamy-sandy and the least slippage was recorded in the clay-loam soil. Results finally revealed that the highest draft force (10.8kN/m) was obtained by the plough, followed by the harrow and ridger with equal draft force values of 10.5kN/m respectively and least draft was recorded by the rotovator (5.1kN/m).

Key words: Field performances, machineries, soil conditions, agricultural zone, south-east.

INTRODUCTION

The modern agricultural operation involves using machines for different farm operations from land clearing to harvesting (Onwualu et al. 2006). Very large areas of land are available in the world today, but all of them are not fit for crop production, and in order to bring these areas into an economically fit condition for crop production, variety of mechanical operations have to be performed. The key operations involved are preparation of the fine seed bed for ideal crop germination and better start of seeding, mechanical weeding or application of weed/pest controls, application of fertilizers, harvesting and transporting the farm produce to the designed destination (Ojha and Michael, 2012). The authors further noted that farm machineries are designed to perform these agricultural operations/tasks at specified time and cost; and that if these designed objectives are not met or achieved; it means that such machineries and /or equipment and their power units are questionable.

A successful farmer according to Yohanna and Ifem (2003) strives to make judicious use of agricultural inputs such as farm machinery and equipment, seeds, fertilizer, herbicides/pesticides, irrigation water etc; in order to maximize production with minimum cost. They added that farm machineries act as devices to ensure that other inputs give the desired results and that it may be said that farm machineries and the techniques associated with their use broadly constitute the field of agricultural mechanization. Some of the increased production that has been realized in agriculture is accredited to essentially the increased utilization of effective machines and implements (Kepner, 1982).

Farmers are very much concerned about the qualitative and quantitative field performances of the farm equipment during operation to enable them buildup the expenses incurred in the purchase, hiring and/or maintenance of such machines/equipment (Oduma et al. 2015). Sale et al (2013) noted that agriculture is very sensitive to timely operations and weather conditions, and huge amount of money is spent on the investment, therefore there is the need to evaluate the capacitive performance of agricultural machines for proper selection, optimization and farm scheduling. This huge investment involved in tractors and/ or machinery give cause for better assessment and /or evaluation of the field efficiencies of the tractor coupled implements used in farming operations.

Withney (1988) asserts that efficient machinery management requires accurate performance data on the capabilities of individual machines in order to meet a given work schedule and to form balanced mechanization systems by matching the performance of separate items of equipment. There is therefore considerable variation in operating conditions, such as in topography, surface roughness, hardness, stoniness and soil traficability; machines can be evaluated over a short period in productive work- equivalent to speed trials or they can be monitored over-time taking into account associated delays (Yohanna and Ifem, 2003). According to Braid and Gwarzo (1985), the four types of machine ding performances that must be evaluated if a true knowledge of an agricultural machine is to be secured are; functional performance, mechanical performance, capacitive and economic performance. The field performances of agricultural machineries are however affected by many factors. The major factors according to the authors include those of power units, machine condition, field crop type, weather, soil type and management.

Onwualu et al (2006) stipulated that it is necessary to know how a machine performs a given tasks and the rate at which it does the work. This information is important from the point of view of farm machinery management and other economic aspects as well as timeliness of the farm operations. According to them timeliness is the ability to perform an activity in such a time that the quality and quantity of the products are optimized. Sale et al (2013) maintained that capacitive performance is a factor which determines how a machine completes a job or task within allowable constraints of time. They revealed that the capacitive performance of an agricultural machine give answers to the question, “will the machine completes a job or task given within the allowable constraints of time under a variety of field conditions” or is it a poor investment regardless of its cost? Tractor coupled implements should perform tasks satisfactorily in seeding/planting and harvesting with minimum damage of crops; prepare seed bed while conserving moisture content of the soil; create good aeration of the soil and necessary environment condition for crop growth and conserve the soil against erosion and nutrient/sediment losses etc.

Energy is another important factor in agricultural operations. Updhyaya et al (1984) said that energy plays key role in various land tillage, seeding/planting operation, harvesting of agricultural productivities etc, however, fuel cost of tillage and / or agricultural productivities must be kept at an absolute minimum level so that any amount of operation will not put the cost per hour into prohibitive range. Therefore tractors and implements operation must be simple, inexpensive, reliable and low in fuel consumption (Udo and Akubuo, 2003).

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According to Bukhari and Baloch (1982), the speed of operation, width and depth of cut, soil type and skill of operation affect fuel consumption. This therefore implies that implement size and speed must be matched to tractor size to enhance field performance efficiencies of operation (Collins et al. 1998).

The performance of agricultural machineries can generally be assessed by the rate of operation and the quality of output. Gbadamosi and Magaji (2003) revealed that field machine performance or capacity is the rate at which it can cover a field while performing its intended function or useful work. Onwualu et al (2006) and kuel and Egbo(1985) stated that field capacity is measured by the rate of work in hectares per hour, and that the factors involved are the width of the useful work and speed of travel with the allowance for the lost time in turning and servicing the machines. Efficiency of machines shows how well they do or are made to do work that they are designed to perform. According to Oduma et al (2015), a good farmer will always ensure the effective and efficient operation of his farm equipment because inefficient operation or poor utilization may result to great operating expenses and reduces profit or cause total loss in productivity.

Anazodo et al (1983) noted that, because of variation in the ecological soil conditions, performance data of the field efficiencies under different soil conditions is very important for tractor and implement selection as these are the important parameters for measuring and evaluating performances of farm tractors/ implements. Unfortunately, such data are not made available to farmers here in Nigeria by the manufacturers of the machines to enable them assess and possibly make proper selection of the equipment before purchase. The data according to the authors would have been a good guide for a better understanding and selection of the machine capabilities especially in rural areas. This detailed time study of various field operations with tractor coupled implements will therefore provide data on the field efficiencies of the machineries in South-East agricultural zone of Nigeria to enable the farmers in this area select the appropriate equipment for their farming operations.

The key operation necessary in agricultural operation are mechanical clearing, land preparation, seed planting, weeding, fertilizer application and harvesting. These are achieved by effective utilization and management of tractors and their coupled implements. Efficient machinery utilization and/ or management requires accurate performance data on the capabilities of the individual machines to meet a given work schedule and to form balanced mechanization system by matching the performance of separate items of equipment. The variation in ecological soil condition also requires the knowledge of the field efficiencies or capabilities of the coupled implements. Unfortunately, the manufacturers did not make the data available for the farmers in Nigeria, which would have been a good guide in the proper selection of the implements based on the soil differences applicable in various agricultural regions in Nigeria. The result of this study will constitute the important data of the parameters in the selection of tractor coupled implements for field preparation, harvesting of crops and reduce machine breakdown/failure, energy loss and time wastage in operation.

The objectives of this research are: to determine the operation speed of the field machineries; to determine the field efficiency, effective and theoretical field capacities of the machines; to determine the fuel consumption rate of the equipment in operation and to determine the power (draft and drawbar power) requirement of various field machineries under study.

MATERIALS AND METHOD

Description of Experimental Site:

The experiments were conducted at five different locations, namely: demonstration farm of veterinary school, Ezzangbo, Ohaukwu L. G. A. Ebonyi State; demonstration farm of department of Agricultural and Bio-Resources Engineering, college of engineering and Engineering technology, Michael, Okpara University of Agriculture, Umudike, Abia State; demonstration farm of department of Agricultural and Bio-Resources Engineering, faculty of engineering, Nnamdi Azikiwe

University, Anambra State; demonstration farm of department of Agriculture, Federal College of Education Ehamufu, Enugu State and in Achara Ubo Ubowalla Emekuku, Oweri North L.G.A., Imo state. The soil in the first and second locations is clay-loam, in the third location the soil is loamy-sandy while in the fourth and fifth locations the soil was sandy clay. These soil types according to soil map of south-eastern Nigeria are the dominant soils found in the five component states (Obinna, *et al.*, 2013).

The experimental sites have an average area of 8100m^2 (0.81ha) each. The land area was divided into four units of 45 x 45m^2 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 was conducted in May, through June, July and August which coincide with planting season of the year; and which also offer the tractor and the coupled implements an exposure to wide range of soil conditions.

Description of Machine/Apparatus Used for the Test:

Three different tractors, namely: Massey Ferguson of model MF430E and capacity of 55.2kW (74hp), New Holland of model NH5610SE and capacity of 55.9kW (75hp) and Mahindra of model M7570E and capacity of 55.9kW (75hp) with 3- point hitch systems and average age of 1.3 years were used for the test. The same operator was used for the operation of the machine throughout the test to ensure minimal variations in operation skill/style throughout the study. Stop watch was used to keep time of operation; Measuring Tape was used for linear measurement of land, working distance and working width of the machine and Wooden Metre Rule was used for measuring depth of cut for tillage and seed planting.

The coupled implements that were studied include ploughs, harrows, rotovators, ridgers, and planters. The performance characteristics/efficiencies of the implements which include field efficiency, effective field capacity, theoretical field capacity, energy consumption rate, and the power requirements of the implements were tested.

Field Performance Characteristics Test:

Measurement of Speed of Operation, Productive and Delay (Idle) Time:

The speeds of operation, Productive and Delay (Idle) Time were evaluated using the methods described by Sale et al (2013) and adopted by Oduma et al 2015.

Measurement of Fuel Consumption:

A graduated cylindrical container was used to measure the amount of fuel required to refill the fuel tank of the tractor immediately after each operation as used by Udo and Akubuo (2000). This measurement provided the quantity of fuel consumed during each experiment. The fuel consumption rates was calculated in liter/ha and liter/hr as follows- as suggested by Alnahas (2003).

$$\text{a. Rate of consumption (L/ha)} = \frac{\text{Reading of cylinders, litres}}{\text{Area of land covered, hacters}} \quad - \quad (3)$$

$$\text{b. Rate of consumption (L/hr)} = \frac{\text{Reading of cylinders, litres}}{\text{Time taken to cover the land area, hours}} \quad - \quad (4)$$

Development of Model Equation for Determination of Field Performances of the implements:

Model equation for determination of the field efficiency:

The performance of machines/implements depend on the working width, speed of operation, working time, draft power of the implement and depth of cut of the machine.

Let □ be the field efficiency of the implement. But efficiency of machine from mechanics of machine (Okeke and Anyakoha, 1989) is given by

$$\square = \frac{\text{Work output}}{\text{Work input}} \times 100\% \qquad - \quad - \quad (5)$$

But work output is the product of load and distance moved by the load in the direction of the application of force/effort (Newton's second law, Okeke and Anyakoha, 1989); and work input is the product of effort and distance moved by the effort in delivering the work. This reduces equation 3.11 to

$$\square = \frac{\text{Load x load distance}}{\text{effort x effort distance}} \text{ x } 100\% \quad - \quad (6)$$

But load = mg = ma (i.e. mass of soil multiplied by the linear acceleration of the soil as it initiate some movement when scooped by the machine)

But acceleration, $a = \frac{v}{t}$ - - - (7)

Therefore load $= \frac{mv}{t}$ - - - (8)

Where m = mass of soil, kg; v =velocity, m/s and t = time taken in seconds.

Given that:

W = working width of the implement and

D = draft power per unit width of the implement

Therefore effort = WD - - (9)

Effort distance = depth of cut/penetration of the implement = P

This implies that, effort x effort distance = WDP - - - (11)

Substituting equation 3.14 and 3.16 in equation 3.12, we have

$$\square = \frac{\frac{mv}{t}\ distance}{WDP} \text{ x } 100\% \quad - \quad (12)$$

But $\frac{Distance}{Time}$ = speed, S of the implement in operation

Therefore equation 3.17 becomes

$$\square = \frac{MVS}{MDP} \text{ x } 100\% \quad - \quad - \quad (13)$$

But velocity, $V = \frac{Displacement}{Time}$ - - (14)

Let x = resultant displacement and t = time taken for the displacement

The efficiency of the implement becomes:

$$\frac{\frac{MxS}{t}}{MDP} \text{ x } 100\% \quad - \quad - \quad (15)$$

If we introduce a constant, K to represent 100% in the equation, we have

$$\frac{\frac{MxS}{t}}{MDP} \text{ x } 100\% \quad - \quad - \quad (16)$$

If we introduce a constant, K to represent 100% in the equation, we have

$$\square\ \frac{\frac{MxS}{t}}{MDP} = K \quad - \quad - \quad (16)$$

By rearrangement;

$$\square\ \frac{MxS}{MDPt} = K \quad - \quad - \quad (17)$$

The value of x was obtained thus: If the disk bottom or cutter device penetrates vertically to scoop the soil and deposits it at a horizontal distance on the land surface in a given direction; using vector diagram to demonstrate this operation, we have;

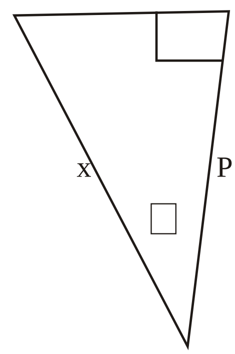

Figure 1. Vector diagram showing resultant displacement of soil mass scooped.

Let p = depth of cut or penetration of the implement

x = resultant displacement of the mass of the scooped soil

Therefore;

$$x = \frac{P}{cos\theta} \quad - \quad - \quad (18)$$

Where P = depth of cut, cm

? = angle of cut = 30° (measured during operation).

Substituting equation 3.23 in equation 3.22, we have

$$? = \frac{M\frac{P}{cos\theta}S}{MDPt} K \quad - \quad - \quad (19)$$

$$? = \frac{MS}{MDtcos\theta} K \quad - \quad - \quad (20)$$

Substituting equation 3.22 in equation 3.26, we have

From $Ce = \frac{WS}{1000}$ - (21)(kepner, 1982)

Substituting equation 3.22 in equation 3.26, we have

$$Ce = \frac{WS}{1000} \; \frac{MxS}{MDPt} \; K$$

But k = constant =100%

Therefore

$$Ce = \frac{MxS^2}{10DPt} \qquad - \qquad - \qquad (22)$$

Substitute equation 3.23 in equation 3.27, we have

$$Ce = \frac{M\frac{P}{\cos\theta}S^2}{10DPt} \qquad - \qquad - \qquad (23)$$

or

$$Ce = \frac{MS^2}{10DPt\cos\theta} \qquad - \qquad - \qquad (24)$$

Model equation for theoretical field capacity (Tc):

Substituting equation 3.22 and 3.27 in equation 3.30, we have

$$TC = \frac{Ce}{} \qquad - \qquad - \qquad (25)(Kepner, 1982)$$

Substituting equation 3.22 and 3.27 in equation 3.30, we have

$$Tc = \frac{\frac{MxS^2}{10DPt}}{\frac{MxS}{WDPt^K}} \qquad - \qquad - \qquad (26)$$

By rearrangement, we have

$$Tc = \frac{MxS^2}{10DPt} \; \frac{10DPt}{MxSK} \qquad - \qquad - \qquad (27)$$

$$Tc = \frac{SW}{10K} \qquad - \qquad - \qquad (28)$$

Estimation of Power Requirements for tillage implements:

Draft:

Draft is the power, in relation to pull-type or mounted implements, actually required to pull or move the implement at uniform speed. Draft was calculated due to drawbar power by the following equation (Hunt, 2013):-

$$D = \frac{C \times DBP}{S} \qquad - \qquad - \qquad (29)$$

Where: *D* = draft kN [Ib],
C = constant 3.6[375],
DBP = drawbar power kW [hp],
S = travel speed km/hr [mi/hr].

Drawbar:

The drawbar power was estimated from the following expression suggested by Hunt (2013)

$$\text{Drawbarpower} = \frac{\text{Total draft } ft\text{, KN x speed km/hr}}{3.6 \text{ (constant)}} \quad - \quad (30)$$

Tyre slippage (travel reduction):

Slip is the relative movement in the direction of travel at the mutual contact surface of the traction or transport device and the surface which supports it. It is also known as power loss during operation.

The tyre slippage was estimated from the following formula suggested by Ani et al. (2007)

$$\text{Tyre slip} = \frac{Va}{Vt} \qquad - \qquad - \qquad (31)$$

Where Va = speed of tractor when implement is engage (under load), km/hr
Vt = speed of tractor when implement is disengaged (no load), km/hr

Plates: Pictorial Views of The Experiment/Measurement on the Various Sites Under Study

RESULT AND DISCUSSION:

Table 1. Effect of Speed on Productive/Delay Time of Implement Field Operation in South-East Agricultural Zone of Nigeria.

Location	Soil type	Field operation	Selected implement speed range for 3trials with each tractor, km/hr	Average speed, km/hr	Production time per hacter, mins	Delay time per hacter, mins	Total time per hacter, mins
Abia/Ebonyi	Clay-loam	Plough	5.48 – 7.20	6.34	139.53	25.33	161.9
		Harrow	5.72 – 7.41	6.57	128.27	23.12	151.4
		Ridger	5.11 – 7.63	5.37	126.06	20.14	146.2
		Rotovator	5.23 – 7.47	6.35	123.89	17.31	141.2
		Planter	5.10 – 7.15	6.13	127.46	18.34	145.8
Anambra	Loamy -sandy	Plough	5.48 – 7.20	6.34	133.22	19.35	152.6
		Harrow	5.72 – 7.41	6.57	126.26	18.12	144.4
		Ridger	5.11 – 7.63	6.37	124.78	20.30	145.1
		Rotovator	5.23 – 7.47	6.35	123.03	18.36	141.4
		Planter	5.10 – 7.15	6.13	126.35	17.42	143.8
Imo/Enugu	Sandy clay	Plough	5.48 – 7.20	6.34	131.62	23.61	155.2
		Harrow	5.72 – 7.41	6.57	123.04	19.32	142.4
		Ridger	5.11 – 7.63	6.37	122.35	16.91	139.3
		Rotovator	5.23 – 7.47	6.35	124.18	17.21	141.4
		Planter	5.10 – 7.15	6.13	125.31	18.32	143.6

Table 1 reveals the effect of speed on productive/delay time of implements field operation in south-east agricultural soil. It is observable from the results obtained that for

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clay-loam soil ploughed at speed range of 5.48 – 7.20km/hr, the effective/productive time per hacter is 139.5mins while the delay period is 25.33mins/ha and a total of 161.9mins (2.7hrs) will be used to plough one hacter of clay-loam soil. Furthermore, harrow recorded a productive time of 128.27mins/ha and delay period of 23.12mins/ha at speed range of 5.72 – 7.41km/ha; and a total of 151.4mins (2.52hrs) will be used to harrow one hacter of clay-loam soil. The ridger operated at speed range of 5.11 – 7.63km/hr had a productive and delay time of 126.06 and 20.14mins per hacter respectively and a total working period of 146.2mins/ha (2.4hrs/ha). Rotovator and planter operated at speed ranges of 5.23 – 7.47km/hr and 5.10 – 7.15 respectively recorded productive and delay periods of 123.89 and 17.31mins/ha respectively for rotovator; 127.46 and 18.34mins/ha respectively for planter. A total of 141.2mins (2.35hrs) was used to pulverize one hacter while 145.2mins (2.42hrs) was used to plant one hacter of clay-loam soil.

For loamy –sandy soil ploughed at the same speed range (5.48 – 7.20km/hr), the productive time was 133.22mins/ha and delay time was 19.35mins/ha while a total of 152.6mins (2.54hrs) was used to plough one hacter. Harrow operated at speed range of 5.72 – 741km/hr as in clay-loam soil had a productive and delay period of 126.26 and 18.12 mins/ha with a total working time of 144.4mins (2.41hrs) per hacter. Ridger recorded 124.78mins/ha productive time, 20.30mins/ha delay time and a total working period of 145.1mins (2.42hrs) per hacter under the speed range of 5.11 – 7.63km/hr. Rotovator had a productive and delay period of 123.03 and 18.36mins/ha respectively; and total working period of 141.4mins (2.36hrs) per hacter under speed range of 5.23 – 7.47km/hr in loamy – sandy clay. Planter spent 126.35mins/ha as productive time; 17.42mins/ha as delay time and 143.8mins (2.40hrs) as total working time within speed range of 5.10 – 7.15km/hr.

Furthermore, for sandy – clay soil, under the same speed ranges as in clay – loam and loamy – sandy soils for different implements; the plough recorded productive time of 131.62mins/ha and delay time of 23.61mins/ha and a total working period of 155.2mins (2.59hrs) per hacter. Harrow registered a productive, delay and total working time per hacter of 123.04mins, 19.32mins and 142.4mins (2.37hrs), respectively. Ridger had a productive time of 122.35mins/ha, delay time of 16.91mins/ha; and it took a total of 139.3mins (2.32hrs) to ridge one hacter in sandy – clay soil. Rotovator and planter recorded 124.18mins/ha, 17.21mins/ha and 125.31mins/ha and18.32mins/ha as productive and delay times respectively. It took the rotovator a total of 141.4 mins (2.36hrs) to pulverize a hacter of sandy-clay soil while the planter used 143.6mins (2.39hrs) to complete its planting.

Generally, in tillage operation, ploughing recorded slightly the lowest average working speeds (6.34km/hr) as compared to other tillage operation, followed by seed planting with average planting speed of 6.13km/hr. The lower working speed and higher time of ploughing operation as observed in the study is in agreement with Sale et al (2013) and Oduma et al (2015); and are generally attributed to higher tractive and draft force required in ploughing operation than other field operations under study. More so, the low speed of the planting operation may be attributed to the precision taken in the opening of the soil, deposition and arrangement of the seed stands to avoid damage and/or wastage during planting; which can only be achieved in a low or moderate working speed of the equipment. Finally, clay – loam recorded the highest operation time with all implements followed by the sandy – clay soil and least was the loamy - sandy soil.

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Table 2. Field performance of tractors and implements in ploughing different soils under different conditions.

Locations	Soil type	Tractor make	Average speed (km/hr)	Ploughing Depth (cm)	Theoretical field capacity (ha/hr)	Effective field capacity (ha/hr)	Field efficiency (%)
Abia	Clay-	New Holland	6.58	24.5	1.184	1.031	87.08
	loam	Massey Ferguson	6.24	24.5	1.123	0.990	88.11
		Mahindra	6.24	24.5	1.124	0.978	87.05
Ebonyi	Clay-	New Holland	6.55	24.5	1.179	1.019	86.45
	loam	Massey	5.48	24.5	0.987	0.846	85.74
		Ferguson	6.38	24.5	1.149	1.002	87.24
		Mahindra					
Anambra	Loamy	New Holland	6.28	24.5	1.130	0.981	86.79
	sandy	Massey Ferguson	6.22	24.5	1.119	0.991	88.55
		Mahindra	5.58	24.5	1.005	0.875	87.07
Enugu	Sandy	New Holland	6.33	24.5	1.134	0.974	85.90
	clay	Massey Ferguson	7.08	24.5	1.275	1.062	83.23
		Mahindra	7.12	24.5	1.282	1.113	86.23
Imo	Sandy	New Holland	7.20	24.5	1.296	1.143	88.23
	clay	Massey Ferguson	5.34	24.5	0.961	0.848	88.22
		Mahindra	6.22	24.5	1.122	0.985	87.78
		Overall mean	**6.34**	**24.5**	**1.140**	**0.990**	**86.91**

Table 2 presents the field performance of the plough in different soil conditions/characteristics. Results of this table indicates that the disc plough has field efficiency range of 85.74 to 88.55% with effective and theoretical field capacities range of 0.846 t0 1.164ha/hr and 0.961 to 1.319ha/hr respectively. The highest ploughing efficiency of 88.55% was recorded on loamy-sandy soil when the plough was operated with Massey Ferguson tractor. This was followed by clay – loam soil which gave the ploughing efficiency of 86.95% and least was sandy- clay that gave 86.60% efficiency. The plough has average cutting depth of 24.5cm at average speed of 6.34km/hr.

Table 3. Field performance of tractors and implements in harrowing different soils under different conditions

Locations	Soil type	Tractor make	Average speed (km/hr)	Harrowing Depth (cm)	Theoretical field capacity (ha/hr)	Effective field capacity (ha/hr)	Field efficiency (%)
Abia	Clay	New Holland	5.72	22.3	1.287	1.063	82.59
	laom	Massey Ferguson	6.00	20.4	1.350	1.126	83.42
		Mahindra	6.08	20.7	1.368	1.097	80.17
Ebonyi	Clay	New Holland	6.51	23.1	1.465	1.289	87.98
	laom	Massey Ferguson	6.13	20.5	1.379	1.196	86.70
		Mahindra	6.22	22.4	1.399	1.239	88.56
Anambra	Loamy	New Holland	6.34	20.8	1.426	1.192	83.58
	sandy	Massey ferguson	7.11	22.0	1.600	1.389	86.82
		Mahindra	7.33	24.3	1.649	1.436	87.08
Enugu	Sandy	New Holland	5.56	20.6	1.251	1.095	87.55
	clay	Massey Ferguson	6.22	21.5	1.400	1.204	86.05
		Mahindra	6.55	20.3	1.473	1.281	86.95
Imo	Sandy	New Holland	6.53	20.4	1.470	1.343	91.38
	clay	Massey Ferguson	6.58	21.8	1.480	1.311	88.54
		Mahindra	7.41	20.0	1.667	1.458	87.45
		Overall mean	**6.57**	**21.4**	**1.444**	**1.248**	**85.78**

Table 3 revealed that harrow has field efficiency range of 80.17 to 91.38% with effective and theoretically field capacities of 0.931 to 1.458 ha/hr and 1.151 to 1. 667ha/hr respectively. The highest harrowing efficiency of 91.38% was obtained on sandy-clay with New Holland tractor. This was followed by caly - loam that gave the harrowing efficiency of 88.56% and least was clay-loam with 82.59%. The harrow operated at average cutting depth of 21.4cm at average speed of 6.37km/hr.

Table 4. Field performance of tractors and implements in ridging different soils und different conditions

Locations	Soil type	Tractor make	Averag e speed	Ridging Depth	Theoretical field capacity	Effective field capacity	Field efficiency
Abia	Clay-loam	New Holland	6.06	25.1	1.273	1.065	83.65
		Massey Ferguson	5.18	23.8	1.088	0.932	85.68
		Mahindra	6.00	25.4	1.260	1.057	83.90
Ebonyi	Clay-loam	New Holland	6.38	24.8	1.340	1.152	86.00
		Massey Ferguson	5.11	25.0	1.073	0.945	88.06
		Mahindra	7.63	24.6	1.603	1.409	87.92
Anambra	Loamy -sandy	New Holland	5.48	25.2	1.150	1.007	87.54
		Massey Ferguson	6.40	25.0	1.344	1.175	87.45
		Mahindra	6.34	24.8	1.332	1.166	87.54
Enugu	Sandy clay	New Holland	6.40	26.1	1.344	1.170	87.07
		Massey Ferguson	6.50	25.6	1.365	1.182	86.60
		Mahindra	6.43	25.4	1.351	1.165	86.26
Imo	Sandy clay	New Holland	6.44	24.9	1.352	1.206	89.19
		Massey Ferguso	5.54	25.2	1.164	1.002	86.09
		Mahindra	6.53	25.5	1.371	1.218	88.82
		Overall mean	**6.37**	**25.1**	**1.294**	**1.123**	**86.42**

The field performance of ridger was recorded in Table 4. According to results of this table, the ridger has field efficiency range of 83.65% to 88.82% with effective and theoretical field capacity range from 0.932 to 1.322ha/hr and 1.073 and 1.504ha/hr respectively. The highest ridging efficiency was observed on sandy-clay soil. The average ridging depth of the ridger was measured to be 25.1cm at average working speed of 6.37km/hr.

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Table 5. Field performance of tractors and implements in pulverizing different soils under different conditions.

Locations	Soil type	Tractor make	Average speed (km/hr)	Pulverizing Depth (cm)	Theoretical field capacity (ha/hr)	Effective field capacity (ha/hr)	Field efficiency (%)
Abia	Clay-loam	New Holland	6.23	20.1	0.903	0.775	85.81
		Massey Ferguson	6.20	19.8	0.869	0.759	87.38
		Mahindra	7.47	19.7	1.091	0.962	88.20
Ebonyi	Clay-loam	New Holland	5.23	20.7	0.758	0.669	88.24
		Massey Ferguson	6.23	21.2	0.903	0.811	89.81
		Mahindra	6.33	20.0	0.918	0.795	86.63
Anambra	Loamy-sandy	New Holland	6.29	19.9	0.913	0.804	81.10
		Massey Ferguson	6.38	20.3	0.925	0.803	86.79
		Mahindra	6.45	23.0	0.935	0.812	86.83
Enugu	Sandy-clay	New Holland	6.34	19.7	0.919	0.800	87.05
		Massey Ferguson	6.43	18.9	0.933	0.778	89.40
		Mahindra	5.44	19.7	0.788	0.685	86.88
Imo	Sandy-clay	New Holland	7.11	20.1	1.031	0.902	87.51
		Massey Ferguson	6.34	19.8	0.919	0.812	88.36
		Mahindra	6.55	19.6	0.950	0.828	87.13
		Overall mean	**6.35**	**20.2**	**0.917**	**0.800**	**86.61**

Table 5 shows the field performance of the rotovator. Results as obtained in this table revealed that the rotovator has pulverizing efficiency range of 81.10 to 89.815 with effective and theoretical field capacities range of 0.759 to 0.902ha/hr and 0.759 to 1.031ha/hr respectively. Clay – loam gave the highest pulverizing efficiency obtained using the Massey Ferguson tractor. The least pulverizing efficiency was obtained when working on the loamy- sandy soil with New Holland tractor. The average depth of cut of the rotovator was 20.2cm at average speed of 6.22km/hr.

Table 6. Field performance of tractors and implements in planting in different soils under different conditions.

Locations	Soil type	Tractor make	Average speed	Planting Depth (cm)	Theoretical field capacity	Effective field capacity	Field efficiency
Abia	Clay-loam	New Holland	5.10	2.6	1.224	1.012	82.71
		Massey Ferguson	6.14	2.4	1.474	1.316	89.30
		Mahindra	6.35	2.7	1.524	1.319	86.53
Ebonyi	Clay-loam	New Holland	6.28	2.5	1.507	1.338	88.78
		Massey	5.41	3.1	1.299	1.137	87.54
		Ferguson	6.24	2.3	1.491	1.327	88.59
		Mahindra					
Anambra	Loamy-sandy	New Holland	6.43	3.0	1.543	1.332	86.30
		Massey Ferguson	7.16	2.8	1.719	1.386	80.63
		Mahindra	6.54	2.4	1.570	1.397	88.99
Enugu	Sandy-clay	New Holland	6.47	2.5	1.553	1.346	86.69
		Massey Ferguson	6.46	2.6	1.550	1.334	86.06
		Mahindra	7.15	2.5	1.716	1.481	86.30
Imo	Sandy-clay	New Holland	6.49	2.4	1.558	1.392	89.37
		Massey Ferguson	6.45	2.3	1.548	1.348	87.09
		Mahindra	6.53	2.5	1.532	1.368	87.30
		Overall mean	**6.13**	**2.6**	**1.472**	**1.188**	**86.04**

Table 6 reveals the planting efficiencies of the planter under study. The planter has efficiency range of 80.63 to 89.37% with effective and theoretical field capacities range of 1.012 to 1.481ha/hr and 1.224 to 1.716ha/hr respectively. The planter according to results obtained sows seeds at average depth of 2.6cm at average planting depth of 6.13km/hr.

The field efficiencies obtained for tillage implements in the study are within the typical ranges of field efficiencies of implement recorded by Yohanna (1998). The efficiencies also fall within the ranges obtained by Sale et al (2013), and Oduma et al (2015); but slightly higher than the efficiencies obtained by Kaul (1995) for tillage implements. The variations in the efficiencies may be due to differences in field conditions/physical characteristics, frequent breakdown/down times, skill of operation etc encountered in different agricultural/ ecological zones.

Table 7. Fuel consumption rate in operation

Soil type	Tractor make	Quantity of fuel consumed									
		Ploughing		Harrowing		Ridging		Pulverization		Planting	
		L/ha	L/hr	L/ha	L/hr	L/ha	L/hr	L/ha	L/hr	L/ha	L/hr
Clay	New Holland	24.67	9.57	21.38	8.82	21.42	8.97	19.60	8.32	15.38	6.33
loam	Massey Ferguson	23.74	9.79	20.41	8.33	20.32	8.57	17.55	7.59	15.16	6.29
	Mahindra	24.30	9.35	21.66	8.47	21.50	8.99	19.72	8.46	14.68	6.22
	Mean	**24.24**	**9.57**	**21.15**	**8.54**	**21.08**	**8.84**	**18.96**	**8.12**	**15.07**	**6.28**
Loam	New Holland	21.32	8.73	18.43	7.50	18.12	7.52	15.48	6.71	15.39	6.30
sandy	Massey Ferguson	20.80	8.30	17.63	7.21	17.41	7.28	14.56	5.99	14.42	5.97
	Mahindra	21.76	8.74	18.71	7.63	18.60	7.99	15.70	6.81	14.94	6.33
	Mean	**21.46**	**8.59**	**18.26**	**7.45**	**18.04**	**7.60**	**15.25**	**6.50**	**14.92**	**6.20**
Sandy	New Holland	22.83	8.34	19.75	8.32	19.62	8.46	16.78	7.10	15.62	6.25
-clay	Massey Ferguson	21.60	8.22	18.60	7.78	18.33	7.59	15.22	6.55	14.93	6.27
	Mahindra	22.43	8.93	19.53	8.32	19.46	8.15	16.45	7.20	15.34	6.37
	Mean	**22.29**	**8.50**	**19.29**	**8.14**	**19.14**	**8.07**	**16.15**	**6.95**	**15.30**	**6.30**

Table 7 shows the rate of fuel consumption in litre/hacter and in litre/hour of the various field operations with different tractors and implements. Ploughing recorded the highest fuel consumption rate of 21.60L/ha to 24.67L/ha with New Holland tractor having the highest average fuel consumption of 24.67L/ha (9.57L/hr) on clay-loam soil, followed by Mahindra with average fuel consumption of 24.30L/ha (9.35L/hr) and least is Massey Ferguson with average fuel consumption of 23.74L/ha (9.35L/hr) in ploughing operation. Harrowing recorded fuel consumption rate of 17.63 to 21.66L/hand average of 8.14L/hr.

The tractor rate of fuel consumption in harrowing operation follow the same trend as in ploughing operation. Rdging operation have average fuel consumption of 17.41 to 21.50L/ha (8.07L/hr); rotovator consumed 15.22 to 19.72 and average of 6.95L/hr of fuel. The planter has the least fuel consumption rate of 14.42 to 15.62L/ha and average of 6.30L/hr. The highest fuel consumption obtained in ploughing operation may be attributed to the higher tractive and draft force per unit width of plough than other implements as observed by Oduma et al (2015) and Sale et al (2013). More so, in all the operations, the New Holland tractor recorded the highest fuel consumption followed by Mahindra and least was the Massey Ferguson.

Generally, the highest fuel consumption was recorded when working on clay-loam, followed by sandy-clay and least was on loamy-sandy soil. This is in line with the observation made by Bele and Dahab (1997) and Alnahas (2003). The variation may be due to the high draft force needed to break the high soil compaction in the higher bulk density soil locations than the lower bulk density areas; which may consume much energy in working in such areas.

Table 8. Implement power requirements/losses based on soil conditions

Soil type	Implement power requirement/loss														
	Plough			Harrow			Ridger			Rotovator			Planter		
	Dp	Db	Ts	Dp	Db	Ts	D p	Db	Ts	Dp	Db	Ts	Dp	Db	Ts
Clay-loam	10.8	18.7	12.6	10.5	17.5	11.4	10.5	18.2	10.9	5.1	8.8	11.5	8.4	13.8	11.2
Loamy-sandy	10.8	18.1	15.5	10.5	20.2	13.1	10.5	20.2	12.6	5.1	9.0	12.7	8.4	15.7	12.7
Sandy-clay	10.8	19.7	18.3	10.5	18.9	14.8	10.5	18.9	14.3	5.1	9.0	13.9	8.4	15.4	14.1
Average	10.8	18.8	15.5	10.5	18.9	13.1	10.5	19.0	12.6	5.1	8.9	12.7	8.4	15.0	12.7

Dp =Draft power (KN); Db = Drawbar power (kW) and Ts = Tyre slippage (power loss), %

Table 8 presents the results of power requirements and slippage of the implements in different soil locations. In all the locations each implement maintained constant draft depending on the working speed and draft per unit width of the implement. The plough has the highest drat force of 10.8kN/m; followed by the harrow and ridger with the same draft force of 10.5kN/m respectively, while the planter and rotovator have least draft force of 8.4 and 5.1kN/m respectively. The entire implement recorded highest drawbar power in the sandy-clay location; followed by the clay-loam and the least was the loamy- sandy soil. The variation in the drawbar power may be attributed to the difference in soil conditions and/or characteristics (moisture contents, bulk densities and/or porosities) of the soils.

Table 8 also revealed that the average percentage of tyre slippage of the entire implements in different locations are below the top limit of wheel slippage of 20% as recorded by Pensson et al (1986) and also as observed by Alnahas (2003). All implements recorded highest tyre slippage in sandy-clay-soil; followed by loamy-sandy and least slippage was recorded in the clay – loam soil. This may be as a result of high bulk density/compaction in the clay-loam soil which made it more firm and resistant to slippage than the other soils. The plough gave the highest average slippage of 15.5%; followed by harrow with 13.1% slippage, rotovator and planter with 12.7% average slippage each and least was the ridger that recorded 12.6%. The highest average slippage recorded by the plough may be due to increased load transfer to the rear drive wheel of tractors as observed by Riethmuller (1989).

CONCLUSION

1. Ploughing recorded slightly the lowest average working speeds (6.34km/hr) with highest operation time (161.9mins) as compared to other implements; because of higher tractive and draft force required for its operation.

2. Planting operation requires high precision in opening the soil, deposition; proper closing of the seeds after sowing and good arrangement of the seed stands to avoid damage and wastage of seeds. These can only be achieved in a low speed (6.13km/hr) or moderate working speed of the machine.

3. The plough gave its highest field efficiency of 88.55% on loamy-sandy soil when it was powered by Massey Ferguson tractor. It operated at average depth of 24.1cm.

4. The harrow recorded its highest field efficiency of 91.38% on sandy-clay with New Holland tractor operated at average cutting depth of 21.4cm.

5. The ridger has the highest field efficiency of 89.19% on the sandy –clay soil operated with New Holland tractor at an average cutting depth of 25.1cm.

6. The rotovator has the highest pulverizing

efficiency of 89.85% with a Massey Ferguson tractor on the clay-loam soil. It has average cutting depth of 20.2cm.

7. The planter recorded the highest field efficiency of 89.37% on sandy-clay soil when operated with New Holland tractor. It plants seeds at average sowing depth of 2.6cm.
8. Ploghing recorded the highest fuel consumption rate of 21.60L/ha to 24.67L/ha, followed by harrow (17.21 to 21.66L/ha), rotovator (15.22 to 19.72L/ha), and least is the planter with fuel consumption rate range from 14.42 to 15.62 L/ha. The highest fuel consumption was recorded when working on clay-loam, followed by sandy-clay and least was on loamy-sandy soil. The variation is due to the high draft force needed to break the high soil compaction in the higher bulk density soil locations than the lower bulk density areas.
9. The plough has the highest draft force (10.8kN/m), followed by the harrow and ridger with the same draft force of 910.5kN/m) and the least was the planter with draft force of 5.1kN/m.
10. All the implements in different locations recorded the average wheel slippage below the top limit of wheel slippage (20%). Sandy-clay soil recorded the highest tyre slippage for all the implements, followed by loamy-sandy and the least tyre slippage was recorded on clay-loam soil.

RECOMMENDATIONS

Results of this study form a database that will guide the farmers and agriculturists in selecting farm machineries/implements that will suit the soil conditions in south-east agricultural zone and other agricultural areas with similar soil and ecological conditions.

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, minimize 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 other to provide database in their performances as to guide farmers here and other agricultural zones in machine/implement selections.

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