Effects of Soil Physical and Mechanical Properties on Field Efficiency of Ox-drawn Mouldboard plough in Yola, Adamawa state

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ABSTRACT

An assessment of the effects of soil physical and mechanical properties on field efficiencies of Ox-drawn mouldboard plough was conducted in four (4) sub-locations within Yola environment, between May and July, 2005. Soil samples, taken at 15-20 cm depth and under four (4) moisture regimes (10, 15, 20 and 25%) by means of auger were put into polyethylene bags and properly labeled. The soils were investigated for relevant properties (bulk density-δ_b, moisture content-M.C., texture, consistency$_)$ following laboratory procedures. The data were statistically compared using the Student's t-test. The mouldboard plough efficiencies at various soil M. C. varied significantly (P=0.05) among the soil units at differing compaction limits (1.35-1.50 Mgm^{-3}). Effective field capacity-EFC, was highest (0.133 ha/h) in Sabon-gari and lowest (0.112ha/h) in Futy demonstration farm-FDF at the same soil M.C. (25%). Lowest time losses of 13 and 14 minutes was at 10 and 25% soil M. C. in Sabon-gari with relatively lower (1.35 Mgm^{-3}) soil compactions. In view of the results obtained, it suffices to recommend that ox-drawn mouldboard plough utilization should be encouraged in areas with low soil compaction (i.e., 1.35 Mgm^{-3}) and up graded into multiple bottoms implement for team of animal traction, as it effectively conserves valuable physical and mechanical soil properties.

Keywords: Animal drawn tillage tools, mouldboard plough, physical and mechanical soil properties, field efficiencies, Nigeria

1. INTRODUCTION

Over the decades, attention has been drawn to soil property impacts on field efficiencies of most agricultural farm machineries and implement. In most of the developing countries, over 90% of farm power is derived from animal sources. The major uses of animal power in the third world countries include: tillage, seeding, weeding, water lifting, threshing and transportation. In most of these countries, the progenies of the animals are readily available for use as draught animals on the farms. For instance, in Indian agriculture, draught animals (DAs) provide the major tractive force for field operations. Presently, the DAs are contributing about 27,000 Mega watts of power, which is about 30% of the total power of the installed electrical generation capacity of India (Ojha and Michael, 2003). It is estimated that about two-third of the total cultivated area is managed by DAs and remaining area is cultivated by other sources of farm power namely tractors, power tillers and human labors, among others (Ojha and Michael, 2003). Thus, it suffices to mention that, DAs are still having a great importance in Indian economy. Recently, it was estimated that about 75% of vast highlands of Ethiopia is cultivated using a Mahresha or Scratch ploughs as described by Goe (1990), which is driven by a pair of oxen.

Prior to the advent and introduction of farm tractors into the Nigeria agriculture, animal traction power was already famous among most arable farmer communities. Kaul (1989) reported that there were about 400 million draught animals providing 50% of energy used in rural agriculture. Animal drawn mouldboard plough appears obsolete, but still an important tillage implement that is by far most applied in farm cultivation and seedbed preparations (Kepner *et al*, 1990). The implement has remained the most resourcefully cheap farm power sources and best substitute for large tractor equipment on small scale farms especially in Savannah region of Northern Nigeria (Gbadamosi and Magaji, 2004). The ease of animal traction in the Nigeria verse Savannah region has been linked to its soil moisture ranges, topography, sparse trees and grass vegetations with negligible barrier to efficient animal power applications. In nature, farm cultivation implements work efficiency is often directly related to the inherent physical and mechanical soil properties such as compaction, adhesion, moisture content, soil texture, shear and frictional forces opposing plough tractions (Kepner *et al*, 1990). Most often, Oxen, buffaloes, horses, mules, camels and donkeys drag the variable animal drawn mouldboard ploughs on several farms around the globe.

Fatigue and low power generation are the common limitations to manual labor. Ox-drawn mouldboard plough power sources and soil workability properties are great determinants to efficient animal power utilization, and as such, this study is posed at identifying the influence of soil physical and mechanical properties towards recommending the most conducive limits for efficient animal power application in the study area.

2. MATERIALS AND METHODS

2.1 The study area

The study was conducted in four (4) sub-locations namely; Sangere, Sabon-gari, Vinikilang and Futy demonstration farm (FDF), all within the Yola area (9°14'N and 12°32'E) during the 2005 cropping season to examine the effects of physical and mechanical soil properties on field efficiency of Ox- drawn mouldboard plough. Yola is located in the central part of Adamawa State, at an elevation of 200m above sea level and falling within the Sudan Savannah ecological zone. The area is an agrarian tropical environment marked by dry (November to March) and wet (April to October) seasons. The mean annual rainfall usually ranges from 700mm to 1,050mm, while the soils of the experimental area are predominantly of sandy clay loam textures (Adebayo and Tukur, 1999).

2.2 Field study

Field experiment was conducted between May and July 2005. The study adopted the field investigative survey approach (FISA), whereby field reconnaissance survey of the entire area was conducted.

2.3 Soil sampling

Soil samples were collected randomly from all the four (4) study locations at prescribed plough depth (15-20cm) immediately after the tillage treatment, using soil auger. The samples were put into polyethylene bags and properly labeled, then air dried, crushed and sieved using 2mm sieve for laboratory analysis of desired parameters.

2.4 Field performance test

A complete mouldboard plough assembly of an average weight of 35 kg was used with a pair of bulls (White-fulani) as a prime mover. This breed was chosen because of its availability in the study area. The bulls were equally aged with tilling experience of 6 and 2 years respectively. The bulls tilling duration are comparable to those engaged in field trials carried out using draught animals in Adamawa State by Haque *et al* (2000).The harnessing system consists of a wooden yoke, plastic robe and chain that connects the plough to the yoke.

The field performance test was conducted using materials such as a measuring tape and stop watches in all the study locations. The draught system consists of wooden yoke, plastic robe and a chain that connects the plough to the yoke. Evaluation of field operation capacities and efficiencies where tested in accordance with Gbadamosi *et al* (2004), using relevant parameters which includes effective operation time (EOT) and time losses due to obstructions on the field. Each plot area measuring 100m by 10m was used, exactly forty (40) passes were taken to cover every plot. Time to cover each complete pass was taken using two (2) stop watches. One recorded the overall time spent to cover a single pass (including time losses due to obstructions and turnings), while the other watch was used to record the effective time of operation (watch was stopped whenever an obstruction was noticed). The field performance rates per plot were measured in terms of time lapse per pass in meters (m).

Other parameters computed from the field performance data were; working speed (km/h), overall field capacity (ha/h), theoretical field capacity (ha/h), effective field capacity (ha/h) and percentage field efficiency (%) (Gbadamosi *et al*, 2004), expressed as:

Working speed, $v = D_w/t_o$………………………………………..…………………… (1)

where; D_w = distance of run (km)

t_o = overall time taken (h)

Effective field capacity, EFC = A/TAEOT ….……………………..………………… (2)

where; A = area cultivated in hectares (ha)

TAEOT = total average effective operation time (h)

Also, Kepner *et al* (1990) expressed the Theoretical field capacity (TFC) as:

$TFC = 0.1bv$ ………………………………..……………………………………… (3)

where; b = optimum operation width of the plough (m)

v = optimum operation speed (km)

Field efficiency, FE = EFC/TFC ×100 (%) …………………….………………… (4)

2.5 Laboratory Study

Soil analysis was conducted in the laboratory to determine relevant physical and mechanical properties of the soil, such as; moisture content M.C., soil consistency, particle size distribution, soil texture and bulk density (δ_b).

2.6 Determination of physical and mechanical properties of the soil

The moisture contents of soils were determined using an oven drying method. The soil samples were collected at random, immediately after each tillage treatment for each study location. Each soil sample was collected in a well labeled container and weighed on a platform scale, and then oven dried at a temperature of 105°C in an oven for 24 hours. The soil moisture contents were computed using the expression (Brady and Weil, 2002):

$$\text{Soil M.C} = (m_2 - m_3) / (m_3 - m_1) \times 100 \qquad (5)$$

where; M.C = moisture content (%)

m_1 = mass of container in grams (g)

m_2 = mass of container + wet soil sample in grams (g)

m_3 = mass of container + oven dried soils in grams (g)

The soil consistency at various moisture contents were measured by hand feel method and physical manipulation of the soil (Brady, 1988). Also soil particle size distribution was determined by Bouyoucus hydrometer method (Wolf, 2003).

The soil textural classes were determined from the amounts of sand, silt, and clay in the soils by subjecting the results of the particle size distributions in to the Marshall’s textural triangle to obtain precise soil textural class (Brady, 1988; Wolf, 2003). While the soil bulk density was determined using the clod method (Blake, 1965; Wolf, 2003).

2.7 Data Analysis

The Student's t-test and simple descriptive statistics were used to compare the means of plough field efficiencies at different soil moisture content levels in accordance with the procedures of Gomez (1984) and Bluman (2004).

3. RESULTS AND DISCUSSION

The results obtained from the sieve analysis carried out for all the study locations when subjected to a textural triangle showed that the soils are sandy clay loam but with differing bulk densities. Also the field performance evaluation results are presented in Tables 1 and 2. It showed that Sabon-gari had the least soil compaction with a bulk density (δ_b) of 1.35Mgm^{-3} and the fastest effective operation time (EOT) of 1.08 minutes per pass at 25% soil moisture content (M.C). In sequence, Sangere and Vinikilang locations recorded δ_b of 1.40 and 1.45Mgm^{-3} with respective EOT of 1.09 and 1.10 minutes under same 25% M.C while Futy Demonstration Farm (FDF) which emerged with the highest δ_b (1.5 Mgm^{-3}) recorded the slowest EOT of 1.20 minutes per pass amongst other locations studied.

Similarly, both Vinikilang and Sabon-gari had lowest operation time losses which tied at 13 minutes per plot at 10% soil M.C., with a slight variation (14 minutes loss) in Vinikilang at 25% M.C. (Tables 1 and 2). This was followed by FDF, with losses of 15 and 16 minutes at 10% and 25% M.C. respectively. The results further revealed that Sangere recorded the highest time losses of 17 minutes per plot at both 10% and 25% soil M.C. levels. This could be attributed to the presence of obstructions such as stumps, roots, and stones during field operations.

Table 1: Ox-drawn Plough field efficiencies at 10% and 15% soil moisture contents.

Study location	Bulk density (Mgm^{-3})	Plough time per pass		Plough time per plot (100m*10m)		Time loss AOT-AEOT (min)	Field capacity		Field efficiency (%)
		EOT (min)	OT (min)	AEOT (min)	AOT (min)		EFC (ha/h)	TFC (ha/h)	
10% Moisture Content									
FDF	1.50	2.05	2.25	83.00	98.00	15.00	0.070	0.140	52.0
Vinikilang	1.45	2.00	2.20	79.00	93.00	14.00	0.075	0.140	54.0
Sabon-gari	1.35	1.45	2.08	70.00	83.00	13.00	0.090	0.140	64.0
Sangere	1.40	1.50	2.15	73.00	90.00	17.00	0.080	0.140	57.0
15% Moisture Content									
FDF	1.50	1.45	2.05	70.00	86.00	16.00	0.090	0.140	64.3
Vinikilang	1.45	1.30	1.53	60.00	75.33	15.33	0.100	0.140	71.4
Sabon-gari	1.35	1.15	1.36	50.00	64.00	14.00	0.120	0.140	86.0
Sangere	1.40	1.22	1.47	55.00	71.00	16.00	0.110	0.140	79.0

Key: EOT= Effective operation time, OT= Operation time, AOT = Average operation time, AEOT = Average effective operation time, EFC = Effective field capacity (ha/h), TFC = Theoretical Field capacity (ha/h), FDF = Futy demonstration farm

Table 2: Ox-drawn Plough field efficiencies at 20% and 25% soil moisture contents.

Study location	Bulk density (Mgm^{-3})	Plough time per pass		Plough time per plot (100m*10m)		Time loss AOT-AEOT (min)	Field capacity		Field efficiency (%)
		EOT (min)	OT (min)	AEOT (min)	AOT (min)		EFC (ha/h)	TFC (ha/h)	
20% Moisture Content									
FDF	1.50	1.39	1.59	66.00	82.00	16.00	0.091	0.140	65.3
Vinikilang	1.45	1.29	1.50	59.00	73.00	14.00	0.101	0.140	72.0
Sabon-gari	1.35	1.15	1.38	50.00	63.00	13.00	0.120	0.140	86.5
Sangere	1.40	1.21	1.42	54.00	68.00	14.00	0.111	0.140	79.2
25% Moisture Content									
FDF	1.50	1.20	1.24	53.00	69.00	16.00	0.112	0.140	80.0
Vinikilang	1.45	1.10	1.32	47.00	61.00	14.00	0.128	0.140	91.0
Sabon-gari	1.35	1.08	1.29	45.00	59.00	14.00	0.133	0.140	95.0
Sangere	1.40	1.09	1.35	46.00	63.00	17.00	0.130	0.140	93.0

Key: EOT= Effective operation time, OT= Operation time, AOT = Average operation time, AEOT = Average effective operation time, EFC = Effective field capacity (ha/h), TFC = Theoretical Field capacity (ha/h), FDF = Futy demonstration farm

Fig.1 showed the relationship between the soil M.C. (at different levels) and field efficiencies of ox-drawn mouldboard plough. It revealed that plough performance in Sabon-gari soils recorded the highest field efficiencies (FE) of 64% and as high as 86% at 10% and 15% soil M.C. respectively. Also at 20% and 25% soil M.C, Sabon-gari maintained its lead with FE of 86.5% and 95% respectively. This was followed by Sangere and Vinikilang having differing FE at same soil M.C. This difference could be due to non-uniform conditions of land levels and barriers during field operations. Comparatively, FDF had consistently lower FE of 52%, 64.3%, 65.3% and 80% at soil M.C. of 10%, 15%, 20% and 25% respectively. This was probably due its relatively high δ_b and presence of field obstructions. The results showed that soil M.C., δ_b and field conditions had marked influence on FE of Ox-drawn mouldboard plough as was similarly reported by Yusuf (2006).

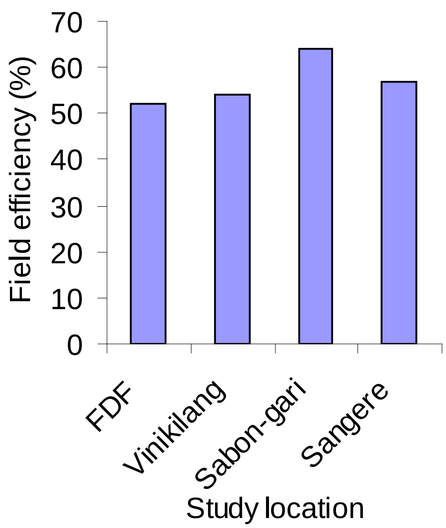

Fig.1: Field efficiency of Ox-drawn Mouldboard plough at 10% soil M.C

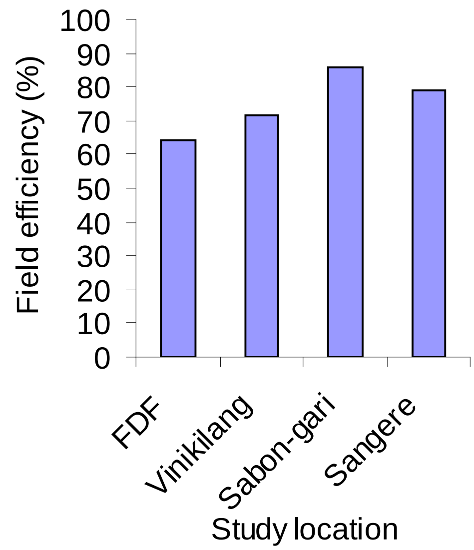

Fig.2: Field efficiency of Ox-drawn Mouldboard plough at 15% soil M.C

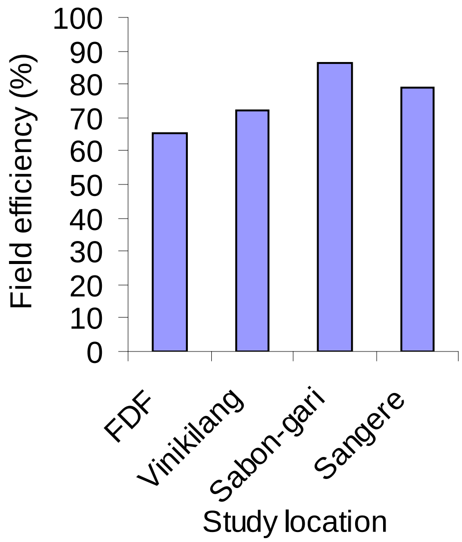

Fig.3: Field efficiency of Ox-drawn Mouldboard plough at 20% soil M.C

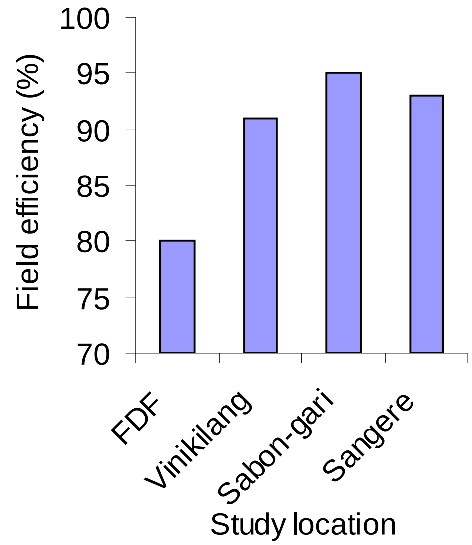

Fig.4: Field efficiency of Ox-drawn Mouldboard plough at 25% soil M.C

Further statistical (Student's t-test) comparison between the means of ox-drawn mouldboard plough efficiencies at soil M.C. levels of 10% and 15% is presented in Table 3 below.

Hypothesis (H_o): there is no significant difference (P>0.05) between ox-drawn mouldboard plough efficiencies at 10% and 15% soil M.C. in the study areas.

Table 3: Student's t-test of ox-drawn mouldboard plough mean FE at 10% and 15% soil M.C.

S/No	Soil (%)	M.C.	ΣX	X	SS	N	df	t_{cal}	t_{crit}	Remarks
1	10		227.0	56.75	12965.0	4				Reject
2	15		300.7	75.18	22869.5	4	7	3.425	2.365	H_o

Tested at 0.05 level of significance

Key: ΣX = Sum of field efficiencies X = Mean of field efficiency
SS = Sum of squares N = No. of observations
df = degree of freedom t_{cal} = t-calculated
t_{crit} = t-critical M.C. = Moisture content

Since t-critical (2.365) is less than the t-calculated (3.425), then we reject the Ho, implying that there is a significant difference (P = 0.05) between ox-drawn mouldboard plough efficiencies at 10% and 15% soil M.C.

Also, a similar Student's t-test was used to compare the FE of ox-drawn mouldboard plough at 20% and 25% soil M.C. (Table 4).

Hypothesis (H_o): there is no significant difference (P>0.05) between ox-drawn mouldboard F.E.at 20% and 25% soil M.C.

Table 4: Student's t-test of ox-drawn mouldboard plough FE at 20% and 25% soil M.C.

S/No	Soil (%)	M.C.	ΣX	X	SS	N	df	t_{cal}	t_{crit}	Remarks
1	20		325.4	81.35	26656.0	4				Reject
2	25		347.0	86.75	30207.0	4	7	2.436	2.365	H_o

Tested at 0.05 level of significance
Key: ΣX = Sum of field efficiencies   X = Mean of field efficiency
SS = Sum of squares   N = No. of observations
df = degree of freedom t_{cal} = t-calculated
t_{crit} = t-critical   M.C. = Moisture content

Since t-critical (2.365) is less t-calculated (2.439), then we reject the H_o, implying that there is a significant difference (P = 0.05) between the ox-drawn mouldboard plough FE at 20% and 25% soil M.C. in the study areas. The relatively high levels of soil M.C. in the later (20% and 25%), possibly contributed to the higher field efficiencies observed in this study. This adequate estimates of FE, at various soil M.C. levels certainly explains the limits of M.C. at which the optimum field performance efficiencies are achievable

4. CONCLUSION AND RECOMMENDATIONS

Mouldboard plough tillage implement still retains considerable efficiencies among peasant farmers within Yola environment. The study locations are characteristically an agrarian environment having land topography and vegetation density with favorable conditions for Ox-drawn applications. However, Sangere and Vinikilang appeared to occupy a non-uniform land condition that posed impedance to the scouring of the tillage implement during field operations. Similarly, the low soil compaction in Sabon-gari facilitated its fastest EOT and lowest time loss per plot compared to its reversed case in FDF at the same soil M.C. (Table 1 and 2). Both δ_b and M.C. appeared as the primary determinants to field performance efficiencies of the mouldboard plough tillage implement in the study areas.

Recommending that Ox-drawn mouldboard plough utilization should be encouraged particularly on soils of low compaction (1.35-1.40Mg^{-3}) and moderate moisture contents (15-25%). Similarly, the common single bottom ploughs should be upgraded into multiple bottom implement for team of animal traction, as it could also be compatibly effective in conserving valuable physical and mechanical properties of soils in the study areas.

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Appendix 1: Field parameters used in determining theoretical field capacities (TFC)

Field parameter	**Value**
Types of animal used	A pair of oxen
Weight of animals (kg)	480 each
Operating speed (kmh^{-1})	4.5
Weight of plough (kg)	35
Effective plough depth (m)	0.15
Effective plough width (m)	0.25
Theoretical plough depth(m)	0.20
Theoretical plough width (m)	0.30
Effective area cultivated (ha)	0.10