

# THE EFFECT OF SPEED AND DEPTH OF OPERATION ON DRAUGHT OUTPUT OF OX-DRAWN MOULDBOARD RIDGER IN SANDY LOAM SOIL IN YOLA, ADAMAWA STATE, NIGERIA

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## ABSTRACT

*Tool speed and soil depth are the most prominent operational parameters that influence the draught of tillage tools and implements. A study to investigate the effect of speed and depth of operation on draught requirements of mouldboard ridger tillage implement was conducted on the upland sandy loam soils of the Modibbo Adama University of Technology, Yola under draught animal power situation. Soil physical properties were also analyzed to determine their effects on draught output. A 1 x 3 x 3 factorial experimental design was arranged in a Randomized Complete Design (RCD) for the study using mouldboard ridger implement at different speed of  $S_1, S_2, S_3$  ( $0.67, 0.97$  and  $1.25 \text{ ms}^{-1}$ ) and depths of  $d_1, d_2, d_3$  (8, 12, and 18 cm). Results show that the highest and lowest mean draught values of 362.62 N and 305.17 N were obtained in treatments  $T_9$ , the combination ( $S_3d_3$ ) of  $1.25 \text{ ms}^{-1}$  and 0.183m depth and  $T_1$  ( $S_1d_1$ ) of  $0.67 \text{ ms}^{-1}$  and 0.083m depth respectively for the mouldboard ridger. A general regression equation to predict the draught output of the mouldboard ridger implement was developed. It was also found that, draught increased with increased in tillage speed and depth of operation. The analysis showed that tillage depth and speed of operation significantly affected the draught output of the mouldboard ridger with the depth of operation having greater influence than the set tillage speed. It was also found that the highest draught value (362.62 N) fall within the animals' draught ability of 12 percent of their body weight. It is therefore useful in maintaining an optimum desire tillage depth through the hitch assembly, to achieve a larger water and nutrients extraction zone for the plant.*

**Keywords:** Ox-drawn implement, Tillage operation, Draught and power, ridger

## 1 INTRODUCTION

**N**owadays, improvements in farm power availability through development and improvement of soil specific and farmer-friendly technologies for predominantly global agro-eco-regions, humans, draught animals and engines provide the motive power in various proportions for crop production, harvesting, transport and processing [1]. [2] reported that of recorded history, man has been tilling the soil in order to increase the production of food. Soil tillage, in general, is one of the fundamental field operations in agriculture due to its influence on soil properties, environment and crop production [3]. Tillage practice modifies the soil structure by changing its physical properties such as moisture content, bulk density, and penetration resistance. These Changes affect the seedling emergence, plant population density; root distribution and crop yield [3]. The soil can be tilled using either tractor or animal with the appropriate implement to achieve the desired objective. Therefore, it is very important to know the source of power and operational parameters that can reduce the cost of tillage and traffic in fields during operation. Animal drawn tillage implements hold immense potentials for reducing the cost of production of crops especially if methods for reducing its excessive power requirements in tillage operation can be found. Practically, this can be accomplished by carrying out studies on the soil-tool interaction system that can be used to study its performance [4, 5].

The soil physical properties must be managed adequately. The performance of tillage implements are determined by their specific draught and energy requirements which are considered essential parameters to match tillage implement to any source of power. Many studies conducted on draught and power requirements under various soil conditions showed that the quality of work depends on soil type and conditions, manner of implements movement and shape [6, 7]. All these researchers observed that draught output varies with variations in soil conditions, tool design and operational parameters. Tool speed and soil depth are the most prominent operational parameters that influence the draught of tillage tools and implements. This holds true because the soil strength usually increases with increasing bulk density [5, 7]. [8] Provide mathematical expressions for draught and power requirements for tillage implements in several soil types. All the draught data presented in [8] as parts of the ASAE Data D497 were based mostly on USA soils [5, 9]. Presently there are very few published data available on draught and power requirements of agricultural implements operating on soils of Nigeria. This data constraint hinders farmers and extension workers from selecting the appropriate size of animals and implements for a particular farm operation [5]. The objective of this study was to determine the effects of speed and depth of operation on the draught requirements of animal drawn mouldboard ridger tillage implement on sandy loam soil and to provide a decision support system for agricultural planners and development agencies for efficient utilization of animal traction through choice of animals and implements combination to perform specific field operations.

## **2 MATERIALS AND METHODS**

### **2.1 Experimental Procedure**

The field study was conducted at the Department of Agricultural and Environmental Engineering Research Farm of the Modibbo Adama University of Technology Yola within the Savannah region, Yola area ( $9^{\circ} 14'N$  and  $12^{\circ} 32'E$ ) of Adamawa State – Nigeria. The area is at an elevation of 200m above sea level and falls within the Eastern Sudan Savanna ecological zone of Nigeria. The area is an agrarian tropical environment marked by dry season (November-April) and wet season (May-October) with mean annual rainfall usually ranges from 700mm to 1,050mm [10]. The soils type in the area is predominantly of sandy loam textures [5]. Two white Fulani bulls (Zebu) ages between five and six years with two years tillage experience and weighed between 253 -285kg live weights were used as draught animals (Plate I) and the animal-drawn mouldboard ridger which is the most commonly used in the study area[4, 11] was used. A spring type dynamometer (500 kg) was used to pull mouldboard ridger implement at various speed ( $0.67, 0.97$  and  $1.25 \text{ ms}^{-1}$ ) and depths (8, 12, and 18 cm) of operation to measure the pull exerted by the oxen on the implement [12]. Other equipment used included two stop watches, measuring tape, soil moisture meter MD750, soil penetrometer MD350, AMS soil samplers, graduated measuring cylinders, electronic and spring weighing balance and plastic ruler to measure the depth of soil cut. Common methodology of soil analysis, data collection and analysis were applied to all the experimental treatment plots.

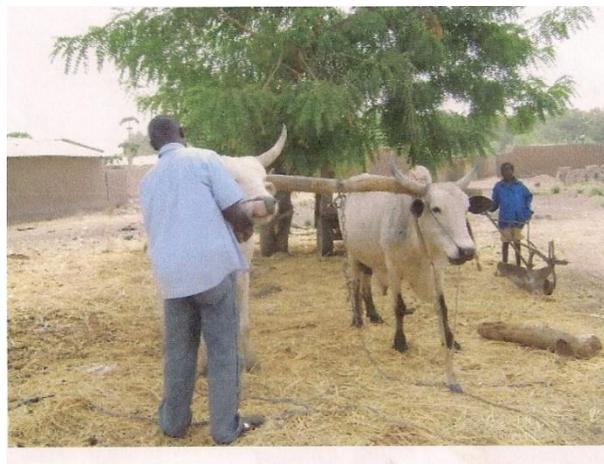


Plate I. Draught Animals Used for On-Station Operation

## 2.2 Treatment and Experimental design

A 1x3x3 factorial experiment in completely randomized design (CRD) was formulated involving three speed level ( $S_1, S_2, S_3$ ) and three depth levels ( $d_1, d_2, d_3$ ) for the study. An area of about 0.18 ha of land with each plot size of 10 m long x 5 m wide was used. The combination of the implements, speed and depth resulted into nine treatments applied each to a 450 m<sup>2</sup> experimental unit in three replications as presented below.

$$\begin{array}{lll} T_1 = I_1S_1d_1 & T_2 = I_1S_1d_2 & T_3 = I_1S_1d_3 \\ T_4 = I_1S_2d_1 & T_5 = I_1S_2d_2 & T_6 = I_1S_2d_3 \\ T_7 = I_1S_3d_1 & T_8 = I_1S_3d_2 & T_9 = I_1S_3d_3 \end{array}$$

## 2.3 Determination of Soil Properties

Soil samples of the top soil (0 – 15 and 15 – 30 cm) were obtained from the field before and after tillage by the use of auger, core samplers, cutting blade and nylon bags for the laboratory determination of particle size analysis, bulk density and soil moisture content using recommended procedures. Soil texture classifications were determined in terms of percentage using the equation given by [13].

$$S_p = \frac{(R - R_L \pm r)}{w} \times 100 \quad (1)$$

Where,  $S_p$  is the percentage of particles on suspension (%);  $R$  is the sample reading for hydrometer;  $R_L$  is the blank reading for hydrometer;  $r$  is the temperature correction factor (0.36);  $w$  is the weight of sample used (g). Soil moisture content was determined on the field using in-situ soil moisture meter. Soil bulk density of the soil samples randomly collected in a container from each test field in the surface of 0-25cm at 5cm depth increment was determined using the relationship given by [13].

$$BD = 4 \frac{W_d}{\pi d^2 h} \quad (2)$$

Where,  $BD$  is the soil bulk density (g/cm<sup>3</sup>);  $W_d$  is the weight of dry soil (g);  $d$ , the internal diameter of core sampler (cm);  $h$ , the height of core sampler (cm). The soil particle density was determined on the field using the relation by [13]:

$$PD = \frac{M_s}{V_w} \quad (3)$$

Where,  $PD$  is the particle density (g/cm<sup>3</sup>);  $M_s$  the mass of soil sample (g);  $V_w$  is the volume of water (cm<sup>3</sup>).

Draught force of the ridger tillage implement was determined using the equation as given by [19]

$$D_R = P_F \cos(\alpha) \quad (4)$$

Where,  $D_R$  = Draught requirement by the implement (N);  $P_F$  = dynamometer pull force (N);  $\alpha$  = angle of pull (deg.).

The power required to move the implement is obtained as:

$$P = DR \times V \quad (5)$$

Where,  $P$  = power;  $W$ ;  $V$  = velocity or speed of operation; m/s.

The field and laboratory data collected were analyzed statistically based on randomized complete design (RCD) by Analysis of Variance (ANOVA) technique as reported by [14] to investigate the interactions between the implement forward speed and operating depth in Excel programme to analyses their significant effect. A correct evaluation of the impact of the technology will help farmers to have a better understanding of the effects of animal traction on the achievement of their production goals.

### 3 RESULTS AND DISCUSSIONS

#### 3.1 Soil Condition

The physical properties of the soil samples are presented in Table 1.

Table 1. Mean values of soil physical properties of the experimental site

Depth of soil profile (cm)	Sand (%)	Silt (%)	Clay (%)	Texture class (USDA)
0 – 15	62.7	20.2	17.1	Sandy loam
15 – 30	67.8	17.5	14.7	

Each value is a mean of three measurements USDA, triangle in: [13]. From the USDA triangle, the soil can be classified as sandy loam. The soil constituents consists of high sand fraction (62.9 - 67.8 %). This result confirms the observation of [5, 15]. In determining the Draught–Speed and Draught –Depth Relationship of animal drawn mouldboard ridger based on the draught values measured, two approaches were tried; Draught–Speed and Draught –Depth Relationship. The combination of the draught requirement, speed and depth of operation used in the experiment are given in Table 2 and the results of the analysis are presented in figures 1 and 2 respectively. Results in Table 2 show that the highest and lowest mean draught values of 362.62 N and 305.17 N were obtained in treatments T<sub>9</sub>, the combination (S<sub>3</sub>d<sub>3</sub>) of 1.25 ms<sup>-1</sup> and 0.183m depth and T<sub>1</sub> (S<sub>1</sub>d<sub>1</sub>) of 0.67 ms<sup>-1</sup> and 0.083m depth respectively for the mouldboard ridger.

Table 2. Maximum Draught Requirement Means of the Animal Drawn mouldboard ridger with Speed and depth of operation

Sn	Treatment	Draught (N)	Speed (m/s)	Depth (m)
1	S <sub>1</sub> d <sub>1</sub>	305.17	0.67	0.083
2	S <sub>1</sub> d <sub>2</sub>	316.11	0.97	0.135
3	S <sub>1</sub> d <sub>3</sub>	329.03	1.25	0.183
4	S <sub>2</sub> d <sub>1</sub>	324.54	0.67	0.083
5	S <sub>2</sub> d <sub>2</sub>	338.62	0.97	0.135
6	S <sub>2</sub> d <sub>3</sub>	351.15	1.25	0.183
7	S <sub>3</sub> d <sub>1</sub>	323.53	0.67	0.083
8	S <sub>3</sub> d <sub>2</sub>	343.26	0.97	0.135
9	S <sub>3</sub> d <sub>3</sub>	362.62	1.25	0.183
	Mean	332.70		
	Minimum	305.17		
	Maximum	362.62		
	Cv (%)	5.3		
	Stdev	17.5		

The results of the analyses are presented in figures 1 and 2. Figure 1, shows the predicting equations of draught-speed relationship for various depths. It showed a good correlation between the draught and speed of operation for the ridger implement with values of r<sup>2</sup> very close to 1. It shows that increase in draught requirement at various depths of operation with increased in speed of operation.

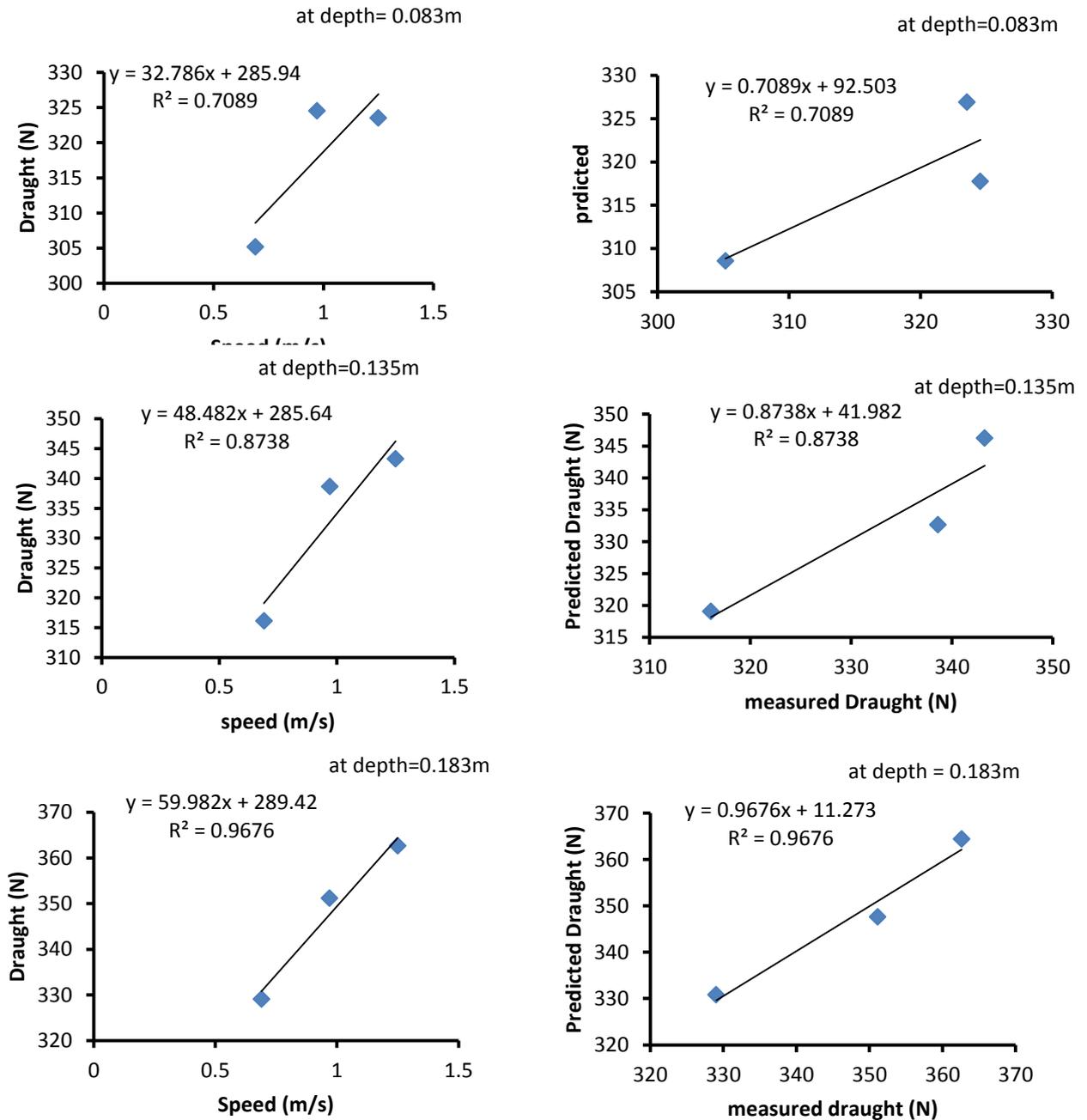


Figure 1. Comparison of the predicted and experimental draught showing the effect of speed at different depth of operation

Figure 2, shows the increase in draught force for the mouldboard ridger with the increase in working depth at various speed of operation. This value was true for both measured and predicted  $r^2$ . Equations of best fit lines to these data were used to estimate the expected draught data. Although both approaches gave very close estimation of draught data to each other, the speed was employed because this approach generally showed a higher  $r^2$  values for the relationship between the corresponding data points. The rate of this increment is same at different forward speed as reported by [16]. This shows that the more soil is cut and turned over by the implement operating at deeper range the higher the draught values. Similar trend was reported by [15].

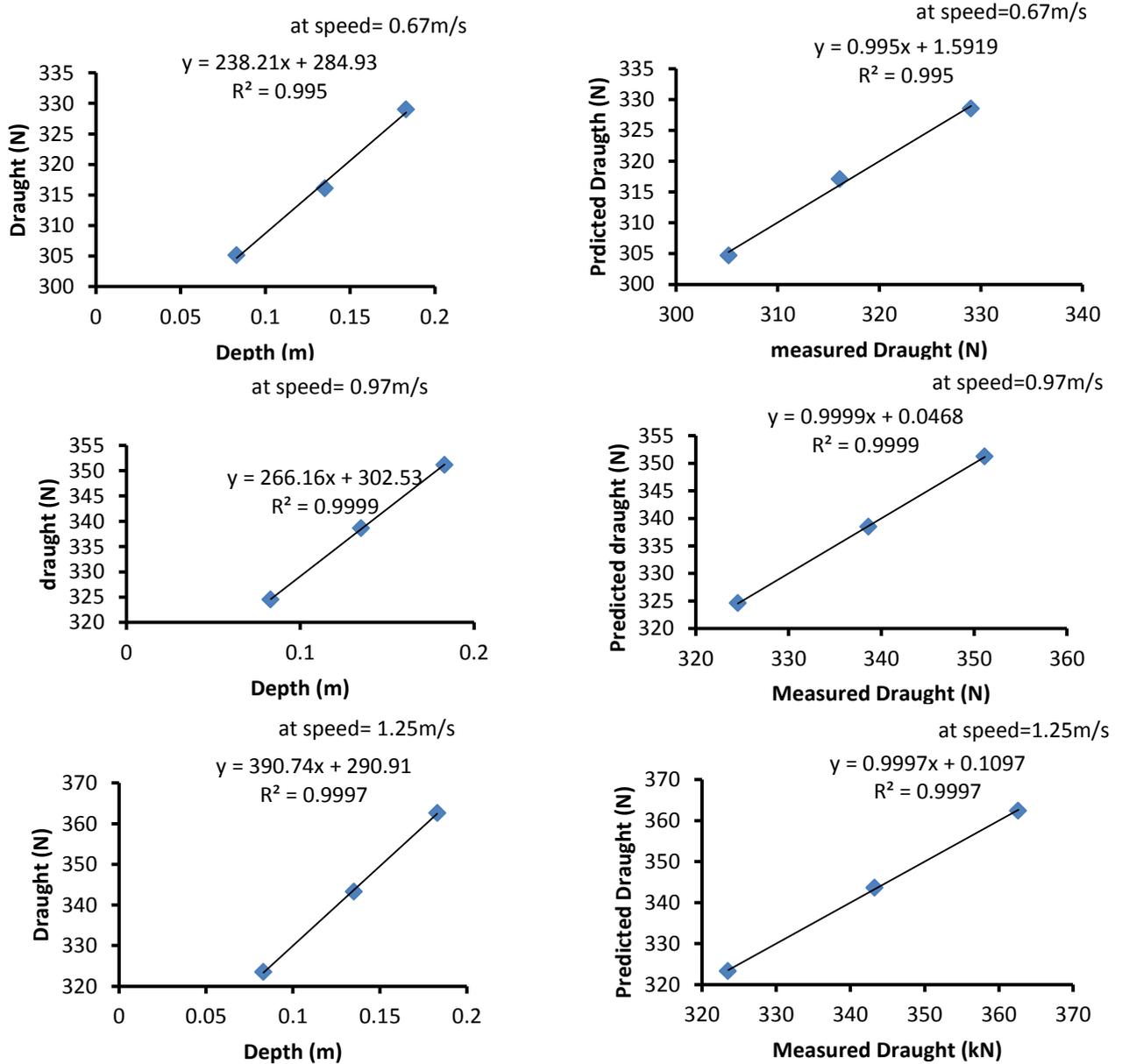


Figure 2. Comparison of the predicted and experimental draught showing the effect of depth at different speed of operation

#### 4 CONCLUSION

In this research, it was found that both speed and depth of operation affect draught of mouldboard ridger implement. The increase in draught due to increase in speed has less effect compared to increase in depth. Draught increases as depth of operation increases, but the rate of this increment is same at different forward speeds. Depth has the greatest effect on the total draught force compared to other parameters as shown in the value of  $r^2$  figure 2. It was found that the implement Maximum draughts of 362.62N obtained at various depths and speeds are less than the oxen's combined draught ability of 12 % of their live weight (633.33N) at all situations.

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