



## Determination of Selected Soil Properties for Selecting Appropriate Land Preparation Equipment in Samaru – Zaria, Nigeria

Saleh, A., Takalafia, S.M. and Suleiman, M.L.

**Abstract:** Food production for the ever growing population without damaging the soil quality, fertility and productivity is a major challenge in the present agriculture scenario. The objective of this study was to determine selected soil properties of Samaru-Zaria that would be used in tillage research in order to address the problem of inadequacy of local design data and unsuitability and inadaptability of agricultural implements used in the area. Soil samples collected from different points in the field were analyzed for moisture content, bulk density, organic matter content, texture and particle size in the laboratory for the purpose of selecting suitable agricultural machines for land preparation and profitable crop production. Results obtained showed that the soil is loam, moisture content varies from 8.40 - 15.11%, bulk density varies from 1.62 g/cm<sup>3</sup> from the shallow soil layer to 1.77 g/cm<sup>3</sup> at deeper depth 15 - 20 cm and beyond, down the soil profile. Similarly, organic matter varies from 4.207 % by weight at 0 - 10 cm, 1.660 % between 10 - 15 cm and 0.652 % from 15 - 20 cm depths of the soil profile. Knowledge of soil type and its properties present in the soil profile would assist the designer in selecting the appropriate materials to be used in manufacturing the land preparation equipment.

**Keywords:** Determination, Equipment Soil properties, Land preparation, Soil profile

### I. Introduction

Soil is an organic material found on the topmost surface of the earth that serves as a natural medium for crop growth. It contains several organisms that play important roles in defining its condition and quality [1]. The composition and proportion of these organisms greatly influence soil physical properties, including texture, structure, and porosity, the fraction of pore space in a soil. These properties, in turn, affect air and water movement in the soil and therefore determine the ability of the soil to function in agricultural production systems [2 - 4]. Soil could thus be viewed in a variety of ways depending on the intended use. To a farmer, it is the constituent that supports plant life and a basin for water

and nutrients needed by plants, whereas an agricultural engineer views it as an important resource for crop and livestock production. Generally, agricultural soil is viewed as a three-dimensional body that supports plant establishment and growth as well as a natural and dynamic medium. The cultivated top layer of agricultural soil (i.e. surface soil) is between 15 – 18 cm of the plough depth. Therefore, the importance of soil management and its physical properties to achieve the set goals in crop and livestock production cannot be overemphasized.

As the characteristics and properties of soils vary, the knowledge of their properties becomes important for optimum use and the best management for efficient and productive use. An immeasurable variety of constituents may be found in soils in the varying composition of about 45% minerals, 20-30% water, 20-30% air, and 1-5% organic matter components that vary greatly from one place to another [4, 5]. In selecting suitable tillage implements for a particular farm operation,

Saleh, A., Takalafia, S.M. and Suleiman, M.  
(Department of Agricultural and Bio-Resources  
Engineering, Ahmadu Bello University, Zaria,  
Nigeria)

Corresponding author: [salehaminu@gmail.com](mailto:salehaminu@gmail.com)

Phone Number: +234-803-577-4780

Submitted: 01-01-2022

Accepted: 26-01-2022

knowledge of soil condition is, therefore, an important factor that must be analyzed and considered since the draft of the tillage implement is affected by soil condition. It thus becomes obvious for agriculturists to take informed and thorough decisions on the selection of appropriate power sources and implements to be used for agricultural productions based on the soil parameters obtained. This is essential to reduce operational costs and ensure efficient farm machinery usage. Other implement parameters that affect draft power requirement significantly include effective working width of the implement, its working depth and operational forward speed. To enhance profitable crop production, the use of appropriate equipment becomes essential for a suitable seedbed in order to obtain better seed germination and plant growth, hence the objective of this study.

## II. Materials and Methods

### A. Materials Selection

#### i. Experimental Site

The experiment was conducted at the Research Farm of the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Samaru-Zaria, Nigeria (Figure 1). It is located at Samaru on latitude  $11^{\circ} 11' 19.3''\text{N}$ , longitude  $07^{\circ} 37' 02''\text{E}$  and an altitude of 550-700 m.

Samaru evolved from a small colonial farming settlement to become a large community that is often referred to as a “University village”. It is cosmopolitan in nature, drawing and blending people of divergent national and international backgrounds. Generally, Zaria and its environs is characterized by gently rolling plains dotted with groups of rocky residual hills developed on granite bedrock [6].

#### ii. Instrumentation

The instruments were used for the purpose of this study are: Measuring tape— Steel measuring tape of 100 m length was used for distance measurements in the field.

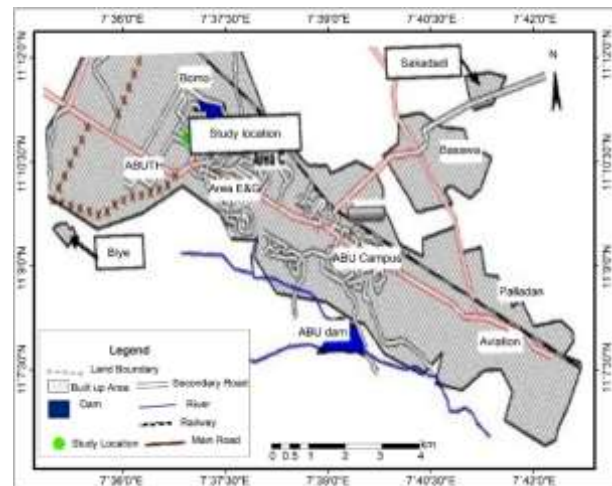


Figure 1: Map of Samaru Showing the Study Area

Metre rule – Steel metre rule 1 m long was used for depth measurements during the experiment. It measures the depths of cut from the bottom of the furrow to the surface level of the soil at randomly selected points within the selected area of study. Wooden pegs – used for marking starting and ending points in the field.

Recording apparatus – labelled sheet of papers and a biro were used for recording the draft at appropriate times. A digital camera for taking pictures and video clips were used during the experiment to ensure adequate record keeping. Laboratory Equipment – various laboratory equipment were used in the soil laboratory of the university. Soil sampling apparatus – Ten steel core samplers and twelve polythene bags were used to collect the soil samples at various depths during each experiment, absolute care was taken to prevent moisture loss through evaporation.

## B. Methods

### i. Soil Sampling and Analysis

Soil samples were collected from the exposed soil at 5 - 10 cm, 10 - 15 cm and 15 - 20 cm from the Research Farm of the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Samaru-Zaria, Nigeria. After ploughing, core-samplers were used to collect samples while samples were collected with an excavator after harrowing and ridging. These samples were analyzed in to determine the soil moisture content, bulk density, humus content and particle size distribution (Sand, Silt and Clay) in the Processing Laboratory and Soil Laboratory of Ahmadu Bello University, Zaria using the *Bouyoucos* method of soil analysis.

### ii. Soil Textural and Particle Size Analysis

The soil samples were analyzed for particle size according to *Bouyoucos* Standard in the Soil Science General Laboratory, Institute for Agricultural Research, Ahmadu Bello University, Zaria. Hydrometer readings (g/l) were obtained by substituting the blank reading (g/l) from the hydrometer readings in the soil suspensions (g/l) and 0.36 g/l was added for every degree above 20 °C as expressed in equations (1) – (4):

$$C = R - RL (0.36T) \quad (1)$$

where, C = Corrected Hydrometer Readings  
 T = Room temperature less 20 °C  
 R = Hydrometer Readings in the Soil Suspensions  
 RL = Blank Reading

The percentages by weight of the SILT + CLAY and SAND fractions are obtained by:

$$\text{Clay (\%)} = \frac{\text{Corrected 2 hrs reading} \left(\frac{g}{l}\right) - \text{Blank reading} \left(\frac{g}{l}\right) \times 100}{\text{Weight of Soil taken (g)}} \quad (2)$$

$$\text{Silt (\%)} = \frac{\text{Corrected 40 Secs reading} \left(\frac{g}{l}\right) - \text{Blank reading} \left(\frac{g}{l}\right) \times 100 - \% \text{ CLAY}}{\text{Weight of Soil taken (g)}} \quad (3)$$

$$\therefore \% \text{ Sand} = 100 - (\% \text{ Clay} + \% \text{ Silt}) \quad (4)$$

### iii. Determination of Organic Matter Content

The organic matter content of the soil was analyzed in Soil Science General Laboratory according to *Bouyoucos* standard [2, 7] as expressed in equations (5) – (8).

$$\text{Organic Carbon (\%)} = \frac{(\text{Blank titre} - \text{Actual titre}) \times 0.3 \times m \times f}{\text{weight of air dry soil taken}} \quad (5)$$

where, m = Concentration of Ferrous Ammonium Sulphate, f = Correction factor

$$\text{Organic Matter Content (\%)} = \frac{\text{Organic Carbon (\%)} \times 1.724}{\text{Organic Carbon (\%)}} \quad (6)$$

### iv. Determination of Soil Moisture Content and Bulk Density

The bulk density and moisture content of the soil was determined in the Processing Laboratory of Agricultural and Bio-Resources Engineering Department, Ahmadu Bello University [8]:

$$M_c(\%) = \frac{W2 - W3}{W3 - W1} \times 100$$

$$M_c(\text{wet basis}) = \frac{W_w - W_d}{W_d} \times 100 = \frac{W_m}{W_d} \times 100 \quad (7)$$

$$\text{Volume of core-sampler (v)} = \frac{\pi \times d^2}{4} \times h$$

$$\text{Mass of Oven dried soil sample (M)} = W2 - W3$$

$$\text{Bulk Density (D}_b\text{)} = \frac{M}{v} \quad (8)$$

where:  $W_w$  = Weight of wet soil;  
 $W_d$  = weight of dry soil;  
 $W_m$  = weight of moist soil;  
 $h$  = height of the cone  
 – sampler,

$d = \text{diameter of the cone}$   
 – sampler;  
 $M = \text{mass of the soil and}$   
 $V = \text{voulme of the cone}$   
 – sampler.

### v. Statistical Analysis

The data obtained were analyzed using descriptive statistics to draw inferences from the study in order to draw conclusions.

## III. Results and Discussion

### i. Soil Analysis

Results of the selected properties of the soil that include bulk density (B.D), moisture content (M.C.), texture and organic matter content investigated were presented in Table 1. The study showed that the amount of sand, silt and clay vary in their proportions. Sand fraction constituted a high percentage (52%) in the constituent components. This result was confirmed by the observation of Ibrahim *et al* [2] on Samaru Savannah zone soils and on upland soils of Samaru but disagreed with the findings of [9] on Samaru soil. Similarly, the findings agree with a study on ‘Effect of Land Management on Soil Hydraulic Conductivity’ conducted on Samaru soils indicating that it is good for optimum plant growth [10].

There was no considerable variation in the soil constituents down the soil profile (0-20 cm): silt percentage remained constant over all the three depths considered.

The clay and sand percentages slightly varies by 2% at a depth range of 10 - 15 cm. This might be as a result of previous cultivation on the soil, which caused the transported sand sediments to be moved into the deeper soil profile while the compacted inner layer was brought to the surface due to soil inversion by the implements. Clay and sand fractions remained constant over the other two depth profiles. This agrees with the study of Musa *et*

*al.* [5] that the highest value of sand was obtained with the depth of the soil profile that also has the lowest percentage of clay.

Table 1: Physical Properties of Samaru Soil at the Field of Study

Depth (cm)	5-10	10-15	15-20
M.C. (% w.b.) after ploughing	9.67	10.62	15.11
M.C. (% w.b.) after harrowing and ridging	8.40	9.02	10.11
B.D. (Mg/m <sup>3</sup> )	1.62	1.63	1.77
O. M. Content (% w.b)	4.21	1.66	0.65
% Clay	10	8	10
% Silt	38	38	38
%Sand	52	54	52
Textural Class	Loam	Sandy Loam	Loam

\*B.D. = Bulk Density; M.C. = Moisture content, O.M. = Organic Matter; w.b. = weight basis

The moisture content of the soil was also noted to progressively increase with the depth of the profile indicating little porosity which means the soil is too compacted than the topsoil as observed in an earlier study [11]. However, the moisture content decreases after the primary tillage operation (ploughing). The reduction in moisture content during the field operations would promote the workability of the soils thus signifying that less energy would be expended while conducting the secondary operations (harrowing and ridging). This finding was also in agreement with the studies of Oduma *et al.* [12]. Thus lighter material should be used while choosing the secondary tillage equipment as compared with the materials used for the primary tillage equipment.

### ii. Humus (Organic Matter) Content

The soil organic matter investigated in this study decreases with an increase in depth of soil profile as shown in Table 1. The increase could be as a result of the decaying plant

properties as rightly observed by [5, 10, 11]. The 5 - 10 cm depth profile has 4.21% of organic matter content, while the corresponding values for 10 - 15 cm and 15 - 20 cm depths profiles were 1.66% and 0.65% respectively. This indicates that the soil is rich in organic matter content compared to the results of [2, 10, 11] who reported that a soil profile between 0 -15 cm depths has 1.18 - 1.26% organic matter has a moderate level of organic matter content. The soil is, therefore, very good for plants development. This study agrees with a previous study that soil compaction increases soil strength and decreases soil physical fertility through decreasing storage of water and nutrients supply leading to additional fertilizer requirement and increasing production cost [13].

### iii. Soil Bulk Density

The effect of soil bulk density on the draft force of the three tractors powered tillage implements were considered in this study. Results of the study showed that there is an increase in draft with an increase in soil bulk density and also there is an increase in bulk density with a corresponding increase in depth (Table 1), this could be due to the clay particles movement into the lower soil profile which makes them compacted (denser). This agreed with another study that ploughing beyond 20 cm depth means compacting the top soil as denser clay fractions are being exposed to the surface from a deeper soil layer [10]. The result also agreed with another research report that there was an increase in bulk density and draft with increasing depth [5, 11].

The percentage of dry bulk density produced (1.62 and 1.63 Mg/m<sup>3</sup>) in 5 – 10 and 10 – 15 cm depth of the soil was higher than that of the than that of 15 – 20 cm soil depth (1.77 Mg/m<sup>3</sup>). This is an indication that the soil

would be more compacted causing so much pressure on the implement as well as the tractor that is pulling it. It is expected, therefore, that wear and tear on the implement used within 15 – 20 cm depth (loamy soil) would be more than in sandy loam soils. Soil compaction was noted to have problems of limiting the growth of microorganisms, moisture removal and difficult root and implement penetration. This finding is in agreement with another study that reported that repetitive tillage degraded soil qualities and caused the rapid collapse of soil structure [14]. The study was also agreed that intensive soil cultivation increase soil bulk density that may result in reduced soil penetration [15]. With the increase in bulk density, soil compaction is expected to increase and the soil penetration resistance became high, consequently, the implements in the firm soils require a greater draft force to overcome a considerable amount of soil resistance, thus the draft force required to pull the implement in firm soil condition was greater than that of loose condition. This agrees with the earlier findings that energy requirements in land preparation increase with an increase in bulk density [16, 17].

## IV. Conclusion

Results from this study revealed that tillage practices resulted in the decline of soil nutrients, moisture content but an increase in bulk density. The reduction observed in nutrients may be attributed to the loss of soil organic matter. The higher moisture status of the dipper soil profile could be adduced to the minimum soil disturbance with little exposure of the soil surface to the atmospheric demand. The study also observed that the higher the bulk density was, the higher the soil compaction and the higher the resistance to penetration the soil offers to the implement was; thus requiring a greater draft force to overcome a considerable amount of soil

resistance. Finally, the results of this research work will help the farmers to know the effect of some soil physical properties on the performances of various agricultural field machineries and to select the right equipment for their agricultural activities.

### Acknowledgement

The authors wish to acknowledge with thanks, Institute of Agricultural Research (IAR) and the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University Zaria for giving us an unrestricted access to the equipment in Engineering Workshop needed for the study.

### References

- [1] U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), "Soil Quality Management: Key Strategies for Agricultural Land", *National Soil Survey Center, Soil Quality for Environmental Health*, 2001 pp 1-2
- [2] Ibrahim, J.A., Lazarus, M.A., Dolapo, A., Agaku, D.T. and Sim, H. "Impact of Toposequence on Soil Properties and Classification in Zaria, Kaduna State, Northern Guinea Savanna, Nigeria", *EQA, International Journal of Environmental Quality*, vol. 3, no. 3, 2020, pp 48–58. <https://doi.org/10.6092/issn.2281-4485/10043>
- [3] Majid, R., Iman, N., Jabak, J., Seyyed, M.E. and Mahmud, F. "Effect of Soil Moisture Content, Tillage Depth and Operation Speed on Draft of Mouldboard Plow", *Middle-East Journal of Scientific Research*, vol. 16, no. 2, 2013, pp. 245-249.
- [4] McCauley, A., Jones, C. and Jacobsen, J. "Basic Soil Properties", *MSU Extension Service Continuing Education Series*, 2005,(4481-1).
- [5] Musa, J.J., Akpoebidimiyen, O.E., Adewumi, J.K., Eze, P.C., Adesiji, R. and Gupa, Y.U. "Influence of Soil Bulk Density and Porosity on Soil Hydraulic Conductivities for Selected Land Management Practice in North-Central Nigeria", *International Journal of Agricultural and Environmental Sciences*, no. 5, 2020, pp 1-7.
- [6] *ABU Zaria Official Website*. Retrieved December 20, 2021, from ABU Zaria: [www.abu.edu.ng](http://www.abu.edu.ng), pp. 1-2.
- [7] Ilu, M. "Soil Analysis Using Bouyoucous Procedure", *Laboratory Manual Zaria*, Nigeria: Department of Soil Science General Laboratory, Ahmadu Bello University, 2018, pp.1-3.
- [8] Kawuyo, U.A. "Mathematical Modelling of Draught Characteristics of Selected Animal-Drawn Implements on the Upland Soils of Samaru, Nigeria", Ahmadu Bello University, Agricultural and Bio-resources Engineering. Zaria: *Unpublished Phd Thesis*, 2011, pp.1-2, 7&51.
- [9] Muhammed, M.M. "Determination of Soil Physical Properties Dug from Collector Well Constructed Using Low Cost Technology", Ahmadu Bello University, Agricultural and Bio-resources Engineering. Zaria: *Unpublished B.Eng. Project*, 2014, pp. 62-63.
- [10] Musa, J.J., Oturo, E.A., Pius, O.O.D., Adewumi, J.K. and Gupa, Y.U. "Effect of Land Management on Soil Hydraulic Conductivity in Gidan Kwano, Niger State, Nigeria", *Open Journal of Forestry*, vol. 11, no.2, 2021, DOI: 10.4236/ojf.2021.112008
- [11] Fidelis, C.O., Chikere Njoku, C., Oduaro, J.I. and Chikwendu, L. "Geospatial Analysis of Soil Properties and Their Effects on Maize and Cassava Production in Ohaji/Egbema Imo State, Nigeria", *Open Access Library Journal*, vol. 7, no. 4, 2020, DOI: 10.4236/oalib.1106259.
- [12] Oduma, O., Oluka, S.I. and Eze, P.C. "Effect of Soil Physical Properties on Performance of Agricultural Field Machinery in South Eastern Nigeria", *Agricultural Engineering International: CIGR Journal*, vol. 20, no. 1, 2018, pp. 25–31.
- [13] Hamza, M.A. and Anderson, W.K. "Soil Compaction in Cropping Systems: A Review of the Nature, Causes and Possible Solutions", *Soil*

and *Tillage Research*, vol. 82, no. 2, 2005, pp. 121-145.

[14] Ojeniyi, S.O. and Agboola, A.A. "A Review of Tillage Requirement of Food Crops in Africa", *African Soils*, vol. 28, 1995, pp. 259 - 266.

[15] Ojeniyi, S.O. "Effect of Bush Clearing and Tillage Method on Soil Physical and Chemical Properties of Humid Tropical Alfisol", *Soil Tillage Research*, vol. 15, 1990, pp. 269 - 277.

[16] Kepner, R.A., Bainer, R. and Barger, E.L. "Principles of Farm Machinery", *Avi Publishing Company Inc*, 1982.

[17] Shebi, J.G., Oni, K.C. and Braide, F.G. "Comparative Tractive Performance of Three Tractors", *Journal of Agricultural Mechanization in Asia, Africa and Latin America (AMA), Japan*, vol.19, no. 2, 1988, pp.25–29.