International Journal of Innovative Environmental Studies Research 14(2):157-163, April-June, 2026

© SEAHI PUBLICATIONS, 2026 www.seahipublications.org ISSN: 2354-2918

DOI:10.5281/zenodo.20390603

Determination Of Thermal Conductivity And Textural Classification Of Soils In Some Farming Area Of Biu, Borno State, Nigeria

[*]Jibrin Salihu; Simon Kwarki & Yusuf Mohammed Jimoh

Department of Physics,
School of Science Education
Federal College of Education (Tech.), Gombe State, Nigeria
***Corresponding Email: salihujibrin94@mail.com**

ABSTRACT

This study investigates soil thermal conductivity and textures of soils in farming areas of Biu, Borno state. The study adopted experimental survey design and Random sampling techniques were used in collecting the samples in all the sample points at each of the five-farming area in which three soil samples were collected per farm making a total
of fifteen samples. A hydrometer analysis was carried out in determining the texture of the soil while Lee Disc apparatus was employed for the determination of thermal conductivity. The result shows clay, clay-sand and silt with slow water drainage capacity at NTA farm area, clay, clay-sand and silt with higher susceptibility to erosion at Tum farm area, clay, clay-sand with cat ion exchange capacity and high nutrient retention at Farm Centre, clay, clay-sand with soil tilt, but with poor retention capacity at Waka secondary school farm area and clay, clay-sand with good pH buffering capacity and reach organic content at Shangul farm area Thermal conductivity (k) for the fifteen soils measured ranged from 0.90 - 1.55 W m^{-1} $^{o}C^{-1}$ and was within 0.1 W m^{-1} $^{o}C^{-1}$ of the corresponding laboratory-measured values for standard soils, which ranged from 0.5 - 2.00 W m^{-1} $^{o}C^{-1}$. The clay soil had lower values of thermal conductivity and pH than the clay loam and the sandy loam soil. Good agreement was found between the field and laboratory and the findings reveals almost all the samples has greater mean percentage of clay compared to sand and silt in the order of Clay>Sand>Silt (75% > 21.25% > 3.75%) using one way variance Anova statistics double of ($p< 0.05$) degree of significance. The paired sample test at 95% confidence interval of the difference also shows 0.995, significance under three nominal data used with 1.0 mean correlation

Keywords: Thermal Conductivity, Hydrometer, Soil texture and Biu

1.0 INTRODUCTION

Soil thermal properties are required in many areas of engineering, science, agronomy and soil science. While soil texture is one of the most important physical properties of soils, Soil texture is related to soil characteristics such as Heat Capacity, water holding capacity, soil drainage, and soil fertility (Robert U. W., Etuk S. E., Agbasi O. E. & Okorie U. S., 2021). Soil texture is simply defined as the relative proportion of Sand; and Clay separates found in the Soil. These particles differ amongst each other in terms of their size. Thus, particles that range in size from 0.05-2.0 mm are Sand, Particles that fall between 0.002-0.05 mm are considered to be Silt, and the smallest which is less than 0.002 mm in size are

referred to as Clay (Hristov, 2013). Soil texture has huge significance for soil development. It can help us to understand the age of the soil and soil development process (Hristov, 2013). Practically, all soil properties and as a whole fertility, depend on it. Soil properties are influenced by its texture as; derange water holding capacity, thermal conductivity, aeration, susceptibility to erosion, organic matter content, cat-ion exchange capability, PH buffering ability etc. The cultivation Soil, Heavy Metals characteristic and impact of the soil cultivation tools as well as fertilization application depend to a great extent on the soil texture (saadie J. H., 2016). Also understanding soil texture helps to informed, efficient and cost-effective management for building a road, Houses, farms settings, gardens and landscapes (Dilkowa, R., 1998).

Soil texture and textural class can be determined by a variety of ways, some of them includes texture feel method, Ribbon method, Hydrometer or mechanical method, but the most robust and most scientifically approach to determine Soil texture from all aforementioned, is the hydrometer or Mechanical method (Gonzalez-Dominguez P. L., Monzonvetona J. M., & Garcia-Alonso S., 2019). Mechanical analysis of texture takes advantage of the fact that particles of different sizes will fall out of suspension at different speeds and upon this research base on it. In this approach, Soil is suspended in a Chemical mixture and as the soil particle begins to settle (Larger granules settling first) the density of the suspension is then measured by a Hydrometer that is Stokes law (Robert U. W., Etuk S. E., Agbasi O. E. & Okorie U. S., 2021). Stokes law describes the speed at which particles of different sizes settle out of a suspension. Particles of sand are much larger in diameter than particles of silt and clay. Silt particles are larger in diameter than clay particles (ASTM D5334, 2022).

Stokes Law tells us, in essence, that the larger the particle, the more quickly the particle will settle out of suspension (Dipankar D., Binayak P. M. & Lesikar B. J, 2016). In other words, as the particles settle out of suspension, the sand fraction of the soil will accumulate on the bottom as a fairly discrete layer, followed by the silt and the clay particles. Typically, most of the sand particles in the soil will settle to the bottom in about 40 seconds. The silt and clay particles will take quite a bit longer, perhaps as long as 2 hours (Ubong W. R. Sunday E. E. Okechukwu E. A. Uduakobong S. O. Nsikala E. E. & Armstrong U. A., 2022).

2.0 The Study Area

Biu City is a town (and a local government area) in southern Borno State of north eastern Nigeria; it is the capital and administrative Centre of Biu Local Government. The town lies on a plateau which is precipitous escarpment that stretches over a wide area close to the River Hawul and overlooking the River Gongola and the scenic Adamawa Landscape (Usman, 2015). Biu has an estimated population of 208,330 people (2006 census) projection, with an area of $3{,}315\ Km^2$ and situated between Latitude $10^0 36' 40''$ and $10.6111^0\ N$ and longitude $12^0 11' 42''$ and $12.195^0 E$ of the Greenwich meridian. It has two distinct climates, the rainy season (April–October) and the dry season (November-March) with an average rainfall of 850mm, along with temperature ranges from $16.0^0 C - 39.4^0 C$ around year (Institute N. M., 2017).

Fig 1: Map of Nigeria Showing Biu

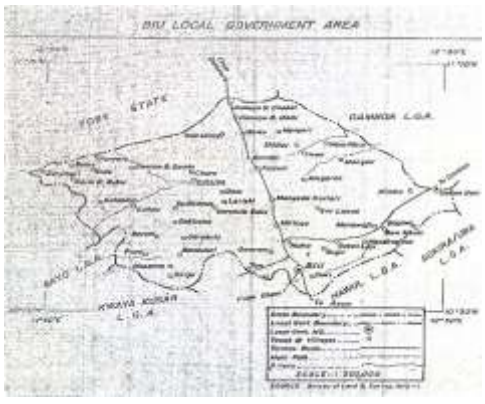

Fig 2: Map Biu Showing Data Area

3.0 MATERIAL AND METHOD

3.1 Geo referencing

Geometric data were acquired using handheld GPS. The coordinates of five different points observed within Biu area were obtained, this includes Nta layout farm area (10.644277, 12.177956), Tum-Hill Site farm area (10.608397, 12.114901), Farm-center area (10.616214, 12.153367), Waka secondary school farm area (10.634950, 12.198765), and Shangul farm area (10.638771, 12.165960). These coordinates were used for ground truth and in case of geo-referencing the satellite imagery

3.2 Sample Collection and Preparation

The best undisturbed sample, are those in which the Soil Water Content and the composition remain unchanged with the structure as little as possible (Kharshiduzzaman M., Hossain M. S., Ali S., & Ahmed S., 2091). But this seem to be impossible and for this, Soil was carefully dug out with some digging tools to an average depth of $50\ cm$ from there a reasonable samples quantities were collected using Hands Trowel transfer into polyether Bags wrapped up to preserve the Water content, and then placed into a Container (Laskwoski J., Millow B., & Ratke L., 2016). The samples were then open into desiccators to dried it thoroughly, and letter transferred to a Hotplate to remove some micro- organism and then granule with the used of Mortar and Pestle, sieved to a diameter of $4.0\ mm$.

3.2.1 Sample Digestion

A $40\ g$ was accurately weighed out of each sample and then transferred separately into $600\ ml$ Beakers in which $100\ ml$ of Water and $5\ ml$ $30\ \%$ Hydrogen peroxide (H_2O_2) was added to removed organic matter from the samples. The Beakers was then covered, heated to a boiling point and was then allowed to cool for the oxidation of the organic matter to take place. A $50\ ml$ of $5\ \%$ Sodium hexametaphosphate $(N_aPo_3)_6$ was added and it is then transferred to a dispersing Cup, where it will be allowed to disperse for $5\ mins$. Finally, each suspension was transferred into $1000\ ml$ Cylinders with their particles thoroughly washed to add to their maximum volume with distilled Water and temperature θ_2^0C was noted and recorded

Another blank suspension was also prepared with $50\ ml$ of $5\ \%$ $(N_aPo_3)_6$ in a $1000\ ml$ measuring Cylinder, which is then fill up with Water to the nearest maximum volume level and it temperature θ_1^0C was recorded which in equilibrium with Room temperature T_0, a hydrometer was immersed into this solution and it level was noted as R_L. Immediately after setting the hydrometer level down, the hydrometer was carefully inserted into the suspension for exactly 40 seconds, the temperature of the cylinder hydrometer level was also set down to record. The suspension was allowed to stand for another two hours before second hydrometer reading was taken without stirring the mixture with plunger. After setting all the readings down, the formula shown below was then used to compute the percentage composition of Sand Clay and Silt from the respective samples

$$\%\ S = \frac{R - R_L + r}{W} \times 100$$

Where:

S = % of material in suspension

R_L= Calibration correction

R = Hydrometer reading for the sample

r = Temperature correction factor (Temp. r $\times$ 0.36)

W = Weight of the Soil sample

Note; the value of r is variable depending on the temperature and 0.36 units was added for every 1^0C to 20^0C and above. Similarly, 0.36 units was subtracted as well for every 1^0C and below 20^0C

3.3 Statistical Analysis of Data

Percentage data obtained were evaluated and expressed as mean. The data obtained were subjected to Analysis of Variance (ANOVA) to determine whether there was significant difference between soils of the investigated Farm areas. A two-tailed probability value of less than 0.05 was considered to be statistically significant, by procedure of Clay, Silt and Sand for the soil samples textural classification with the use of temperature and density corrections base Stokes law after 40 second, and 2 hours respectively.

RESULT AND DISCUSSION

After 40 seconds the Hydrometer readings for both suspended solution R and the blank solution R_L was found to be R = 29.5 and R_L= -2.0 respectively. Similarly, after 2 hours the Hydrometer readings for both suspended solution R and the blank solution was found recorded as R= 29 and R_L = -1.0 respectively.

$$\%\, S = \frac{R - R_L + r}{W} \times \frac{100}{1}$$

$$= \frac{29.5 - (-2.0) \pm 3.24}{40} \times \frac{100}{1}$$

$= 86.85$ (Clay and Silt),

$$\%\, S = \frac{R - R_L + r}{W} \times \frac{100}{1}$$

$$= \frac{29.5 - (-2.0) - 3.24}{40} \times \frac{100}{1}$$

= 70.65 (Clay and Silt)

$$\%\, S = \frac{R - R_L + r}{W} \times \frac{100}{1}$$

$$= \frac{29 - (-1.0) + 3.42}{40} \times \frac{100}{1}$$

$= 83.55$ (Clay)

$$\%\, S = \frac{R - R_L + r}{W} \times \frac{100}{1}$$

$$= \frac{29 - (-1.0) - 3.42}{40} \times \frac{100}{1}$$

= 66.45% (Clay)

Silt (%) = $86.85 - 83.55 = 3.3$,

Silt (%) = 70.65− 66.45 = 4.

Sand (%) = 100 − 86.85 % = 13.15

Sand (%) = 100 − 70.65 = 29.35

Average Clay = 75%, Sand = 21.25% and Silt = 3.75%

Table 3.1: Shows temperature and temperature difference of suspended solution, blank solution with their respective temperature corrections (r) after 40 seconds

Sample Locations	Solution Temp.$\theta_1^0 C$	Suspension Temp. $\theta_2^0 C$	Temp. diff. $\Delta\theta = \theta_2^0 - \theta_1^0$	Temp. corrt. factor $r = 0.36 \times \Delta\theta$
NTA layout farm area	20.00	29.00	9.00	3.24
Tum Hill-site farm area	20.00	27.00	7.00	2.52
Farm-center area	20.00	25.00	5.00	1.80
Waka secondary School farm site	20.00	28.00	8.00	2.88
Shangul farm site	20.00	26.00	6.00	2.16

Table 3.2: Shows temperature and temperature difference of suspended solution, blank solution with their respective temperature corrections (r) after 2 seconds

Sample Locations	Suspension Temp. $\theta_2^0 C$	Solution Temp.$\theta_1^0 C$	Temp. diff. $\Delta\theta = \theta_2^0 - \theta_1^0$	Temp. correction $r = 0.36 \times \Delta\theta$
NTA layout farm area	29.50	20.00	9.50	3.42
Tum Hill-site farm area	28.00	20.00	8.00	2.88
Farm Centre area	26.00	20.00	6.00	2.16
Waka secondary School farm site	29.00	20.00	9.00	3.24
Shangul farm site	27.00	20.00	7.00	2.52

Table 3.3: Percentage Average summary of Clay, Sand and Silt content after hydrometer corrections and the computational analysis using Soil samples triangular diagram

Sample Locations	Percentage of Clay	Percentage of Sand	Percentage of Silt	Textural Class and their Properties in the content
NTA layout farm area	66.45-83.55	13.15-29.35	3.30-4.20	Clay, Clay-Sand, and Silt with very slow water drainage capacity
Tum Hill-site farm area	67.80-82.20	14.95-27.55	2.85-4.65	Clay, Clay-sand, and Silt with high Susceptibility to erosion
Farm-center area	69.60-80.40	16.75-25.75	2.85-4.65	Clay, Clay-Sand with Cat ion exchange capacity, and high nutrient retention
Waka secondary School farm site	66.90-83.10	14.05-27.70	2.84-5.14	Clay, Sand-Clay with Soil tilt, but with poor aeration capacity
Shangul farm area	68.70-81.30	15.86-26.65	2.85-4.65	Clay, Clay Sand with good pH buffering capacity, and reach Organic content

Table 3.5: Paired samples correlation with a significantly double different ($p < 0.05$)

Paired samples correlations				
		N	Correlation	Sig.
Pair 1	Tum-Hill Site & NTA layout	3	1.000	0.019
Pair 2	Farm Centre & Shangul	3	1.000	0.009
Pair 3	NTA layout & Waka secondary schoo lfarm	3	1.000	0.011
Pair 4	Shangul & Farm Centre	3	1.000	0.009
Pair 5	Tum-Hill Site & Waka secondary school farm	3	1.000	0.008

CONCLUSION

From the data obtained on the different soil samples collected of five farm areas in Biu area, and the statistical variance analysis subjected to 0.05 limit of significance, it now an established fact that there was high percentage concentration of Clay soil all-round the areas studied compared Sand and Silt. The area that had highest concentration in all the samples collected are NTA layout farm area followed by Waka secondary school farm, and Tum-Hill site while Shangul had the lowest concentration in all the samples. Due to the public concerns on these, it may be stated that their properties classified needs to be more familiar to the populaces due to fact that they play key role in constructions, research and Agricultural purposes, especially if adequate protective guidelines are adhered for it to achieve desirable results.

REFERENCES

ASTM D5334. (2022). *Standard test method for determination of thermal conductivity of soil and soft Rock by Thermal needle probe procedure* . West conshohoken PA: ASTM International .

Dilkowa, R. (1998). Physical Properties of Soil a Lecture; a lecture of Soil Science project FOA Bulgaria. *Balkan Journal of Ecology*, 231-248.

Dipankar D., Binayak P. M. & Lesikar B. J. (2016). impact of the linked surface water-soil water-groundwater systemon trasport of Ecoil in the substance. *Journal of air and soil pollution 227 (9)*, 351.

Gonzalez-Dominguez P. L., Monzonvetona J. M., & Garcia-Alonso S. (2019). New Thermal conductivity constitutive matrix in Fourier Law for heat transfer using the cell method. *Journal of applied sciences 9(21)*, 452.

Hristov, B. E. (2013). Importance of soil Texture in Soil Classification System. *Journal of Balkan Ecology Vol. 16(2)*, 137-1139.

Institute, N. M. (n.d.). Retrieved from Weather Forecas: http//www.yr.no/place/Nigeria/Biu/Satistics.htt

Institute, N. M. (2017, July 13). *Weather Forecast For Biu.* Retrieved from Norwegian Metrological Institute: http://www.yr.no/place/Nigeria/Borno/BIU/Statistics.html

Kharshiduzzaman M., Hossain M. S., Ali S., & Ahmed S. (2091). Determination of Thermal conductivity of poor conductive materials in the form of of disc by sel-constructed Lees DiscApparatus . *AIP Conference* (p. 140). Tehran: AIP.

Laskwoski J., Millow B., & Ratke L. (2016). Arrogel-Aerogel Composites for normal temperature range Thermal Insulation. *Journal of non-crystalline solid 441(1)*, 40-45.

Robert U. W., Etuk S. E., Agbasi O. E. & Okorie U. S. (2021). Quick determination of Thermal conductivity of thermal insulators using a modefied Lee-Charitons Disc Apparatus Techniques. *International Journal of Thermophysics 42 (8)*, 1-15.

saadie J. H. (2016). Assessement of thermal conductity of physical and Mechanical properties of building insulation materials prepared from waste materials and gypson. *Journal of Engineering and Technology 16 (4)*, 36-40.

Texas Commission on Enviroment. (2005). *Soil Textural Classification.* Texas: Texas Commission on Enviromental Quality.

Ubong W. R. Sunday E. E. Okechukwu E. A. Uduakobong S. O. Nsikala E. E. & Armstrong U. A. (2022). Soil particle Analysis procedure. *Research Journal of science and Technology*, 2-6.

Usman, B. (2015). *A History of Biu.* Abuja, Nigeria: Klamidas Communucations Ltd Suit B04 Plaza,Jabi Expressway, Utako District.

APPENDIX

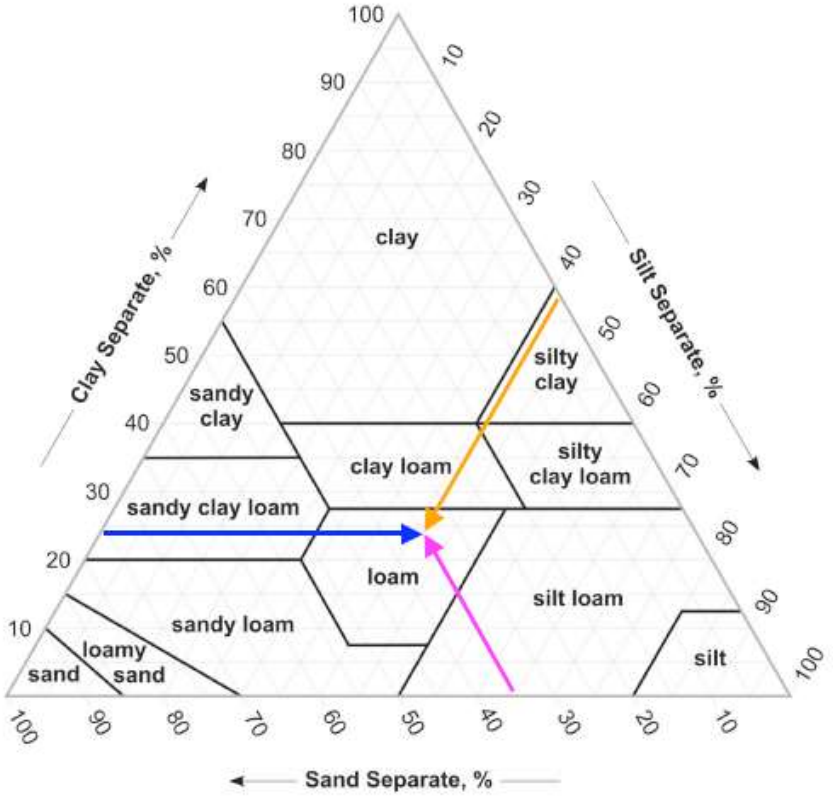

Fig 3: Soil textural classification (Texas Commission on Enviroment., 2005).