FIELD SOIL DETERMINATION ASSESSMENT FOR PARTICLE SIZE DISTRIBUTION

Awoniyi, G. O.[1], James, D.[2] and Adeniran, K. A.[3]
[1]Department of Agricultural and Bio-environmental Engineering, Federal Polytechnic, Bida, Niger State, Nigeria.
[2]Department of Land and Water Management Engineering, National Centre of Agricultural Mechanization.
[3]Department of Agricultural and Biosystems Engineering, University of Ilorin, Nigeria.
E-mail: gbengaawoniyi30@gmail.com

ABSTRACT

Sieving method of particle size distribution is practically most common in laboratories but most times, silt and clay are always lumped together and not distinctly separable. Besides, clogging of soil would definitely result in errors in the finest soil particles of soil composition therefore the method is better used for more coarse sizes rather than finer ones. Soil particles distribution is largely dependent on its solubility (suspension) in appropriate solution (suitably chemical basic). Distinct particles that are made up of soil were found to be dependent of settlement time, colloidal forms and their visual clarity in solution. This research work was conducted at University of Ilorin main campus, Ilorin, Nigeria. The institution lies on the latitude 8^0 30^1 N and longitude 4^0 35^1 E at an elevation of about 340 m above the sea level. Both sieving and sedimentation hydrometer methodology were adopted for the site soil assessment. The experiment was conducted using Latin Square Design of four samples with four replications. Results from sieving indicated that 96%, 95%, 96% and 96% of soil samples are finer than 2 mm with approximately 10%, 9%, 9 % and 8% finer than 0.075 mm for experimental soil sample I, sample II, sample III and sample IV respectively. Sedimentation hydrometer assessment confirmed that the field soil contains 28.6% clay-silt, 13.22% clay, 71.23% sand and 15.52% silt on an average. Textural class of the experimental soil was found to be sandy loam. Analysis of the soil sample inferred 0.98, 0.96 and 0.2 for R^2, adjusted R^2 and Mean Square Error (MSE) respectively.

Keywords: *Particle size, Sieving, Sedimentation Hydrometer.*

1. INTRODUCTION

Physical and mechanical properties of any soil cannot be completely determined without the soil particle size distribution (Gorasczko and Topolinski, 2020). Sieving and sedimentation hydrometer methods are popular methods of determining the particle size distribution in soil. Buretta et al. (2014) used pipette method as a control while comparing modifications of Bouyoucus method (hydrometer) to access soil texture class, erodibility coefficient (k), permanent wilting point (PWP) and field capacity (FC). It was found that both hydrometer and pipette methods were well correlated. Poullet et al. (2019), Malewski (2017) and Wen (2002) simulated sieve equipment and thereby confirmed that particle distribution does not represent the true grain distribution of soil sample. It was discovered that sieve analysis reliability is largely dependent of laboratory techniques and standard procedures involved. A combination of sieve analysis and sedimentation hydrometer was used to affirm that particle size distribution determine to a large extent the soil type of a region (Adeniran and Awoniyi, 2017). It has been discovered that hydrometer method accuracy is slightly less in sand compare to pipette method nonetheless, it is better in determining texture of soils (Elfaki et al., 2016). Drainage catchment radar discharge has been found to be dependent of intrinsic properties of the catchment soil particle distribution (Awoniyi et al., 2020).

Description of the grain size distribution of soil particles according to their texture (particle size, shape, and gradation) is summarized in Table 1 (Michael, 2008). Further classification of soil into agricultural soils such as clay loam, sandy loam, silt loam, etc., could be obtained using textural triangle after the determination of the soil particle sizes (Pannel, 2002). This research aimed at assessing and analyzing both sedimentation hydrometer and sieve method in determining particle size distribution in agricultural soil and thereby determine the class of agricultural soil present in the experimental field.

Table 1. Soil Class according to their Particle Size

S/No	Soil	Size (mm)
1	Gravel	< 2
2	Sand	0.1 – 2
3	Silt	0.01 – 0.1
4	Clay	< 0.01

Source: Michael (2008)

2. METHODOLOGY

This research experimental site was located at University of Ilorin main campus, Ilorin, Kwara State, Nigeria. The institution is situated at Ilorin South Local Government Area, Ilorin, Nigeria which lies on the latitude 8^0 30^1 N and longitude 4^0 35^1 E at an elevation of about 340 m above the sea level (Ejieji and Adeniran, 2009). Ilorin, the capital city of Kwara State is in Southern Guinea Savannah Ecological Zone of Nigeria with an annual rainfall of about 1300 mm. Samples were taken from four strategic places marking the out sketch of the university premises. This made the soil of four samples with each sample having four blocks where replicates were made. Experimental planning is indicated in Tables 2 and 3.

Table 2. Initial Experimental Planning

Block	**Observation (g)**			
X_1	Y_{a1}	Y_{a2}	Y_{a3}	Y_{a4}
X_2	Y_{b1}	Y_{b2}	Y_{b3}	Y_{b4}
X_3	Y_{c1}	Y_{c2}	Y_{c3}	Y_{c4}
X_4	Y_{d1}	Y_{d2}	Y_{d3}	Y_{d4}

Table 3. Final Experimental Planning

Sample (Soil)	**Observation (g)**			
1	X_1Y_{a1}	X_1Y_{a2}	X_1Y_{a3}	X_1Y_{a4}
2	X_2Y_{b1}	X_2Y_{b2}	X_2Y_{b3}	X_2Y_{b4}
3	X_3Y_{c1}	X_3Y_{c2}	X_3Y_{c3}	X_3Y_{c4}
4	X_4Y_{d1}	X_4Y_{d2}	X_4Y_{d3}	X_4Y_{d4}

Sieving and sedimentation hydrometer experiments were carried out for the field soil mainly to determine the experimental soil type. At the start of the hydrometer sedimentation experiment, all particles were in suspension while after 40 seconds, only clay and silt were in suspension while clay particles only were in suspension after 2 hours and above (See plate 1). The various percentages particles that made up the experimental soil was determined using equation (1) to equation (4) (SFU, 2020).

$$\text{Percentage (Silt + Clay)} = \text{40 seconds corrected hydrometer reading} \times \frac{100}{\text{Wt of Sample}} \quad (1)$$

$$\text{Percentage Clay} = \text{2 hrs corrected hydrometer reading} \times \frac{100}{\text{Wt of Sample}} \quad (2)$$

$$\text{Percentage Sand} = 100 - \text{Percentage (Silt + Clay)} \quad (3)$$

$$\text{Percentage Silt} = \text{Percentage (Silt + Clay)} - \text{Percentage Clay} \quad (4)$$

Corrected Hydrometer Reading:

1. For every 1 ^{0}C above 20 ^{0}C add 0.36 g/l
2. For every 1 ^{0}C below 20 ^{0}C subtract 0.36 g/l

The room temperature during the sedimentation hydrometer experiment was 29 ^{0}C.

Plate 1. Sedimentation Hydrometer Experiment for Soil Particle Size Determination

2.1 Analysis and Modeling

Regression Calculator statistical software was employed for regression analysis of the experimental data. It does not require any programming or some sort of command. Couple of options was adopted for data input. This include making data on screen, restoration of software from that of the last session and generating a random data set. Hence, OLS (Ordinary least squares) estimates for regression slope parameters, t-statistics for each slope parameter and its p-value, analysis of variance, other model statistics such as F, R^2, and the like, critical values for t-distribution and F-distribution were obtained.

3. RESULTS AND DISCUSSION

Results from obtained from sieving is given in Table 4, Table 5, Table 6 and Table 7 for soil samples I, II, III and IV respectively. While sedimentation hydrometer readings as obtained from the experiment is shown in Table 8, Table 9 Table 10 and Table 11 for soil samples I, II, III and IV respectively. Meanwhile, Table 12 shows the sample average for sedimentation hydrometer reading. Regression analysis conducted for the experiment is given in Table 13. Figure 1 – 5 shows the graphical analyses for the sieve analyses. Adopting a polynomial function of order 2, Sample I, II, III, IV and sample mean gave R^2 of 0.986, 0.985, 0.987, 0.981 and 0.985, respectively.

Table 4. Sieve analysis of the experimental field (Sample I)

Sieve Size (mm)	weight retain (g)	% retain	% passing
2	91	4.12	95.88
1.7	72	3.26	92.61
1.4	86	3.90	88.72
0.3	1011	45.81	42.91
0.15	509	23.06	19.85
0.075	229	10.38	9.47
< 0.075	209	9.47	0.00

Table 5. Sieve analysis of the experimental field (Sample II)

Sieve Size (mm)	weight retain (g)	% retain	% passing
2	112	4.98	95.02
1.7	62	2.76	92.26
1.4	78	3.47	88.79
0.3	1020	45.39	43.39
0.15	503	22.39	21.01
0.075	270	12.02	8.99
< 0.075	202	8.99	0.00

Table 6. Sieve analysis of the experimental field (Sample III)

Sieve Size (mm)	weight retain (g)	% retain	% passing
2	101	4.22	95.78
1.7	49	2.05	93.74
1.4	87	3.63	90.10
0.3	1120	46.76	43.34
0.15	603	25.18	18.16
0.075	230	9.60	8.56
< 0.075	205	8.56	0.00

Table 7. Sieve analysis of the experimental field (Sample IV)

Sieve Size (mm)	weight retain (g)	% retain	% passing
2	98	4.32	95.68
1.7	58	2.55	93.13
1.4	87	3.83	89.30
0.3	998	43.95	45.35
0.15	540	23.78	21.58
0.075	301	13.25	8.32
< 0.075	189	8.32	0.00

Table 8. Sedimentation Hydrometer Particle Size Distribution (Sample I)

Block	Hydrometer Readings after 40 s (g/l)	Hydrometer Readings after 2 hrs (g/l)	Silt + Clay (%)	Clay (%)	Sand (%)	Silt (%)
1	15	5	33.24	13.24	66.76	20.00
2	13	5	29.24	13.24	70.76	16.00
3	13	5	29.24	13.24	70.76	16.00
4	10	5	23.24	13.24	76.76	10.24
Mean			**28.24**	**13.24**	**71.26**	**15.56**

Table 9. Sedimentation Hydrometer Particle Size Distribution (Sample II)

Block	Hydrometer Readings after 40 s (g/l)	Hydrometer Readings after 2 hrs (g/l)	Silt + Clay (%)	Clay (%)	Sand (%)	Silt (%)
1	14	5	31.05	13.27	68.95	17.78
2	13	5	30.34	12.94	69.66	17.40
3	15	5	29.16	13.51	70.84	15.65
4	10	5	25.54	13.26	74.46	12.28
Mean			**29.02**	**13.25**	**70.98**	**15.78**

Table 10. Sedimentation Hydrometer Particle Size Distribution (Sample III)

Block	Hydrometer Readings after 40 s (g/l)	Hydrometer Readings after 2 hrs (g/l)	Silt + Clay (%)	Clay (%)	Sand (%)	Silt (%)
1	15	5	28.26	13.24	71.74	15.02
2	12	5	30.56	13.35	69.44	17.21
3	15	5	29.64	13.31	70.36	16.33
4	12	5	26.04	13.08	73.96	12.96
Mean			**28.63**	**13.25**	**71.38**	**15.38**

Table 11. Sedimentation Hydrometer Particle Size Distribution (Sample IV)

Block	Hydrometer Readings after 40 s (g/l)	Hydrometer Readings after 2 hrs (g/l)	Silt + Clay (%)	Clay (%)	Sand (%)	Silt (%)
1	15	5	31.01	12.98	69.00	18.03
2	13	5	28.65	13.29	71.35	15.36
3	13	5	26.24	13.22	72.76	13.02
4	12	5	28.04	12.99	71.96	15.05
Mean			**28.49**	**13.12**	**71.28**	**15.37**

Table 12. Sedimentation Hydrometer Particle Size Distribution (Sample Mean)

Sample	Silt + Clay (%)	Clay (%)	Sand (%)	Silt (%)
1	28.24	13.24	71.26	15.56
2	29.02	13.25	70.98	15.78
3	28.63	13.25	71.38	15.38
4	28.49	13.12	71.28	15.37
Mean	28.60	13.22	71.23	15.52

Table 13. Regression Analysis

β Estimates				
Variable	β estimate	SE	t-value	Pr> |t|
X0	-1.72	0.33	-5.19	0
X1	0.05	0	11.63	0
ANOVA				
Source	DF	SS	MS	F
Model	1	5.2	5.2	135.37
Error	14	0.54	0.04	
Total	15	5.74		
Other Stats				
F	135.37			
p-value(F)	0			
R-SQR	0.98			
Adj. R-SQR	0.96			
root MSE	0.2			

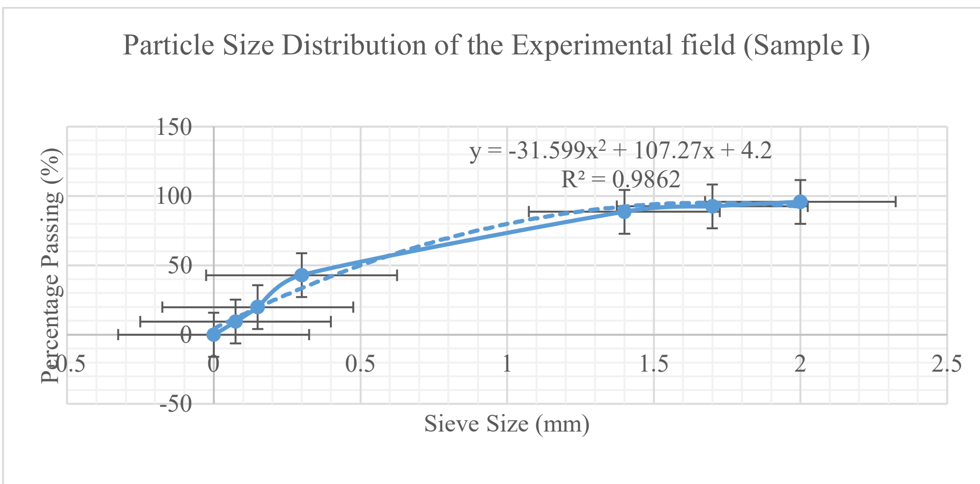


Figure 1. Particle Size Distribution of the Experimental field (Sample I)

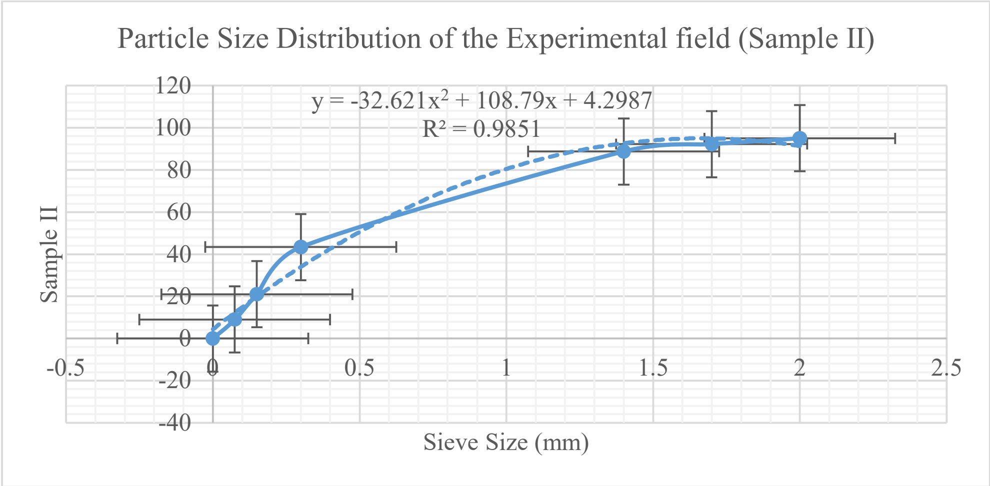


Figure 2. Particle Size Distribution of the Experimental field (Sample II)

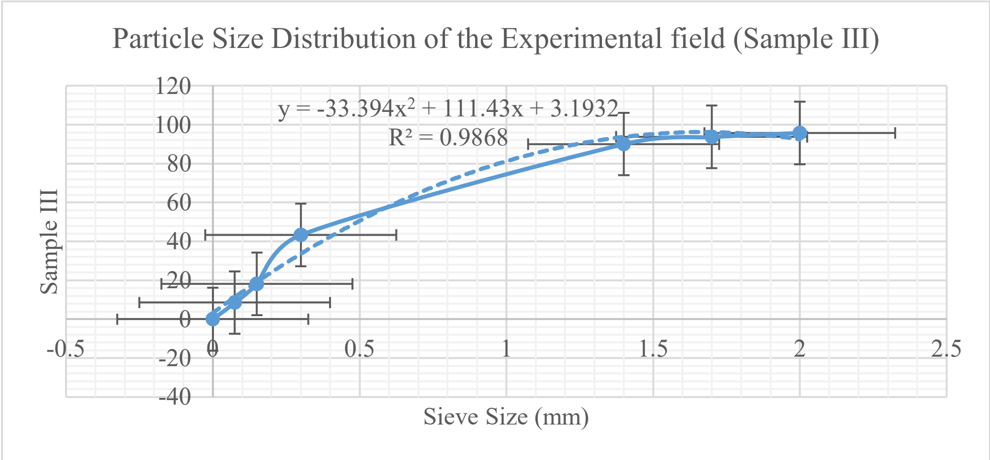


Figure 3. Particle Size Distribution of the Experimental field (Sample III)

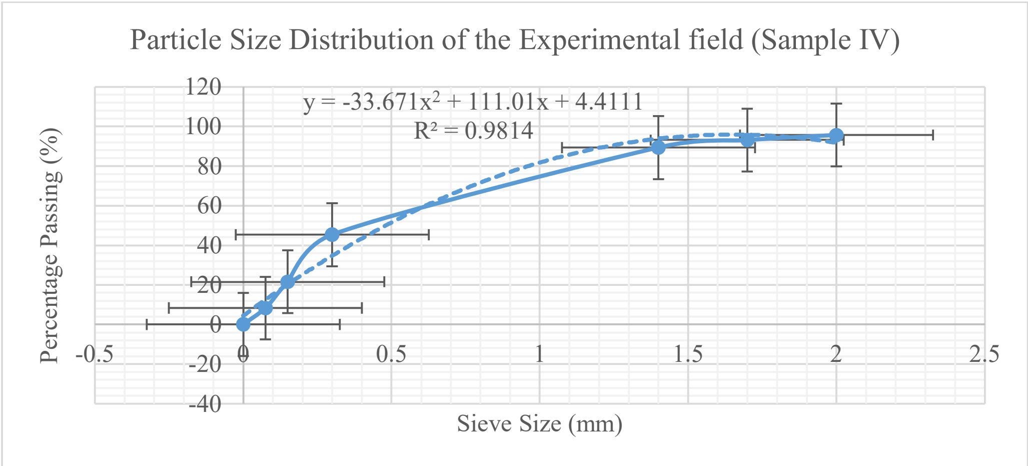


Figure 4. Particle Size Distribution of the Experimental field (Sample IV)

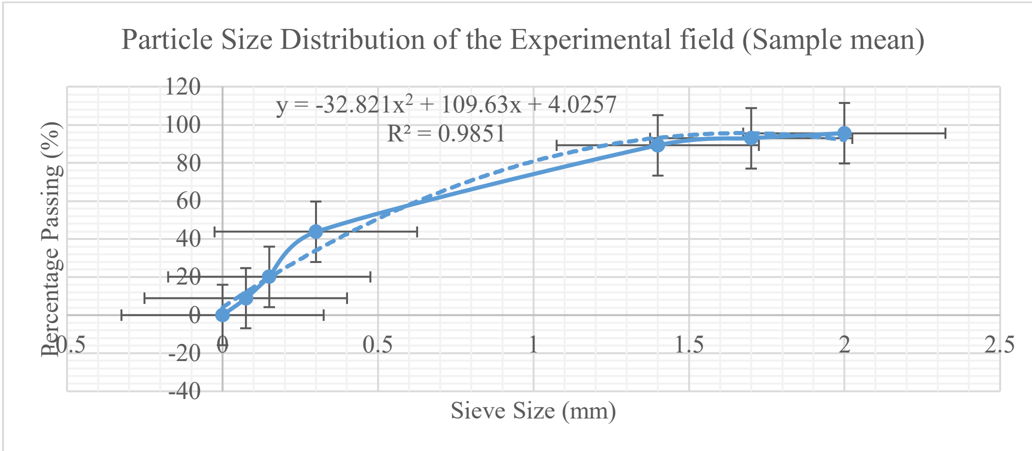
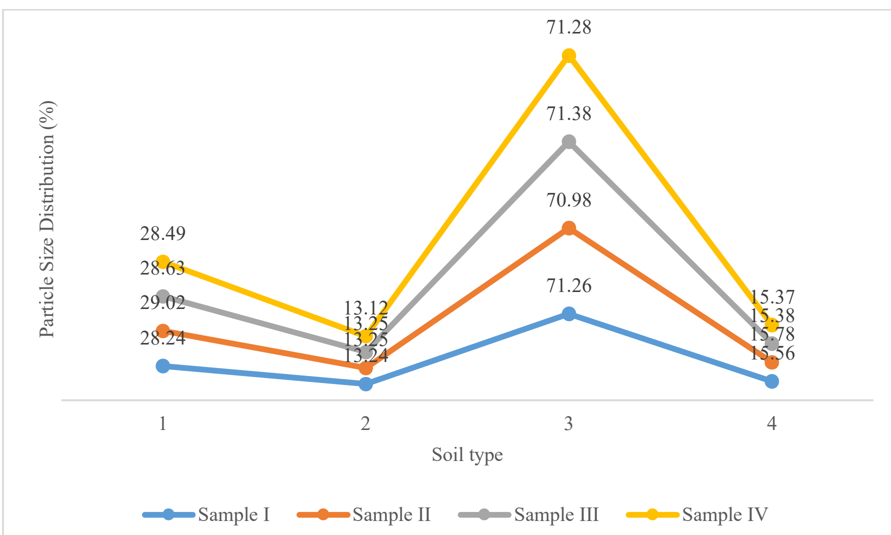


Figure 5. Particle Size Distribution of the Experimental field (Sample mean)

3.1 Result Validation

Sedimentation hydrometer observation means were used to validate the results of the experiment through graphical analysis of individual sample mean at every distinct soil composition (clay, silt and sand) (see Figure 6). Block mean for each sample were correlated with overall sample mean as obtained in Figure 7, 8, 9 and 10, respectively. Sample blocks means were adequately correlated with sample mean with $p < 0.05$ and R^2 of 0.99, 0.99, 1.00 and 1.00 for Sample I, Sample II, Sample III and Sample IV respectively. This showed that there is no significant difference between the soil samples. The experimental field soil was established to be sandy-loam using textural triangle (see Figure 11).



LEGEND

I	Silt + Clay
II	Clay
III	Sand
IV	Silt

Figure 6. Graphical Analysis of Sample Block mean

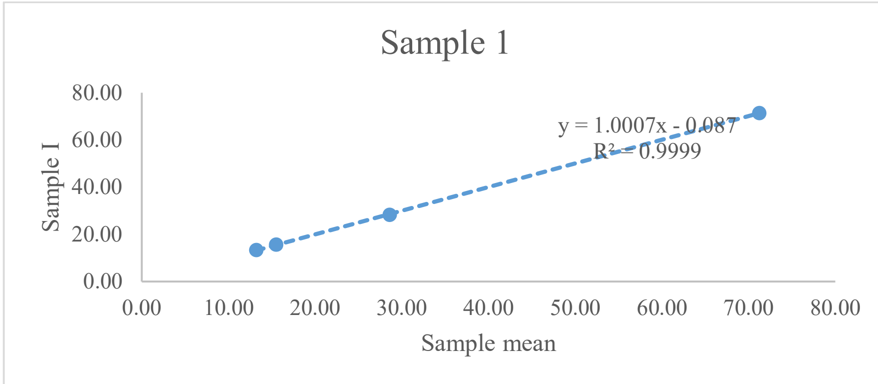


Figure 7. Sample I (Block mean vs Sample mean

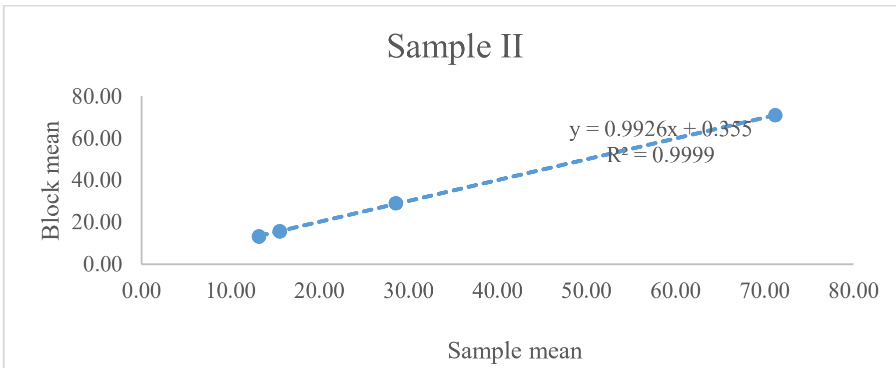


Figure 8. Sample II (Block mean vs Sample mean)

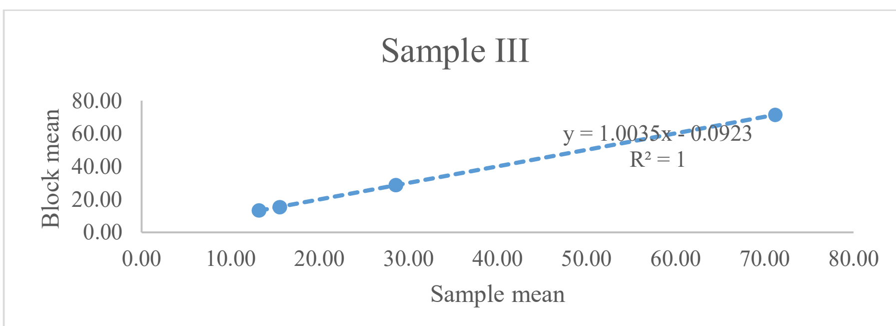


Figure 9. Sample III (Block mean vs Sample mean)

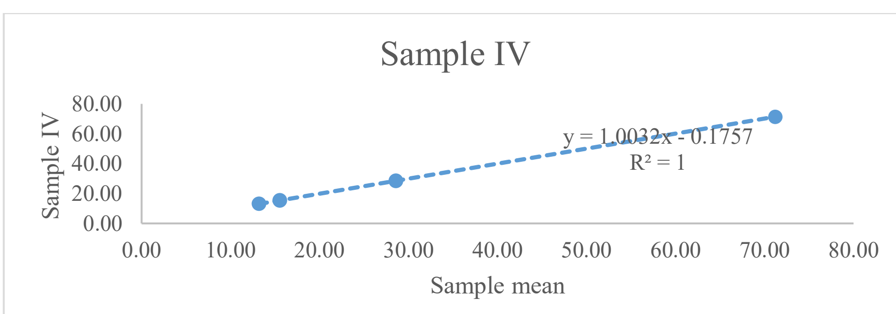


Figure 10. Sample IV (Block mean vs Sample mean)

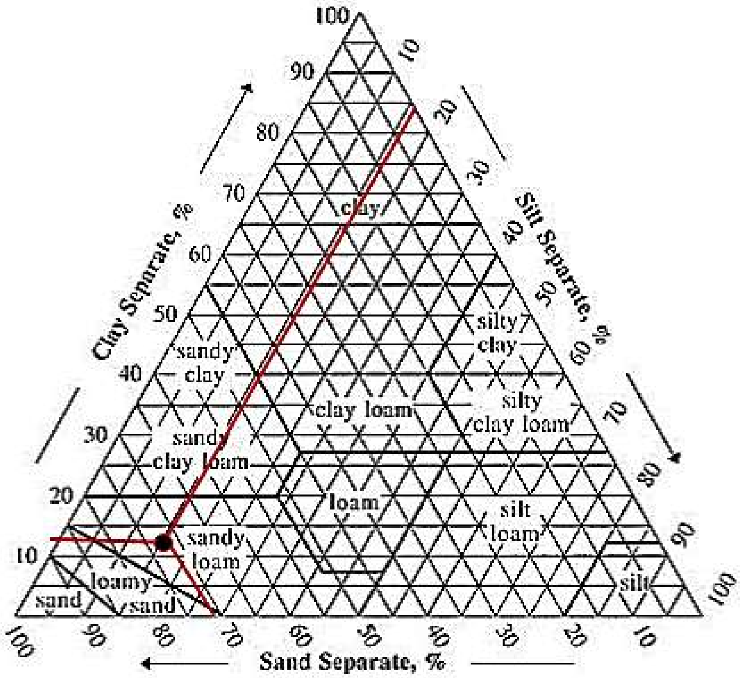


Figure 11. Textural Triangle Showing Sandy loam Soil Analyzed from Particle Size Distribution

4. CONCLUSION

Sieving method of particle size distribution is less technical but most time not adequately enough to determining the soil type. The usage would not be enough to determine field soil type as always experienced in soil with much combined clay and silt particles which cannot be distinctly separated especially when appropriate sieve size is not readily available. Moreover, finer soil particles are easily suspended in solution since they have different densities and would always settle at different time and phases. Settlement time, colloidal forms and clarity in solution are functions of individual particles that made up the soil.

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