RESEARCH ARTICLE

A time-efficient and accurate texture analysing method for tropical soils

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ABSTRACT

Analysing soil texture involves aggregate separation followed by fractionation. Among different methods of soil texture analysis, pipette method is considered as the most accurate although it is laborious and time consuming due to lengthy pre-treatment procedures. This study compares two variants of pipette method with the objective of selecting a time-efficient method without compromising the precision and accuracy of assessment. The International Soil Reference and Information Centre (ISRIC) method is lengthier and more chemical consuming than the Kellogg Soil Survey Laboratory (KSSL) method despite assuring better accuracy and precision. In this study, thirteen soil samples with different textural compositions were subjected to both procedures. Coefficient of variation (CV) values of two methods were similar indicating comparable precision of the KSSL method (KSSL; 0.22, 0.42, 0.44 and ISRIC; 0.19, 0.47, 0.33 for sand, clay and silt, respectively). Pearson correlations analysis revealed high correlations for sand (0.99), clay (0.91) and silt (0.72) for two methods indicating strong resemblance of analytical results. A very low root mean square error (sand 4.4%) of KSSL method further indicated similarity of analytical results. Furthermore, two sample t-test results revealed no significant difference (P<0.05) between each particle sizes of the two methods. Therefore, the KSSL method can be recommended as a time and cost effective method over the ISRIC method for soils of Sri Lanka for analysing texture.

Keywords: *ISRIC method, KSSL method, pipette method, pre-treatment, soil texture analysis*

INTRODUCTION

Soil particle size distribution is one of the important soil properties in expressing physical, chemical and biological characteristics of soil. It refers to the relative size distribution of primary soil particles; sand (diameter range: 2 to 0.05 mm), silt (0.05 to 0.002 mm) and clay (<0.002 mm) (Kettler *et al.*, 2001). Soil textural composition affects soil-water retention characteristics, hydraulic parameters, leaching and erosion potential, plant nutrient and organic matter storage (Taubner *et al.*, 2009; Plante *et al.*, 2006; Kettler *et al.*, 2001; Cosby *et al.*, 1984).

In complex soil systems, soil particles are mostly in the form of aggregates as a result of rearrangement, flocculation and cementation of particles. Aggregating agents such as soil organic matter (OM), biota, ionic bridging, clay and carbonates can be synergistic or disruptive to the aggregation (Bronick and Lal, 2005). Most widely used methods of determining soil texture are pipette method (Olmstead *et al.*, 1930) and hydrometer method (Gee and Bauder, 1986). Pipette method is considered more accurate. Different pre-treatment procedures of soil samples have been incorporated to pipette method with varying complexity. Some methods involve time consuming processes while others are time efficient.

In pipette method of soil textural analysis, the soil is first dispersed chemically and mechanically and then fractionated. Thereafter, sand fraction is quantified by sieving, followed by sedimentation (Kettler *et al.*, 2001) to determine silt and clay fractions. Dispersion refers to removal of colloid coatings on primary particles and separation of aggregates into single grains (Olmstead *et al.*, 1930). Destruction of aggregates is done by destroying the binding agents (Olmstead *et al.*, 1930) such as OM, carbonates and iron oxides using pretreatments. The basic principle of chemical dispersion is particle repulsion (Gee and Bauder, 1986). Sodium hexametaphosphate ($(NaPO_3)_6$; Calgon) is commonly used for chemical dispersion by enriching the iron exchange complex of particle surface with Na^+ (Kettler *et al.*, 2001). Physical dispersion is performed using a mechanical shaker. Separation of size classes of clay and silt at suspension is based on the relationship of the size of particle to its terminal velocity when settle freely in a suspension (Gee and Bauder, 1986).

The International Soil Reference and Information Centre (ISRIC) method (Van Reeuwijk, 2002) is one of the methods of soil texture determination that has been used in research, and was in use at the ISRIC Laboratory. It comprises of lengthy time consuming pre-treatment procedure with higher accuracy and precision. The Kellogg Soil Survey Laboratory (KSSL) method (Kellogg Soil Survey Laboratory Methods Manual, 2014) is another variant of the pipette method that uses the principle of the ISRIC method but is more efficient and cost effective.

Sri Lanka is a proper place to compare texture analysis methods since it has a range of soil textural classes. This study is aimed at comparing the KSSL method with the ISRIC method to find a time efficient method of texture analysis for highly weathered tropical soils.

MATERIALS AND METHODS

Sample selection and preparation

Soil samples were selected representing major great soil groups of Sri Lanka from the soil archive of the Department of Soil Science, University of Peradeniya. Thirteen samples representing a wide range of textural classes were selected using the feel method (Thien, 1979) and considering organic carbon (OC) and $CaCO_3$ percentage ranges of the samples. The Walkley and Black method modified by Nelson and Sommers (1982) was used to determine OC. Calcium carbonate percentages were determined as described in the ISRIC method (Van Reeuwijk, 2002).

Air dried samples were sieved through a 2 mm sieve to separate fine earth fraction. Moisture contents of the samples were determined by oven drying.

Twenty grams of <2 mm fraction of air dried soil was obtained for the analysis.

Methods of sample analysis

Selected samples were analysed using the ISRIC (Van Reeuwijk, 2002) and KSSL methods (Kellogg Soil Survey Laboratory Methods Manual, 2014). The major difference between the two methods was the method of $CaCO_3$ treatment. In the ISRIC method, $CaCO_3$ was treated using HCl by considering the $CaCO_3$ content of samples. In comparison, KSSL method used a same amount of sodium acetate buffered at pH 5 to remove $CaCO_3$ irrespective to the initial carbonate contents. Furthermore, the steps followed in the ISRIC method to remove dissolved salts are lengthy and time consuming.

Settling time calculation

The settling times for the fractions <0.05 mm and <0.002 mm were calculated for a depth of 10 cm using the Storks' law (Gee and Bauder, 1986; Jackson and Saeger, 1935) to obtain sub-samples of silt and fractions, respectively, as given below.

$$T = \frac{9\eta L}{2r^2(\rho_p - \rho_l)g}$$

T = time after shaking (s)

L =depth of settling (cm)

η=viscosity of dispersing medium (poises)

ρ_p= density of particles (g cm^{-3})

ρ_l= density of dispersing medium (g cm^{-3})

g = acceleration of gravity (cm sec^{-2})

r = radius of particles (cm)

Fractionation

The suspension in the sedimentation jar was thoroughly shaken using a plunger for 1 min. Prior to relevant settling times, a 25 mL bulb pipette was immersed to a depth of 10 cm of soil suspension and 25 mL was pipetted out at exact settling times. Pipetted suspensions were transferred to a 50 mL beaker and then oven-dried at 104 °C until a constant weight was achieved. The remaining soil solution was washed through a 0.05 mm sieve and sand particles remained on the sieve were washed into a beaker and oven dried at 104 °C.

Calculation of particle sizes

All the oven dried weights were taken after obtaining a constant weight to the nearest 0.001 g. Calculations were done using the below equations.

$$\text{Sand \%}= \frac{\text{Mass of sand in total sample}}{\text{Mass of sand+silt+clay}} X100 \tag{1}$$

$$\text{Silt + Clay \%}= \left[\frac{\text{(Silt+ mass of clay in 25 ml aliquot/Pipette volume)X1000}}{\text{Mass of sand+silt+clay}}\right] X100 \tag{2}$$

$$\text{Clay \%}= \left[\frac{\text{(Mass of clay in 25 ml aliquot/ Pipette volume)x1000}}{\text{Mass of sand+silt+clay}}\right] \text{X100} \tag{3}$$

Sand and clay percentages of the samples were obtained from the Equations 1 and 3, respectively. Silt percentage was obtained by the difference between the Equations 2 and 3.

Statistical analysis

Two sample t-test was used to determine similarity of textural fractions measured by two methods. The relationship between textural measurements made using the two methods was analysed using scatter diagrams and Pearson correlations.

RESULTS AND DISCUSSION

Range of soil textural classes

Soil samples for the analysis were selected representing several soil textural classes in Sri Lanka. Texture analysis of the samples showed a range of soil textural classes as sandy loam, sandy clay loam, loam, loamy sand and clay representing Rhodudults, Plintustalfs, Ustropepts and Pellusterts in USDA soil taxonomy.

Distribution of organic matter contents

Soils of Sri Lanka have a range of soil OM content. Different researchers have found out a range of soil OC contents under different plantations. According to Wickramasinghe and Wijewardena (2003), soil OM varies from <1 – 3% in paddy soils. Loganathan *et al.,* (1984) have stated that OM content of coconut growing soils varies from 0.26 – 3.65%. Considering research findings on OM, it can be said that the soil OM varies from <1 to 4% in Sri Lanka. Table 1 shows the contents of OM and $CaCO_3$ in tested soil samples. Organic matter percentage of the samples ranged from 0.32 to 3.21% covering the OM range of soils in Sri Lanka.

Table 1: Contents of organic matter and calcium carbonate of the samples.

Sample	Organic Matter ($g\ kg^{-1}$)	$CaCO_3$ ($g\ kg^{-1}$)
1	18.8	15.0
2	3.2	10.0
3	15.5	5.0
4	11.1	7.5
5	17.0	15.0
6	32.1	35.0
7	5.3	7.5
8	18.8	5.0
9	3.2	12.5
10	15.5	2.5
11	11.1	12.5
12	17.0	2.5
13	32.1	5.0

Distribution of calcium carbonate contents

Calcium carbonate contents of soils of Sri Lanka have not been well documented. However, the value of $CaCO_3$ ranged from 0.25 to 3.5% in thirteen samples (Table 1). Total removal of OM, $CaCO_3$ and moisture from the initial soil weight ranged from 3.08 to 9.28%. A large range in the total removal indicated that there is a possibility to get different percentages of sand, silt and clay according to the texture analysis method used.

Statistical analysis

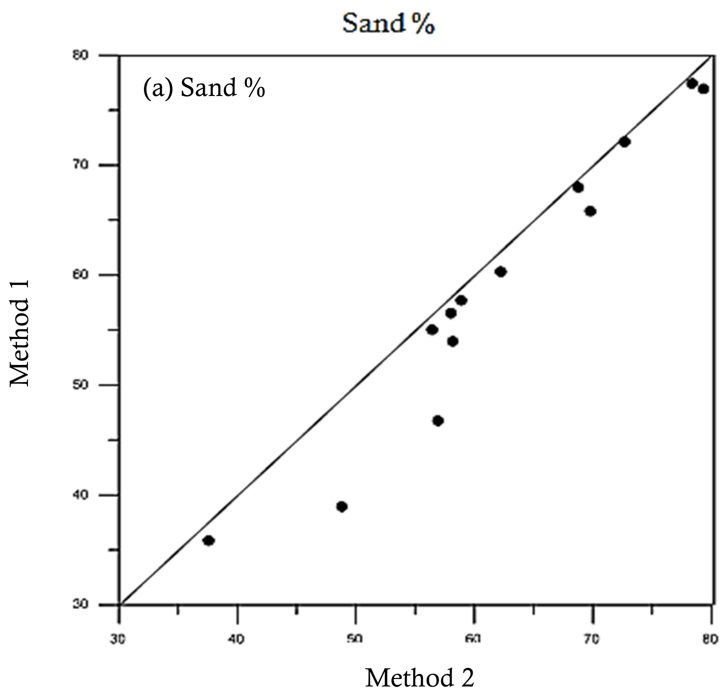
According to the statistical analysis, clay percentage of the samples ranged from 7.4 to 41.3% in ISRIC method and 11.5 to 50.2% in KSSL method. Sand percentage ranged from 37.4 to 83.7% in ISRIC method and 37.5 to 82.6% in KSSL method. It indicated that the samples are having a well distribution among sandy and clayey soils.

The coefficient of variation (CV) is a dimensionless measure of the dispersion of data around the mean. Statistical analysis showed almost similar CV values for sand, clay and silt percentages of the two methods (Table 2). This result explained a comparable precision of the KSSL method compared to the ISRIC method.

Table 2: Coefficient of variation values of sand, silt and clay percentages of the two methods.

Parameter	ISRIC Method	KSSL method
Sand (%)	0.19	0.22
Clay (%)	0.47	0.42
Silt (%)	0.33	0.44

Correlation measurements indicate the strength of the linear relationship between two variables. The closer the points lie to the 45° line in scatter plots, the stronger accuracy of the KSSL method. Pearson correlations analysis revealed strong positive correlations of sand (r = 0.99), clay (r = 0.91) and silt (r = 0.72) percentages measured with the two methods. Figure 1 shows scatter plots of textual fractions measured using two methods. The KSSL method showed little underestimation of sand compared to the ISRIC method and clay content measurements of the KSSL method showed an overestimation (Figure 1).



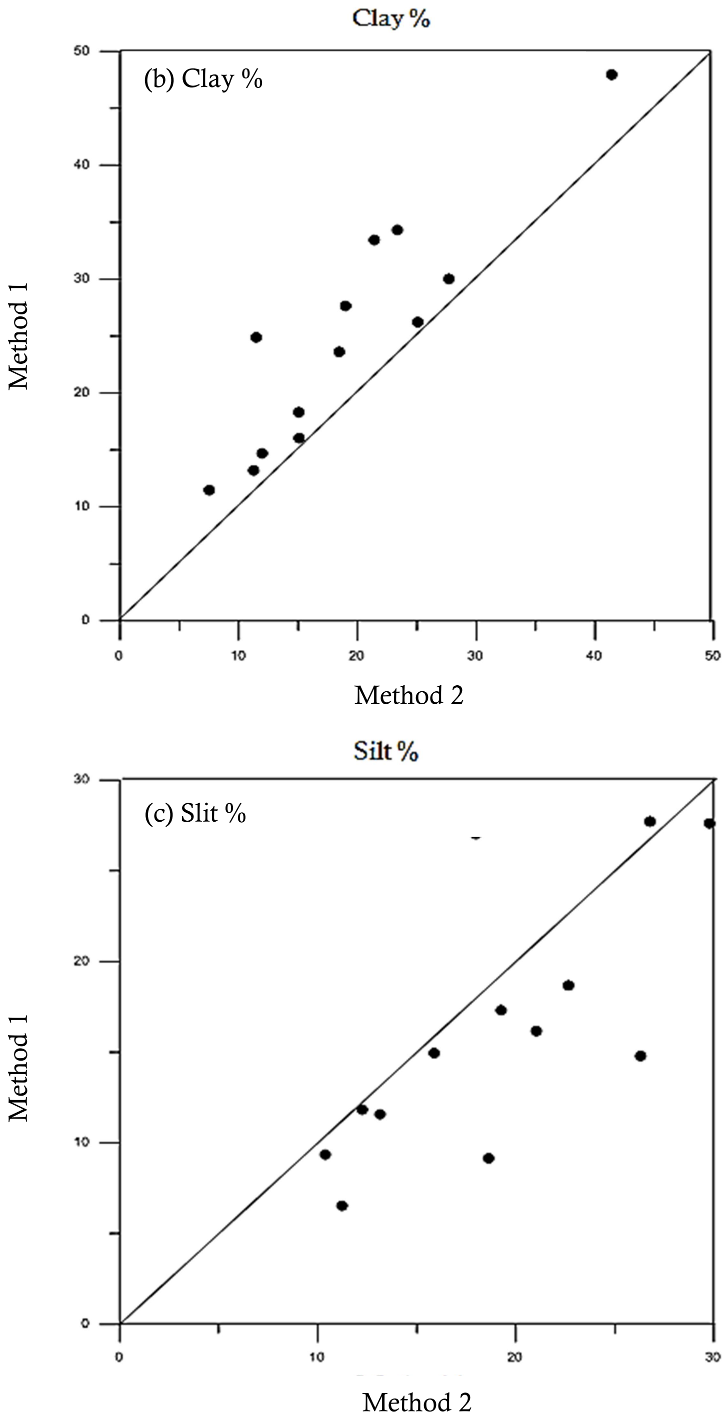


Figure 1: Scatter plots of (a) sand, (b) clay and (c) silt percentages of two methods (Method 1: ISRIC method and Method 2: KSSL method).

Root mean square estimation errors (RMSEE) of sand, clay and silt of the two methods were 4.4, 6.9 and 5.4, respectively. Root mean square estimation error measures the square root of the difference between the predicted and actual values (residual error). Low RMSEE values showed less errors of the methods tested.

Two sample t-test results did not show any significant difference (P>0.05) between average sand, silt and clay percentages of two methods of soil texture analysis.

CONCLUSION

The results of textural fractions determined showed more or less same analysis results with both methods. Therefore, cost and time effective KSSL method can be considered as more acceptable and highly potential alternative method for ISRIC to analysis of soil texture.

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