Measuring particle size distribution: Can the differences among examined soils and methods be proven?

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Abstract
Knowledge on particle size distribution of soils is the basis for construction activities (green field investments, houses, roads etc.), land use, soil management, soil protection, soil fertilizing etc. It plays an important role in the everyday life of people. Numerous methods exist for measuring particle size distribution. Older ones are used just as well as new technologies. A continually increasing need for precisely measured soil parameters is obvious and there is also a big need for easier methods and for exclusion of as much influencing circumstances as possible. The present research focuses on the comparison of different methods used in Hungarian institutions. Eight soils were analysed in four institutions with three methods. Different analytical methods produced different results for particle size distribution. χ^2 analyses revealed significant differences with different p values. There was a big influence detected by laboratory personnel (the analyses were repeated and one method had less than 5% error, while another had more than 20%). It appears that not only do the well known differences between methods, sample preparation and physical background matter but also there are other factors (e.g. routine vs closely checked analyses) which may influence the results.

Key Words
Particle size, laboratory measurement, comparison of methodologies, comparison of classes.

Introduction
Soil particles serve as a basis for understanding numerous soil processes. Particle-size distribution (PSD) is often used in estimating soil moisture characteristics or hydraulic conductivity (e.g. water-retention curve (Gupta and Larson 1979), saturated conductivity (Mishra *et al.* 1989), unsaturated conductivity (Bittelli *et al.* 1999; Arya and Paris 1981; Campbell and Shiozawa 1992, Alexander *et al.* 1987), and for various other purposes, e.g. for nutrient acquisition (Anderson *et al.* 2006), etc. Determination of PSD by sieving, hydrometer, pipette methods or by laser diffraction (LD) (Bah *et al.* 2009, Hernádi *et al.* 2008) suffers from inherent flaws, mainly due to the difficulty in defining the size of irregularly shaped particles (Eshel *et al.* 2004). Estimating hydraulic properties from particle-size data is preferred when studying soil moisture at catchment or watershed scales. In these cases a detailed characterization of hydraulic properties is usually not possible but particle-size data may be available from regional or national soil databases (Skaggs *et al.* 2001, Nemes *et al.* 1999). Unfortunately, many databases do not contain the full particle-size distribution; only the sand, silt, and clay mass fractions (Skaggs *et al.* 2001, Arya *et al.* 1999). In the present study we wish to analyse different samples and methods to show the possibility of proving similarities or differences.

Methods
Aerometer method: the method is based on measuring the density of soil suspension at different times during sedimentation (MSZ 14043/3: 1979). The aerometer method was used by the University of Szeged.
Pipette method: samples are taken from the settling soil suspension at 5 different times with a pipette. Samples are dried and weighed then the different fractions are calculated based on Stokes' law (MSZ-08-0205: 1978). The pipette method was used by the University of Szeged, Debrecen and West Hungary.
Laser method: the Geographical Research Institute of the Hungarian Academy of Sciences used the laser

method to measure particle sizes with Laser Particle Sizer Analysette 22 MicroTec.
Explanation of codes of sample sites is in Table 1. Hierarchical Cluster Analysis was used to find similar samples, while the χ^2 test was used to find similarities among the methods used.

Results

Results of particle size measurements with different methods applied on eight samples are in Table 1.

Table 1. Results of particle size measurements in different institutes with various methods.

Sample code	Particle size class, Replicate 1/3				Sample code	Particle size class, Replicate 2			
	<0.002	0.002-0.02	0.02-0.05	0.05-2		<0.002	0.002-0.02	0.02-0.05	0.05-2
S_BOR_A_1	5.0	26.3	34.7	34.0	S_BOR_A_2	11.4	15.6	48.0	25.0
S_GAH_A_1	18.2	36.3	18.5	27.0	S_GAH_A_2	18.2	36.3	22.0	23.5
S_GFH_A_1	21.6	30.4	18.0	30.0	S_GFH_A_2	19.5	31.5	14.5	34.5
S_SZG_A_1	15.0	33.8	29.2	22.0	S_SZG_A_2	15.0	32.2	31.8	21.0
S_TUR_A_1	29.0	31.0	21.5	18.5	S_TUR_A_2	29.0	29.0	23.0	19.0
S_KMA_A_1	0.0	1.0	3.0	96.0	S_KMA_A_2	0.0	2.0	5.2	92.8
S_FES_A_1	15.5	18.0	26.5	40.0					
S_GAL_A_1	11.8	32.7	37.7	17.8	S_GAL_A_2	11.0	32.0	26.4	30.6
S_BOR_P_1	4.2	8.4	7.0	80.4	S_BOR_P_2	5.1	8.7	6.2	79.9
S_GAH_P_1	39.6	29.1	1.2	30.1	S_GAH_P_2	37.9	28.1	1.0	33.1
S_GFH_P_1	37.0	32.8	11.2	19.1	S_GFH_P_2	35.9	36.4	12.0	15.7
S_SZG_P_1	10.0	31.5	24.8	33.7	S_SZG_P_2	9.8	30.1	24.7	35.5
S_TUR_P_1	18.4	31.1	17.1	33.3	S_TUR_P_2	18.2	30.2	17.0	34.6
S_KMA_P_1	0.4	2.6	0.2	96.8	S_KMA_P_2	0.4	2.7	0.2	96.7
S_FES_P_1	12.6	22.8	15.9	48.7	S_FES_P_2	10.9	22.4	15.3	51.4
S_GAL_P_1	10.2	26.3	32.2	31.2	S_GAL_P_2	10.1	25.7	33.2	31.1
F_BOR_L_1	3.4	38.2	26.6	31.8	F_BOR_L_1	3.4	38.2	26.6	31.8
F_GAH_L_1	20.1	65.7	8.0	6.2	F_GAH_L_1	20.1	65.7	8.0	6.2
F_GFH_L_1	21.0	64.0	9.2	5.8	F_GFH_L_1	21.0	64.0	9.2	5.8
F_SZG_L_1	9.7	58.4	16.6	15.3	F_SZG_L_1	9.7	58.4	16.6	15.3
F_TUR_L_1	21.1	61.8	10.5	6.7	F_TUR_L_1	21.1	61.8	10.5	6.7
F_KMA_L_1	1.1	4.5	1.7	92.7	F_KMA_L_1	1.1	4.5	1.7	92.7
F_FEF_L_1	7.3	41.6	12.4	38.7	F_FEF_L_1	7.3	41.6	12.4	38.7
F_GAL_L_1	14.7	53.6	19.5	12.2	F_GAL_L_1	14.7	53.6	19.5	12.2
D_BOR_1	1.9	16.2	20.5	61.4	D_BOR_2	5.3	28.7	21.9	44.1
D_GAH_1	27.0	44.8	15.6	12.6	D_GAH_2	31.4	39.6	17.9	11.1
D_GFH_1	27.5	47.2	12.6	12.7	D_GFH_2	25.0	42.9	17.1	15.0
D_SZG_1	8.4	39.7	27.1	24.8	D_SZG_2	7.4	38.0	26.5	28.1
D_TUR_1	32.1	40.4	15.8	11.7	D_2UR_2	26.5	37.2	21.3	15.0
D_KMA_1	0.0	0.7	6.1	93.2	D_KMA_2	0.0	0.2	1.4	98.4
D_FES_1	10.6	32.5	21.5	35.4	D_FES_2	5.3	22.9	20.7	51.1
D_GAL_1	9.0	38.7	34.8	17.5	D_GAL_2	7.8	36.2	32.0	24.0
N_BOR_1	7.0	30.0	53.2	9.8	N_BOR_2	5.0	32.0	51.7	11.3
N_GAH_1	45.0	28.0	24.7	2.3	N_GAH_2	47.0	24.0	26.5	2.6
N_GAH_3	47.0	24.0	26.3	2.7					
N_GFH_1	47.0	26.0	25.0	2.0	N_GFH_2	49.0	22.0	27.1	1.9
N_GFH_3	47.0	24.0	26.8	2.2					
N_SZG_P_1	25.0	28.0	44.6	2.4	N_SZG_P_2	23.0	34.0	40.6	2.4
N_SZG_P_3	25.0	32.0	40.4	2.6					
N_TUR_1	47.0	26.0	24.2	2.8	N_TUR_2	47.0	26.0	24.1	2.9
N_TUR_3	47.0	24.0	26.2	2.7					
N_KMA_1	3.0	0.0	25.1	71.9	N_KMA_2	3.0	0.0	25.7	71.4
N_KMA_3	3.0	0.0	26.8	70.3					
N_FES_1	21.0	16.0	35.6	27.4	N_FES_2	21.0	20.0	36.0	23.0
N_FES_3	21.0	18.0	37.3	23.7					
N_GAL_1	21.0	32.0	43.5	3.6	N_GAL_2	21.0	30.0	45.2	3.8
N_GAL_3	27.0	28.0	41.7	3.3					

S=Univ. of Szeged, F=Hungarian Academy of Sciences, D=Univ. of Debrecen, N=Univ. of West Hungary, BOR=Borzsony, GAH=Gyongyostarjan, lower slope third, GFH=Gyongyostarjan, upper slope third, SZG=Szt.Gyorgyvar, TUR=Tura, KMA=Kiskunmajsa, FES=Fs, GAL=Galgaheviz, A=Aerometer, P=Pipette, L=Laser

Based on the results of particle size measurements (Table 1) two approaches were used to analyse the data. First the groups were formed by Pearson Correlation. Hierarchical cluster analyses show the connection between the different examined soils (Figure 1).

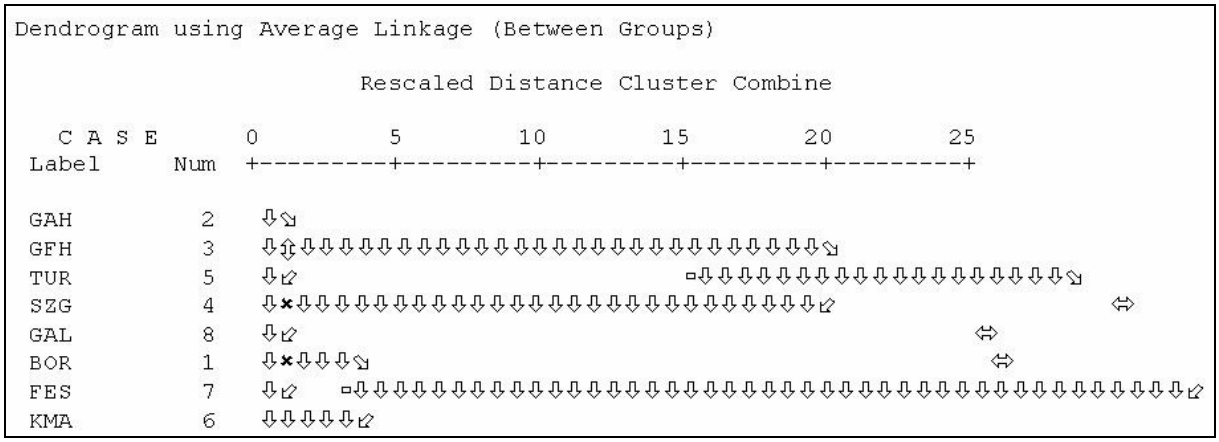

Figure 1. Hierarchical Cluster Analyses of the data of groups formed by Pearson Correlation

The second group was formed by Squared Euclidean Distance method.

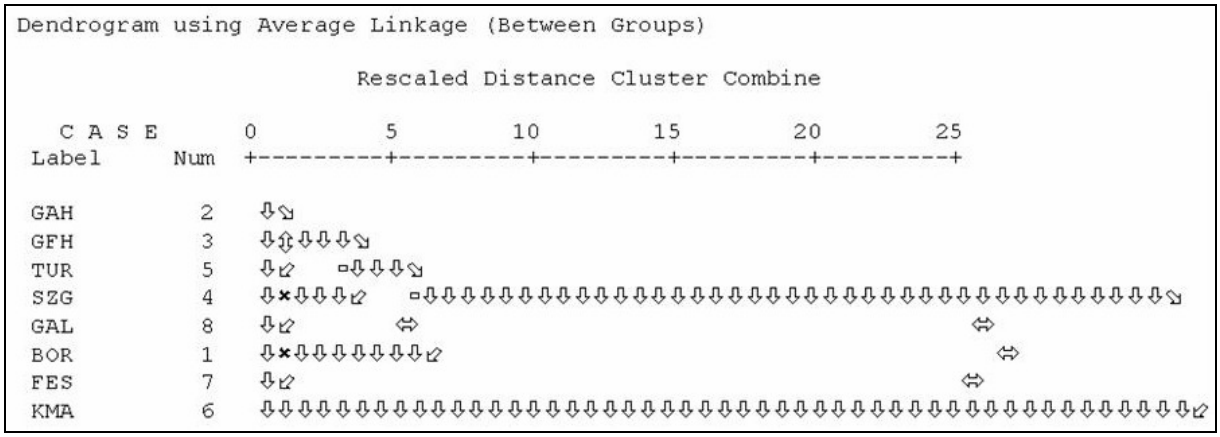

Figure 2. Hierarchical Cluster Analyses of the data of groups formed by Squared Euclidean Distance method.

Both methods of group separation gave the same results, revealing similar groups are as follows:

1. GAH, GFH, TUR;
2. SZG and GAL;
3. BOR and FES (similar but a little further away is KMA);

Values for χ^2 were examined to reveal significant differences among the measurement methods. The measured values were compared to the theoretical values, based on the homogeneity test of the measured values (Table 2).

Table 2. Results of statistical analyses.

Sample sites	df	Critical value	p	χ^2 value
Borzsony (BOR)	6	16.8	<0.01	19.83
Gyongyostarjan (GAH)	6	22.5	<0.001	43.80
Gyongyostarjan (GFH)	6	22.5	<0.001	52.54
SztGyorgyvar (SZG)	6	16.8	<0.01	18.53
Tura (TUR)	6	22.5	<0.001	29.33
Kiskunmajsa (KMA)	6	12.6	<0.05	15.09
Fs (FES)	6	16.8	<0.01	20.97
Galgaheviz (GAL)	6	16.8	<0.01	18.79

According to Table 2, there are significant differences between the measurements. In case of the Borzsony site the clay fraction was measured the most accurately and the pipette method measured higher amounts

than the other methods. On the Gyongyostarjan site at the bottom third of the slope, the fine sand fraction was measured the most accurately and the pipette method measured clay more accurately, the aerometer method measured the coarse sand and the laser method the silt fraction more accurately than other methods. On the Gyongyostarjan site over the upper third of the slope the very fine sand fraction was measured most accurately. In case of Szt.Gyorgyvar the clay and coarse sand fractions were measured most accurately. In the other two fractions the laser method gave the best result, with the other two methods giving less than the theoretical values. In case of the Tura site, despite a high sand content the clay fraction was estimated the most accurately. In case of Kiskunmajsa, the coarse sand fraction was measured most correctly because there were only very small proportions of the other size fractions. On the Fs site the coarse sand fraction was measured best. The laser method results differed the most. On the Galgaheviz site the clay fraction was measured best and the laser method differed the most.

Conclusions

Different analytical methods produced different results for particle size distribution. χ^2 analyses revealed significant differences with different p values. These results can be helpful in seeking the sources of errors. In the present case there was a big influence detected by laboratory personnel (the analyses were repeated and one method had less than 5% error, while another had more than 20%). It appears that not only do the well known differences between methods, sample preparation and physical background matter but also there are other factors (e.g. routine vs closely checked analyses) which may influence the results.

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