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Short communication

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Short communication to the determination of soil structure

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Soil structure can be evaluated and assessed a number of ways; therefore, sometimes it is very difficult to compare these results. The aim of this study was to examine the water resistance of soil structure in different soils two different ways – Baksheev method and using the AS 200 device. Obtained results showed large differences in size fractions of water stable aggregates dependent on method or device of determination. If we only assessed the vulnerability of soil structure, the results are comparable regardless of what method or device was used.

Keywords: soil structure, water stable aggregates, vulnerability of soil structure

1. Introduction

Soil structure is an important aspect of agricultural soil quality and soil ecology (Kay et al., 2006; Roger-Estrade et al., 2010). Soil structure refers to the size, shape and arrangement of solids and voids, continuity of pores and voids, their capacity to retain and transmit fluids and organic and inorganic substances, and ability to support vigorous root growth and development (Lal, 1991). Soil aggregates are the basic units of soil structure (Lynch and Bragg, 1985). Several authors (Oades, 1993; Dalal and Bridge, 1996) presented that formation of soil aggregates is a function of the physical forming forces, however, its stabilization is influenced by other factors, for example: quantity and quality of organic or inorganic cementing substances, therefore soil structure is a complex system. One of the reasons for the complexity of soil structure is the range of scales it expresses. Structural processes occur at a scale ranging from a few Å to several cm. Another cause of complexity is the dynamic nature of soil structure. Structural attributes vary in time and space, and the attributes observed at any given time reflect the net effect of numerous interacting factors that may change at any moment (Lal and Shukla, 2004), and is difficult to characterize (Coughlan et al., 1991). Methods of aggregation assessment (structural state) show two principal techniques: field and laboratory. Field methods are used primarily by pedologists in routine soil surveys. Laboratory methods of aggregate analyses can be broadly grouped into three categories: (1) ease of dispersion, (2) assessment of aggregation and aggregate size distribution, and (3) evaluation of aggregate strength. In most works, the soil structure is evaluated on the basis of soil stability aggregates (their different sizes). Measurements of stability of aggregates raised considerable attention over the last 60 years. It is well-known that the stability of soil structure mainly depends on the strength of micro-aggregates bound to the macro-aggregates. On the basis of analysis of individual size fractions (soil samples sieved through a variety of sieves: 1. dry and, 2. wet sieving) the stability of aggregates in soils is usually determined. Attention of scientists is focused primarily on macro-aggregates in the size fraction of >0.25 mm (Dormaar, 1983), with a focus mainly on agronomically valuable fractions of macro-aggregates from 0.5 to 3 mm (Šimanský, 2013).

The purpose of this study was to examine the water resistance of soil structure in different soils. The specific objectives of this work were (i) determination of water stable aggregates by two different ways (ii) comparison and discussion of possible changes/matches in fractions of water stable aggregates determined by different ways, and (iii) to recommendation to determination of soil structure. Results from this study will increase the scientific understanding of the soil structure determination.

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2. Material and methods

2.1 Soil samples

During the spring of 2013, soil samples for analyses of soil structure were taken from selected localities of Slovakia. Brief characteristics of different sites are shown in Table 1. The twenty-eight collected soil samples included a large range of parent materials and climates. Soil samples also had a large range of soil textures and had been classified to different soil types. Some soils were in use for crop production or viniculture with different soil management practices. Some soils were abandoned or after wildfire.

Table 1 Experimental site locations with basic information

Sites	Mark	Location	Soil classification (WRB, 2006)	Soil use and management	Depth in m	Plant cover
Dražovce S1	1	48° 21′ 22.50″ N 18° 3′ 24.80″ E	Rendzic Leptosol	Arable soil	0–0.2	–
Ľudovítová S1	2	48° 23′ 34.88″ N 18° 4′ 46.06″ E	Calcaric Fluvisol	Fallow soil	0–0.2	Fallow
Dolná Streda S1-1	3	48° 15′ 26.12″ N 17° 44′ 1.14″ E	Mollic Fluvisol	Arable soil	0–0.1	Spring barley
Dolná Streda S1-2	4	48° 15′ 26.12″ N 17° 44′ 1.14″ E	Mollic Fluvisol	Arable soil	0.1–0.3	Spring barley
Dolná Streda S2-1	5	48° 16′ 18.78″ N 17° 42′ 16.08″ E	Mollic Fluvisol	Arable soil	0–0.1	Winter wheat
Dolná Streda S2-2	6	48° 16′ 18.78″ N 17° 42′ 16.08″ E	Mollic Fluvisol	Arable soil	0.1–0.3	Winter wheat
Dolná Streda S3-1	7	48° 15′ 25.30″ N 17° 43′ 17.88″ E	Mollic Fluvisol	Arable soil	0–0.1	Winter wheat
Dolná Streda S3-2	8	48° 15′ 25.30″ N 17° 43′ 17.88″ E	Mollic Fluvisol	Arable soil	0.1–0.3	Winter wheat
Rišňovce S1	9	48° 21′ 56.37″ N 17° 54′ 44.15″ E	Mollic Fluvisol	Arable soil	0–0.2	Sunflower
Rišňovce S2	10	48° 21′ 49.80″ N 17° 54′ 43.53″ E	Calcaric Arenosols	Arable soil	0–0.2	Sunflower
Rišňovce S3	11	48° 21′ 55.55″ N 17° 54′ 51.26″ E	Molic Fluvisol	Arable soil	0–0.2	Sunflower
Vieska n/Ž. S1	12	48° 19′ 26.66″ N 18° 22′ 12.00″ E	Haplic Luvisol	Vineyard	0–0.2	–
Vieska n/Ž. S2	13	48° 18′ 50.29″ N 18° 22′ 7.67″ E	Stagni-Haplic Luvisol	Arable soil	0–0.2	Corn
Bučany S1	14	48° 25′ 25.03″ N 17° 43′ 25.92″ E	Gleyi-Haplic Chernozem	Arable soil	0–0.2	–
Bučany S2	15	48° 25′ 43.48″ N 17° 42′ 21.65″ E	Luvi-Haplic Chernozem	Arable soil	0–0.2	Sunflower
Jacovce S1	16	48° 36′ 20.43″ N 18° 8′ 22.05″ E	Stagni-Haplic Luvisol	Arable soil	0–0.2	Peas
Jacovce S2	17	48° 36′ 0.81″ N 18° 8′ 48.00″ E	Stagni-Haplic Luvisol	Arable soil	0–0.2	Spring barley
Dražovce S2-1	18	48° 21′ 25.37″ N 18° 3′ 29.12″ E	Rendzic Leptosol	Unburied soil	0–0.05	–
Dražovce S2-2	19	48° 21′ 25.37″ N 18° 3′ 29.12″ E	Rendzic Leptosol	Unburied soil	0.05–0.2	–
Dražovce S3-1	20	48° 21′ 25.37″ N 18° 3′ 29.12″ E	Rendzic Leptosol	After fire – low temperature	0–0.05	–
Dražovce S3-2	21	48° 21′ 25.37″ N 18° 3′ 29.12″ E	Rendzic Leptosol	After fire – low temperature	0.05–0.2	–

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Continuation of the table 1

Sites	Mark	Location	Soil classification (WRB, 2006)	Soil use and management	Depth in m	Plant cover
Dražovce S4-1	22	48° 21′ 25.37″ N 18° 3′ 29.12″ E	Rendzic Leptosol	After fire – high temperature	0–0.05	–
Dražovce S4-2	23	48° 21′ 25.37″ N 18° 3′ 29.12″ E	Rendzic Leptosol	After fire – high temperature	0.05–0.2	–
Dražovce S5	24	48° 21′ 22.50″ N 18° 3′ 24.80″ E	Rendzic Leptosol	Vineyard – grass	0–0.25	Grass
Dražovce S6	25	48° 21′ 22.50″ N 18° 3′ 24.80″ E	Rendzic Leptosol	Vineyard – tilled	0–0.25	–
Dražovce S7	26	48° 21′ 22.50″ N 18° 3′ 24.80″ E	Rendzic Leptosol	Vineyard – appied farmyard manure	0–0.25	–
Dražovce S8	27	48° 21′ 22.50″ N 18° 3′ 24.80″ E	Rendzic Leptosol	Vineyard – added NPK in 1. intensity	0–0.25	Grass
Dražovce S9	28	48° 21′ 22.50″ N 18° 3′ 24.80″ E	Rendzic Leptosol	Vineyard – added NPK in 3. intensity	0–0.25	Grass

2.2 Analytical methods

Soil samples were taken with the aid of a spade to maintain the soil in their natural aggregates. Roots and large pieces of litter were removed from the soil samples. Collected soil samples were transported to the laboratory and large clods were gently broken up along natural fracture lines and samples were air-dried at laboratory temperature. Before determination of water stable aggregates all soil samples were sieved to provide a range of aggregate sizes (>7, 7–5, 5–3, 3–1, 1–0.5, 0.5–0.25, <0.25 mm). These size fractions of air-dried aggregates were used for the determination of size distribution of water stable aggregates (WSA) by Baksheev method (Vadjunina and Korchagina, 1986). Briefly, soil sample was overflowed with distilled water (water level 1 cm above aggregates). Two hours later, the sample was transferred to the top sieve (>5 mm) in a cylindrical container (Baksheev device), which has been filled with distilled water. Cylinder was hermetically closed and the sample was sieved 12 minutes (angle 45o, length of one cycle = 1 minute). The size fractions of water-stable aggregates (WSA) were following: >5, 5–3, 3–2, 2–1, 1–0.5, 0.5–0.25 (macro-aggregates) and <0.25 mm (micro-aggregates). The material retained was quantified in each sieve except micro-aggregates. Their content was calculated as difference between total weight of soil sample and sums of macro-aggregates. For determination of water stable aggregates, the device AS 200 was used as well. The analysis began with samples, with 200 g of aggregates, placed over a set of six sieves with meshes of 5, 3.15, 2, 1, 0.5 and 0.25 mm. On the top sieve the clamping cover with spray nozzle for wet sieving and after the last sieve the base pan with water drain were given, and aggregates were then sieved 10 minutes with amplitude 1.2 (manufacturer's recommendation). After the sieving process, the fractions were transferred from the individual sieves to suitable filters (e.g. filter paper) and dried in a drying cabinet at 80 °C.

The mean weight diameters of aggregates for dry and wet sieving as well as vulnerability coefficient were calculated according to following equations:

$$MWD_d = \sum_{i-1}^{n} xiwi$$

where:
MWD_d – mean weight diameter of aggregates for dry sieving (mm)
xi – mean diameter of each size fraction (mm)
wi – portion of the total sample weight occurring in the corresponding size fraction
n – number of size fractions

$$MWD_w = \sum_{i-1}^{n} xiWSA$$

where:
MWD_w – mean weight diameter of water stable aggregates (mm)
xi – mean diameter of each size fraction (mm)
WSA – portion of the total sample weight occurring in the corresponding size fraction
n – number of size fractions

$$Kv = \frac{MWD_d}{MWD_w}$$

where:
MWD_d – mean weight diameter of aggregates for dry sieving (mm)
MWD_w – mean weight diameter of water stable aggregates (mm)

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2.3 Statistical analysis

The statistical processing of the data was accomplished using the Statgraphics Centurion XV.I (Statpoint Technologies, Inc., USA). The descriptive statistics (minimum; maximum; average; median; variance) were used to describe the individual size fractions of water stable aggregates. A simple *t*-test was carried out to test significance between the same fractions of water stable aggregates that were measured using different methods. Significant differences were marked at p level ≤ 0.05. The Pearson test was used to estimate the correlation matrix between the same parameters of soil structure that were measured using different methods.

3. Results and discussion

The contents of size fractions of water stable aggregates were different and some of them were in a relatively large range (Table 2). Their values were significantly dependent on the method of determination. If the content of water stable micro-aggregates (<0.25 mm) was determined by the AS 200 device, their average content was 5-times greater compared to Baksheev method (Table 2). Almost the same content was observed in the fraction macro-aggregates size classes from 0.5 to 0.25 mm – determined by both methods. Overall, the higher content of water stable macro-aggregates (by 104 %) was determined by the method of Baksheev more than the AS 200 device. We have hypothesized that the results can be different because of dependence on method of determination and re-distribution of size classes of water stable aggregates because it is influenced by various factors, such as: the uniformity of the test portion, temperature and water quality and the number of repetitions, but also the stability of individual aggregates. We have hypothesized that the greater vulnerability of water stable aggregates will be determined by using of the Baksheev method in comparison to their determination by the AS 200 device. In case of Baksheev method, the soil samples had been underwater two hours, what means that there is enough time for water penetration to capillary pores inside of aggregates as well as for violation of hydrophobicity. Penetration of water to inside of aggregates was more intensively, what is connected with temperature of water. The warmer water was the faster and stronger brake down that soil aggregates had. This fact is associated with density and viscosity of water (Hraško et al., 1962). On the other hand, we hypothesized that length of the sieving with the AS 200 device (10 minutes) will not be sufficient for adequate wetting of aggregates because the AS 200 device for determination water stable aggregates used colder water (flowing tap water) of higher density and viscosity. All in all, obtained results were contradicted with the assumption (Table 2).

Before the wet sieving of soil samples the soil aggregates were sieved by dry sieving with following re-distribution of size fractions of structural aggregates. These have provided input for the calculation or determination of other soil structure characteristics such as: water resistance and the vulnerability of soil structure. Very important parameter of soil structure is mean weight diameter of aggregates for dry sieving (MWD_d). Between calculated MWD_d resulting from the AS 200 device and calculated MWD_d before the Baksheev method – wet sieving statistical significant positive correlation ($r = 0.916$, $P \leq 0.001$) was observed. This means that dry sieving is almost identical in case of the AS 200 device as well as before Baksheev method. Recommended set up of the AS 200 device is consistent with prepared samples for the determination of water stable aggregates by Baksheev method. Diametrical difference occurs only during

Table 2 Statistical evaluation of size fractions of water-stable aggregates

	Size fractions of water-stable aggregates in mm													
	>5		5-3.15	5-3	3.15-2	3-2	2-1		1-0.5		0.5-0.25		<0.25	
Used methods	AS200	BM	AS200	BM	AS200	BM	AS200	BM	AS200	BM	AS200	BM	AS200	BM
Count	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Average	9.76	15.18	5.35	12.32	4.59	13.40	6.84	15.34	5.94	18.89	11.13	13.64	56.68	11.13
Standard deviation	8.52	12.79	3.29	6.01	3.10	5.65	4.59	6.59	2.57	10.23	8.90	6.11	17.98	10.57
Coeff. of variation	87.35	84.31	61.51	48.82	67.52	42.16	67.09	43.00	43.31	54.17	79.98	44.78	31.71	94.96
Minimum	0.42	2.60	0.10	2.03	0.55	3.50	1.02	4.97	0.92	3.17	2.38	2.87	23.02	0.03
Maximum	32.51	50.67	11.03	25.03	10.44	22.77	19.12	31.30	11.00	46.77	34.05	28.93	93.87	41.23
Range	32.09	48.07	10.93	23.00	9.89	19.27	18.1	26.33	10.08	43.60	31.67	26.06	70.85	41.20
***t*-test**	-1.86		-5.38		-7.24		-5.59		-6.50		-1.23		11.56	
***P*-value**	0.067		0.000		0.000		0.000		0.000		0.223		0.000	

AS200 – the AS 200 device, BM – Baksheev method

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the wet sieving. This indicated that water resistance is different, which was confirmed by the results (Table 2). Calculated values of mean weight diameter of water stable aggregates (MWD_w) were essentially different depending on the method of water stable aggregates sieving. Between calculated MWD_w resulting from the AS 200 device and calculated MWD_w resulting from the Baksheev method no significant relationship was observed. Water resistance is very important feature of soil structure, however, there is shown that it occurs only once (Hraško et al., 1962; Šimanský, 2013). It is principally influenced by the characteristics of binding agents of aggregates and their interrelationships (Kemper and Rosenau, 1986; Jastrow and Miller, 1991; Amézketa et al., 1996; Amézketa, 1999; Bronick and Lal, 2005). The vulnerability coefficient (*Kv*) is very important indicator of soil structure as well. It shows how many times that aggregate size at the beginning is decreasing in dependence on degradation mechanisms (Valla et al., 2002). The values of *Kv* were calculated and compared with dependence on method/device of determination of water stable aggregates. There was observed statistical significant positive correlation (r = 0.835, $P \leq 0.001$) between calculated Kv resulting from the AS 200 device and calculated Kv resulting from the Baksheev method was, which means that assessment of soil structure vulnerability is possible without different method or device which are used for re-distribution of water stable aggregates.

4. Conclusions

Presently, precise determination and evaluation of soil structure is very difficult. Obtained results showed that differences in size fractions of water stable aggregates with dependence on method or device of determination were large. For this reason, in the same experiment the water resistance should be evaluated by the same methodology. In order to retain continuity of results it's not recommended to change the methodology or use modern equipment for determination of soil structure. In the future, for the elimination of differences between the results (Baksheev method versus the AS 200 device) is necessary to adjust the time of sieving or its frequency on the AS 200 device. The results showed that if only vulnerability of soil structure was assessed, values were comparable regardless of what method or device was used.

For comprehensive assessment of the soil is not suitable to indicate only one parameter. Except of soil structure, in order of responsible assessing the quality of the soil there also several soil properties (chemical, physical and SOM) have to be quantified.

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