Scientific Papers. Series A. Agronomy, Vol. LIX, 2016
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

RESEARCH ON THE IMPACT OF THE MORPHOLOGICAL VARIATION OF MINERAL FRAGMENTS ON SOIL HYDRAULIC PROPERTIES

Viorel FILER[1], Florian STĂTESCU[1], Madalin BODEA[1], Daniela RUSU[2], Florica DOROFTEI [2]

[1]"Gheorghe Asachi" Technical University, Mangeron Dumitru Str. 63, 770800, Iasi, Romania
[2]Institute of Macromolecular Chemistry "Petru Poni" Iasi, Romania

Corresponding author email: stef_vio2000@yahoo.com

Abstract

This paper aims to highlight the relationship between soil particles morphological (shape, size and surface area) and hydraulic properties (hydraulic conductivity - saturated and unsaturated and soil suction). Determination of morphological characteristics of soil particles was achieved by: a) size analysis and b) SEM microscopic analysis type. Determination of soil hydraulic properties was performed by laboratory methods for hydraulic conductivity was used the constant-head method (ks) and the falling head method (kθ), suction was determined using experimental plant which comprises sandbox, sand/kaolin box and pressure membrane apparatus.

***Key words**: hydraulic conductivity, suction, particle size analysis, microscopic analysis.*

INTRODUCTION

According to classical literature soil can be defined as being a porous medium characterized by the existence of a very complicated system of grooves, paths and storages that allow transit and storage of different types of fluids. This description can help us in achieving an overview on how water and various chemicals move. This movement is due to the existence of two types of phases: the solid one (soil matrix) and the liquid one (soil solution) that is moving through the pores of the soil.

In most cases when leaching process occurs - highlighted by penetration of water into soil, soil permeability ranges. In a first stage the transport capacity is high and then begins to decline relatively rapidly until the soil or medium in which the movement of the water reaches saturation.

Since then the amount of water that is entering the soil and throughput certain section under a hydraulic gradient becomes constant.

The ingress of water when the soil is saturated is defined by filtration process and if the soil is unsaturated by infiltration action. These processes are governed by some properties of the two media characterized by their nature and composition. When referring to this aspect only the solid part of soil represented by soil matrix is taken into account. The matrix can be composed of mineral fragments with different morphological traits (size, shape and surface area).

Study on the impact of particle morphology variation on soil hydraulic proprieties plays a very important role when you want to highlight how the transport of water and various substances takes place. This is important in a lot of applications: hydrology, pedology, geotechnical etc. In the context of the issues mentioned above we can shed light on purpose of this paper represented by highlighting the relationship between variation in morphological characteristics of the mineral particles of the soil (size, surface area and typology of the porosity from the particle surface) and hydraulic properties (hydraulic conductivity - saturated and unsaturated and soil suction). The result of this study realized on soil samples collected from various depths between 0-80 cm (0-20 cm, 20-40 cm, 40-60 cm and 60-80 cm) from the research area Dancu - Iași (Figure 1.a) can provide some information about the hydrological regime of soil types that have different textures displayed on all four depths study.

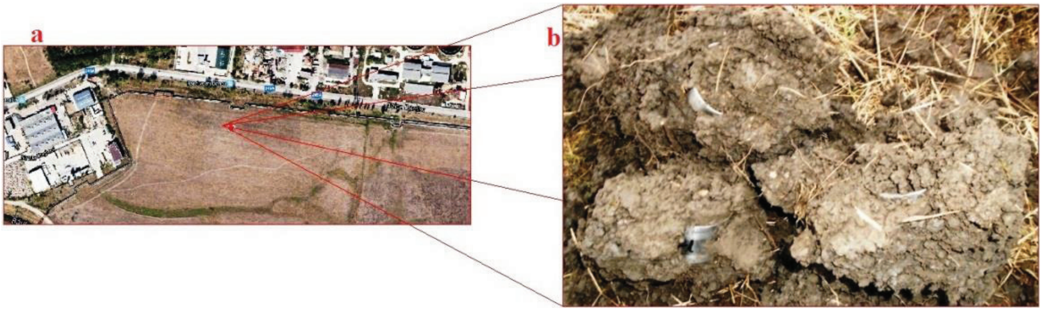

Figure 1. Presentation of the location study: a - zone of sampling soil; b - samples harvested

MATERIALS AND METHODS

All research was conducted on soil samples disturbed (stored in labeled bags) and undisturbed harvested (collected by the method of metallic cylinders with a volume of 100 cm^3) shown in Figure 1.b).

Highlighting soil particles morphology was achieved by: a) size analysis (Figure 2.1a) and SEM (Scanning Electron Microscope) microscopic type (Figure 2.1b).

Microscopic research was performed using scanning electron microscope Quanta 200, manufactured by FEI Company. All samples were analyzed in Low Vacuum, approximately 60 Pa to 20 Kv shown in Figure 2.1b).

The analysis of hydraulic characteristics of soil samples was achieved by the laboratory methods for hydraulic conductivity was the constant-head method (K_s) (Lungu, 2013) give us in Figure 2.2d and the falling head method (K_θ) (Stanciu and Lungu, 2006) presented in Figure 2.2e. Suction was determined on a value range between pF 0 and pF 4.2 using experimental plant comprising: sandbox (pF 0 - pF 1.8) remarked in Figure 2.2a, sand/kaolin box (pF 2 - pF 2.7) shown in Figure 2.2b and the pressure membrane apparatus (pF 3 - pF 4.2) noticed in Figure 2.2c (Dumitru, 2009).

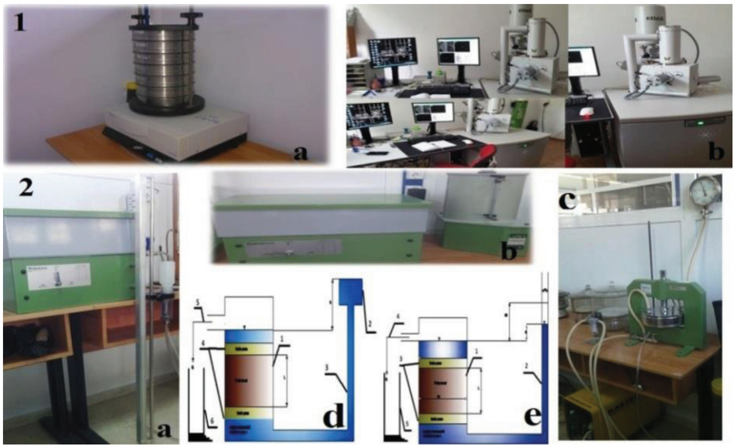

Figure 2. The apparatus used in research: 1: equipment used to analyze the morphology of mineral particles: a: shaker electromagnetic; b: equipment used in microscopic analysis SEM; 2: all equipment used in the study of hydraulic properties a: sandbox; b: sand/ kaolin box; c: pressure membrane apparatus; d: constant-head method; e: falling head method

CALCULATION PROCESS

Hydraulic conductivity Ks on vertical direction of the water flow is calculated from the relationship:

$$K = \frac{V * L}{T * A * h} \quad (1)$$

where:

V- volume of water collected;
L - length of the soil sample;
T - time for the collection volume of water (the excess);
A -cross-sectional area of the sample.

Unsaturated hydraulic conductivity values were enteritis with relation:

$$K = \frac{a * L}{T * A} * \ln\left(\frac{h_1}{h_2}\right) \quad (2)$$

where:

a - the cross -section of graduated tube;

L - length of the soil sample;
T - time for the collection volume of water (the excess);
A - cross-sectional area of the sample;
h_1 and h_2 - height of water column after a time T.

The dates of water retention curve in the soil were obtained using the relations 5:

$$W = \frac{\text{weight of soil water} \cdot 100\%}{\text{weight of soil}} \quad (3)$$

$$\rho_d = \frac{\text{dry soil weight (without ring, canvas)}}{\text{weight of soil}} \quad (4)$$

$$\theta = W \,.\, \rho_d \quad (5)$$

where:

θ - volumetric water content;
W - soil humidity;
ρ_d - bulk soil density.

RESULTS AND DISCUSSIONS

The results from the research have been pooled and stored in tables and figures.

Table 1 shows the values of the unsaturated hydraulic conductivity and in the 1 give us the values of two types of essential characteristics of our study. Thus in the first part of the table are presented morphological values that were studied by the methods mentioned in the previous section. In the second part of Table 2 are mentioned the values of satured hydraulic conductivity. SEM analysis results will be presented in Figure 3, which will be highlighted in the morphological characteristics of two soil mineral fragments for example: 1 mm and < 63 µm to 0-20 cm depth - the shape of fragment, the size and the particle surface area (done with AutoCAD 2007).

Table 1. Unsaturated hydraulic conductivity values

Kθ D 0-20 cm at 15 °C		Kθ D 20-40 cm at 15 °C		Kθ D 40-60 cm at 15 °C		Kθ D 60-80 cm at 15 °C	
ΔT	Kt (cm/s)	ΔT	Kt (cm/s)	ΔT (sec)	Kt (cm/s)	ΔT (sec)	Kt (cm/s)
2	0.139435	2	0.139435	2	0.139435	20	0.013943
11	0.026962	6	0.049431	9	0.032954	128	0.006105
16	0.019827	11	0.028840	15	0.021149	147	0.002408
22	0.015490	16	0.021299	19	0.017936	170	0.002256
27	0.013631	21	0.017526	24	0.015335	212	0.003032
33	0.012127	25	0.016008	30	0.013340	234	0.002071
38	0.011537	30	0.014614	36	0.012178	280	0.001302
43	0.011538	36	0.013461	40	0.012115	327	0.003139
49	0.011057	41	0.013214	48	0.011287		
55	0.011163	46	0.013348	53	0.011585		
62	0.011432	51	0.013898	59	0.012014		
67	0.012517	57	0.014713	66	0.012707		
74	0.013871	63	0.016292	73	0.014061		
The average	0.023891	The average	0.028621	The average	0.025084	The average	0.004282

Table 2. Results of the morphological analysis and hydraulic analyzsis

The study area	Depth harvest	Morphological properties: Size composition p (%)	Size composition µm	The surface area of the particle (mm^2)	The particle dimension P.D. (mm)	Hydraulic properties: Suction (θ %) θ	pF	Saturated hydraulic conductivity Ks (cm/s): ΔT (sec)	Ks (cm/s) at 20 °C
		100	1000	8.023	3.3	52.21	0	2	0.139435
		44	500	5.286	2.43	51.32	0.4	8	0.037073
		15	250	0.143	0.507	50.44	1	13	0.024403
		9.5	125	0.244	0.192	48.67	1.5	21	0.016228
		4.5	63	0.0077	0.107	47.36	1.8	26	0.014155
		2	< 63	0.0012	0.04	46.9	2	32	0.012506
Dancu	0-20 cm					46.49	2.3	49	0.011537
						44.73	2.7	51	0.010769
						37.57	3	59	0.010406
						30.13	3.4	66	0.010739
						15.39	4.2		
								Average	0.027079
		100	1000	11.389	4.15	45.16	0	2	0.139435
		45. 5	500	5.544	2.85	43.68	0.4	9	0.032954
		12	250	0.0711	0.343	43.54	1	14	0.022660
		7	125	0.015	0.161	41.93	1.5	18	0.018933
		3.5	63	0.0058	0.104	41.12	1.8	23	0.016002
		1	< 63	0.0019	0.47	39.51	2	27	0.014822
Dancu	20-40 cm					36.14	2.3	33	0.013285
						33.77	2.7	39	0.012425
						33.59	3	44	0.012313
						32.81	3.4	58	0.010586
						31.25	4.2	69	0.010272
								Average	0.027608
		100	1000	8.442	3.46	48.33	0	2	0.139435
		36	500	6.147	3.29	47.5	0.4	6	0.032954
		18	250	0.086	0.483	45.83	1	12	0.021149
		11	125	0.026	0.219	45	1.5	17	0.017936
		5	63	0.011	0.205	42.5	1.8	22	0.015335
Dancu	40-60 cm	2	< 63	0.0031	0.08	35.86	2	28	0.013340
						27.9	2.3	34	0.012178
						26.11	2.7	38	0.012115
						25.37	3	45	0.011287
						23.88	3.4	51	0.011585
						12.22	4.2	57	0.012014
								Average	0.139435
		100	100 0	13.292	4.27	42.7	0	600	0.000464
		42	500	2.151	1.84	40.6	0.4	1080	0.000723
		35	250	0.061	0.303	37.5	1	2520	0.000723
		10	125	0.034	0.227	35.41	1.5	3240	0.000118
		8	63	0.0096	0.113	33.33	1.8	3720	0.000172
		5	< 63	0.0011	0.042	30.33	2	4500	0.000107
Dancu	60-80 cm					27.42	2.3	5640	0.000148
						24.78	2.7	6720	0.000152
						20.05	3		
						16.59	3.4		
						8.45	4.2		
								Average	0.000326

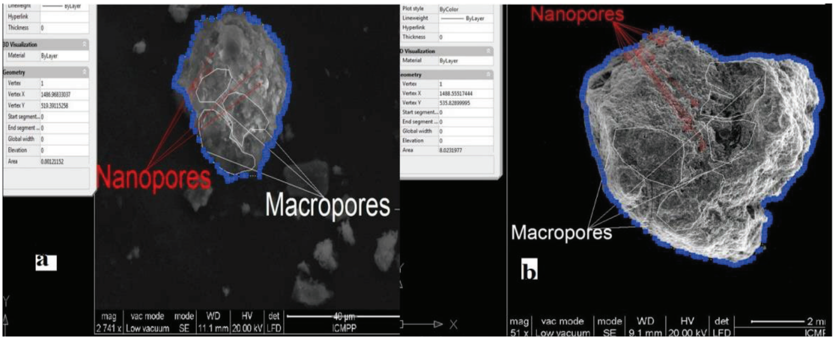

Figure 3. SEM image at 2741 and 51 x - morphological particularities of mineral fragments from Dancu 0-20 cm a: particle < 63 µm - specific surface area and particle size and distribution of soil particle pore surface. b) particle 1 mm - specific surface area and particle size and distribution of soil particle pore surface

In determining the change of soil hydraulic properties in the Dancu area only maximum and minimum of two types of pores were taken into acount: maximum macropores surface and minimum surface of nanopores. To determine the relationship between morphological characteristics associated to different sizes of particles that are in direct relation with pore system and saturated hydraulic conductivity, only nanopores characteristics were taken into account because they have a smaller carrying capacity. Macropores were used to calculate unsaturated hydraulic conductivity because they own a bigger transportation capacity.

This relationship is shown in Figures 4 and 5. In analyzing ties between the morphological characteristics associated particles of different fractions directly related to pore system that lies across the surface of their ability to note the water of mineral particles to focus only on two categories of pores (macropores and nanopores). Suction lowest (pF 0 - pF 2.0) thresholds were associated with macropores because they can store a higher amount compared to nanopores that can retain water volume much smaller at higher pF values (pF 2.3 - pF 4.2). This relationship between morphological characteristic of particle with different grains dimension (size) and soil suction is presented in Figures 6 and 7.

The values of morphological characteristics are shown in Tables 3 and 4 (done with AutoCAD 2007).

Table 3. Results of the morphological analysis for particles of different size fractions with macropores system

Dancu 0 - 80 cm	Fraction size	The surface area of the particles S.A of part. (mm^2)	The type of pores	The pore surface (max) P.S. (mm^2)	The pore dimension P.D. (mm)
D 0-20 cm	1 mm	8.023	Macropores	0.642	1.19
D 0-20 cm	500 µm	5.286	Macropores	0.156	0.547
D 0-20 cm	250 µm	0.143	Macropores	0.144	0.155
D 0-20 cm	125 µm	0.244	Macropores	0.00013	0.049
D 0-20 cm	63 µm	0.0077	Macropores	0.00033	0.026
D 0-20 cm	< 63 µm	0.0012	Macropores	0.00018	0.023
D 20-40 cm	1 mm	11.389	Macropores	1.037	1.551
D 20-40 cm	500 µm	5.544	Macropores	0.251	0.628
D 20-40 cm	250 µm	0.0711	Macropores	0.008	0.136
D 20-40 cm	125 µm	0.015	Macropores	0.0011	0.053
D 20-40 cm	63 µm	0.0058	Macropores	0.00028	0.024
D 20-40 cm	< 63 µm	0.0019	Macropores	0.00009	0.018
D 40-60 cm	1 mm	8.442	Macropores	0.762	1..29
D 40-60 cm	500 µm	6.147	Macropores	0.738	1..40
D 40-60 cm	250 µm	0.086	Macropores	0.346	0.984
D 40-60 cm	125 µm	0.026	Macropores	0.0014	0.060
D 40-60 cm	63 µm	0.011	Macropores	0.00058	0.042
D 40-60 cm	< 63 µm	0.0031	Macropores	0.00026	0.023
D 60-80 cm	1 mm	13.292	Macropores	1.068	2.057
D 60-80 cm	500 µm	2.151	Macropores	0.160	0.597
D 60-80 cm	250 µm	0.061	Macropores	0.0038	0.111
D 60-80 cm	125 µm	0.034	Macropores	0.0022	0.071
D 60-80 cm	63 µm	0.0096	Macropores	0.0014	0.060
D 60-80 cm	< 63 µm	0.0011	Macropores	0.0001	0.015

Table 4. Results of the morphological analysis for particles of different size fractions with nanopores system

Dancu 0 - 80 cm	Fraction size	The surface area of the particles S.A (mm^2)	The type of pores	The pore surface (min) P.S. (mm^2)	The pore dimension P.D. (mm)
D 0-20 cm	1 mm	8.023	Nanopores	0.00028	0.022
D 0-20 cm	500 µm	5.286	Nanopores	0.0002	0.019
D 0-20 cm	250 µm	0.143	Nanopores	0.000007	0.002
D 0-20 cm	125 µm	0.244	Nanopores	0.0000003	0.0009
D 0-20 cm	63 µm	0.0077	Nanopores	0.00000067	0.001
D 20-40 cm	1 mm	0.0012	Nanopores	0.0008	0.003
D 20-40 cm	500 µm	11.389	Nanopores	0.0005	0.028
D 20-40 cm	250 µm	5.544	Nanopores	0.0000052	0.003
D 20-40 cm	125 µm	0.0711	Nanopores	0.0000010	0.0014
D 20-40 cm	63 µm	0.015	Nanopores	0.00000073	0.001
D 40-60 cm	1 mm	0.0058	Nanopores	0.00007	0.014
D 40-60 cm	500 µm	0.0019	Nanopores	0.00004	0.014
D 40-60 cm	250 µm	8.442	Nanopores	0.00007	0.012
D 40-60 cm	125 µm	6.147	Nanopores	0.0000026	0.001
D 40-60 cm	63 µm	0.086	Nanopores	0.0000022	0.002
D 60-80 cm	1 mm	0.026	Nanopores	0.00012	0.017
D 60-80 cm	500 µm	0.011	Nanopores	0.00002	0.008
D 60-80 cm	250 µm	0.0031	Nanopores	0.000003	0.0031
D 60-80 cm	125 µm	13.292	Nanopores	0.0000019	0.0024
D 60-80 cm	63 µm	2.151	Nanopores	0.0000006	0.001

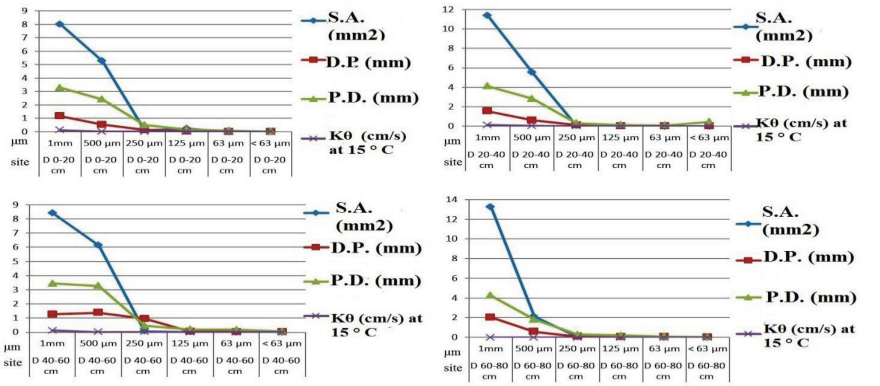

Figure 4. The relationship between morphological characteristics associated particle with different sizes and unsaturated hydraulic conductivity

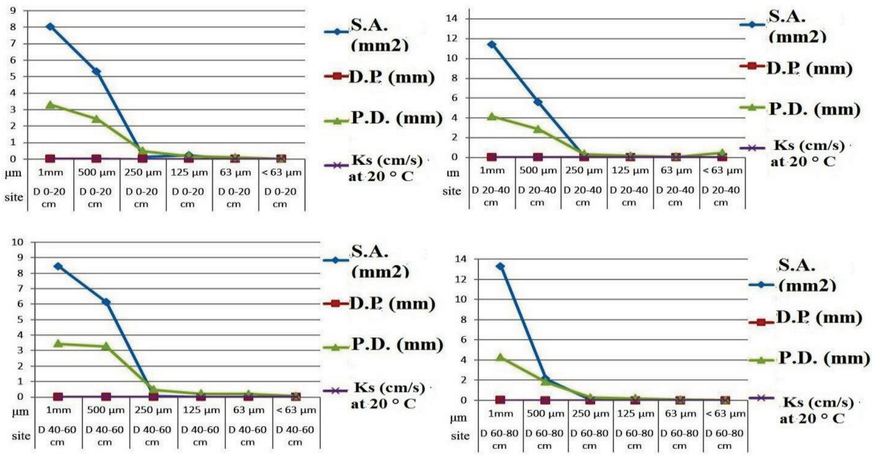

Figure 5. The relationship between morphological characteristics associated particle with different sizes and saturated hydraulic conductivity

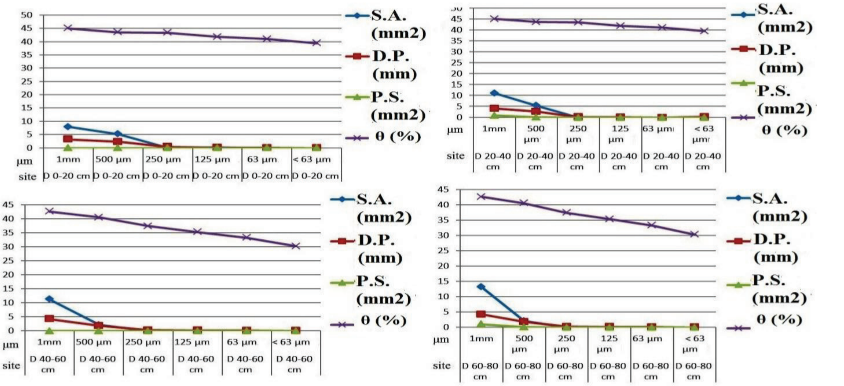

Figure 6. The relationship between morphological characteristic of particle with different sizes and soil suction (macropores)

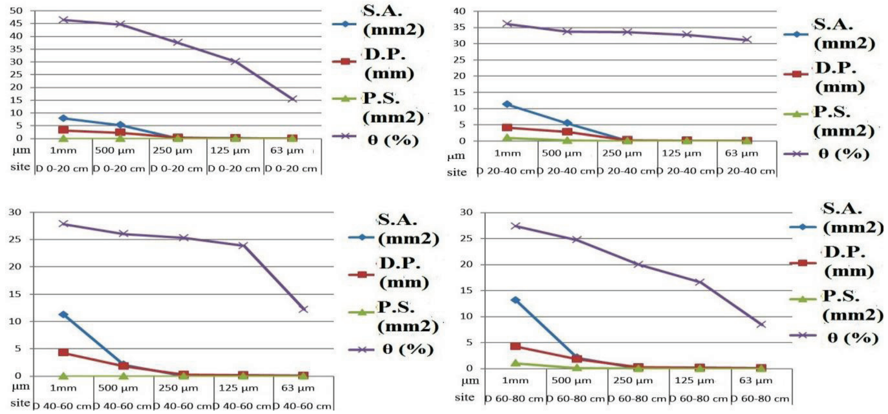

Figure 7. The relationship between morphological characteristic of particle with different sizes and soil suction (nanopores)

RESULTS INTERPRETATION

The results of size analysis can highlight a variation of the percentages corresponding to each particle size fractions in direct proportion with increasing depth of soil sampling analysis. Following the analysis of SEM type, we can achieve an overview on the morphological characteristics of soil particles for each particle size. The morphological characteristics of soil particles ranged in depth from six different particle sizes. If the surface of soil particles, it has changed depending on the size of granule fraction, decreasing in direct proportion to their size and the other features taken into account (pore size and pore surface).

One of the hydraulic properties - unsaturated hydraulic conductivity varied significantly from one depth to another. Saturated hydraulic conductivity recorded the lowest values in the case of D 60-80 cm depth compared to the other three. In the case of 0-20 cm and 20-40 cm depths the values have been differed very little. This difference can be attributed to relatively significant variation the contents of sand, dust and clay.

Unsaturated hydraulic conductivity was higher than those observed for saturated hydraulic conductivity evidenced in the comparative analysis of average values for the two types of conductivity. Thus for D 0-20 cm Kθ was slightly higher than D 40-60 cm, the same variation was observed for D 20-40 cm and D 60-80 cm latter being 80% lower than previous case where the percentage was much lower.

The suction soil analysis results showed a survey taken in distribution of water the contents was varieted from a harvest depths to another depths. As examples D 40-60 cm was higher in comparation with D 60-80 cm.

One difference was recorded for D 0-20 cm where the content has not decreased but increased. This change can be justified by a higher content of clay and silt found at 0-20 cm depth. The relationship between morphological characteristics of soil particles at different sizes and hydraulic properties of soil samples collected from the Dancu study area presented a real situation characterized by a change in water regime governed by a morphological variation (size, particle surface, pore size and pore surface) of mineral fragments that goes into the soil analyzed. Relating to all the above we can mention a similarity between D 20-40 cm and D 60-80 cm. The difference between D 0-20 cm and D 40-60 cm in this case is determined by the relationship between the morphological characteristics of the soil particles with different sizes and unsaturated hydraulic conductivity - shown in Figure 4. When you looked at the relationship between morphological characteristics of the soil particles at various dimensions and soil suction was considered, as in the case of hydraulic conductivity, only two kinds of pores (macropores and nanopores).

If it notices a decrease in the macropores water contents with decreasing values of morphological characteristics of mineral fragments.

Regarding the situation nanopores, it could highlight a change in the form of suction of curves for the four depths. The curve shapes change according to the size of each particle fraction retention, different size and surface.

Water contents fell as the two types of pore surface began to decrease depending on size fraction. As with hydraulic conductivity this relationship has changed from a depth to another.

CONCLUSIONS

The percentages variation of sand, silt and clay has exerted considerable changes in terms of ground water regime for Dancu harvested area, as evidenced in the case of each depths.

The results of SEM analysis type have been a dominant factor in determination of the relationship between morphological characteristics of soil particles with different sizes and analyzed soil hydraulic properties.

We emphasize that the relationship between morphological characteristics of soil particles with different sizes and hydraulic properties of soil samples collected from the Dancu study area presented a real situation, characterized by a change in water regime governed by morphological characteristics variation (size surface particles, pore size and pore surface) of mineral fragments that goes into the soil analyzed.

This study respect the conference theme in question through careful research of the main characteristics of the soil in the study, and the opportunity to highlight their influence on the regime of transport of various fluids regardless of the type and concentration, which can have a high impact on the speed leaching study characterized by a significant concentration and composition of various chemicals and their ability to be stored in the saturated and unsaturated soil - considereat as being a living environment without which our existence is not justified.

Regarding the influence of variation of soil hydraulic properties have studied according to the physical changes, in this case the distribution of sand content, silt and clay on the entire section analyzed (0-80 cm) can greatly influence on the soil by providing an development of the activities with favorable conditions for agriculture (Stătescu and Pavel, 2011).

REFERENCES

Dumitru E. et al., 2009. Metode de analiză utilizate în laboratorul de fizică a solului. Ed. Sitech, Craiova.

Lungu I. et al., 2013. Geotehnică - Lucrări de laborator. Politehnium, Iaşi.

Stanciu A., Lungu I., 2006. Fundaţii şi mecanica pământurilor. Ed. Tehnică, Bucureşti.

Stătescu F., Pavel L.V., 2011. Știința solului. Politehnium, Iaşi.