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

BY

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Abstract. This paper aims to highlight the relationship between soil particles morphology (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 ($k\theta$) and suction was determined using the sandbox, sand/kaolin box and pressure membrane apparatus.

Keywords: hydraulic conductivity; suction; particle size analysis; microscopic analysis.

1. Introduction

According to classical literature, soil can be defined as being a porous medium characterized by the existence of a very complicated system of

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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 matrices) and the liquid one (soil solution) that is moving through the pores of the soil (Stătescu & Chiriac, 1998).

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 (Stătescu & Pavel, 2011).

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

The increase of water when the soil is saturated is defined by filtration process and if the soil is unsaturated by infiltration action (Filipov & Lupaşcu, 2003).

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 matrices was taken into account. The matrices can be composed of mineral fragments with different morphological traits (size, shape and surface area).

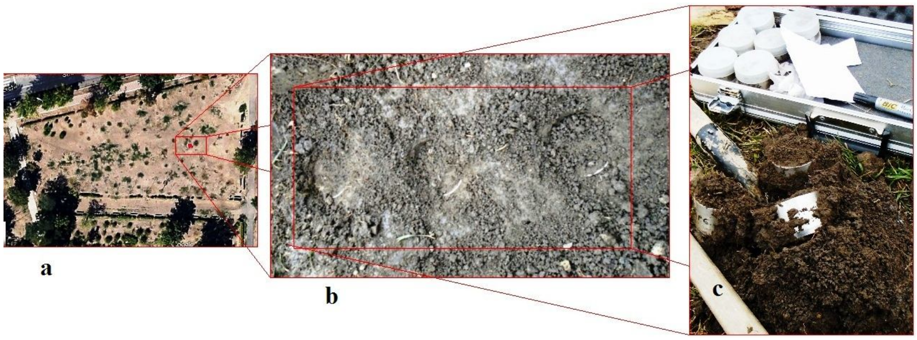

Fig. 1 – Presentation of the location study: *a* – zone of sampling soil; *b* – the extraction of samples; *c* – samples harvested.

Study on the impact of particle morphology variation on soil hydraulic properties 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 was 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 Tătăraşi – Iaşi (Fig. 1 *a*) and can provide some information about the hydrological regime of soil types that have different textures displayed on all four depths study.

2. 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 Fig. 2 2*c*).

Soil particles morphology analyses were achieved by: a) size analysis (Fig. 2 2*a*) and b) SEM (Scanning Electron Microscope) microscopic type.

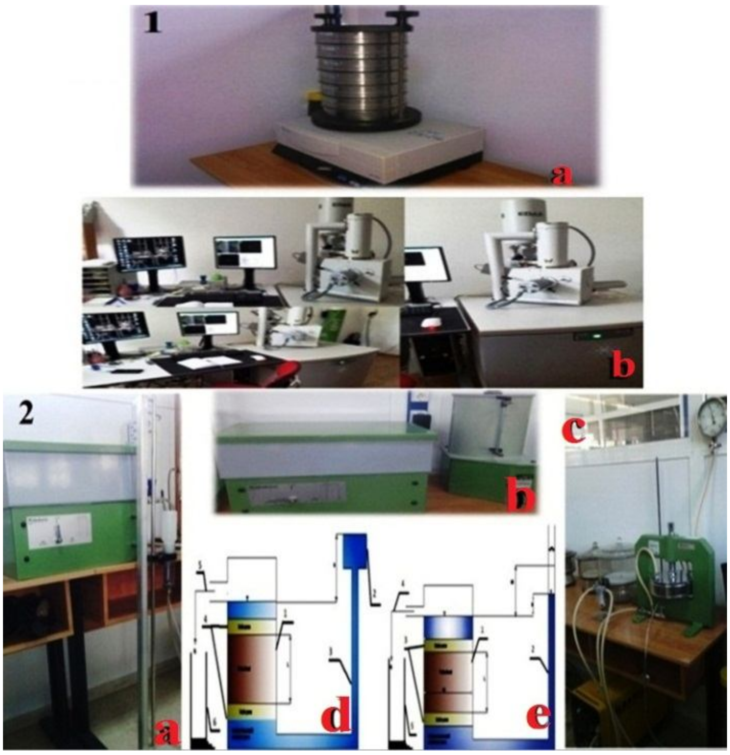

Fig. 2 – The tools used in research: 1: equipment used to analyze the morphology of mineral particles: *a* – shaker electromagnetic; *b* – equipment used in microscopic analysis SEM 2: all equipment used in the study of hydraulic properties: *a* – sandbox; *b* – sand/kaolin box; *c* – pressure membrane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

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 Fig. 2 *b*). 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 Fig. 2 2*d*) and the falling head method (K_θ) (Stanciu and Lungu. 2006) presented in Fig. 2 2*e*). 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 Fig. 2 2*a*, sand/kaolin box pF 2 – pF 2.7) shown in Fig. 2 2*b*), and the pressure membrane apparatus (pF 3 –pF 4.2) noticed in Fig. 2 2*c*) (Dumitru, 2006).

3. Calculation Process

Hydraulic conductivity K_s on vertical direction of the water flow is calculated from the relationship (King, 1965):

$$K_s = \frac{V \times L}{T \times A \times h}, \quad (1)$$

where: *V* is the 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 $K_{(\theta)}$ were determined with relation (King, 1965):

$$K_{(\theta)} = \frac{a \times L}{T \times A} \ln\left(\frac{h_1}{h_2}\right), \quad (2)$$

where: *a* is 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 relation (Ahuja, 1998):

$$W = \frac{\text{Weight of soil water} \times 100\%}{\text{Weight of soil}}, \quad (3)$$

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

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

where: θ is the volumetric water content [%], *W* – soil humidity [%], ρ_d – soil bulk density, [g/cm^3].

3. Results and Discussions

Table 1 shows the values of the unsaturated hydraulic conductivity and in Table 2 are mentioned the values of saturated hydraulic conductivity. SEM analysis results will be presented in Fig. 3, which will be presented 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

	$K_{(\theta)}$ T 0-20 cm at 15°C		$K_{(\theta)}$ T 20-40 cm at 15°C		$K_{(\theta)}$ T 40-60 cm at 15°C		$K_{(\theta)}$ T 60-80 cm at 15°C
ΔT	K_t , [cm/s]	ΔT	K_t , [cm/s]	ΔT	K_t , [cm/s]	ΔT	K_t , [cm/s]
5	0.055774	2	0.139435	2	0.139435	3	0.092956
10	0.029658	11	0.026962	7	0.042369	10	0.029658
15	0.021149	20	0.015862	16	0.019827	21	0.015106
19	0.017936	28	0.012171	27	0.012622	38	0.008968
26	0.014155	36	0.010223	47	0.007830	51	0.007216
37	0.010816	44	0.009095	58	0.006900	68	0.005885
46	0.009530	52	0.008431	67	0.006543	86	0.005097
57	0.008501	62	0.007816	78	0.006212	114	0.004250
65	0.008335	71	0.007631	89	0.006087	138	0.003926
77	0.007974	80	0.007675	103	0.005961	176	0.003488
89	0.007964	90	0.007875	117	0.006058	207	0.003424
100	0.008386	100	0.008386	130	0.006451	234	0.003553
115	0.008925	112	0.009164	141	0.007279	280	0.001593
		121	0.010935	150	0.008821		
Average	0.016085		0.020119		0.020171		0.016361

Table 2
Saturated Hydraulic Conductivity Values

	K_s T 0-20 cm at 20 ° C		K_s T 20-40 cm at 20 ° C		K_s T 40-60 cm at 20 ° C		K_s T 60-80 cm at 20 ° C
ΔT	K_s (cm/s)	ΔT	K_s (cm/s)	ΔT	K_s (cm/s)	ΔT	K_s (cm/s)
2	0.139435	3	0.092956	2	0.139435	840	0.000331
8	0.037073	13	0.022814	15	0.019772	2,040	0.000221
13	0.010610	21	0.015106	31	0.010233	2,820	0.000116
20	0.017039	29	0.011751	43	0.003445	3,600	0.000098
46	0.008001	37	0.009947	56	0.006572	4,500	0.000085
40	0.010005	47	0.008515	70	0.005717	5,400	0.000077
47	0.009328	56	0.007829	85	0.005157	6,300	0.000073
54	0.008974	64	0.007572	99	0.004895	7,320	0.000069
61	0.008881	75	0.007224	116	0.004670	8,400	0.000068
68	0.009029	85	0.007223	132	0.004651	9,540	0.000069
		96	0.007383	148	0.010159	10,620	0.000072
Average	0.0258375		0.0180290		0.0195187		0.00011627

Determining the change of soil hydraulic properties in the Tatarasi area, only maximum and minimum of two types of pores were taken into account: maximum macro pores surface and minimum surface of nanopores. To determine relationship between morphological characteristics that belong to particles with different dimensions which are in direct relation to pore system and hydraulic conductivity unsaturated was taken into account only one type of pores – macro pores considering that it has a greater carrying capacity than the nanopore. Nanopores were being used for determining the saturated hydraulic conductivity because they have a much lower transmission capacity.

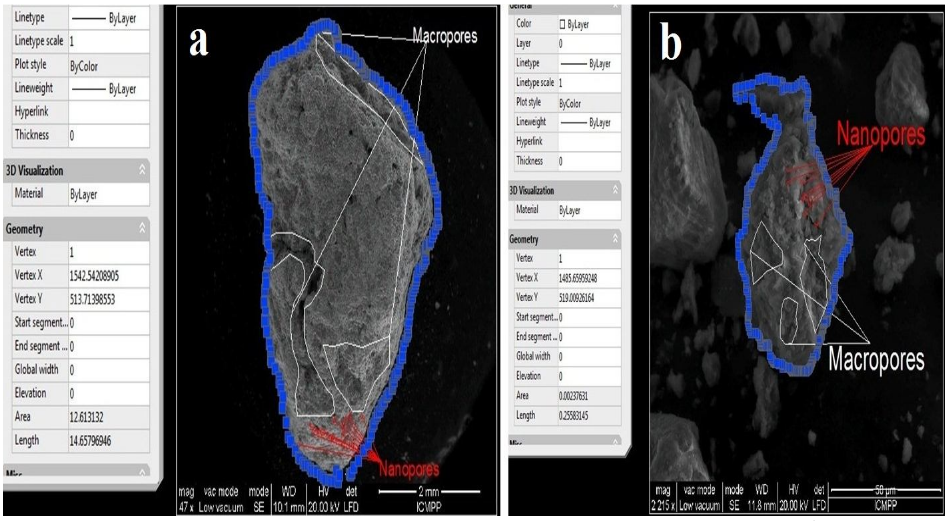

Fig. 3 – SEM image at 47x and 2215 x- morphological particularities of mineral fragments from Tătăraşi 0-20 cm: *a* – particle 1 mm - specific surface area and particle size and distribution of soil particle pore surface; *b* – particle < 63 µm - specific surface area and particle size and distribution of soil particle pore surface.

The highest values of $K_{(\theta)}$ were attributed to the macro pores and lowest values of K_s have been distributed to the nanopores according to the argument mentioned above. This relationship for first depth is shown in Figs. 4 and 5 and and for other depths was similary proceeded. 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 Figs. 6 and 7 and and for other depth was similar. The values of morphological characteristics are shown in Tables 2 and 3 (done with AutoCAD 2007).

5. Result Interpretation

The preliminary data obtained from the $K_{(\theta)}$ analysis noted in Table 1 showed a speed of transport who has gradually varied from a depth to another one, depending by size distribution presented in Figs. 4, 5, 6 and 7. Hydraulic conductivity research conducted on soil samples collected from the site of Tatarasi study revealed that in the first depths (T 0-20 cm) was determined the highest value of K_s compared to other depths where $K_{(\theta)}$ values showed a strong concordance K_s values in all three situations: T 20-40 cm, T 40-60 cm and T 60-80 cm in which we have seen a variation of these two types of conductivity variation attributed to the contents of sand, silt and clay.

Table 3

The Morphological Analysis for Particles of Different Size Fractions with Macro Pores System

Tătăraşi 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 (max) P.D. (mm)
T 0-20 cm	1mm	12.624	Macropores	0.950	2.33
T 0-20 cm	500 µm	1.322	Macropores	0.093	0.442
T 0-20 cm	250 µm	0.032	Macropores	0.001	0.078
T 0-20 cm	125 µm	0.0170	Macropores	0.0019	0.052
T 0-20 cm	63 µm	0.0178	Macropores	0.001	0.053
T 0-20 cm	< 63 µm	0.0023	Macropores	0.0001	0.022
T 20-40 cm	1mm	8.401	Macropores	0.675	1.47
T 20-40 cm	500 µm	1.341	Macropores	0.0015	0.054
T 20-40 cm	250 µm	0.159	Macropores	0.013	0.134
T 20-40 cm	125 µm	0.02	Macropores	0.124	0.456
T 20-40 cm	63 µm	0.01	Macropores	0.0007	0.032
T 20-40 cm	< 63 µm	0.0034	Macropores	0.00019	0.023
T 40-60 cm	1mm	8.139	Macropores	0.778	1.24
T 40-60 cm	500 µm	0.885	Macropores	0.089	0.435
T 40-60 cm	250 µm	0.08	Macropores	0.0076	0.122
T 40-60 cm	125 µm	0.021	Macropores	0.0024	0.187
T 40-60 cm	63 µm	0.004	Macropores	0.0004	0.037
T 40-60 cm	< 63 µm	0.001	Macropores	0.0002	0.025
T 60-80 cm	1mm	10.048	Macropores	1.119	1.49
T 60-80 cm	500 µm	1.067	Macropores	0.089	0.499
T 60-80 cm	250 µm	0.165	Macropores	0.013	0.195
T 60-80 cm	125 µm	0.033	Macropores	0.0038	0.090
T 60-80 cm	63 µm	0.0036	Macropores	0.00029	0.020
T 60-80 cm	< 63 µm	0.0029	Macropores	0.00018	0.020

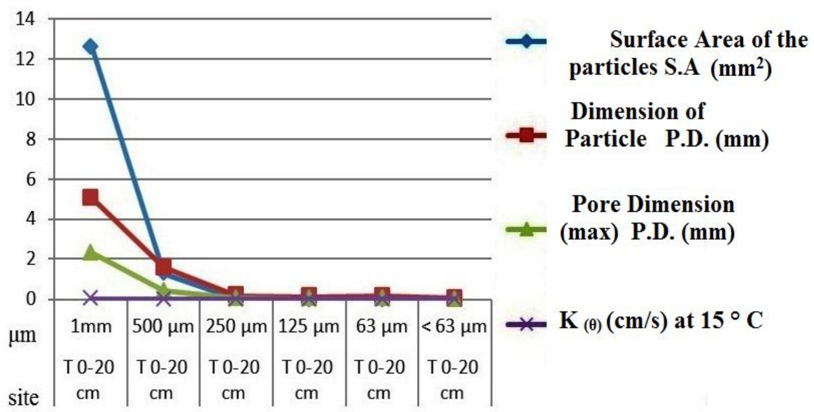

Fig. 4 – The relationship between morphological characteristics associated particle at different particle size fractions and unsaturated hydraulic conductivity for first depth.

Table 4

The Morphological Analysis for Particles of Different Size Fractions with Nanopores System

Tătărași 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 (min) P.D. (mm)
T 0-20 cm	1mm	12.624	Nanopores	0.0004	0.029
T 0-20 cm	500 µm	1.322	Nanopores	0.00005	0.012
T 0-20 cm	250 µm	0.032	Nanopores	0.0000019	0.0028
T 0-20 cm	125 µm	0.0170	Nanopores	0.000001	0.001
T 0-20 cm	63 µm	0.0178	Nanopores	0.0000002	0.0006
T 20-40 cm	1mm	0.0023	Nanopores	0.0002	0.027
T 20-40 cm	500 µm	8.401	Nanopores	0.000001	0.001
T 20-40 cm	250 µm	1.341	Nanopores	0.000005	0.003
T 20-40 cm	125 µm	0.159	Nanopores	0.000059	0.008
T 20-40 cm	63 µm	0.02	Nanopores	0.0000003	0.0008
T 40-60 cm	1mm	0.01	Nanopores	0.778	0.016
T 40-60 cm	500 µm	0.0034	Nanopores	0.089	0.01
T 40-60 cm	250 µm	8.139	Nanopores	0.0076	0.009
T 40-60 cm	125 µm	0.885	Nanopores	0.0024	0.005
T 40-60 cm	63 µm	0.08	Nanopores	0.0004	0.003
T 60-80 cm	1mm	0.021	Nanopores	0.0001	0.014
T 60-80 cm	500 µm	0.004	Nanopores	0.00003	0.007
T 60-80 cm	250 µm	0.001	Nanopores	0.000009	0.004
T 60-80 cm	125 µm	10.048	Nanopores	0.000001	0.001
T 60-80 cm	63 µm	1.067	Nanopores	0.0000004	0.0009

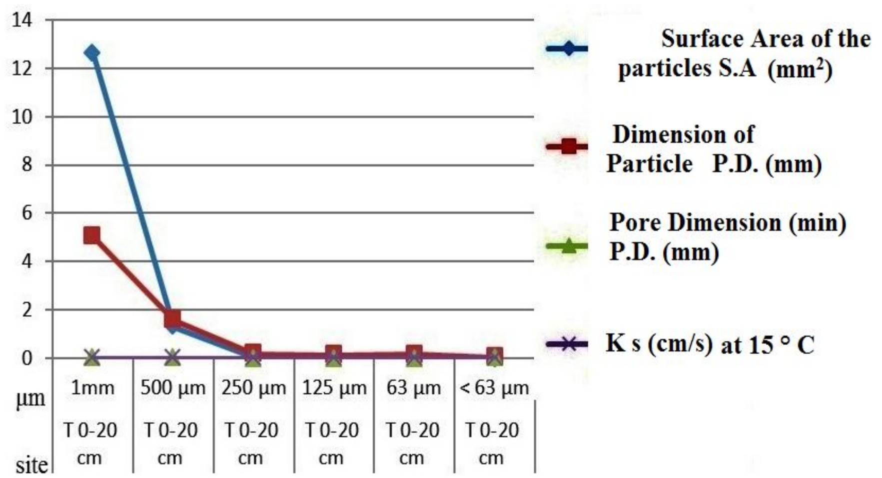

Fig. 5 – The relationship between morphological characteristics associated particle at different particle size fractions and saturated hydraulic conductivity for first depth.

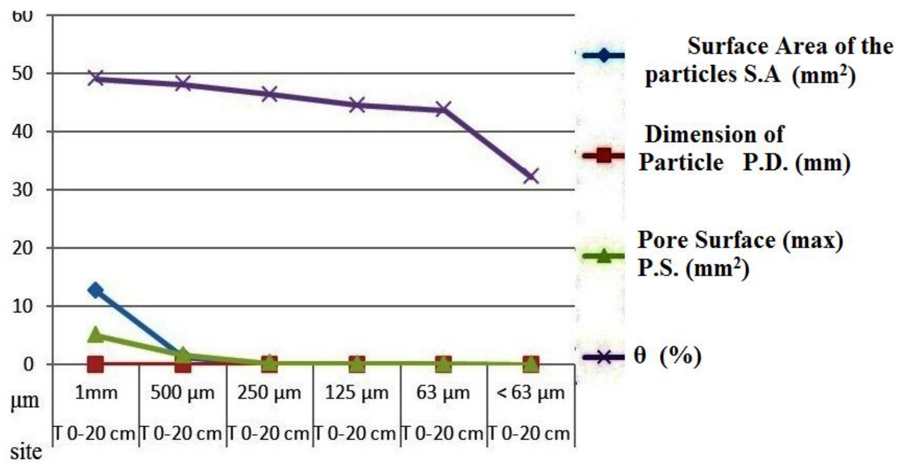

Fig. 6 – The relationship between morphological characteristic of particle at different particle size fractions and soil suction for first depth (macropores).

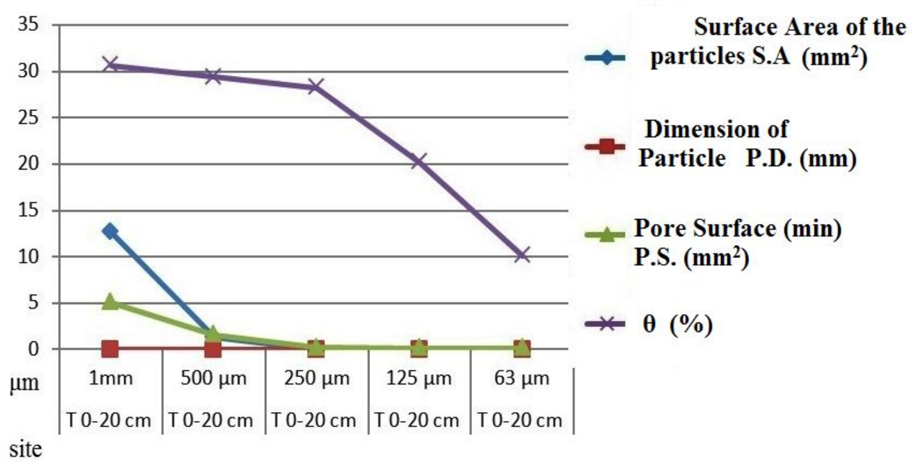

Fig. 7 – The relationship between morphological characteristic of particle at different particle size fractions and soil suction for first depth (nanopores).

According to data of Tables 3 and 4 materialized in graphs format – shown in Figs. 4 and 5 (for first depth and for other depths was similary proceeded), in case of an oscillation of transmission capacity for soils collected from 4 depths of Tatarasi study area, depending on the particular morphology of particles which has been active contributed in soil composition process.

For example we consider the particles 1 mm and less than 63 mm, and will notify the considerable oscillation of transmission capacity for the soil profile due to reduced values corresponding with morphological particularities of the two pores type (macro pores and nanopores) distributed on the most important basic morphological features of skeletal elements represented by the surface area.

After conducting a type of comparative analysis between $K_{(\theta)}$ and K, we will highlight the major difference between the two, resonated by the lowest K values of soils which has been composed by the different grans size, as in the case of $K_{(\theta)}$ was presented a modified proportional decrease in other morphological particularities characterizing the transmission power of aggregates often treated like a matrices essential elements. According to the previously mentioned aspects that are found in soil taken from the Tatarasi site in 60-80 cm depth, was determined the lowest value of K_s of all four depths.

The average value of K_s was noted in the sample T 20-40 cm and the highest values was determined in soil sample extracted from the first depth. An overview of the storage capacity on 0-80 cm section gave us a situation characterized by the gradual decease of the particle size contents proportional directly to depth increasing.

Following the graphic investigation of Figs. 6 and 7 (for first depth and for other depths was similary proceeded) and the values of Table 2 in correlation with the Tables 3 and 4 we can note one aspect represented by the soil suction of Tătăraşi site, who has been decreased significantly from one depth to the other one, which reinforces the claim that suction is closely correlated to possible changes to the basic parameters and any variation of them may induce an oscillation series of the volumetric water content. The lowest value of θ was observed in soil taken from the T 60-80 cm depth compared with other three stages of harvest which provided higher values of the volumetric content because the values of macro pore surfaces were greater.

Thus, we can mention that the average value was noticed at T 20-40 cm soil compared with the largest volumetric content observed in T 0-20 cm topic.

6. Conclusions

The distribution of percentage contents of sand, silt and clay on study section greatly influenced hydric regime of soil from the Tatarasi site. When we are referring to the soil we relate at a homogeneous formation composed by well-structured aggregates which are formed to particles with different diameters, sizes and shapes. All characteristics mentioned above are taken in to account when we want to determine the transport and storage mode of all fluids types when they come into direct contact with two of the three phases soil characteristics as field of study.

The results of the SEM analysis type help us in making accuracy determination of possible relationship between morphological characteristics representative for each particle and the most important hydraulic properties of the soil with a major impact on water regime corresponding with the each type of soil.

This work has focused on how the variation of certain basical characteristics of particles shows the possibility of changing the regime for the various fluids when you want to determine the main particularities of agricultural soils. Soils used for farming activities often after intensive exploitation for satisfying the needs of the last rings of the food chain are in long process of decay with a knowingly subject.

We, as the main beneficiaries of all vital resources without we could not exist, should realize that these environmental components called so simple - SOIL and WATER are more important than any desire in our universe because these two endorsements taken together with the AIR represents the most expensive things that the future generations should enjoy and respect.

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CERCETĂRI PRIVIND IMPACTUL VARIAŢIEI MORFOLOGIEI FRAGMENTELOR MINERALE DE SOL ASUPRA PROPRIETĂŢILOR HIDRAULICE

(Rezumat)

Lucrarea de faţă îşi propune să evidenţieze relaţia dintre morfologia particulelor de sol (forma, mărimea şi aria suprafeţei) şi proprietăţile hidraulice (conductivitate hidraulică (saturată şi nesaturată) şi sucţiunea solului). Determinarea caracteristicilor morfologice ale particulelor de sol a fost realizată prin: a) analiza granulometrică şi b) SEM tip de analiză microscopică. Determinarea proprietăţilor hidraulice ale solului a fost realizată prin metode de laborator: pentru conductivitatea hidraulică a fost folosită metoda cu gradient hidraulic constant (K_s) şi metoda cu gradient hidraulic variabil ($K_{(\theta)}$) iar sucţiunea a fost determinată folosind cutia cu nisip, cutia cu nisip/caolin şi aparatul cu membrană.