Moisture Retention Characteristics in the Vertisols of the Stip, Probistip and Sv. Nikole Region

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Summary

This paper has studied the moisture retention in the vertisols of the Stip, Probistip and Sv. Nikole region at eight different tensions (0.1; 0.33; 0.75; 1; 2; 6.25; 11; 15 bars) using Bar extractor and Pressure membrane extractor. The moisture retention curves from these data were drawn for each of the soil samples separately. Results showed that the moisture retention is enormously high throughout the soil profiles depth and depends primarily on the richness of the parent material in clay and montmorillonite, and to some extent on pedogenesis (organic matter accumulation, pedoturbation). Hydropedological constants (field water capacity, wilting point) are in positive correlation with the clay content, but, in case of equal clay content between some profiles, every change of the montmorillonite (MLM) content affects the moisture retention intensiveness. Field water capacity (0.33 bars) varies from 22.47 to 40.47 mass %, or in average 32.40 mass %. But, in spite of the high water preservation, plants in these soils are not provided with enough water because the wilting point (15 bars) has also high values, from 13.55 to 24.68 mass % (average 20.09 mass %). For that reason, available water capacity is 12.32 mass %, or only 38 mass % of the whole moisture, which is retained in the soil, is available to plants. The retention curves are relatively close one to another and do not show big differences between them in the profiles (same mechanical and clay mineralogical composition, profiles homogeneity). They are almost horizontal at 2-15 bars in all cases. The greatest decline of the curves occurs at lower pressures (to 2 bars).

Key words

vertisol, clay, montmorillonite, hydropedological constants, retention curves

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Received: May 27, 2011 | Accepted: August 11, 2011

Introduction

The Republic of Macedonia is small in its territory (25,713 km^2), but it shows a great diversity of natural conditions. Here, as in a natural museum, can be seen almost all relief forms, geological formations, climatic influences, plan associations and soils which appear in Europe. In the great heterogeneity of the soils, vertisols are widespread of around 61,900 ha or 2.41% of the whole soil surface. On cultivated surfaces in the Republic of Macedonia, which are 540,000 ha, vertisols participate with 11.34% (Filipovski, 1996). These soils have unique morphology and capacity to change volume with changes in water content (swelling and contraction), which has an affect on the differential porosity and the ability of plants to adopt water.

Vertisols, which are the object of our research, are widespread in the valleys and melioration areas in the central part of Macedonia, where irrigation systems are built, by which the introduction of intensive agricultural production is made possible. Here valuable agricultural crops that cannot be cultivated without irrigation should be mentioned (grapevines and fruit, garden-stuff and fodders). In this situation being familiar with the characteristics of the moisture retention has significant meaning in reaching the maximum effect from the irrigation and obtaining high, stable and qualitative yields.

That implicates the need of researching the intensity of moisture retention in the examined soils, represented through retention curves that have practical and theoretical importance (Richards, 1955). They give us data for soil available water capacity, whose upper limit is field water capacity (retention of moisture up to 0.33 bars) and lower limit is wilting point (moisture retention up to 15 bars). Looking at the retention curves it is more than obvious that we can judge on the moisture content in different tensions, and make conclusions about the time and quantity of irrigation by taking into consideration the cultivated crops needs. The curves are used for explaining the relations between the crop and the soil moisture, and the direction of the moisture through the soil.

The problem of moisture retention was investigated because it has great theoretical and practical importance and because such a detailed moisture retention study had not been done earlier on the Macedonian vertisols. As far as we know, in our country, only Filipovski and Pradan (1980) reported on one vertisol soil profile retention curves characteristics.

Material and methods

Field research

The field research of the soils was made during 2009 on three localities (Stip, Probistip and Sv. Nikole) in the central part of the Republic of Macedonia. Four basic pedologic profiles of the vertisols were rutted: profile N° 2 (Stip - 41°49'06.42" N, 22°11'59.71" E); profile N° 5 (Probistip - 41°54'20.74" N, 22°09'47.95" E); profile N° 7 (Probistip - 41°53'34.76" N, 22°11'05.64" E) and profile N° 9 (Sv. Nikole - 41°53'54.74" N, 21°52'54.78" E). Seventeen soil samples were collected from the Ap (cultivated layer of humus-accumulative horizon), A (non-cultivated layer of humus-accumulative horizon), AC (intermediate horizon) and C (parent material) horizons of profiles for laboratory analysis.

In the examined soils it is found that there is an appearance of all the processes characteristics for the genesis of the vertisols: 1. accumulation of humus of specific character by forming deep humus-accumulative horizon A; 2. decarbonization; 3. periodical hydromorphism and 4. pedoturbation.

According to the classification of soils in the Republic of Macedonia (Filipovski, 1996), the examined soils belong to different sub-types and varyeties of the vertisols. Profiles N° 2 and 7 belong in the sub-type noncalcareous vertisols, variety on clayish sediments (profile N° 2) and variety on pyroclastic sediments (profile N° 7). Profiles N° 5 and 9 belong to the sub-type of calcareous vertisols, variety on pyroclastic sediments (profile 5) and variety on clayish sediments (profile 9).

Determination of the soil characteristics

Laboratory analyses were performed in the chemistry laboratory at the "Goce Delcev" University - Stip (mechanical composition, hygroscopic moisture, pH, carbonates content and organic matter content), laboratory for irrigation at the "Ss Cyril and Methodius" University, Faculty of Agricultural Sciences and Food - Skopje (moisture retention) and Faculty of Mining and Geology - Belgrade (clay mineralogical composition), according to the following methods:

- Mechanical composition of the soil was determined by the International pipette B method and preparation of the soil samples for mechanic analysis was done by means of 0.4 N natrium pyrophosphate - $Na_4P_2O_7$ (Thurin et al., 1955). The fractioning of the mechanical elements was done according to the International Classification, while the classification of the soils in texture classes was done according to Schefer and Schachtcshabel (1956). Hygroscopic moisture was determined by drainage of the soil on 105 °C to constant mass (Korunović and Stojanovič, 1986).
- For each soil sample the moisture content (in mass %) in eight different tensions (0.1; 0.33; 0.75; 1; 2; 6.25; 11; 15 bars) was determined using Bar extractor (Richards and Fireman, 1943) and Pressure membrane extractor (Richards, 1947). The moisture retention to 1 bar tension was determined by Bar extractor, and the moisture retention to tension from 2 to 15 bars was determined by Pressure membrane extractor.
- Clay mineralogical composition was determined with a difractometer, PHILIPS, type PW 1051, in area $2\theta = 5^0 \div 60^0$. For the determination of clay, from each soil sample, two preparations were made. The first one was typed untreated, and then satiated with glycerin, and the other one was heated on 480^{0}C temperature in order to obtain the type of the clay mineral in the area $2\theta = 3^0 \div 14^0$ (Đurić, 1999).
- Soil pH was determined in a suspension in water and 1 M KCl at the ratio of soil:solution ratio of 1:2.5 after a 0.5 h equilibration period; the carbonates content was determined gravimetrically with glasses; the organic content was determined using the humus method of Kotzmann (Colombo et al., 1998).

Results and discussion

Mechanical composition

Review of the mechanical composition of the soils is presented in Table 1. It can be seen that the mechanical composition of the examined soils, according to the clay content is a characteristic of the vertisols, which have high level of clay content, over 30% to 50 cm soil depth (Soil Survey Staff, 1970; Driessen and Dudal, 1989).

In all depths the examined soils contain more than 35% clay from the fine separates. This fraction participates with 35.10 to 52.50% in the soils, or on average 41.80%. Second place is for the fraction of fine sand (23.03%), then the silt (22.40%) and on the last place is coarse sand (12.83%). The content of the "physical clay" (silt+clay) varies from 51.30 to 86.20% and dominates over the sandy part. The high content of the "physical clay" and clay itself is reflecting on the moisture retention. The results of the textural analysis show that, according to Schefer and Schachtcshabel (1956) textural classification, about 82% of the analyzed samples belongs to loamy clays and only three samples to heavy clays. High values of hygroscopic moisture (5.32-10.09 mass %) show great hydrofilitey of the colloids.

Chemical properties and clay mineralogical composition

The data in the Table 2 show that organic matter content is low, but its accumulation has depth of over 100 cm (pedoturbation) with maximum in the cultivated layer Ap (2.33-3.99%).

Table 1. Mechanical composition of vertisols

Profile N⁰	Horizons and depth, cm	HM (mass %)	CF	Fine soil separates in %					Texture
				CS	FS	S	C	S+C	
2	Ap (0-23)	7.28	1.80	18.96	25.54	16.90	38.60	55.50	LC
	A (23-75)	10.09	1.68	19.65	26.65	11.00	43.70	54.70	LC
	AC (75-95)	9.06	1.01	23.23	24.17	12.20	40.40	52.60	LC
	C (95-115)	7.66	0.41	24.34	24.36	17.20	35.10	51.30	LC
5	Ap (0-18)	9.22	2.19	3.74	27.36	28.80	40.10	68.90	LC
	A (18-73)	8.45	0.26	6.57	24.03	20.80	48.60	69.40	HC
	AC (73-107)	7.86	0.21	4.83	15.87	27.70	51.60	79.30	HC
	C (107-130)	7.87	0.04	3.57	10.23	33.70	52.50	86.20	HC
7	Ap (0-26)	6.60	2.60	22.08	23.82	15.40	38.70	54.10	LC
	A (26-54)	6.68	2.94	23.36	23.04	18.00	35.60	53.60	LC
	Aca (54-105)	9.38	1.20	16.29	24.61	15.60	43.50	59.10	LC
	AC (105-150)	8.72	1.06	15.21	18.89	23.50	42.40	65.90	LC
	C (150-165)	7.86	0.76	19.55	27.35	15.60	37.70	53.10	LC
9	Ap (0-25)	5.76	0.50	6.23	27.87	30.30	35.60	65.90	LC
	A (25-68)	5.57	0.47	4.93	25.17	28.20	41.70	69.90	LC
	AC (68-113)	5.34	0.07	2.50	24.00	30.70	42.80	73.50	LC
	C (113-125)	5.32	0.19	3.08	18.58	35.24	43.10	78.34	LC

HM: Hygroscopic moisture; CF: Coarse fragments (> 2 mm); CS: Coarse sand (0.2 - 2mm); FS: Fine sand (0.02 - 0.2 mm); S: Silt (0.002 - 0.02 mm); C: Clay (< 0.002 mm); S+C: Silt+clay-"Physical clay" (< 0.02 mm); LC: Loamy clay; HC: Heavy clay.

Table 2. Chemical properties and clay mineralogical composition of vertisols

Profile N⁰	Horizons and depth, cm	Chemical properties				Clay mineralogical composition					
		OM (%)	$CaCO_3$ (%)	pH H_2O	pH KCl	M	I-M	M-C	I	K	C
2	Ap (0-23)	2.68	0.00	6.76	5.65	44.00	32.00	-	18.60	-	5.50
	A (23-75)	2.22	0.00	7.18	6.95	-	69.60	-	30.40	-	-
	AC (75-95)	1.91	0.00	7.46	6.09	-	68.80	5.10	16.90	9.10	-
	C (95-115)	1.60	24.96	8.35	7.23	26.20	40.50	-	11.90	4.70	16.70
5	Ap (0-18)	3.99	9.39	7.92	6.96	9.90	31.50	13.50	38.70	6.30	-
	A (18-73)	2.42	11.90	7.79	7.14	23.50	12.70	21.70	28.30	13.90	-
	AC (73-107)	2.01	21.69	8.01	7.31	13.80	14.70	25.70	28.50	17.40	-
	C (107-130)	1.72	24.05	8.49	7.60	10.60	24.00	25.50	28.00	11.20	-
7	Ap (0-26)	3.70	0.00	6.84	5.94	35.20	-	15.50	40.30	9.00	-
	A (26-54)	3.41	0.00	7.44	6.20	15.30	51.80	-	23.50	-	9.40
	Aca (54-105)	3.34	1.74	8.31	7.30	51.60	22.00	-	26.40	-	-
	AC (105-150)	2.55	6.67	8.54	7.41	79.30	-	-	18.50	-	2.10
	C (150-165)	2.14	7.18	8.54	7.54	46.30	35.60	-	18.10	-	-
9	Ap (0-25)	2.33	14.27	7.59	7.19	23.00	15.10	-	28.30	30.70	3.00
	A (25-68)	1.57	26.92	7.83	7.39	37.80	-	7.40	21.30	21.80	11.70
	AC (68-113)	1.07	25.95	7.75	7.30	21.40	9.70	-	21.40	25.30	22.11
	C (113-125)	0.99	27.20	7.92	7.52	24.80	7.90	-	20.20	24.20	22.90

OM: Organic matter; M: Montmorillonite; I-M: Illite-montmorillonite; M-C: Montmorillonite-chlorite; I: Illite; K: Kaolinite; C: Chlorite

At non-calcareous vertisols (profiles Nº 2 and 7) carbonates are deeply eluviated in the ground and go up with pedoturbation, while at calcareous vertisols (profiles Nº 5 and 9) carbonates are on the surface. In non-calcareous parts of the profiles the reaction in water is neutral to moderately alkaline and in the calcareous parts medium to highly alkaline.

Clay mineralogical composition is almost equal in all depths of the profiles and it is inherited by the parent material. It equalizes with pedoturbation. Profile Nº 2 has dominant presence of montmorillonite and mixture-layer minerals (MLM) in which it prevails (mostly illite-montorillonite), average 71.55%. Then follows: the illite, average 19.45%; chlorite (5.5%), and the least prevalent clay mineral is kaolinite, average only 3.45%. That means that the following association of the clay minerals appears: montmorillonite (MLM) – illite – kaolinite – chlorite. In the profile Nº 5 montmorillonite (MLM) presents the dominant part too, but with lower percentage (56.95%) than in profile Nº 2. On second place is illite (25.36%) and the third and last place is kaolinite (12.20%). Chlorite does not appear in this profile that means that the association montmorillonite (MLM) – illite – kaolinite is present. Profile Nº 7 is similar to the profile Nº 2 with same association of the clay minerals, which show similar average values: montmorillonite (70.52%), illite (25.36%), chlorite (2.87%) and kaolinite (1.80%). Profile Nº 9 is differentiated from the other three. The first difference is that the domination of the montmorillonite (MLM) is not as big as in the other profiles (36.77%). The second difference is that the presence of kaolinite (25.50%) is greater than illite (22.80%) that was not the case in the other profiles. And in the end this is the only profile where chlorite appears on the whole depth and with a higher average value (14.95%) compared to other profiles. Analyzing the mineralogical composition of the clay fraction of the examined vertisols, the conclusion is that montmorillonite (MLM) is the most present mineral. In the whole mineralogical composition of this fraction its presence is 59.36%, on second place is illite (24.66%), on third place is kaolinite (10.21%), and on the last place is chlorite (5.49%).

In loams, even more in the clay soils, especially if the clay fraction is of minerals that swell (smectites: montmorillonite, nontronite), large active surface with the small pores proportions represent their characteristic (Voronin, 1974). According to Dudal (1965) in the vertisols from Mississippi the smallest clay fractions have 2-3 times higher capacity of ion adsorption (more montmorillonite) than the larger ones.

Moisture retention

Water is known as a “medium of life” and good supply of water is extremely important for all living organisms. The biological meaning of water consists of two facts: that life originates from water and that without water there is no life. In most of the cases water is a decisive factor in the plant production providing stable and qualitative yields. Crops have great need for water that is received through the root system from the soil. Soils where the crops are being cultivated should have such characteristics that can keep a certain amount of water needed by plants, and the water surplus should be pushed deeply. Quantitative indicators for soil ability to retain water are its hydropedological constants. Hydropedological constants are the quantities of water that soil contains in certain retention strengths. In our research hydropedological constants that are the most important for plants are obtained. They are: field (retention) water capacity (FWC), wilting point (WP), available water capacity (AWC) and the lentocapillary moisture (LM).

Lately, for a more practical and easier determination of these constants, hardworking and long termed field methods are replaced by newer, more practical methods helped by different devices which squeeze the moisture of the soil with certain pressure. Because of this, it is agreed initially that the value of FWC is squeezed under pressure of 0.33 bars, LM of 6.25 bars, and WP of 15 bars. In our examinations, the soil samples were set on eight different regimes with pressure (0.1; 0.33; 0.75; 1; 2; 6.25; 11; 15 bars) using Bar extractor and Pressure membrane extractor. The obtained results for moisture retention in mass % are presented in Table 3.

From the data in the Table 3 it is evident that FWC varies from 22.47 to 40.47 mass %, average 32.41 mass %. But, beside the high maintenance of water, the plants in these soils are still not supplied enough with water. The reason for that are high values of WP, whose average value is 20.09 mass % and varies from 13.55 to 24.68 mass %. Because of this, AWC is 12.32 mass %, or 38 mass % of the whole moisture that is retained in the soil is available to plants. Studying the water-physical features of the vertisols in Kosovo, Babović (1977) found similar average values for FWC (32.50 mass %), WP (23.56 mass %) and AWC (10.45 mass %). In addition, Stojićević (1960) and Pavićević (1969) got similar results for the mutual connection of FWC and WP of the vertisols of Serbia.

For gaining a clearer picture of the intensity of the moisture retention in vertisols, Figure 1 presents the average values of the moisture in mass % with pressure of 0.33 and 15 bars and the AWC through horizons. From this Figure it can be noticed that FWC (31.41-33.51 mass %) and WP (19.20-20.92 mass %) obtain high values and they do not differentiate in the profiles depth. The AWC also varies a little (12.01-12.94 mass %).

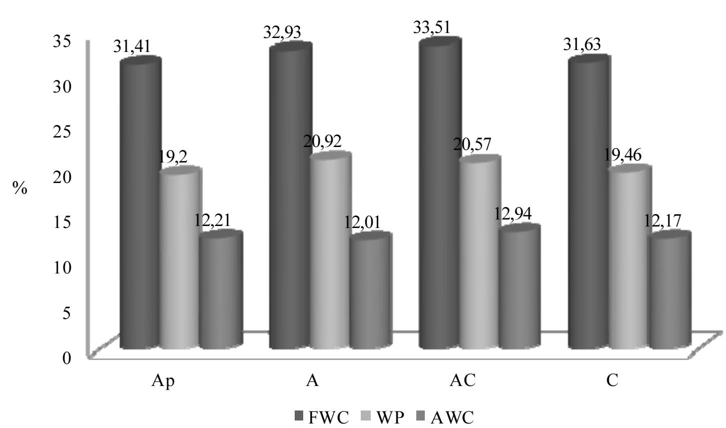

Figure 1. Field water capacity, wilting point and available water capacity by horizons (average values)

Table 3. Moisture retention in mass % of eight points of tension

Profile N⁰	Horizons and depth, cm	Moisture retention in mass % by different tensions in bars								AWC (%)
		0.1	0.33	0.75	1	2	6.25	11	15	
2	Ap (0-23)	34.92	30.68±1.07	29.15	27.58	26.95	23.06±2.92	20.72	20.36±2.33	10.32
	A (23-75)	42.15	36.32±1.45	34.37	32.44	29.59	26.49±4.11	25.61	24.68±3.69	11.64
	AC (75-95)	41.41	36.34±1.69	34.33	32.12	27.56	25.83±2.28	24.35	23.35±2.15	12.99
	C (95-115)	38.26	32.69±0.72	31.20	28.74	25.12	23.05±4.37	20.36	20.02±0.70	12.67
5	Ap (0-18)	42.52	35.09±3.11	32.41	31.17	27.28	25.02±2.61	22.85	21.5±3.95	13.58
	A (18-73)	43.17	33.98±3.48	32.45	29.83	27.24	25.73±2.29	23.89	21.94±1.58	12.04
	AC (73-107)	42.99	36.23±1.71	32.99	30.17	26.92	23.89±1.78	22.82	21.75±2.99	14.48
	C (107-130)	41.47	34.98±5.80	31.61	29.54	26.14	22.63±2.87	22.01	21.73±0.95	13.25
7	Ap (0-26)	35.10	34.97±2.40	30.45	27.55	23.46	22.18±3.36	21.29	19.90±1.81	15.07
	A (26-54)	36.84	31.13±2.77	29.87	28.46	24.84	23.42±3.18	21.46	19.71±0.78	11.42
	Aca (54-105)	44.62	40.47±3.70	37.62	34.92	30.07	28.32±1.57	26.82	24.26±1.57	16.21
	AC (105-150)	45.83	39.03±0.99	37.13	34.95	29.54	27.23±1.53	26.97	23.65±1.26	15.38
	C (150-165)	45.11	35.93±3.07	33.72	31.51	27.82	24.92±3.69	24.76	22.24±2.02	13.69
9	Ap (0-25)	32.92	24.89±3.15	24.55	22.65	20.11	17.35±3.11	16.20	15.05±1.24	9.84
	A (25-68)	29.12	22.79±2.43	22.63	20.68	18.24	16.02±2.13	15.45	14.02±1.29	8.77
	AC (68-113)	27.99	22.47±2.25	22.28	20.46	17.66	15.42±1.55	14.62	13.55±2.32	8.92
	C (113-125)	28.92	22.92±2.50	22.70	20.13	17.86	16.24±1.31	15.76	13.85±2.39	9.07

Results for FWC (0.33 bars), LM (6.25) and WP (15 bars) are average of three replicates ± SD (standard deviation)

Table 4. Correlation between moisture retention and mechanical composition

Soil fraction	Moisture retention in different tensions							
	0.1	0.33	0.75	1	2	6.25	11	15
Coarse sand	-0.55	-0.51	-0.51	-0.52	-0.60	-0.53	-0.46	-0.60
Fine sand	-0.27	-0.28	-0.23	-0.21	-0.16	-0.13	-0.16	-0.21
Total sand	-0.52	-0.49	-0.48	-0.48	-0.52	-0.45	-0.41	-0.55
Clay	0.44	0.37	0.34	0.31	0.30	0.27	0.29	0.35
Physical clay	0.40	0.41	0.35	0.35	0.30	0.29	0.33	0.31

It is known that mechanical composition has the biggest influence on the moisture retention characteristics in soil. Most authors, Bartelli and Peters (1959), Salter et al. (1966), Petersen et al. (1968), say that with the increasing of the content of the smaller particles the touchable surface between the solid phase and the soil moisture is increasing.

The influence of the mechanical composition on the moisture retention in the examined vertisols, is best illustrated by the positive correlation between moisture retention of 0.33 (FWC) and 15 bars (WP) related to the content of the "physical clay" (0.41 and 0.31) and clay (0.37 and 0.35), presented in Table 4. Opposite to this is the determination of the negative correlation between the moisture retention of 0.33 and 15 bars and the content of coarse (-0.51 and -0.60) and total sand (-0.49 and -0.55).

Retention curves

If the obtained values for the moisture content in different tensions are put on the coordinative system for each horizon or sub-horizon, the results are the retention curves and they give data for the AWC, whose upper limit is FWC, and lower limit is WP.

In Figures 2, 3, 4 and 5 the characteristics of the moisture retention in the examined vertisols are presented. From the Figures it can be seen that the retention curves of the four profiles have several common characteristics. In general, because of the deep organic matter accumulation, high content of silt and clay, and domination of clay minerals (smectites) with high retention ability, the moisture retention is very high through the whole depth of the profiles. That is why the retention curves are relatively close one to another which is especially noticed at profiles Nº 5 and 9.

One of the more important characteristics of the retention curves is in their fall with low tensions (up to 2 bars) that is relatively small, and with the further increasing of the tension (up to 15 bars), the curves are almost horizontal with an insignificant fall. That can be explained by the high percentage of microcapillary pores, which released the moisture very slowly. That is why with the increasing of the tension or with the lowering of the moisture the plants in these soils suffer from moisture insufficiency and spend more energy for its supply because it is hold by enormous retention strengths.

There are some differences between the profile Nº 9 and the other three profiles. This profile presents lower capacity of moisture retention, even though it consists of the equal quantity of clay as in the other profiles. The reason for this should be looked for in the different clay mineralogical composition (lower percentage of montmorillonite and higher percentage of illite and kaolinite).

From the presented Figures gradual changes in the retention curves by change of moisture without risings can be noticed.

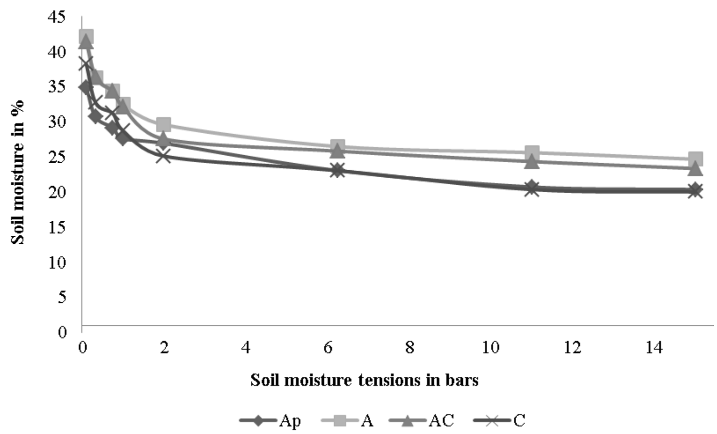

Figure 2. Retention curves of soil moisture (profile 2)

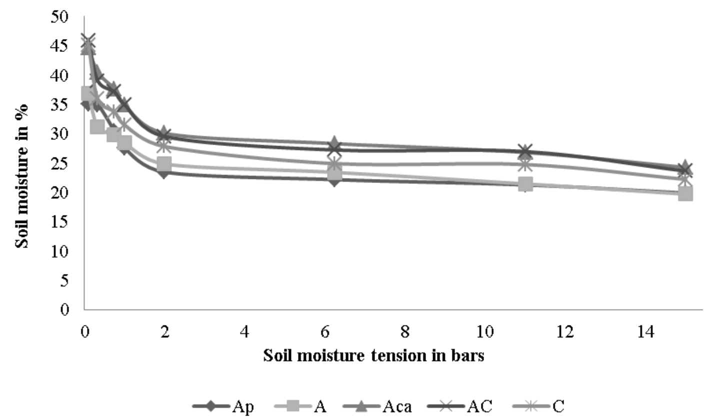

Figure 4. Retention curves of soil moisture (profile 7)

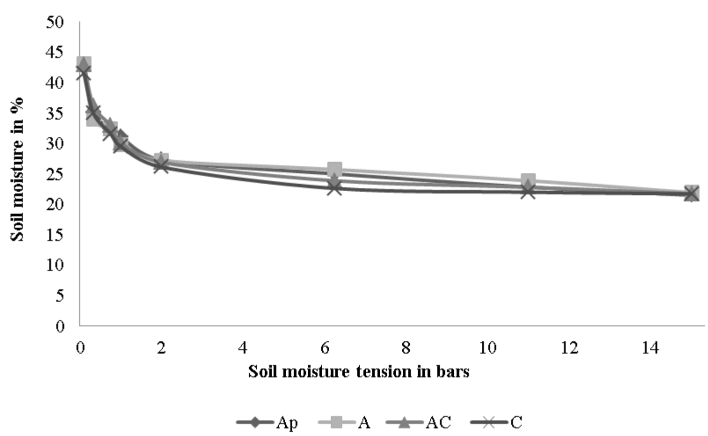

Figure 3. Retention curves of soil moisture (profile 5)

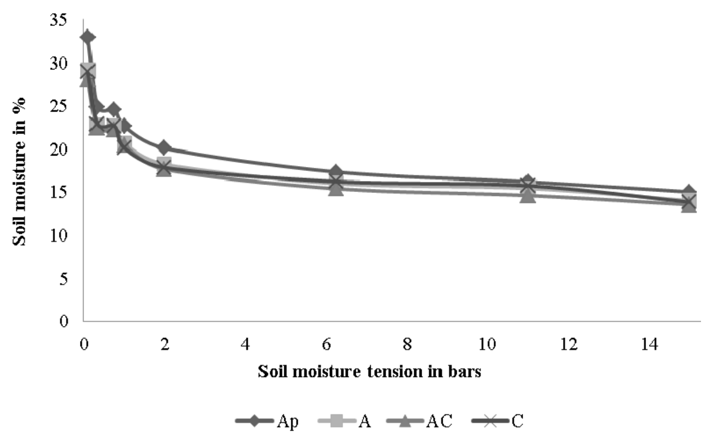

Figure 5. Retention curves of soil moisture (profile 9)

That tells that the division of the soil moisture on different forms does not come to a justification in the retention curve because the decrease of the amount of water does not have great risings at different tensions.

Conclusion

Based on the results obtained from the research on the moisture intensity at eight points of tensions (0.1; 0.33; 0.75; 1; 2; 6.25; 11; 15 bars) in the investigated soils, the following statements can be ascertained:

- Because of the high content of clay (average 41.80%) and montmorillonite-MLM (average 59.36%), and because of the deep organic matter accumulation with maximum in the surface layer Ap (2.33-3.99%), moisture retention in the examined vertisols is very high throughout soil profiles depth.
- The content of moisture that stays in the soil to 0.33 bars (FWC) is high in all horizons and the average value is 32.41%. Values of the WP (15 bars) are also high, with average value of 20.09%. That is why, beside the high water retention, the plants in these soils are not supplied enough with water.
- Positive correlation between the moisture retention of 0.33 and 15 bars and the content of clay (0.37; 0.35) and "physical clay" (0.41; 0.31) was noticed. Furthermore, a negative correlation between the moisture retention of 0.33 and 15 bars and the content of coarse (-0.51; -0.60) and total sand (-0.49; -0.55) has been determined.
- The closeness of the retention curves shows that there is no big difference in the moisture retention between the horizons of the separate profiles. One of the more important characteristics is that their fall at low tensions (up to 2 bars) is relatively small, and with further increase of the tension (up to 15 bars), the curves are almost horizontal with an insignificant fall. That is why, with increase of tension or with decrease of moisture, plants in these soils suffer from moisture insufficiency and spend more energy for its application because it anchors with enormous retention strengths.

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