

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

4,200

Open access books available

116,000

International authors and editors

125M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Soil Moisture Retention Changes in Terms of Mineralogical Composition of Clays Phase

Markoski Mile and Tatjana Mitkova

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/48098>

1. Introduction

The mineral part of the soil is inherited from the parent material but it modifies under the influence of different factors and processes.

The Earth's crust contains almost 100 elements and only 8 of them (O, Si, Al, Fe, Ca, Na, K, and Mg) form 98.5% of the crust and compose the base of the soil body. Most of the soil types contain 60% of all existing minerals where the silicates and aluminosilicates are the most dominating ones. They are present in a form of primary and secondary minerals. The primary minerals originate as a result of igneous, sedimentary, and metamorphic rocks' weathering while the secondary minerals originate as a result of chemical weathering of the primary minerals.

Theoretically, the soil contains all the different types of minerals but the real number and type of the minerals that constitute one type of a soil is quite limited.

The clay minerals are large group with common silicate characteristics. According to (Ilić, et al., 1975), these minerals evolve from a surface weathering of the aluminosilicates in the parent rock or a deposit of surface water.

According to (Kostić, 2000), phyllosilicates (clay minerals) dominate in the clay fraction (<0.002mm or 2 microns) of many soils which affect the physical, physical-chemical, water-physical and physical-mechanical properties of the soil (plasticity, stickiness, swelling, shrinkage, cohesion) and the soil structure and moisture retention as well.

The degree the mineralogical composition affects the soil moisture retention depends on the percentage amount and fraction of the clay minerals present in a soil type. The clay particles represent the most active part of the fine earth because of their large external and internal active surface, cation-exchange capacity (CEC) and mineralogical composition (Skorić, 1991).

Many authors such as Barteli and Peters, Salter et al, Petersen et al. cit. by (Pelivanoska, 1995), state that the increase content in the slightly smaller particles increases the surface of tangency between the solid phase and soil moisture.

In addition to the mineralogical composition of the clay explanation presented before, the paper researches the influence of the moisture retention given the different levels of tension in soil (starting with 0.1 (pF-2) and going to 15 bar or (pF-4.2), which corresponds to the wilting point). The remaining soil moisture above 15 bar is not available to the plant (Bogdanović, 1973).

According to (Filipovski et al., 1980) the presented model research is based on three moments: (1) the unexplored research in influence of the mineralogical composition of soil retention curves in the recent years; (2) their practical and theoretical importance; and (3) the great importance in the periods with aridity conditions and irrigation conditions.

The clay mineral content and the soil retention curves represent a significant characteristic for each soil horizon, subhorizon or layer and the soil profile as a whole. As a result of the laboratory investigation in the mineralogical composition of many soil types the moisture retention curves are created for each horizon, subhorizon or layer.

We are presenting our research and research made by other authors on the mineralogical composition of clay and how it influences the moisture retention in 6 soil types: *Fluvisol*, *Chernozem*, *Vertisol*, *Chromic Luvisol on saprolite*, *Albic Luvisol* and *Molic Vertic Gleysol* (WRB - 2006, World Reference Base for Soil Resources).

The water retention curves are very different because the soils have heterogeneous mineral content.

2. Material and methods

The Republic of Macedonia is situated in the central part of the Balkan Peninsula. Its total territory is only 25,700 km², but it shows a great diversity of natural conditions. Here, as a natural museum, can be seen almost all relief forms, geological formations, climatic influences, plant associations and soil which appear in European. The relief is very heterogeneous, with numerous relief forms, with different expositions and inclinations, and with great differences altitude (from 40 to 2764 m above sea level). In Macedonia, there are numerous geological formations of a very heterogeneous petrographic-mineralogical composition. The mountains are composed of non-calcareous hard rocks, including quartzite and various silicate rocks: acidic, neutral, basic and ultrabasic rocks; as well as of calcareous rocks such as pure limestones, marbles and dolomites. Basins are composed of loose and lightly cemented sediments, and a small quantity of young volcanic rocks. Undulating-hilly terrains in the basins are composed of sea and lake sediments (Mesozoic, Paleogenic, Neogenic, diluvial (superficial) deposits. The sloping terranians consist of colluvial and some fluvioglacial deposits. Macedonia is under the influence of two zonal climates (Mediterranean and temperate – eastern continental) and one local (mountain) climate (Mitkova et. al., 2005).

A great heterogeneity appears in the soil cover, too (40 soil types and even more subtypes, varieties and forms).

The places where the soil profiles have been dug are marked with GPS coordinates (Figure 1). Fluvisol 41°51, 08' 55'' N and 22°26, 14' 15'' E; Chernozem 41°49, 38' 58'' N and 22°00, 45' 29'' E; Vertisol 41°49, 06' 42'' N and 22°11, 59' 71'' E; , Chromic Luvisol on saprolite 41°54, 00' 31'' N and 22°15, 57' 59'' E; Albic Luvisol 41°42, 41' 65'' N and 22°49, 04' 56'' E; Molic Vertic Gleysol 41°20, 45' 63'' N and 21°25, 38' 49'' E.



Figure 1. Location of Profile pits

The following methods were used for analysis of soil materials: mechanical composition was determined with the dispersion of the soil with 1 M solution of $\text{Na}_4\text{P}_2\text{O}_7 \times 10 \text{H}_2\text{O}$. First, 10 g soil sample was put in Erlenmeyer flask, the 25 ml of 1 M $\text{Na}_4\text{P}_2\text{O}_7 \times 10 \text{H}_2\text{O}$ solution was poured into the flask, left for 12 hours, and the mixed for six hours. Finally the suspension was sieved through a 0.2 mm sieve into the 1000 ml cylinder and then pipetted - (Škorić, 1986). Fractionation of mechanical elements was done by the international classification of soil texture by Scheffer & Schachtschabel (Mitrikeski & Mitkova, 2006). The pH of the soil solution was determined electrometrically in a water suspension and in a suspension of H_2O . The humus content was determined on the basis of the total carbon according to the Tjurin method, modified by Simakov (Orlov et al., 1981).

Mineralogical composition of clay was determined by diffractometer, brand PHILIPS, type PW 1051 in range $2\theta = 50 \div 60^\circ$, at wavelength radiation ($\text{Cu}, \text{K}\alpha$). Mineralogical composition analysis was done at Mining and Geology Faculty at University of Belgrad, Republic of Serbia. To determine the clay minerals in each soil sample, two products were made, one of

which was untreated, and the filled with glycerin, while the other was annealed at temperatures of 480° C for the determined type of clay minerals in the range $2\theta = 30 \div 14^\circ$ (methods are described by (Đurič, 1999 and 2002).

The soil moisture retention at pressures of 0.1 bar (pF-2), 0.33 bar (pF-2.54) and 1 bar (pF-3) was carried out with application of pressure by Bar Extractor (Fig. 2), while the soil moisture retention at higher pressures 2.0 bar (pF-3.3); 6.25 bar (pF-3.90); 11 bar (pF-4.04) and 15 bars (pF-4.2) was carried out with Porous plate extractor (Richards, 1982), described by (Resulović et al., 1971).



Figure 2. Preparing soil and placing samples on Bar extractor and Porous plate extractor

3. Review of references and discussion

The soil water retention is a result of two forces: adhesion (soil particles attract the water molecules) and cohesion (mutual attraction of the water molecules). The adhesion is much stronger than the cohesion. The force which retains the water in the soil is called capillary potential and is closely related to the water content. The free flowing water in the soil has a capillary potential equal to zero, a condition where all the soil pores, both capillary and non-capillary, are filled with water. Soil water potential can be determined indirectly by recourse to measurements of soil water content and soil water release or soil moisture characteristic curves that relate volumetric or gravimetric content to soil water potential. The measurement of water potential is widely accepted as fundamental to quantifying both the water status in various media and the energetics of water movement in the soil-plant-atmospheric continuum (Livingston, 1993). Mukaetov (2004) underlines that by decreasing the water content in the soil the value of the capillary potential is increased. In order to assess the humidity of the soil using the capillary potential Schofield 1935 quot. (Vučić, 1987) has proposed the pF values where the force of the water in the soil is expressed on the height of a water column in cm (1 bar = 1063 cm water/cm²). The pF values are affected by the mechanical content and according to the same author, the bigger the participation of the fine fractions the greater the pF values, especially under pressure of 0.33 bars.

It is known that clay minerals that are characterized with swelling (smectites, vermiculite) have stronger moisture retention ability than other clay minerals. Warkentin & Meada (1974), Meada & Warkentin (1975), Rausseaux & Warkentin (1976) concluded that amorphous materials such as allophanes (hydratated aluminosilicate minerals) are characterized with high moisture retention ability.

All the factors mentioned show a strong influence in the specific surface area of the soils. The water retention capacity is defined by the total osmotic surface activity (Shainberg et al., 1971). The loamy soils and the clay soils, especially if their clay fractions contain swelling minerals are characterized with large active surface and fine pores (Voronin, 1974).

According to Hillel, (1980) not only the mineralogical composition but also the mechanical and organic matter content of the soil affects the water- physical relations.

In Table 1 we have a presentation of the mechanical composition of soils.

Profile	Soils (WRB – 2006) ^a	Depth in cm	Total sand 0.002-2mm	Silt 0.002-0.02mm	Clay < 0.002mm	Silt + Clay <0.02mm	Textural class ^b
P1	Fluvisol	0-20	46.30	40.20	13.50	53.70	Loam
		20-35	49.60	37.30	13.10	50.40	Loam
		35-50	48.10	38.60	13.30	51.90	Loam
		50-70	53.10	35.00	11.90	46.90	Sandy loam
P2	Chernozem	0-40	55.80	13.60	30.60	44.20	Sandy clay loam
		40-60	53.20	13.70	33.10	46.80	Sandy clay loam
		60-90	42.50	15.00	42.50	57.50	Clay
		90-110	44.30	18.60	37.10	55.70	Clay loam
P3	Vertisol	0-26	45.90	15.40	38.70	54.10	Loam clay
		26-54	46.40	18.00	35.60	53.60	Loam clay
		54-105	40.90	15.60	43.50	59.10	Loam clay
		105-150	34.10	23.50	42.40	65.90	Loam clay
		150-165	46.90	15.60	37.70	53.10	Loam clay
P4	Chromic Luvisol on saprolite	0-15	38.10	38.10	23.80	61.90	Loam
		15-30	25.10	40.10	34.80	74.90	Clay loam
		30-55	21.50	41.30	37.20	78.50	Clay loam
		55-70	25.00	45.80	29.20	75.00	Clay loam
P5	Albic Luvisol	0-8	45.20	41.90	12.90	54.80	Loam
		8-23	46.90	36.60	16.50	53.10	Loam
		23-33	33.80	35.00	31.20	66.20	Clay loam
		33-44	52.30	29.60	45.10	47.70	Clay loam
		44-65	35.20	26.60	38.20	64.80	Clay loam
P6	Molic Vertic Gleysol	0-30	24.40	23.60	52.00	75.60	Clay
		30-65	26.20	18.70	55.10	73.80	Clay
		65-85	21.50	16.50	62.00	78.50	Clay
		85-124	29.70	14.80	55.50	70.30	Clay

^a(WRB – 2006) World Reference Base for Soil Resources

^bScheffer & Schachtschabel textural class

Table 1. Mechanical composition of soils

(Maclean & Yager, 1972), (Jamison & Kroth, 1958), (Shaykewich & Zwarich, 1968) and (Heinonen, 1971) studied the effect of the organic matter and the mechanical content over the water retention in several soils throughout U.S., Europe and Asia. The research conducted by (Hollist et al., 1977) confirms that the soil water retention in the West Midlands (United Kingdom) depends mostly on the organic matter and the mineralogy content of the soil.

According to Filipovski, (1996), soil water retention in different tension is in tight correlation with humus, clay, and silt content and mineralogical composition of the clay.

The data for the mineralogy content of the clay within the fluvisol (profile 1, table 2) are showing that it consists of a more minerals. This is a result of both the different mineralogy content of the rocks which when weathering result in clay minerals and the conditions where the weathering takes place (Filipovski et al., 1980).

Results in the Tables (2, 3, 4, 5, 6, 7 and 8) are given semi quantitatively, thus the presence of certain minerals is indicated by plus (+), which indicate the presence of the individual minerals (+++++) > 70%; (++++)= 50-70%; (+++)= 30-50%; (++) = 10-30% and (-) = traces (tr.).

Depth cm	Chemical properties			Clay mineralogical composition						
	Organic matter %	CaCO ₃ %	pH in H ₂ O	Montmorillonite	Vermiculite	Illite	Chlorite	Kaolinite	Quartz	Feldspar
0-20	1.40	0.00	6.40	++	-	+++++	+	+++	-	-
20-35	0.85	0.32	7.30	+	-	+++	tr.	+++++	-	+
35-50	0.57	0.47	7.60	+	-	+++	tr.	+++++	tr.	-
50-70	0.26	0.55	7.80	tr.	-	++	tr.	+++++	-	-

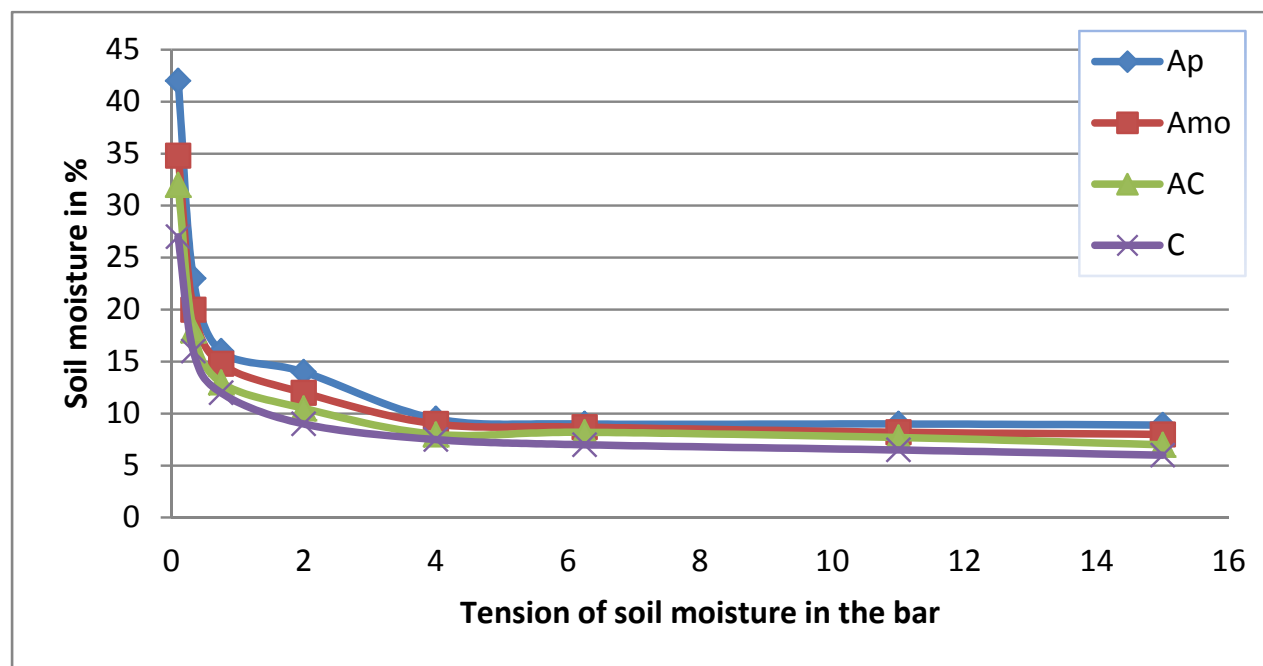
Table 2. Chemical properties and clay mineralogical composition of Fluvisol

In this profile, according to the same authors is deposited detritus that comes from the silicate rocks consisting of albite, quartz, sericite, chlorite schists and from the soils over them with an acid reaction. Therefore the fluvisol is richer in kaolinite and illite arising from the sericites. Parts of the slates contain ferromagnesian minerals and their decomposition result in montmorillonite. The clay minerals in profile 1 are represented with the association: kaolinite-illite-montmorillonite.

If we are continuously measuring the tension of the soil moisture and for each tension we are measuring the amount of moisture expressed in volume percentages and then we put the data on coordinates for each horizon, we come to the retention curves. The express the ratio between the attracting forces (tension) and the amount of soil moisture. The soil water retention curves are sometimes called desorption curves, indicating that the measurement

determines how much water is retained by the soil at each successively lower matric potential (Topp et al., 1993). They indicate the availability of water capacity in which the upper limit is field water capacity while the lower limit is wilting point. Using the given limits, it is easier to understand when the irrigation would take place and how much water the plant requires. Furthermore, the retention curves are also used to explain the water movement in the soil. Soil water retention curves are useful directly and indirectly as indicators of other soil behavior traits, such as drainage, aeration infiltration, and rooting patterns. Retention curves are the relationship between soil water content and soil water potential (matric potential) for soil during a drying phase.

As a result of the values received from the determination of the soil moisture with ten different tensions (0.1; 0.33; 0.75; 2, 6.25; 11 and 15 bars) we get the retention curves (Fig. 3) of the soil moisture for profile 1.



Ap - tillage mineral horizon; Amo- mollic horizon; AC – transitional horizon; C – substrate (parent material)

Figure 3. Soil moisture retention curves for Fluvisol

The retention curves of the profile show that the retention moisture is low (small content of clay and humus). The curves up to tension of 2 bars show quite big slope and afterwards, they are almost horizontal at a tension of 15 bars. Due to the similar mechanic and mineralogy content of the soil, the retention curves do not differ essentially (Filipovski et al., 1980). As a result of the smallest clay content, silt, smectites and humus in the lowest layer of the soil, it shows the lowest retention.

In Table 3 we have a presentation of the clay mineralogical composition in the chernozem (profile 2). The clay mineralogical composition depends on the stratification of the substrate. Until the depth of 90 cm in the chernozem there is almost the same amount of illite and

smectites (montmorillonite) and small contents of vermiculite and kaolinite. The illite prevails until the depth of 40 cm, and the smectites (montmorillonite) prevail deeper, at 90 cm (Markoski, 2008).

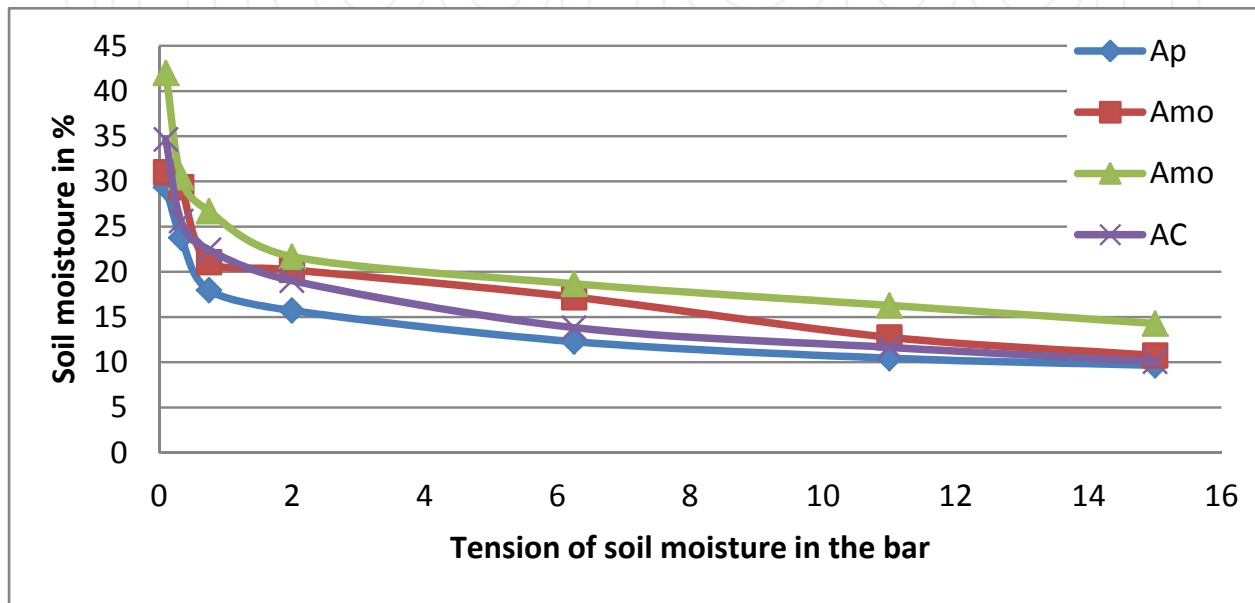
Depth cm	Chemical properties			Clay mineralogical composition					
	Organic matter %	CaCO ₃ %	pH in H ₂ O	Smectite	Vermiculite	Illite	Kaolinite	Chlorite	Quartz
0-40	1.64	0.0	7.4	+	+	++	+	+	-
40-60	1.61	0.0	7.4	++	+	++	+	+	-
60-90	1.33	0.0	7.3	++	+	++	+	+	-
90-110	1.17	17.36	8.2	+++	+	++	+	tr	-

Table 3. Chemical properties and clay mineralogical composition of Chernozem

In conditions of layers and lithological discontinuity it is hard to explain the increase of smectites beneath 90 cm. It is most common in other processes (transformation of other minerals or transfer of the minerals). None of the mineral is absolutely dominant, but the bigger representation of the minerals with the type of layers 2:1 (illite, smectite, vermiculite) compared to the minerals with type of layers 1:1 (kaolinite). The 2:1 layers of the mineral in the group of smectites have a bond weak and thus, when moisturized, water molecules and different ions enter between them and they become distant. The montmorillonite has active an internal areas between the layers and the ions and water molecules are adsorbed in the inside and outside (extramolecular and intramolecular adsorption). Due to this the montmorillonite has a high cation-exchange capacity (CEC), high degree of hydration, dispersion, plasticity, viscosity and swelling in humid conditions. When dried, the layers come nearer and the particles are contracting. Montmorillonite under commonly prevailing pH conditions converted to non-expanding hydrous mica – illite. The structure of illite in comparison with montmorillonite has a higher layer charge arising from isomorphous substitution of Al³⁺ for Si⁴⁺ in the tetrahedral sheet and interlayer is occupied by non-hydrated K⁺ ions. The illite has a lower cation-exchange capacity (CEC) and does not manifest signs of swelling, plasticity or viscosity. Vermiculite is a high-charge 2:1 phyllosilicate clay mineral. It is generally regarded as a weathering product of micas in which the potassium ions between the molecular sheets are replaced by magnesium and iron ions. Vermiculite is also hydrated and somewhat expansible though less so than smectite because of its relatively high charge. As a result, the vermiculite has a bigger cation-exchange capacity (CEC) and similar to the smectites, it manifests swelling, plasticity and viscosity.

The data for the water retention capacity in the chernozem are showing that the biggest value is found in the mollic Amo horizon (bigger content of humus, clay and colloids).

Furthermore, high values for wilting point are received (pressure of 15 bars). The highest value is found in the Amo horizon (high content of the fraction of physical clay (clay and silt), as well as the presence of bigger number of micro-pores). The retention curves of the profile show that in all the horizons starting from tension of 2 bars, are almost horizontal (Fig. 4). A gradual change in the retention forces can be noticed coming with the change of moisture without jumps. This shows that the division of the soil moisture in different forms cannot be justified with the retention curve because the decrease of the amount of water does not have big jumps under different tensions.



Ap - tillage mineral horizon; Amo- mollic horizon; AC – transitional horizon

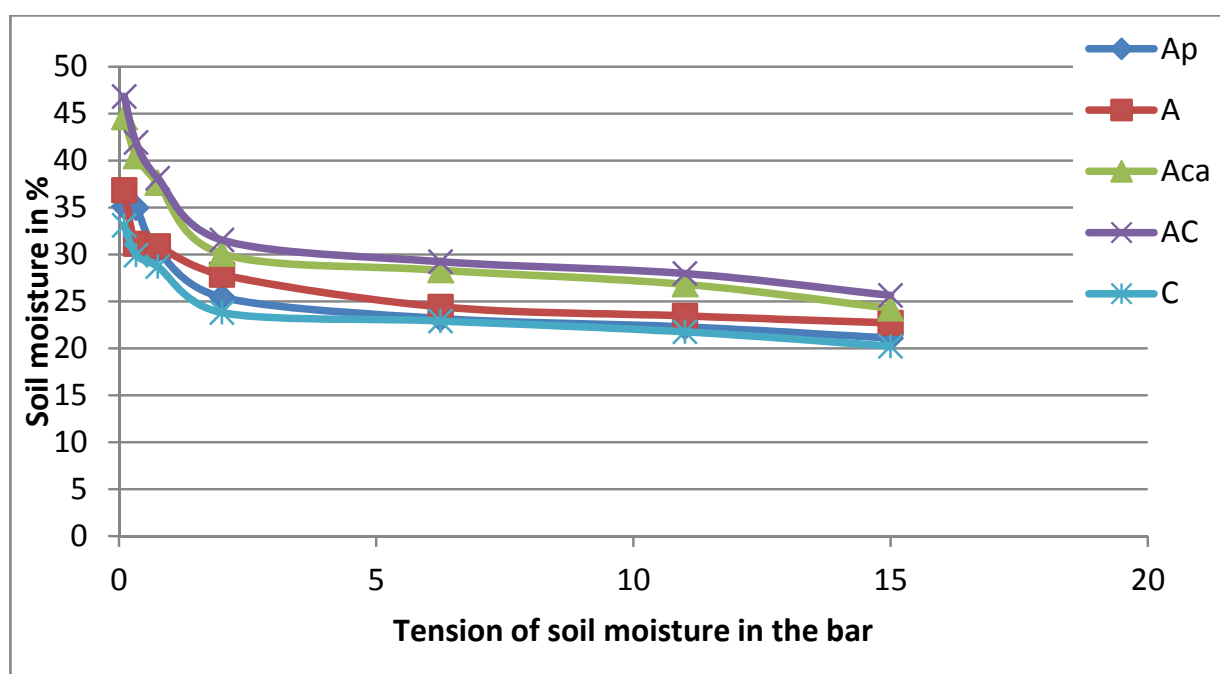
Figure 4. Soil moisture retention curves for Chernozem

When speaking about the mineralogy content of the vertisol we can say that it is equal in the whole depth of the profile (Table 4). It is formed on lacustrine clay sediments and it has inherited the clay minerals from the substrate where all the secondary minerals do not represent products of weathering of the basic rocks only. Between the substrate, the AC horizon and the humus horizon there is no difference; thus the processes of pedogenesis did not change the composition of clay (Jovanov, 2010). It is equaled by the pedoturbation. The equality of the composition of clay in the substrate and the soil is yet another proof for the “lithogenous” character of the vertisols i.e. for its genesis related only to certain substrates rich in smectites (montmorillonite) or such that during weathering were converted mainly to montmorillonite. According to (Dudal, 1956) in the vertisols in Mississippi (U.S.), the smallest fraction (the clay has 2-3 times bigger cation - exchange capacity) contained more montmorillonite than the larger fractions. The presented profile of vertisol is characterized by dominant presence of the montmorillonite and mixed layer minerals (illite - montmorillonite) where it prevails. Afterwards, illite, chlorite and kaolinite which are a result of the weathering of different rocks made up the fields above the lacustrine sediments.

Depth cm	Chemical properties			Clay mineralogical composition						
	Organic matter %	CaCO ₃ %	pH in H ₂ O	Montmorillonite	Vermiculite	Illite	Chlorite	Kaolinite	Quartz	Amorphous minerals
0-15	3.32	0.00	5.8	++++	-	++	-	+	Tr	-
15-77	2.19	0.00	6.3	++++	-	++	-	+	Tr	-
77-94	1.72	0.79	7.2	++++	-	++	-	+	Tr	-
94-117	0.94	5.06	7.6	++++	-	++	-	+	Tr	-
117-145	0.33	3.95	7.5	/	/	/	/	/	/	/

Table 4. Chemical properties and clay mineralogical composition of Vertisol

The vertisol is characterized with several more important characteristics of retention curves (Jovanov, 2010), (Fig. 5).



Ap - tillage mineral horizon; A - humus accumulative horizon; Aca - carbonate/calcareous humus accumulative horizon; AC - transitional horizon; C - substrate (parent material)

Figure 5. Soil moisture retention curves for Vertisol

Firstly, due to the high content of clay and its montmorillonite (smectite) character, the moisture retention is very high in the whole depth of the profile. The second characteristic is that the release of moisture during low tension (not bigger than 2 bars) is slow and therefore the curves do not have a big slope, and with a further increase of the tension (15 bars), the curves are almost horizontal, with an insignificant slope. It can be explained with a high percentage of micro-pores through which the water is slowly released. Therefore, with the

increase of the tension i.e. decrease of the moisture, the plants in these soils are suffering the lack of moisture respectively spending more energy for its reception because it is held with much bigger retention forces. The third characteristic of the curves is that they are relatively close to each other meaning that there is no big difference in the moisture retention between the separate horizons (equal mineralogical content of the soil, homogeneity of the profile).

The profile of the chromic cambisol is composed of andesite breccia rich in volcanic ash and contains a few clay minerals in crystal form. The secondary minerals are a result of the weathering of the primary minerals in the andesites. The volcanic ash mixed with the breccia resulted in amorphous minerals (Filipovski et al., 1980).

In the biggest fractions there are more primary minerals, but only two are dominant – the quartz and the feldspar (together more than 90%), (Table 5). Mostly, quartz is found in the fraction of 0.05 – 0.10 mm. There is a tendency for its decrease in the depth of the profile. Parts of the quartz and feldspar are connected with the fragments of rocks. According to (Filipovski et al., 1980) this points out to the fact that the chromic cambisols usually contain the primary minerals such (quartz) which is resistant to weathering or (feldspars) which are hardly weathers.

Depth cm	Chemical properties			Clay mineralogical composition						
	Organic matter %	CaCO ₃ %	pH in H ₂ O	Montmorillonite	Vermiculite	Illite	Chlorite	Kaolinite	Quartz	Feldspar
0-15	2.65	0.00	6.3	+	-	+	-	+	-	++
15-30	1.72	0.00	6.1	+	-	+	-	+	+	++
30-55	1.00	0.00	6.4	+	-	+	-	+	+	++
55-70	1.12	1.42	7.5	+	-	+	-	+	-	++

Table 5. Chemical properties and clay mineralogical composition of Chromic Luvisol on saprolite

Practically, the mica and ferromagnesian minerals are weathered into secondary minerals. In the lower part of the horizon (B) and the horizon (B)C there are corrections. If we review the mineralogical content of the fraction directly larger than the clay (0.002 – 0.05 mm, Table 6), we can see that the secondary minerals are amorphous and they are dominant throughout the whole profile and are equally distributed in the whole depth.

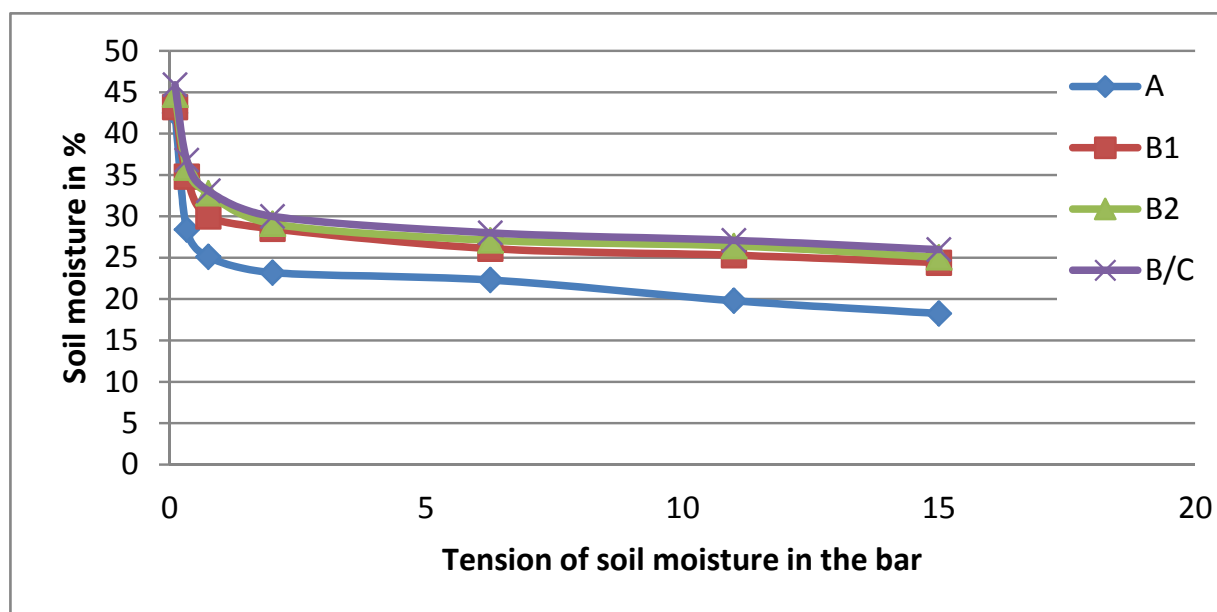
There are no crystal secondary minerals, and the primary ones have the same amount of quartz and feldspar because the breccia is rich in volcanic ash. In the clay fraction the primary minerals are lost meaning that it only contains secondary minerals. It is a result of the weathering of the primary minerals of the substrate, from the basic and neutral rocks. The amorphous minerals are dominant (of the volcanic ash in the substrate) equally distributed throughout the depth. In all the horizons, including the substrate, there are more

crystal secondary minerals: illite, kaolinite and montmorillonite (smectite). Mostly there are amorphous minerals and illite equally distributed throughout the depth. In the profile the following associations of the minerals occur: in horizon A, amorphous minerals-illite-kaolinite-smectite, and in horizon (B) amorphous minerals-illite-smectite, with insignificant presence of quartz.

Depth cm	Mineralogical composition of the soil separate from 0.002 to 0.05 mm							
	Kaolinite	Hydrobiotit	Montmorillonite	Vermiculite	Chlorite	Quartz	Feldspar	Amorphous minerals
0-15	Tr	0	0	0	0	++	++	++
15-30	Tr	++	0	0	0	++	++	++
30-55	Tr	++	0	0	0	++	++	++
55-70	Tr	++	0	0	0	++	++	++

Table 6. Mineralogical composition of the soil separate from 0.002 to 0.05 mm

For the retention curves of this soil the most significant is the fact that it is rich in clay and mostly fine clay (under 0.001 mm). The textural differentiation is very clear and this has reflected in the retention curves where the on the graph (Fig. 6) the retention curves are high meaning that the moisture retention is big (a lot of clay and amorphous minerals).



A- humus accumulative horizon; B1- cambic horizon; B2- cambic horizon; B/C – transitional horizon

Figure 6. Soil moisture retention curves for Chromic Luvisol on saprolite

Having in mind that the mineralogy content of the clay is equal throughout the depth, the retention depends on the clay content: the retention differences between separate horizons are followed by the content of the clay. The fall of the retention curves starting from the lower to the upper tensions is big and this, according to (Filipovski et al., 1980) means that a great part of the water is held with a big force by the soil particles and they are hard to be released. The textural differentiation is clearly reflected on the moisture retention: the lowest retention can be seen in horizon A because it contains the least silt, fine clay and clay. The other probes of the horizon (B) have a bigger retention because they contain more than those fractions. The curves on these probes are approximated because they contain almost equal amount of clay and have the same clay mineralogical composition.

The albic luvisol is formed on clastic sediments. One part of the clay minerals is inherited by the substrate and in that regard the inherited minerals in the upper layer (horizons A and E) are more equal than those in the lower layer (horizon B). Besides, by leaching the clay not all the clay minerals are leached equally. The montmorillonite (smectite), that has finer particles and is easily peptized, can be leached in bigger amounts compared to other clay minerals (Table 7).

Depth cm	Chemical properties			Clay mineralogical composition						
	Organic matter %	CaCO ₃ %	pH in H ₂ O	Montmorillonite	Vermiculite	Illite	Chlorite	Kaolinite	Illite vermiculite mixture mix.mineral mineral	Amorphous minerals
0-8	5.44	0.00	6.0	Tr	++	+	-	+	-	++
8-23	1.79	0.00	5.3	Tr	++	+	-	++	+	++
23-33	0.80	0.00	4.9	+	+	Tr	+	+	+	++
33-44	0.45	0.00	4.6	++	Tr	Tr	-	Tr	+	++
44-65	0.33	0.00	4.6	++	Tr	Tr	-	Tr	-	++

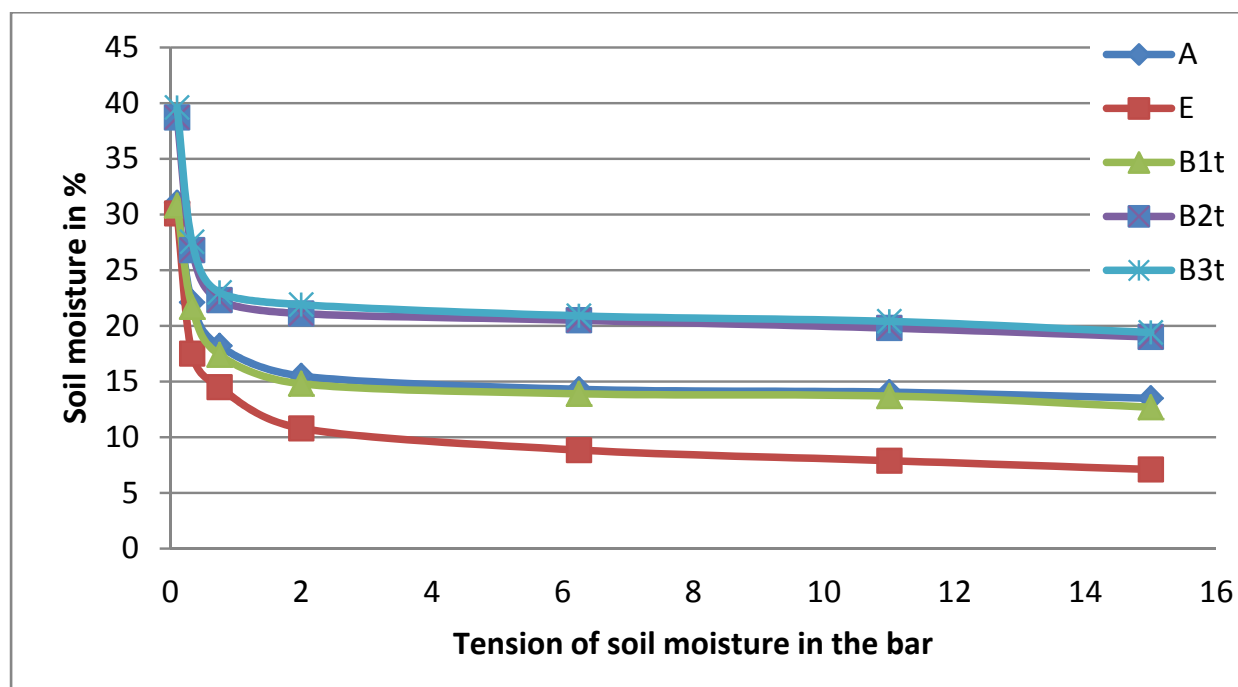
Table 7. Chemical properties and clay mineralogical composition of Albic Luvisol

The profile can be divided into three parts depending on the mineralogical content of the clay: upper part (horizons A and E), middle part (upper part of the horizon Bt) and lower part (the lower part of the horizon Bt). It is obvious that the mineralogical content, especially in (horizons A and E) and the upper part of the horizon B is more complex – it contains 6 different minerals, but in lower amount. In the upper part of the profile is dominated we have the prevail of the vermiculite followed by the kaolinite and the illite, and we can find only traces of montmorillonite. It is characteristic that there are many amorphous minerals (sesquioxides of Fe and Al), nearly as the vermiculite. The middle part has the most complex content: it is dominated by the amorphous minerals and followed by almost equal amounts

of kaolinite, vermiculite, illite-vermiculite, chlorite and it also appears in the montmorillonite. In the lower part of the profile the composition is less complex: it contains mostly amorphous minerals and montmorillonite (due to the bistratified and the upper translocation), followed by the illite-vermiculite, and there are only traces of the other minerals. The content of the illite decreases and of the smectite is increased in the depth of the profile.

According to the data for the content of the organic matter the content of the total and fine clay and its mineralogical composition (Filipovski et al., 1980) we are discussing a bistratified profile where the horizons A and E are formed by one, and the horizon Bt by another layer.

The retention curves (Fig. 7) show the strong differentiation of the profile. The content of the amorphous minerals does not influence this differentiation because their content is equal throughout the depth of the soil. (Filipovski et al., 1980) explain this with the bistratified profile and with the pedogenesis processes.



A – humus accumulative horizon; E- albic (eluvial) horizon; B1t-illuvial horizon, modif. (argillic); B2t-illuvial horizon, modif. (argillic); B3t-illuvial horizon, modif. (argillic);

Figure 7. Soil moisture retention curves for Albic Luvisol

The retention curves are grouped in mostly three groups. The lowest retention can be found in the E horizon (it contains the lowest amount of clay and much less humus compared to horizon A). In the second group we have the upper part of the horizon Bt (it contains more clay compared to horizon E), and here we can mention horizon A (the same characteristics as the horizon E, but with bigger content of humus). It is familiar that the humus has high retention. In the third group, the biggest retention is reserved for the lower part of the horizon Bt (it contains mostly clay dominated by the montmorillonite that is characterized with a high retention of moisture). The ration of the water retention in horizon E to that one in horizon Bt, under tension of 15 bars is 1 : 2.84.

When describing the mineralogical content of the clay in the mollic vertic gleysol we used data by (Mukaetov, 2004) and we would like to underline that the sediments in the valley where the soil were formed have been created during the Quarter. This means that they are very young and the geo-chemical processes did not reach the high degree of weathering of minerals. Besides, the same author claims that the proluvial - deluvial deposits that derive from the surrounding tops are heterogeneous in their composition and consist of granite, gneiss, schists, as well as marbles and limestone rocks (limestone and lesser degree of dolomite).

The mollic vertic gleysol is a homogenous soil that in the bigger part of the year are saturated with the maximum water capacity. In its biochemical activity in neutral and alkali environment, the plants take up the bigger part of the potassium of mica and illite. The pushing of the potassium from the interlayer of illite leads to creation of the so-called "open illite". This is a phase of minerals arising from vermiculite or smectites. According to (Kostić, 2000) replacing K^+ with Mg^{2+} ions which have a smaller dimension, but are significantly more hydrated led to creation of vermiculite. During the formation of smectites the balance is established by introducing water molecules and protons (Hydronium H_3O^+ ion) and the so-called transformative smectite is received. The partial leaching of the potassium from the interlayer of mica within the chlorites leads to creation of the inter-stratified minerals in the soil. This can be proved with the presence of mixed layer of layered silicates of the type chlorite - smectite, as well as of illite -smectite. The presence of chlorite is confirmed. The chlorite is slowly weathering in the low reductive conditions of the environment. Furthermore, there is a significant presence of plagioclase of the type of albite (Na-plagioclase). The biggest part of orthoclase (K - feldspar) was alternated into kaolinite as a result of the pushing out of the potassium with the biochemical processes of the swamp plants in the low drained conditions of the environment and with water of the saturated gley soil. The presence of the amphiboles and chlorite (ferromagnesian minerals) which are easily weathered in well - drained soils at oxygen conditions of the environment confirm the previous statement for the low aeration of the soil.

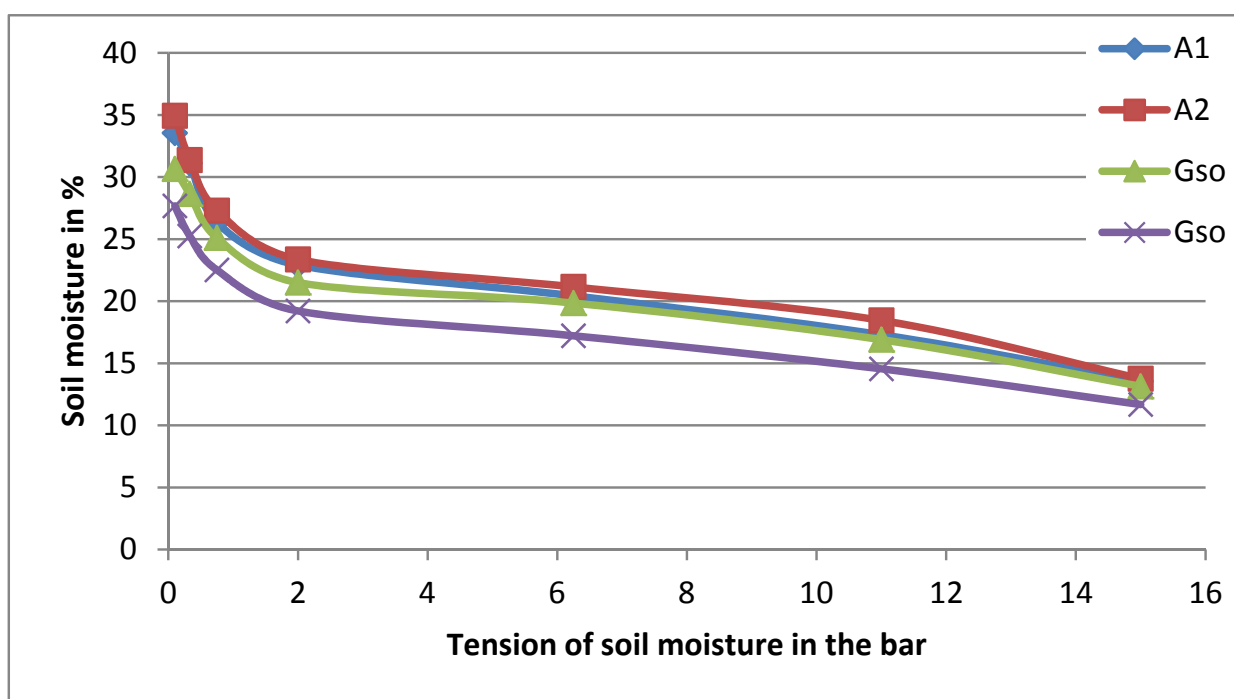
We can see a dominant presence of the montmorillonite (smectites) in the upper part of the soil. In the lower part the content of the montmorillonite and amorphous minerals is almost equal (Table 8). It is obvious that this soil contains a lot of minerals that are characterized with high degree of water retention.

Depth cm	Chemical properties			Clay mineralogical composition					
	Organic matter %	CaCO ₃ %	pH in H ₂ O	Montmorillonite	Vermiculite	Illite	Chlorite	Kaolinite	Amorphous minerals
0-10	3.22	0.0	6.6	+++	-	Tr	-	Tr	+
10-17	1.22	0.0	6.9	++++	-	Tr	-	Tr	+
17-34	1.59	0.0	6.6	++	-	+	-	Tr	++
34-80	1.38	0.0	6.4	++	-	+	-	Tr	++

Table 8. Chemical properties and clay mineralogical composition of Mollic Vertic Gleysol

We received high values for the content of moisture that is retained in the mollic vertic gleysol during the wilting range as a result of the high content of silt, clay, organic matter, presence of clay minerals with high retention (smectites and amorphous phase) as well as the presence of a large number of fine capillary pores. For the influence of the mechanical content over the retention in the soil we can take the high positive correlation between the moisture retention at 0.33 - 15 bars and the content of physical clay and clay (Table 1) and the high negative correlation between the retention of moisture at 0.33 - 15 bars and the content of sand.

The data presented in the graph (Fig. 8) show a decrease of the retention curves and it is most obvious at lower pressures. The reason for this is the high content of clay and clay minerals with high retention (smectites, amorphous minerals), afterwards the retention curves are stabilized and gradually decreasing.



A1- humus accumulative horizon; A2- humus accumulative horizon; Gso – gleyic horizon/sub horizon Gso

Figure 8. Soil moisture retention curves for Mollic Vertic Gleysol

The small difference between the retention curves at the upper three horizons according to (Filipovski et al., 1980) is a result of the combined influence of the clay, humus and mineralogical content of the clay. The highest retention can be seen in the upper two depths (richest in silt, clay, humus and presence of smectites, then the AC horizon and the lowest values can be found in horizon Gso that has the lightest mechanical content and the least amount of humus and smectites.

4. Conclusion

The analyzed mineralogical content and the retention curves of these types of soil show that the water retention depends on the content and the type of the clay minerals.

In general, due to the high content of clay and its smectite character, the water retention within some soil types is big throughout the whole depth of the profile. The others soil types showed, a lower retention as a result of the lower content of clay and other minerals (kaolinite and illite).

The soil water retention curves were successfully used in the prediction of the flow of water and other fluids in soil. Also many attempts have been made to define adequate and yet useful mathematical functions for the retention curve.

The measurement of soil water retention curves and the reliability of the resulting data are very important for adequate characterization of a number of other soil physical attributes. The information can be used to indicate the soil pore size distribution interpreted in relation to aeration and water availability for plants, for water flow and infiltration in soil, and frost susceptibility.

Author details

Markoski Mile and Tatjana Mitkova

Department of Soil Science, Faculty of Agricultural Sciences and Food, Sc. Cyril and Methodius University in Skopje, Republic of Macedonia,

5. References

- Bogdanović, J., Bogdanović, M. (1973): Usporedna ispitivanja metoda za održavanje vlažnosti vena kod različitih tipova zemljišta. *Zemljište i biljka*, Beograd. Vol. 22, No.3, p.p. 325-334.
- Dudal, R. (1965): Dark clay soils of tropical and subtropical regions. *FAO*. Rome.
- Filipovski, G., Pradhan, S. (1980): Moisture retention characteristics in the soils of the Socialist Republic of Macedonia. *Macedonian Academy of Sciences and Arts*. Skopje, p.p. 1-87.
- Filipovski, Đ . (1996): Soil of the Republic of Macedonia. Vol II. *Macedonian Academy of Sciences and Arts*. p. p.175-209.
- Heinonen, R. (1971): Soil management and crop water supply. *Lantbruk - högskolans kompendienämnd*.
- Hollis, J. M., Jones, R. J. A., Palmer, R. C. (1977): The effects of organic matter and particle size on the water retention properties of some soil in the west Midland of England. *Geoderma*. 17. p. p. 225-238.
- Hillel, D. (1980): *Application of Soil Physics*. Department of Plant and Soil Sciences. Massachusetts, Academic press.
- Ilić, M., Karamata, S. (1975): *Specijalna mineralogija*. Prvi deo. Izdavačko-Informativni centar studenata (ICS), Beograd.
- Jamison, V. C., Kroth E. M. (1958): Available moisture storage capacity in relation to textural composition and organic content of several Missouri soils. *Soil Sciences*. Am. Poc. 22. p.p. 189-192.
- Jovanov, D. (2010): Water, physical and physical-mechanical properties of vertisols of the Stip, Probistip and Sv. Nikole region. Master Degree Thesis. p. p. 1-50.
- Kostić, N. (2000): *Agrogeologija*. Beograd. str. 132-149.
- Livingston, N. J. (1993): Soil water potential. *Soil sampling and methods of analysis*. Canadian Society of Soil Sciences. p. p. 559-567.

- Macleán, A. H., Yager, T. V. (1972): Available water capacities of Zambian soils in relation to pressureplate measurements and particle size analysis. *Soil Sciences*.113. p.p. 23-29.
- Meada, T. Warkentin, B. P., (1975): Void changes in allophane soils determining water retention and transmission. *Soil Sciences. Am. Proc.* 398-403.
- Mitrikeski J., Mitkova, T. (2006). *Practicum on pedology*, second edition. University "Ss. Cyril and Methodius", Faculty of Agricultural Sciences and Food, Skopje, p. 63-67.
- Mukaetov, D. (2004): Conditions for formation, genesis and characteristics of the hidromorfnic black soils spread out in Pelagonija. Doctoral Degree Thesis, Faculty of Agriculture, Skopje. p. p. 1-162.
- Markoski, M. (2008): Physical and physical-mechanical properties of chernozems of the Ovče Pole region. Master Degree Thesis. p. p. 1- 64.
- Mitkova, T., Mitrikeski J. (2005): Soils of the Republic of Macedonia: Soil Resources of Europe, second edition, European Soil Bureau Research Report, N^o9, 225-234, EUR 20559 EN, 2005.
- Orlov, S.D. Grishina, A.L. (1981): *Practicum on Chemistry on humus*. Moscow University Press, p. p.1- 271.
- Pelivanoska, V. (1995): Physical and physical-mechanical characteristics of cinnamon forest soils in the Prilep region. Master Degree Thesis, Faculty of Agriculture, Skopje. p. p. 1-60.
- Resulović, H. red. (1971): *Methods of investigation the physical properties of the soil*, JDZPZ, Belgrade.
- Rousseaux, J. M., Warkentin, B. P. (1976): Surface properties and forces holding water in allophane soils. *Soil Sciences Am. Proc.* 40. p. p. 446-451.
- Richards, L.A. (1982): *Soil water and plant growth. Soil physical conditions*, New York.
- Shaykewich, C. F. Zwarich, M. A. (1968): Relationships between soil physical constants and soil physical components of some Manitoba soils. *Can. J. Soil Sciences*. 48. p. p. 199-204.
- Shanberg, J., Bresler, E., Klausner, Y. (1971): Studies on Na/Ca montmorillonite system. I Swelling pressure. *Soil Sic. III*, p. p. 214-220.
- Topp, G.C., Galaganov, Y.T., Ball., Carter, M. R. (1993): Soil water desorption curves. *Soil sampling and methods of analysis. Canadian Society of Soil Sciences*. p.p. 569 - 579.
- Voronin, A. D. (1974): The energy state of soil moisture as related to soil fabric. *Geoderma*. 12. p. p. 183-189.
- Vučić, N. (1987): *Water, air and thermal regime of soil*, VANU. Department of natural sciences. Volume 1. Novi Sad. p. p. 1-320.
- Warkentin, B. P., Meada, T. (1974): Physical properties of allophane soils from the West Indies and Japan. *Soil Sciences. Am. Proc.* 39. p.p. 372-377.
- WRB, (2006): *Diagnostic Horizons, Properties and Materials*. Chapter 3. World Reference Base for Soil Resources. FAO, ISSS-AISS-IBG, IRSIC, Rome, Italy.
- Đurić, S. (1999): Determination of the clay mineral X-ray diffraction. Published 99th 53 (1997) 7,8,9, Belgrade, p.p. 224-227.
- Đurić, S. (2002): *Methods of research in crystallography*. Technical Faculty, Čačak. ITN. SASA. Belgrade, p.p. 207-213.
- Škorić, A. (1986): *Priručnik za pedološka istraživanja*. Sveučilište u Zagrebu, Fakultet poljoprivrednih znanosti, Zagreb.
- Škorić, A. (1991): *Composition and soil properties*. Textbook, Faculty of Agricultural Sciences, University of Zagreb.