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Original scientific paper

SIMULTANEOUS MONITORING OF THE SOIL'S PARAMETERS IN MICROLOCALITY NEAR THE SKOPJE VALLEY

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A b s t r a c t: The soil is a natural medium formed on the Earth's surface. The pedogenic factors have an influence on structure, composition and properties of the soil. As an open system the soil has continuous transfer of energy and matter from the atmosphere. In this research, the temperature and moisture of the agricultural soil from southern slope of the mountain of Skopska Crna Gora were monitored. The measurements of the soil parameters were realized at different periods of the day (8, 11, 14, and 17 h) at various soil depths (0, 5, 10, 15, and 20 cm). In addition, the atmospheric parameters were monitored as well. The soil was characterized by X-ray, mineralogical, granulometric and physico-chemical analysis. Consequently, the impact of the atmospheric conditions upon the soil parameters was studied, in correlation with structure, composition and properties of the soil.

Key words: soil; characterization; temperature; moisture; atmospheric conditions

СИМУЛТАН МОНИТОРИНГ НА НЕКОИ ПАРАМЕТРИ НА ПОЧВАТА ОД МИКРОЛОКАЛИТЕТ ВО БЛИЗИНА НА СКОПСКАТА КОТИНА

А п с т р а к т: Почвата е природен медиум формиран на површината на Земјата. Педогените фактори имаат влијание на структурата, составот и особините на почвата. Како отворен систем, почвата има континуиран трансфер на енергија и материја од атмосферата. Во ова истражување, е направен мониторинг на температурата и влагата на земјоделска почва од јужните падини од Скопска Црна Гора. Мерења на температурата и влажноста се реализирани во различно време од денот (8, 11, 14 и 17 h) на различни длабочини во почвата на (0, 5, 10, 15 и 20 cm). Направен е мониторинг и на атмосферските параметри. За карактеризација на почвата на примероците земени за анализа се направени минералошка, рендгено-структурна, гранулометриска и физичко-хемиска анализа. Следствено е истражувано влијанието на атмосферските услови врз измерените параметри на почвата, во корелација со структурата, составот и особините на почвата.

Клучни зборови: почва; карактеризација; температура; влажност; атмосферски услови

1. INTRODUCTION

The soil is a three-dimensional medium, in the form of a loose layer on the surface of the Earth. The condition of the soil is not permanent, and changes over time under the influence of various pedogenetic factors such as water, air, climate, geological substrate, living and dead organisms, etc. [1]. The soil structure is defined by the arrangement of the soil aggregates and the pores located between them [2]. Aggregation is the result of the interaction of soil grains through rearrangement, flocculation and cementation. Water and air occupy the free spaces between aggregates, creating a network of pores that allow water to move through the soil [3–6]. Various soil types have different characteristics [7, 8].

The soil is in dynamic balance. It is an uninsulated open system that is continuously in interaction with the environment. There is an exchange of energy and matter. The thermal exchange causes changes in the soil temperature. The intensity of temperature changes due to thermal conductivity depends on the depth of the soil [9–11]. The temperature changes in the deeper layers have a smaller amplitude compared to the changes in the surface layers. Temperature and moisture changes due to the influence of the atmospheric conditions on the soil can be daily and seasonal. Therefore, atmospheric conditions should be taken into a consideration for planning of the agricultural activity [12–14].

2. MATERIALS AND METHODS

The microlocality is located in the northeastern part of the Skopje Valley, 14 km away from the city center, near the village Ljubanci on the southern slope of the mountain of Skopska Crna Gora (Figure 1).

Fig. 1. Geographical location of the microlocality – satellite map

The examinations were realized in late autumn when the agricultural activities were finalized, five days after constant low-intensity rainfall. The terrain is sloping, and the measurements were realized with attention, excluding the possibility of horizontal translocation of water in the soil. Therefore, 3 measuring points (1, 2 and 3) have been defined, in order to reduce the probability of false analysis. The top soil horizon is homogeneous as a consequence of several mechanical cultivations according to appropriate agricultural activities (Figure 2.).

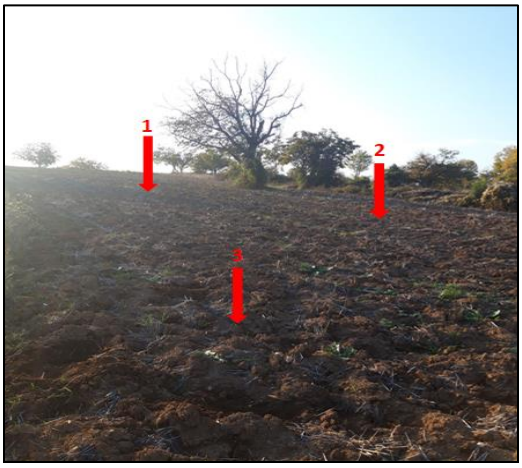

Fig. 2. Examination spot with three measuring points

The soil temperature was measured on a thermometer type TECPEL DTM-3102 (Figure 3.).

The soil moisture was measured on a moisture meter type PMS-714 (Figure 4.).

Fig. 3. Measurement of the soil temperature

Fig. 4. Measurement of the soil moisture

The soil parameters were measured in 3 points at different times of the day (8, 11, 14, 17 h), at various soil depths (0, 5, 10, 15, 20 cm). Also, on a meteorological station type BAL-WS100 the atmospheric parameters were measured: atmospheric temperature, atmospheric humidity and wind speed.

Therefore, it is crucial to characterize the soil [15, 16]. Granulometric composition of the soil was defined applying a wet sieve analysis [17]. A set of standard sieves with a perforation size of 0.125 mm, 0.100 mm, 0.071 mm, 0.050 mm, and 0.032 mm were used. The existing minerals in the soil have been identified on DRON X-ray diffractometer ($2\theta = 2 – 60^o$; UA = 38 kV; IA = 18 mA; 1^o/min.; CuKα/Ni) [18]. The mineralogical-petrographic examination was performed on the SM-POL Leitz-Wetzlar microscope. The soluble carbonates were quantified using the standard method for soluble carbonates, by dissolving the soil sample with HCl acid. The basic physical properties as specific mass, bulk density and porosity were also, determined [19, 20].

3. RESULTS AND DISCUSSION

XRD on Figure 5 detected the minerals contained in the soil. The soil contains large quantities of calcite (limestone) and quartz. It also contains clay and feldspar. In minor quantities the soil contains clinochlore and gypsum.

The chemical composition of the coarse fraction of grains (+0.125 mm) was determined by silicate chemical analysis. The results are presented in Table 1.

The sum of the chemical analysis is 99.34%, while the remaining 0.66% are other micro-elements.

In Table 2 the mass contents of various dimensional fractions of grains in the soil are presented.

In the soil, the fine fraction of grains (-0.032 mm), with over 44.48 % is dominant. The other fractions have a minimal content, with exception of the coarse fraction (+0.125 mm) with a content of 30.34 %. From the curve on Figure 6 three dominant zones can be detected.

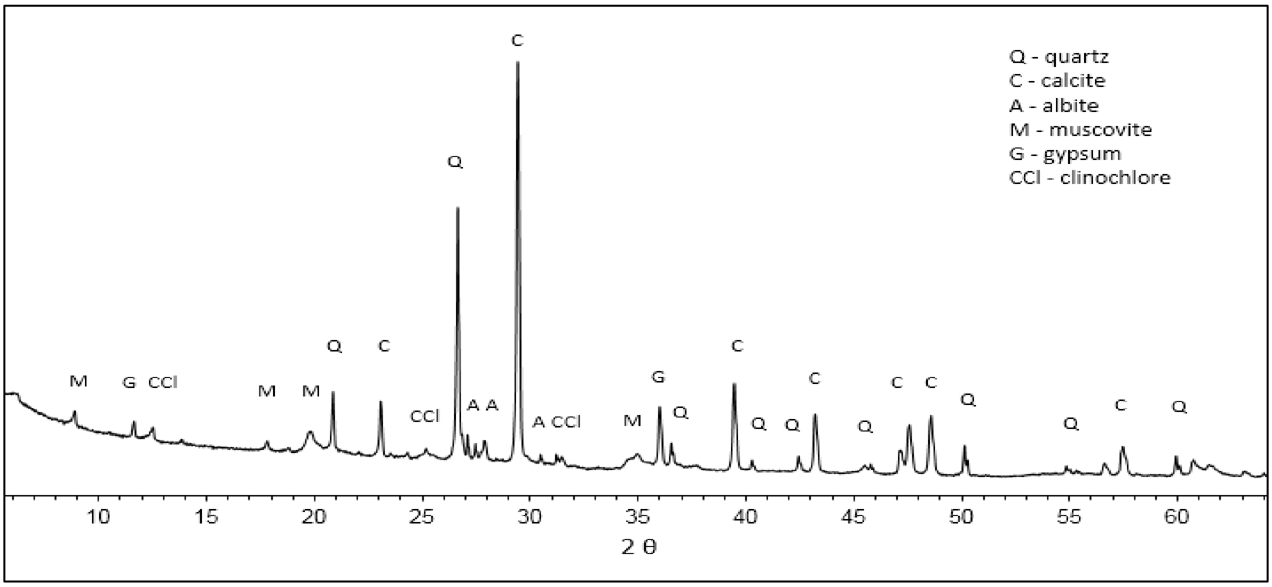

Fig. 5. XRD of the soil

Table 1

Chemical composition of the coarse fraction of grains (+0.125 mm), (mass %)

SiO_2	36.59
Al_2O_3	7.63
Fe_2O_3	3.89
CaO	24.09
MgO	2.84
Na_2O	0.44
K_2O	0.98
SO_3	0.72
l.w	22.16
Σ	99.34

Table 2

Granulometric composition of the soil

Dimensional fraction of grain (mm	Mass (%)
+0.125	30.34
– 0.125 +0.100	5.10
– 0.1 +0.071	9.56
– 0.071 +0.050	6.24
– 0.050 +0.032	3.96
– 0.032	44.48
Σ	100.00

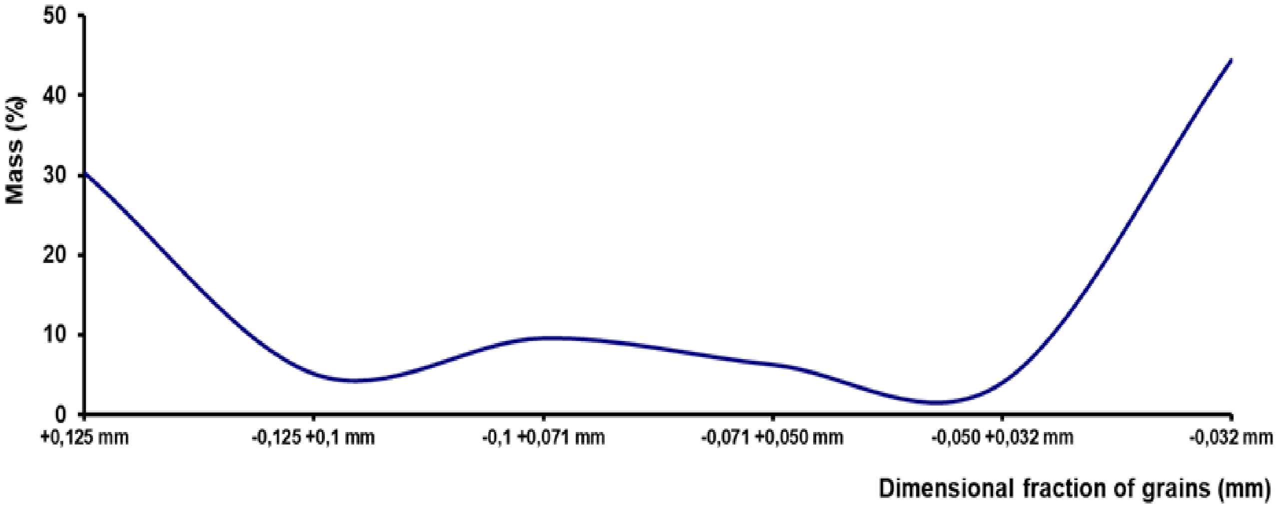

Fig. 6. Mass contents of various dimensional fractions of grains in the soil

The first zone is in the range above 100 μm, dominantly containing secondary, still stable complex agglomerates (red arrow), as well as minimal quantities of homogeneous grains (Figure 7.). The second zone is in the range of 30 – 100 μm, containing primary aggregates (yellow arrow) with similar mineral composition as the agglomerates (secondary aggregates). They are stable in the water suspension as homogeneous grains, even though they have a heterogeneous composition. The third zone is in the range below 30 μm, dominantly containing grains of clay, with originally fine dimensions. It also, contains fine grains of the softer existing minerals as calcite.

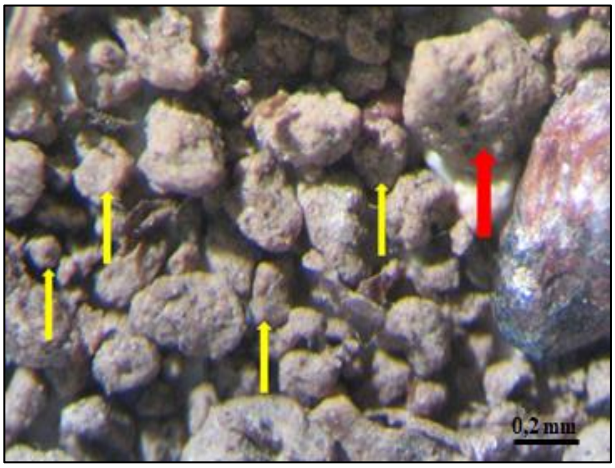

Fig.7. Microscope image of fraction of grains (+0.125 mm)

The dimensional fraction of grains (+0.125 mm) from the wet sieve classification has a dominant content of brown grains, usually aggregated with an irregular shape. They were treated with HCl acid (10%) and had an intensive reaction. After the treatment white transparent grains of quartz were identified (Figure 8.). Aggregated calcite grains coated with clay have been identified, as well as black grains with irregular shape, probably of biogenic origin from the root veins. Other mineral admixtures are in minor quantities. The quantity of limestone in the soil is determined by the standard method for soluble carbonates, with a value of 33.05%.

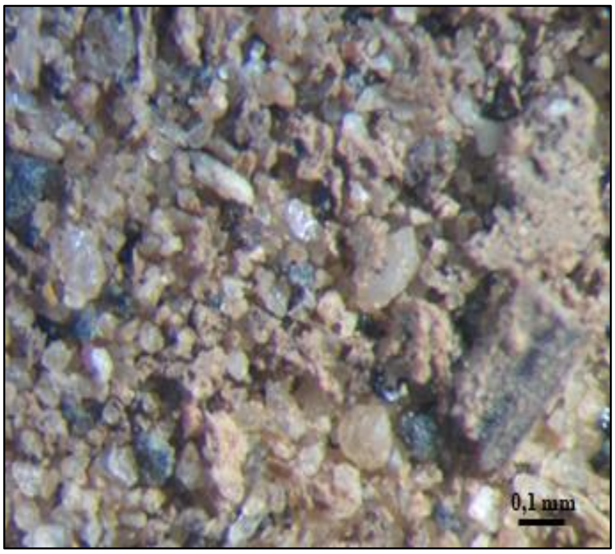

Fig. 8. Microscope image of fraction of grains (+0.125 mm), after treatment with HCl acid (10%)

The basic physical parameters of the soil were also determined. The specific mass of the soil was determined on a pycnometer, and it was $\gamma = 2.695$ g/cm^3. The bulk density was determined using a graduated laboratory beaker. The value of the bulk density of the soil (with 14% natural moisture content of the sample) at loose state is approximately 1.152 kg/dm^3, and at relatively compacted state is 1.580 kg/dm^3. The soil porosity varies in a wide range, depending on the current conditions such as agricultural mechanical cultivation, period of the year, atmospheric parameters, etc. The calculated porosity values of the soil at loose state (simulation of the soil state immediately after agricultural mechanical cultivation, Figure 9.) and at the relatively compacted state (simulation of the soil state after a long period without agricultural activity, Figure 10.), vary from 62% to 50.5%.

Fig. 9. Soil at loose state

Fig. 10. Soil at relatively compact state

The above-mentioned parameters have an impact on macro, meso- and microporosity of the soil. Therefore, micropores dominate at the primary aggregates, mesopores dominate at the secondary aggregates, and macropores are the interspaces between the aggregates. These soil parameters have a dominant impact on the thermal conductivity, and the water conductivity in correlation with the soil depth and the daily and seasonal period.

In Table 3, average values of the soil temperature for the 3 measuring points (1, 2 and 3) at different times of the day (8, 11, 14 and 17 h), and at various soil depths (0, 5, 10, 15 and 20 cm) are presented.

Table 3

Soil temperature (°C) measured at different times of the day and at various soil depths

Soil depth (cm)	Times of the day 8 h	11 h	14 h	17 h
0	4.5	13.0	17.4	11.8
5	5.1	10.6	14.7	12.6
10	7.5	9.4	12.5	12.1
15	7.9	9.6	12.3	11.8
20	8.9	9.6	11.6	11.5

The curves of the soil temperature on Figure 11, pointed the impact of the soil structure on thermal conductivity. The soil surface temperature at 8 h has a lower value than the atmospheric temperature due to the inertia of the cold night. During the day there is an increase of the temperature of the soil surface as a consequence of the increase of the atmospheric temperature. At the maximum value of the daily atmospheric temperature, the soil temperature has a higher value, due to additional direct exposure to the solar radiation. The high degree of thermal absorption is primarily caused by the dark brown color of the soil. Deeper in the soil profile this regularity is maintained, but the phenomenon of convergence of the soil temperature values to a constant value is noticeable, in a state where daily variations in atmospheric temperature no longer affect soil temperature. This phenomenon is characteristic of the specific atmospheric conditions. At different (more extreme: summer or winter) weather conditions, this regularity is also, maintained, and only the value for the convergent temperature and the soil depth will be varying.

In Table 4 average values of the soil moisture for the 3 measuring points at different times of the day and at various soil depths are presented.

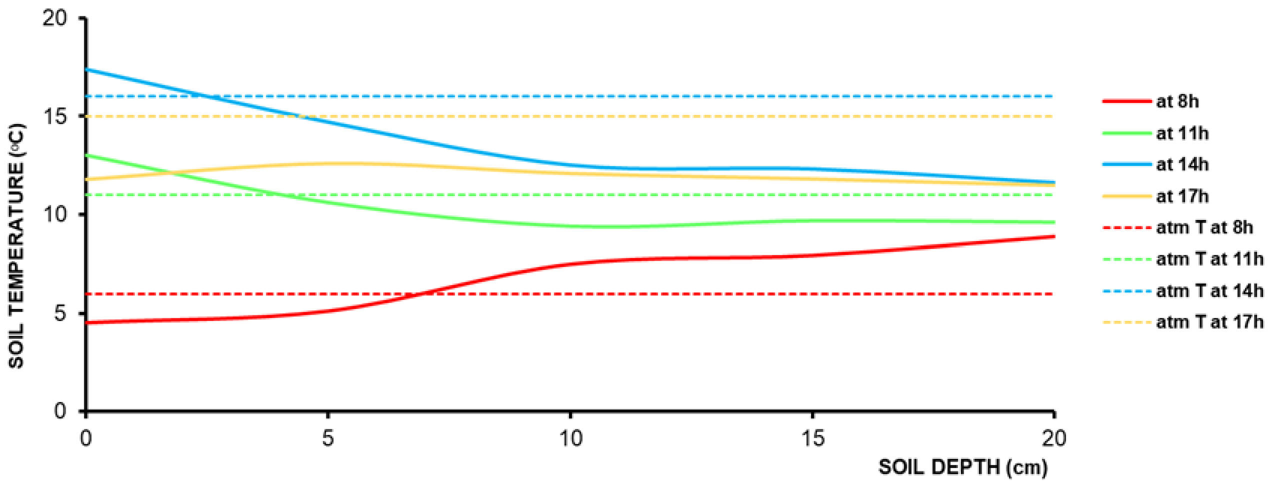

Fig. 11. Soil temperature for various soil depths at different times of the day

Table 4

Soil moisture (%) at different times of the day and at various soil depths

Soil depth	Times of the day 8 h	11 h	14 h	17 h
0 cm	8.9	8.2	8.6	9.0
5 cm	15.8	11.8	13.6	12.1
10 cm	20.7	16.2	13.8	15.5
15 cm	21.1	19.5	18.8	19.5
20 cm	22.7	23.1	22.6	23.5

The curves of the soil moisture have several phenomena (Figure 12.). The moisture of the soil at the surface has a minimum value at all periods of the day because the evaporation is highly intense in contact with the atmospheric air, and the soil porosity is the highest. Deeper into the soil profile, the porosity decreases as a consequence of depth compression, due to the increased mass of the soil column. The soil porosity decreases, reducing the dimension of the pores. Therefore, the capillary water exchange is intense even in the deeper layers of the soil, which constantly contains a larger quantity of water, deposited by rain precipitation 5–6 days before the measurements.

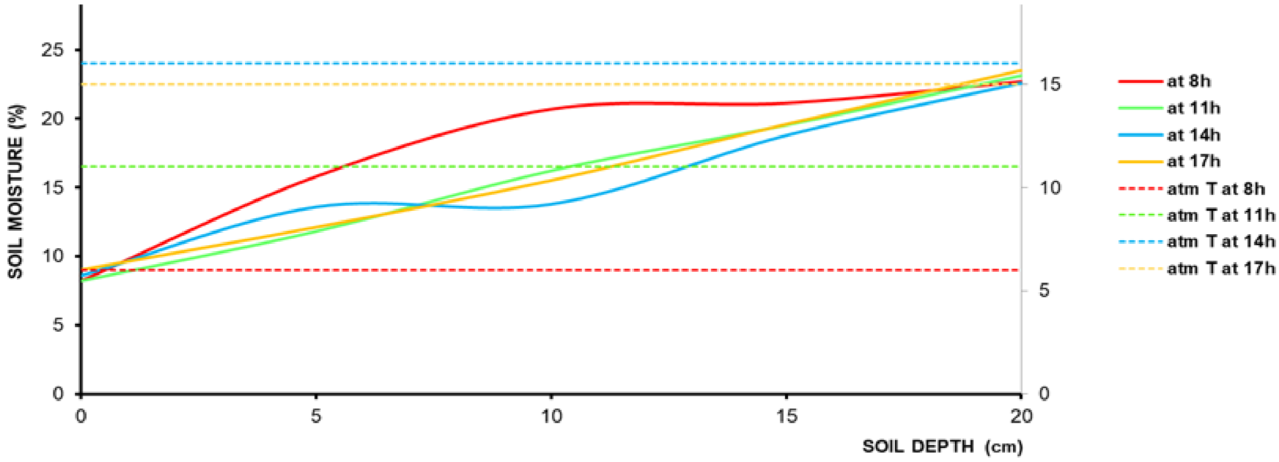

Fig. 12. Soil moisture (%) for various soil depths at different times of the day

As the atmospheric temperature increases, the intensity of the increased soil moisture decreases, even at 10 cm of soil depth. Later in the day (at 17 h) the atmospheric temperature decreases, balancing the soil moisture. This is a consequence of the reduced evaporation of the surface layers, and the capillary transfer of water from the deeper layers. Therefore, the soil moisture at depth of 20 cm has an almost constant value of 22.6 – 23.5 % (Figure 13.). Even at the maximum daily temperature, there is still no balance between the evaporation and capillary transfer of water from the deeper layers. There is an uniform distribution of the soil moisture at 14 h. The uniform distribution of the soil moisture follows in the later period of the day, at 17 h.

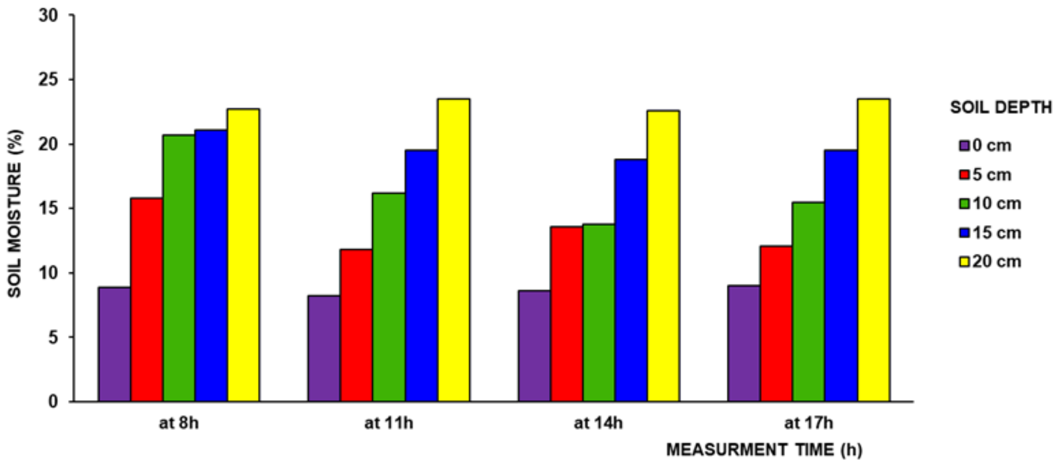

Fig. 13. Histogram of soil moisture (%) for various soil depths at different times of the day

The above-mentioned phenomena are in correlation with the soil structure and the atmospheric conditions. The measurements of the soil parameters were realized in the conditions of calm atmosphere, with all-day wind speed values of 1–2 m /s. The wind speed has a significant impact on the evaporation from the soil surface. The soil, due to the morphological characteristics has a high value of the contact surface with atmospheric air. Therefore, the wind has a minimal impact on the measured parameters of the temperature and moisture of the soil.

4. CONCLUSION

The aim of this research was to define the impact of the atmospheric conditions on the parameters of the agricultural soil from microlocality in the Skopje Valley, located on the southern slope of the mountain of Skopska Crna Gora. Therefore, the soil temperature and moisture were monitored.

Initially, the soil was characterized. The XRD identified calcite (limestone) and quartz as dominant minerals, and clay, feldspars, clinochlore, gypsum as admixtures. The granulometric analysis determined three dominant dimensional fractions of grains: above 100 µm, in the range of 30–100 µm, and below 30 µm. In the finest dimensional fraction clay grains are dominant, as well and fine limestone grains. In the medium dimensional fraction, the primary aggregates are dominant. They contain clay, limestone and quartz. Also, in the coarse fraction secondary aggregates (agglomerates) with a similar composition are dominant. The specific mass of the soil is 2.695 g/cm^3. The bulk density has value of 1.152 kg/dm^3 and 1.580 kg/dm^3, at loose and at compacted state. The soil porosity is in the range of 50–65%.

The soil temperature and the soil moisture were measured at different periods of the day (8, 11, 14, 17 h), and at various soil depths (0, 5, 10, 15, 20 cm). The atmospheric parameters: atmospheric temperature, atmospheric humidity and wind speed were monitored as well. The measurements were realized at conditions of calm atmosphere, 5–6 days after an intensive rain precipitation. The soil parameters are influenced by the soil's properties and are correlated with the atmospheric conditions. The mechanism and kinetics of the temperature and moisture equalization in the soil profile have been defined. All data and conclusions from this research can be applied at specific soil and specific atmospheric conditions in planning of the irrigation regime by the agricultural activities.

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