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Original scientific paper

CONTENT OF HUMUS AND SOIL pH OF THE SOILS FORMED UPON LIMESTONES AND DOLOMITES#

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The soils formed on limestones and dolomites have been examined in different locations on the territory of the Republic of Macedonia. The filed researches have been performed in the course of 2010, 2011 and 2012, during which 52 basic pedological profiles were excavated, of which 34 were Rendzic Leptosol, 13 were Chromic Leptic Luvisol on hard limestones and 5 **were** profiles of Rhodic Leptic Luvisol on hard limestones. These soils are characterized with a profile type O-A-R; A-R; A-(B)rz-R. Seventy eight soil samples were taken for laboratory analyses. The field researches carried out in accordance with the accepted methodology in our country.The pH (reaction) of the soil solution was electrometrically determined with a glass electrode in water suspension and in suspension of 1M KCl. The humus content was determined on the basis of the carbon organic C according the Tyurin method, modified by Simakov. Rendzic Leptosols are characterized with the highest content of humus in relation to the other soils formed on limestone and dolomite. The subtype organogenic Rendzic Leptosols has highest mean value (19.47 %). The content of humus in the Amo horizon amounts to 8.50 % on average, and in the cambic horizon (B)rz 5.18 %. In the Rhodic Leptic Luvisol on hard limestones, the average content of humus in the Amo horizon amounts to 5.33 %, and in the cambic horizon B(rz) it amounts to 2.13 %. pH in H_2O in the subtype organogenic Rendzic Leptosols is an average of 6.99, average value of (6.93) belong to the organomineral Rendzic Leptosols. In the Amo horizon with the cambic Rendzic Leptosols pH in H_2O is 6.12 and in the cambic horizon (B)rz, pH is 6.68. In Chromic Leptic Luvisols on hard limestones there is decarbonization and weak acidification, due to which the soil solution is weak acidified and in the Amo horizon and (B)rz the average value of pH in H_2O is 6.63. In the Rhodic Leptic Luvisol on hard limestones the average pH in H_2O in the humus-accumulative Amo horizon is 6.94 and in the cambic horizon (B)rz pH in H_2O is 6.72.

Key words: humus; soil; limestones; dolomites

INTRODUCTION

Humus defines key soil characteristics and its fertility, and it is an indicator of the processes in soil. Therefore, understanding of its content and quality is important for the sustainable management of agricultural land. Although there is a great interest in the role of humus in ecosystem function, there have been few studies providing unequivocal identification and quantification of humus because of the heterogeneous and polydisperse nature of humic substances, and the complexity of the inter- and intra-molecular reactions [1]. The clear objective of this research is to see the difference between the content of humus and soil pH of the soils formed upon limestones and dolomites. The content of humus and pH reaction in different regions, conditions and different types of soils are formed on the same substrate. Humic substances (HS) constitute a major fraction (60–70 %) of soil organic matter and are possibly the most abundant of naturally occurring organic macromolecules on the earth (2–3 × 10^{10} t), [2].

#Dedicated to academician Gjorgji Filipovski on the occasion of his 100^{th} birthday

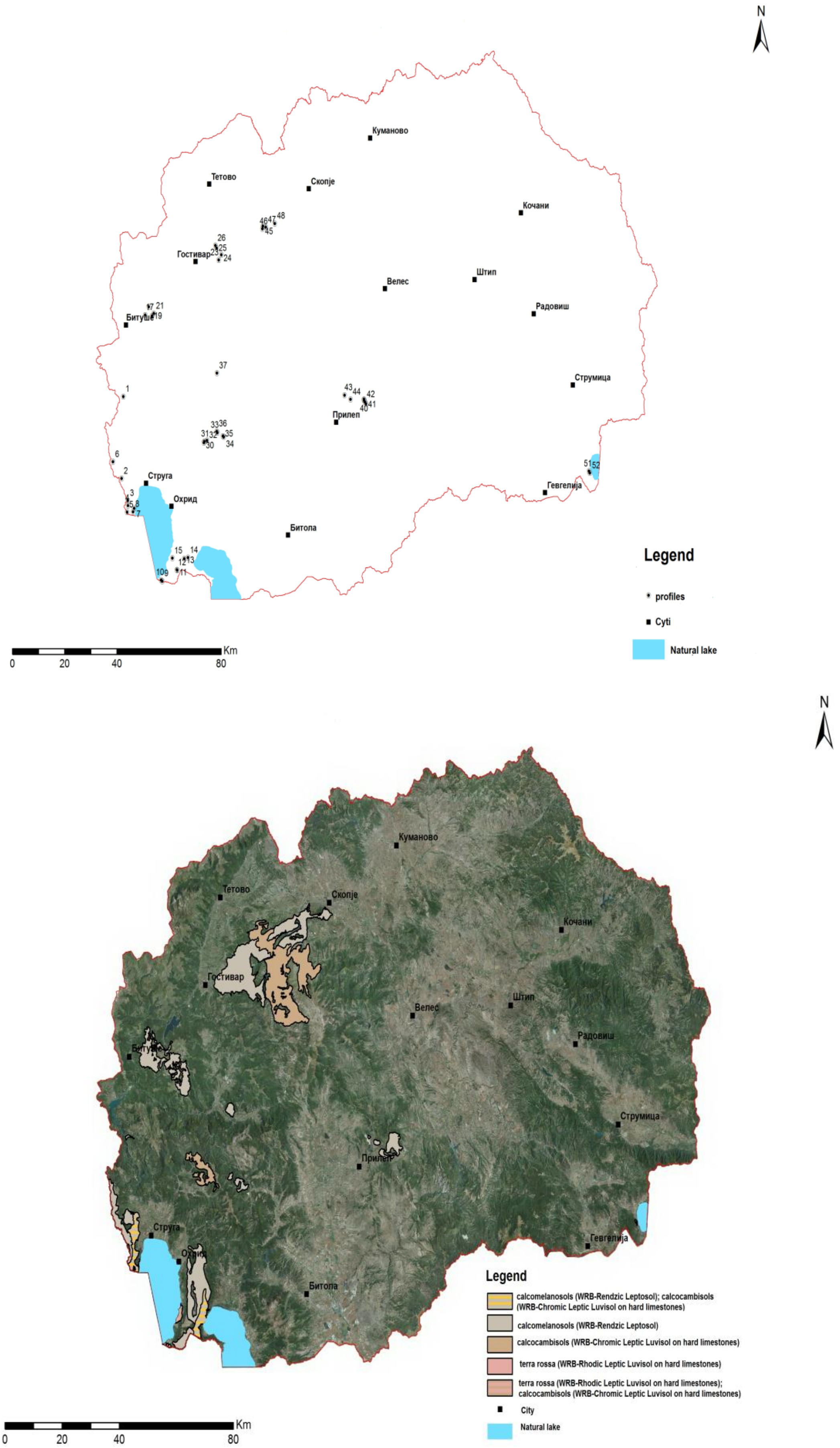

Figure 1. Locations of the soils formed on limestones and dolomites in the Republic of Macedonia

The knowledge of the chemical properties of these soils has a great importance, since these soils are formed only on certain substrates (pure and compact limestones and dolomites), where all physical, physical–mechanical and biological properties greatly depend on the parent material [3]. Data on the humus content, the humus composition, the composition of exchangeable ions, pH - reaction of the soil solution, the sum of exchangeable bases (S), the cation exchange capacity (T), the base saturation percentage (V), and other properties are present in the papers [4–15].

All authors have noted in their research that there is the largest content of humus in the subtype organogenic Rendzic Leptosols [16]. Presented data shows that 38.95 % humus is in the most shallow subtype organogenic Rendzic Leptosols and it reduces to 9.11 % towards Chromic Leptic Luvisols on hard limestones. Also, the content of humus decreases from the Amo horizon to the cambic horizon (B)rz of Chromic Luvic Rendzic Leptosols and Chromic Leptic Luvisols on hard limestones. During the research of the Rendzic Leptosols together with Chromic Leptic Luvisols on hard limestones in Jablanica [17] was found that soils are characterized by acidic and neutral reaction. According to the pH reaction, organogenic and organomineral Rendzic Leptosols fall into three categories (moderately acidic, slightly acidic and neutral). On the Figure 1 can be seen locations of the soils formed on limestones and dolomites in the Republic of Macedonia.

MATERIAL AND METHODS

During 2010, 2011 and 2012, field researches have been carried out on the soils formed on limestones and dolomites, on various locations on the territory of the Republic of Macedonia. The country is divided in 8 climate-vegetation-soil regions, and the studied soils (calcomelanosols) are located in six climate-vegetation belts, in five (calcocambisols) and in two (terra rossa) [18]. The climate of the Sub-Mediterranean modified Mediterranean region differs from the climate of the other regions in terms that the influence of the Mediterranean can be most prominently noticed. The mean annual temperature of this region is 14.2 °C and the average amount of rain is between 611 and 695 mm. According to the Lang’s rain factor, the climate is semi-arid, but in four months (from VI until IX) it is arid. The warm-continental region is dominated by the warm continental climate. The mean annual temperature in this region varies from 9.6 up to 11.8 °C (mean 10.9 °C), and the average amount of rain is around 700 mm. The cold continental region covers a narrow belt of 900 to 1100 m above sea level altitude where the cold continental climate is dominant with some influence from the mountain climate, as a result of the larger above sea level altitude. The climate is colder and more humid when compared to the continental region where the mean annual temperature is 8.6-9.6°C or average of 9 °C. The average amount of rain is 800–850 mm. According to the Lang’s rain factor, the climate is humid. The Piedmont-continental mountain region covers a vertical belt with an approximate above sea level altitude of 1100 m up to 1300 m. The mean annual temperature is between 7.5 °C and 8.6 °C or an average of around 80 °C, and the average amount of rain is around 900 mm. The number of snowfall is greater when compared to the previous belt, and the duration of the snow cover is longer. According to the Lang’s factor, the climate in this belt is humid. The same as in the cold continental region, there is not period of drought. The mountain–continental region covers about 1300 up to 1650 m above sea level. The main difference between this and the previous region arises from the stronger influence of the mountain climate in this area and the mean annual temperature is 1.6 °C lower than the piedmont-continental mountain region and on average it is 6.8 °C, and the average amount of rain is 1044 mm. According to the Lang’s rain factor, the climate is humid and approximates to per humid. The sub-alpine mountain region covers a wide belt from 1650 up to 2250 m. The climate in this region differs greatly from all the other regions due to the domination of the mountain climate which causes a significant drop in the average annual temperature, a drop of the average temperatures in all four seasons, but most prominently in the summer and spring months, causing the annual amplitude to drop. There are no hot days, and the number of days with frost increases. The amount of rainfall in this region does not differ drastically from the mountain continental region. The average temperature in this belt is only 4.8 °C. The vegetation season is short, around 100 days. According to the Lang factor, the climate is per humid [19]. The soils formed on limestones and dolomites occupy a large part of the soil cover of Republic of Macedonia. Based on the pedological (soil) map of the Republic of Macedonia in scale 1:200.000 [1], these soils occupy around 12.45 % of the total area of the Republic of Macedonia or 2.571.300ha. In this area, calcomelanosols / Rendzic Leptosol (RL) covers around 220.000ha or 8.55 %, calcocambisols / Chromic Leptic Luvisol on hard limestones (CLL) covers around 100.000ha or 3.88 %, but terra rossa / Rhodic Leptic Luvisol (RLL) on hard limestones rarely form continuous soil cover.

These can be found on really small areas of karst relief, they have concave shape and are characterized with mosaic and fragmented appearance, and cover around 260ha or 1.00 % of the total area. As a result of our field research, the soils formed on limestones and dolomites were found on Jablanica, Galichica, Ilinska Planina, Bistra, Suva Gora, and Suva Planina at the foot of the accumulation Kozjak, Pletvar, Sivec, as well as on the higher parts in Dojran.

Following the field recognition, locations were selected for digging out the basic pedological profiles. A total of 52 basic pedological profiles were dug out, from which 34 are Rendzic Leptosol, 13 Chromic Leptic Luvisol on hard limestones and 5 profiles of Rhodic Leptic Luvisol on hard limestones, [18]. Seventy eight soil samples were taken for laboratory analyses. The field researches were carried out in accordance with the accepted methodology in our country [20]. The pH (reaction) of the soil solution was determined electrometrically with a glass electrode in water suspension [20] and the classification of soils according to the reaction was performed according to the USA classification [21]. The humus content was determined on the basis of the organic carbon C according the Tyurin method, modified by Simakov [22]. The total N was by determination of Kjeldahl- method [21]. For all analysed properties in both horizons, analysis of variance (ANOVA) for samples of different sizes was made. The impact of the substrate, soil type and their interaction, on the variability of all examined properties was determined. The significance of differences between mean values for the analyzed properties per substrate and soil type was determined using the Tukey test, for the level of $p < 0.05$. All statistical analyzes were made with the R software package.

RESULTS AND DISCUSSION

Content humus of the soils formed upon limestones and dolomites varies extensively and depends on the deposition of nearby materials (from the higher places) and on the degree of erosion, altitude, vegetation, relief, evolution and the intensity of the soil forming process [23].

The occurrence of one or other plant communities is closely connected to the heterogenic climate, relief and soil conditions of the environment.

Table 1. Natural conditions of the studied profiles

Pr of. Nº	Location	Soil types	Parent material	Geographical position		Altitude (m)	Inclination %	Exposition	Phytocenosi
				N.L	E.L.				
1	Jablanica	Eh	ML	$41^0 12' 17\ 35''$	$20^0 34'\ 16\ 83''$	1490	40-50	South	*Ass. Calamintho* **grandiflorae-Fagetum**
2	Jablanica	Eh	ML	$41^0 11' 49\ 89''$	$20^0 34'\ 34\ 37''$	1387	50	North-west	*Ass. Calamintho* **grandiflorae-Fagetum**
3	Jablanica	Eh	ML	$41^0 08' 06\ 35''$	$20^0 35'\ 43\ 17''$	1494	50-60	East	*Ass. Calamintho* **grandiflorae-Fagetum**
4	Jablanica	Lvd	ML	$41^0 07' 23\ 87''$	$20^0 35'\ 41\ 90''$	1440	50-60	East	*Ass. Querno - Quercetum ceries*
5	Jablanica	Eh	ML	$41^0 06' 07\ 06''$	$20^0 35'\ 49\ 27''$	1257	70	East	*Ass. Querco – Osttryetum carpinfoliae*
6	Jablanica	Eh	ML	$41^0 14' 36\ 55''$	$20^0 32'\ 10\ 30''$	1962	70-80	North	*Ass. Onobrichi – Festucetum cyllenicae*
7	Jablanica	Lf	ML	$41^0 06' 14\ 81''$	$20^0 37'\ 49\ 94''$	765	40-50	North	*Ass. Querco Carpinetum orientalis*
8	Jablanica	Eh	ML	$41^0 06' 16{,}66''$	$20^0 37' 46{,}10''$	791	40-50	South	*Ass. Querco Carpinetum orientalis*
9	Galičica	Lf	ML	$40^0\ 54, 37'\ 90''$	$20^0\ 44, 27'\ 73''$	740	40-50	South - East	*Ass. Quercetum frainetto – cerris*
10	Galičica	Lf	ML	$40^0\ 54, 38'\ 33''$	$20^0\ 44, 28'\ 83''$	740	40-50	South - East	*Ass. Quercetum frainetto – cerris*
11	Galičica	Eh	ML	$40^0\ 57, 14'\ 46''$	$20^0\ 48, 45'\ 47''$	1650	50	East	*Ass. Seslerietum wettsteinii*
12	Galičica	Eh	ML	$40^0\ 57, 14'\ 95''$	$20^0\ 48, 45'\ 91''$	1650	50	East	*Ass. Seslerietum wettsteinii*
13	Galičica	Eh	ML	$40^0\ 57, 51'\ 63''$	$20^0\ 48, 48'\ 43''$	1460	40-50	West	*Ass. Festuco heterophillae – Fagetum*
14	Galičica	Lvd	ML	$40^0\ 58, 19'\ 92''$	$20^0\ 48, 32'\ 48''$	1320	30-40	West	*Ass. Querco – Osttryetum carpinfoliae*
15	Galičica	Lvd	ML	$40^0\ 58, 06'\ 24''$	$20^0\ 48, 22'\ 27''$	1154	30-40	West	*Ass. Querco – Osttryetum carpinfoliae*
16	Bistra	Eh	DL	$41^0\ 39, 03'\ 96''$	$20^0\ 42, 48'\ 76''$	1706	40-50	North	*Ass. Calumintho gradiflorae – Fagetum*
17	Bistra	Eh	DL	$41^0\ 38, 25'\ 68''$	$20^0\ 41, 22'\ 37''$	1728	40-50	North	*Ass. Bruckenthalietum – Juniperetum*
18	Bistra	Eh	DL	$41^0\ 38, 25'\ 68''$	$20^0\ 41, 22'\ 37''$	1728	40-50	North	*Ass. Bruckenthalietum – Juniperetum*

Table 1 (continuation)

19	Bistra	Eh	DL	41^0 38, 00’ 52”	20^0 42, 44’ 07”	1730	50	North	*Ass. Bruckenthalietum – Juniperetum*
20	Bistra	Lvd	DL	41^0 38, 29’ 88”	20^0 41, 28’ 26”	1720	50	North	*Ass. Bruckenthalietum – Juniperetum*
21	Bistra	Eh	DL	41^0 38, 22’ 98”	20^0 42, 25’ 69”	1750	40-50	North	*Ass. Bruckenthalietum – Juniperetum*
22	Bistra	Lvd	DL	41^0 38, 07’ 51”	20^0 42, 32’ 37”	1730	40-50	North	*Ass. Bruckenthalietum – Juniperetum*
23	Suva Gora	Eh	BM	41^0 48, 17’ 11”	21^0 01, 06’ 12”	1350	40	South - East	*Ass. Onobrichi – Festucelum cyllericae*
24	Suva Gora	Eh	BM	41^0 48, 21’ 62”	21^0 01, 02’ 58”	1370	40	West	*Ass. Onobrichi – Festucelum cyllericae*
25	Suva Gora	Eh	BM	41^0 49, 05’ 77”	21^0 00, 21’ 28”	1270	20	West	*Ass. Onobrichi – Festucelum cyllericae*
26	Suva Gora	Eh	BM	41^0 49, 27’ 97”	20^0 59, 32’ 07”	1060	20-30	North - West	*Ass. Onobrichi – Festucelum carpinfoliae*
27	Suva Gora	Lvd	BM	41^0 49, 27’ 23”	20^0 59, 31’ 12”	1050	20-30	North	*Ass. Querco – Osttryetum carpinfoliae*
28	Suva Gora	Lvd	BM	41^0 49, 44’ 18”	20^0 59, 04’ 78”	938	30-40	North	*Ass. Querco – Osttryetum carpinfoliae*
29	Suva Gora	Lvd	BM	41^0 49, 45’ 47”	20^0 59, 05’ 57”	830	30	North - West	*Ass. Querco – Osttryetum carpinfoliae*
30	Ilinska	Lvd	PL	41^0 17, 32’ 20”	20^0 59, 07’ 21”	1522	30-40	North - East	*Ass. Calumintho gradiflorae – Fagetum*
31	Ilinska	Lvd	PL	41^0 17, 30’ 11”	20^0 59, 11’ 31”	1524	30-40	North - East	*Ass. Calumintho gradiflorae – Fagetum*
32	Ilinska	Lvd	PL	41^0 17, 28’ 49”	20^0 59, 16’ 71”	1570	30	South	*Ass. Calumintho gradiflorae – Fagetum*
33	Ilinska	Eh	PL	41^0 17, 38’ 58”	20^0 59, 02’ 05”	1501	30	North	*Ass. Calumintho gradiflorae – Fagetum*
34	Ilinska	Eh	PL	41^0 17, 39’ 71”	20^0 58, 56’ 62”	1504	30-40	North	*Ass. Calumintho gradiflorae – Fagetum*
35	Ilinska	Eh	PL	41^0 17, 49’ 18”	20^0 58, 48’ 23”	1487	40	South	*Ass. Calumintho gradiflorae – Fagetum*
36	Ilinska	Eh	PL	41^0 18, 25’ 67”	20^0 58, 47’ 92”	1437	30-40	North - East	*Ass. Calumintho gradiflorae – Fagetum*
37	Ilinska	Eh	PL	41^0 18, 27’ 39”	20^0 58, 45’ 73”	1432	30-40	North - West	*Ass. Calumintho gradiflorae – Fagetum*
38	Pletvar	Lvd	DM	41^0 24, 15’ 54”	21^0 40, 28’ 16”	1166	30	West	*Ass. Juniperus communis intermedia*
39	Pletvar	Eh	DM	41^0 24, 15’ 49”	21^0 40, 27’ 57”	1200	20-30	West	*Ass. Juniperus communis intermedia*
40	Pletvar	Eh	DM	41^0 24, 16’ 41”	21^0 40, 27’ 55”	1205	20-30	West	*Ass. Juniperus communis intermedia*
41	Pletvar	Eh	DM	41^0 24, 15’ 05”	21^0 40, 38’ 83”	1174	40-50	North	*Ass. Juniperus communis intermedia*
42	Pletvar	Eh	DM	41^0 24, 14’ 24”	21^0 40, 41’ 61”	1176	40-50	North	*Ass. Juniperus communis intermedia*
43	Pletvar	Eh	LDC	41^0 24, 51’ 88”	21^0 35, 34’ 13”	1035	50-60	North	*Ass. Juniperus communis intermedia*
44	Pletvar	Eh	LDC	41^0 24, 55’ 90”	21^0 35, 37’ 91”	975	50-60	North - West	*Ass. Juniperus communis intermedia*
45	Suva Planina	Eh	LDC	41^0 52, 32’ 87”	21^0 12, 02’ 90”	600	50-60	East	*Ass.Querco - Carpinetum orientalis subass. Buxetosum*
46	Suva Planina	Lvd	LDC	41^0 52, 51’ 52”	21^0 12, 55’ 05”	725	50-60	South	*Ass.Querco - Ostryetum carpinifoliae*
47	Suva Planina	Eh	LDC	41^0 52, 42’ 24”	21^0 12, 54’ 55”	771	50-60	South - East	*Ass.Querco - Carpinetum orientalis.*
48	Suva Planina	Eh	LDC	41^0 53, 24’ 72”	21^0 15, 29’ 90”	945	40-50	East	*Ass.Querco - Ostryetum carpinifoliae*
49	Dojran	Eh	ML	41^0 13, 44’ 54”	22^0 41, 35’ 39”	255	40-50	East	*Ass. Cocciferro – Carpinetum orientalis.*
50	Dojran	Lf	ML	41^0 13, 43’ 68”	22^0 41, 39’ 22”	233	40-50	South - East	*Ass. Cocciferro – Carpinetum orientalis.*
51	Dojran	Lf	ML	41^0 13, 46’ 36”	22^0 41, 39’ 98”	211	40-50	North	*Ass. Cocciferro – Carpinetum orientalis.*
52	Dojran	Eh	ML	41^0 14, 03’ 29”	22^0 41, 26’ 99”	243	40-50	South - East	*Ass. Cocciferro – Carpinetum orientalis.*

Calcomelanosol.- Eh; Calcocambisol - Lvd; Terra rossa – Lf; Massive limestone- ML; Dolomitic limestone – DL; Bituminous marbels – BM; Plate (flat) limestone – PL;Dolomitic marbels – DM; Laminated dolomite and calcite – LDC

Rendzic Leptosols are characterized with the highest humus content compared to other soils formed on limestone and dolomite. There is the highest average value (19.47 %) in the Rendzic Leptosol, subtype organogenic, in organomineral 13.17 %, and with evolution the humus content decreases, especially in the (B)rz horizon. In Rendzic Leptosol, subtype chromic luvic the Amo horizon there is 12.44 % and in the cambic horizon (B)rz there is 6.66 % humus (Tables 2 and 3).

Table 2. Average values for the chemical properties of Amo

Soil type	N	Humus %		Organic C %		Total N %		pH H_2O	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
1	7	19.47c*	2.62	11.29c	1.52	1.14c	0.18	6.99b	0.44
2	22	13.17b	3.93	7.64b	2.28	0.79b	0.24	6.93b	0.58
3	5	12.44b	2.92	7.22b	1.70	0.75b	0.18	6.12a	0.66
4	13	8.50a	1.97	4.93a	1.14	0.69b	0.26	6.63ab	0.66
5	5	5.33a	1.51	3.09a	0.87	0.32a	0.09	6.94b	0.22

*Values in each column marked with the same letter don't differ significantly between themselves;
1. Rendzic Leptosol organogenic; 2. Rendzic Leptosol, organomineral; 3. Rendzic Leptosol, chromic luvic;
4. Chromic Leptic Luvisol on hard limestones; 5. Rhodic Leptic Luvisol on hard limestones

Table 3. Average values for chemical properties of (B)rz

Soil type	N	Humus %		Organic C %		Total N %		pH H_2O	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
3	5	6.66b	2.02	3.87b	1.17	0.40b	0.12	6.68	0.70
4	14	5.18b	1.48	3.01b	0.87	0.34b	0.09	6.63	0.72
5	7	2.13c*	1.10	1.24a	0.64	0.12a	0.07	6.72	0.33

*Values in each column marked with the same letter don't differ significantly between themselves;
3. Rendzic Leptosol, chromic luvic; 4. Chromic Leptic Luvisol on hard limestones;
5. Rhodic Leptic Luvisol on hard limestones.

Compared to other soils formed on limestone and dolomite, Rendzic Leptosols are formed on higher altitudes so their higher content of humus is due to the lack of moisture and heat in the summer and freezing of the soil mass during the long winter period. The process of mineralization of organic matter during the winter is delayed and slow or entirely prevented (frozen soil), and when there is enough warm periods for decomposition of organic matter, mineralization is slowed down due to lack of soil moisture. Due to the lower amount of rainfall compared to other countries (eg. Montenegro), their altitude, vegetation and conditions under which the soil forming processes (accumulation of humus, decarbonatization and acidification) occur, the limit of 25% humus for the distinction between organogenic and organomineral Rendzic Leptosols is unrealistic for our conditions which was confirmed in the our research. According to [24], a more realistic boundary for distinction of these two subtypes would be where the content of humus is around 15 %. There is less humus in Chromic Leptic Luvisols on hard limestones. They are formed at a lower altitude where the conditions for mineralization are more favourable. The content of humus in the Amo horizon is 8.50 % on average and in the cambic horizon (B)rz it is 5.18 %.

Great decrease in the content of humus is observed in Rhodic Leptic Luvisol on hard limestones as a result of environmental conditions (altitude, type of vegetation), the appearance of the cambic horizon, the manner of utilization (cultivated or uncultivated), erosion and the anthropogenic factor. In addition, the surveyed Rhodic Leptic Luvisols on hard limestones are not in the literal area with a typical Mediterranean climate. The average content of humus in the Amo horizon is 5.33 % and in the cambic horizon (B)rz it is 2.13 %.

Rendzic Leptosols are characterized with the highest content of total nitrogen in relation to the other soils formed on limestone and dolomite. The subtype organogenic Rendzic Leptosols has highest mean value (1.14 %).

The content of total nitrogen (N) in the Amo horizon amounts to 0.69 % on average, and in the cambic horizon (B)rz 0.34 %. In the Rhodic Leptic Luvisol on hard limestones, the average content of total nitrogen (N) in the Amo horizon amounts to

0.32 %, and in the cambic horizon B(rz) it amounts to 0.12 %.

According to [25], Rendzic Leptosols are soils where there is gradual decline in the humus content, while Chromic Leptic Luvisols on hard limestones and Rhodic Leptic Luvisols on hard limestones are soils where there is sharp decline in the humus content. We classified the examined soils according to the content of humus [26], and the results are presented in Table 4.

All organogenic Rendzic Leptosols, belong 100 % to the class of soils with very high content of humus, (Figure 2), 27.27 % organomineral Rendzic Leptosols fall into the class of soils with high content of humus and 72.73 % in the class of soils with very high content of humus. Chromic luvic Rendzic Leptosol, 10.00 % belong to the class of soils with medium content of humus, 60.00 % are soils with high content of humus and 30.00 % are soils with very high content of humus. Chromic Leptic Luvisols on hard limestones, like Chromic luvic Rendzic Leptosol, are classified into three classes as follows: 22.22 % with average humus content, 70.37 % high humus content and 7.41 % belong to the class of soils with very high humus content. In Rhodic Leptic Luvisol on hard limestones there are no samples which fall into the class of soils with high humus content, 41.67 % are soils with low humus contents, there is the same percentage with the soils with medium humus content, and 16.66% are soils with high humus content. The following authors have had similar results on the humus content: [4, 7, 8, 11–14, 16, 17, 23, 27, 28].

Table 4. Number of soil samples according to soil type and subtype allocated into groups with different content of humus

Soil type and subtype	Humus %			
	1 – 3	3 – 5	5 – 10	> 10
Organogenic Rendzic Leptosol	0.00	0.00	0.00	100
Organomineral Rendzic Leptosol	0.00	0.00	27.27	72.73
Chromic luvic Rendzic Leptosol	0.00	10.00	60.00	30.00
Chromic Leptic Luvisol on hard limestones	0.00	22.22	70.37	7.41
Rhodic Leptic Luvisol on hard limestones	41.67	41.67	16.66	0.00

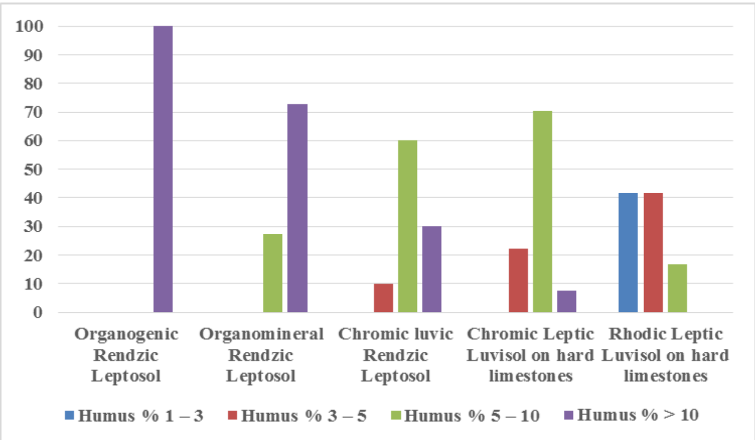

Figure 2. Soil samples according to soil type and subtype allocated into groups with different content of humus in procent

Analysis of the variance (Table 5) showed that in both horizons, the soil type has a significant impact on the variability of the humus content. The parent material, similar as the soil type has significant influence over the content of humus in the Amo horizon.

The soils do not contain carbonates. The reaction of the soil solution varies widely, depending on the developmental stage of the soil type, altitude, vegetation, duration of acidification, erosion, and the manner of use. The brownification that begins to occur in the Chromic luvic Rendzic Leptosols subtype and later the appearance of illimerization in some Rhodic Leptic Luvisol on hard limestones contributes to the gradual change of the reaction of the soil solution in soils.

In order to provide better overview of the heterogeneity of the reaction in these soils, Figure 3 presents data on the reaction in H_2O according to horizons.

Table 5. Analysis of variances of chemical properties of the humus accumulative Amo and cambic horizon (B)rz

Hor.	Factors	Df	Mean Sq				
			Humus	Total C %	Total N %	pH H_2O	pH KCl
Amo	**Soil type**	4	200.82***	67.50***	0.51***	0.78**	1.05**
	Parent material	5	30.26**	10.19**	0.22***	1.84***	2.75***
	Type x substrate	9	12.83*	4.23*	0.03	0.05	0.16
	Error	33	5.73	1.93	0.02	0.17	0.22
(B)rz	**Soil type**	2	34.42***	11.59***	0.13***	0.01	0.11
	Parent material	5	1.16	0.38	0.00	1.28***	1.95***
	Type x substrate	2	6.15	2.09	0.02	0.07	0.04
	Error	16	2.11	0.72	0.00	0.17	0.29

* Significant at the level of 0.05; ** significant at the level of 0.01; *** significant at the level of 0.001.

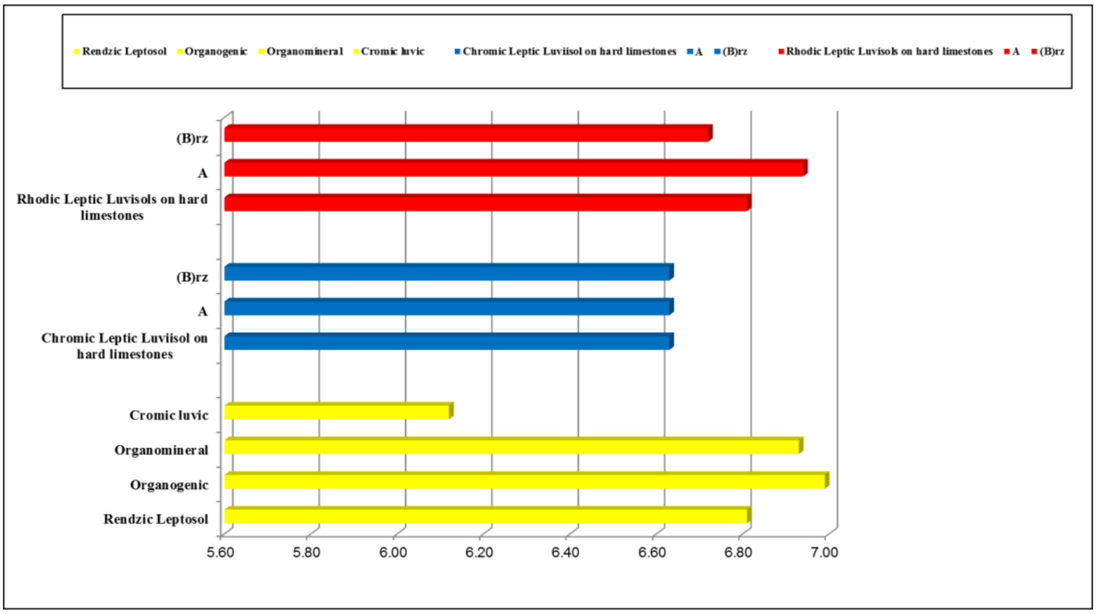

Figure 3. Overview of the pH reaction in H_2O in the soils formed on limestone and dolomites

The high heterogeneousness of the reaction of the soil solution can also be seen from the results in Tables 1 and 2. The average value of pH in H_2O at the subtype organogenic Rendzic Leptosols is 6.99. Organomineral Rendzic Leptosols have slightly lower value (6.93). In the Amo horizon, at the Chromic Luvic Rendzic Leptosols, the average value is 6.12 (statistically lowest value for this soil type) and in cambic horizon (B)rz, the average value is 6.68. With the evolution of the Rendzic Leptosols into Chromic Leptic Luvisols on hard limestones, it comes to a debazification and acidification, due to which the soil solution becomes slightly acidic and the average pH value in H_2O in the horizon Amo and (B)rz is 6.63. In Rhodic Leptic Luvisol on hard limestones, the average pH in H_2O in the Amo horizon is 6.94, while in the cambic horizon (B)rz it is 6.72. Difference was not found between the reactions of the soil solution in Rhodic Leptic Luvisol on hard limestones at various locations and altitudes. We noticed higher values of the reaction of the soil solution at the soils formed on limestone and dolomites in comparison to the same soil types in other countries (Montenegro, Serbia, Bosnia and Herzegovina, Croatia, Slovenia, Albania, Greece, Spain and other) [23].This is a result of a lower quantity of rainfalls and the previously mentioned conditions. Similar values for the reaction of the soil solution for the soils formed on limestone and dolomite, can be found in the studies of: [15, 17, 29, 30]. On the basis of the American classification (Soil Survey Manual, 1951) cit. [20], the reaction of the soils formed on limestone and dolomites ranges from slightly acidic to neutral. At the Rendzic Leptosols, it ranges from slightly acidic to neutral, whereby the subtypes organogenic and organomineral Rendzic Leptosols belong to the class of neutral soils, and the Chromic Luvic Rendzic Leptosols belong to the slightly acidic class. Chromic Leptic Luvisols on hard limestones and Rhodic Leptic Luvisol on hard limestones belong to the classes of neutral soils. The variance analysis has shown that the soil type has strong influence in the Amo horizon over the variability of the pH reaction, while in the cambic horizon (B)rz, the soil type has no influence over the reaction of the soil solution. Unlike the soil type, the parent material has significant influence on the pH-reaction in H_2O in the both horizons Amo and (B)rz, (Tables 1 and 2), whereby the statistically lowest average pH value in H_2O (5.76) can be found in the soils formed on limestone slabs, and the highest value (7.40) can be found at the soils formed over slabs of dolomite and calcite. There is no significant deviation in influence of the other substrates from the highest average value.

CONCLUSION

Rendzic Leptosols are characterized with the highest content of humus when compared to the other soils formed on limestone and dolomite. Chromic Leptic Luvisols on hard limestones have lower content of humus. They are formed on a lower altitude where the conditions for mineralization are favorable. The mean content of humus in the Amo horizon is 8.50 %, while in the cambic horizon (brz) it is 5.18 %. A large decline in the content of humus was noticed in Rhodic Leptic Luvisol on hard limestones, as a result of the environmental conditions (altitude, the type of vegetation), the occurrence of cambic horizon (B)rz, the manner of utilization (cultivated or non-cultivated), the erosion and the anthropogenic factor. In addition, the examined Rhodic Leptic Luvisol on hard limestones are not located in the literal zone with typical Mediterranean climate. The average content of humus in the Amo horizon is amounting to 5.33 %, while in the cambic horizon (B)rz it is amounting to 2.13 %. The information from the variance analysis indicate that in both horizons, the soil type has a significant influence on the variability of the content of humus, and the parent material, similar to the soil type, has significant influence on the content of humus in the Amo horizon.

The soils do not contain carbonates. Based on the American classification, the reaction of the soils formed on limestone and dolomites ranges from strongly acidic to neutral. At the Rendzic Leptosols, it ranges from extremely acidic to neutral, whereby the subtypes organogenic and organomineral Rendzic Leptosols belong to the class of poorly acidic soils, while the Chromic Luvic Rendzic Leptosols belongs to the class of moderate acidic soils. Chromic Leptic Luvisols on hard limestones belong to the class of extremely acidic to neutral soils, and the Rhodic Leptic Luvisol on hard limestones belongs to the class of strongly acidic to slightly acidic soils.

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СОДРЖИНА НА ХУМУС И pH РЕАКЦИЈА КАЈ ПОЧВИТЕ ОБРАЗУВАНИ ВРЗ ВАРОВНИЦИ И ДОЛОМИТИ

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Испитувани се почвите образувани врз варовници и доломити на различни локации на територијата на Република Македонија. Теренските истражувања се извршени во текот на 2010, 2011 и 2012 година, при што беа ископани 52 основни педолошки профили од кои 34 се калкомеланосоли, 13 калкокамбисоли и 5 профили на црвеница. На овие почви оишани се нивната генеза, еволуција, класификација и хемиските својства. Овие почви се карактеризираат со тип на профил O-A-R; A-R; A-(B)rz-R. Калкомеланосолите се карактеризираат со најголема содржина на хумус во однос на останатите почви образувани на варовник и доломит. Најголема средна вредност (19,47 %) има во поттипот органогена В.Д.Ц. Во калкокамбисолите има помалку хумус. Содржината на хумус во хоризонт Amo средно изнесува 8,50 %, а во камбичниот хоризонт (B)rz 5,18 %. Кај црвеницата просечната содржина на хумус во хоризонтот Amo изнесува 5,33 %, а во камбичниот хоризонт (B)rz 2,13%. pH во H_2O кај поттипот органогена В.Д.Ц просечно изнесува 6,99, просечна вредност (6,93) имаат органоминералните В.Д.Ц. Во хоризонтот Amo кај браунизираната В.Д.Ц изнесува 6,12 а во кабичниот хоризонт (B)rz, средно 6,68. Во калкокамбисоли доаѓа до дебазификација и ацидификација, заради што почвениот раствор се закиселува и во хоризонтот Amo и (B)rz просечната вредност на pH во H2O изнесува 6,63. Во црвениците просечната pH во H_2O во хумусно-акумулативниот хоризонт Amo изнесува 6,94 а во камбичниот хоризонт (B)rz 6,72.

Клучни зборови: хумус; почва; варовници; доломити