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ORGANIC CARBON STOCKS IN ARABLE LAND OF REPUBLIC OF SRPSKA - BOSNIA AND HERZEGOVINA

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ABSTRACT

On the territory of Republic of Srpska (RS – Entity of Bosnia and Herzegovina), in the period 2014 - 2017, the fertility control of arable land was performed in 4125 average samples *(taken from top soil, 0 - 30 cm)* representing the surface area of 5776 ha. All samples were geo-positioned and linked to the SOTER database *(soil and terrain databases)*. RS is divided into 262 SOTER units. In each soil sample humus was analysed (colorimetric method, wet burning with K2Cr2O7 and conc H_2SO_4). Soil organic carbon (SOC) was calculated from humus (% humus x factor 0.58). SOC stock *(t ha^{-1})* for each plot were calculated on the basis of the volume mass *(mg m^{-3})* of the soil type on which the plot was located, the soil weights up to 30 cm *(kg ha^{-1})* and the area of the plot *(ha)*. SOC stock on 5776 ha of agricultural land was 225168 t ha^{-1}. The analyzed area was represented by 24 types of soil *(FAO class)*. The highest average SOC stocks of 130 t ha^{-1} *(based on 31 samples)* was found in Calacaric Cambisol and the lowest in Stagnic Luvisol 38 t ha^{-1} *(based on 464 samples)*. In 84% of the tested samples, representing 89% of researched area, the SOC stocks were less than 57 t ha^{-1}. Estimation of the SOC stocks on the total arable land was prepared by GIS analysis interpolation of the SOC results for 4125 samples on the agricultural land area *(arable land, gardens, orchards, vineyards and meadows)*. Estimated SOC stocks on 578894 ha of arable land were 32833549 t. The result of this research is the first step towards the establishment of SOC monitoring system in RS.

Key words: *soil organic carbon, arable land, GIS, Republic of Srpska.*

INTRODUCTION

The term Soil Organic Matter (SOM) is used to describe the organic constituents in soil in various stages of decomposition such as tissues from dead plants and animals, materials less than 2 mm in size, and soil organisms (FAO, 2017). SOM turnover plays a crucial role in soil ecosystem functioning and global warming. SOM is critical for the stabilization of soil structure, retention and release of plant nutrients and maintenance of water-holding capacity, thus making it a key indicator not only for agricultural productivity, but also environmental resilience. SOM contains roughly 55–60 percent C by mass. In many soils, this C comprises most or all of the C stock – referred to as SOC – except where inorganic forms of soil C occur (FAO and ITPS, 2015). Soil plays an important role in the carbon cycle on Earth. The magnitude of the SOC storage is spatially and temporally variable and determined by different abiotic and biotic factors (Weissert *et al.*, 2016). Global SOC stocks have been estimated to be about 1500 PgC for the topmost 1 m (FAO and ITPS, 2015). In most soil types (except for calcareous ones), carbon is typically contained in organic compounds, *i.e.*, in the form of organic carbon (Batjes & Sombroek, 1997). This suggests that changes in organic carbon stocks in the soil (increases or decreases) may be of global significance and they may mitigate or exacerbate climate changes. In addition to soil organic carbon having a positive impact on climate changes, proper land management aimed at raising the level of organic carbon, can increase the productivity and sustainability of agricultural ecosystems (Cole *et al.*, 1997). Increase in SOC concentration to above the threshold level has numerous co-benefits such as increase in food and nutritional security through improvements in soil health and the attendant increase in use efficiency of inputs (*e.g.*, fertilizer, water, energy) (Lal, 2017). To evaluate the role of soil in carbon cycling, it is necessary to estimate organic carbon stocks (Yang *et al.*, 2007). Such assessment is necessary from the points of both, environmental protection and agricultural production. Considering the vital importance of organic carbon for the functioning of ecosystems, its effect on soil structure and soil water capacity, and its role in numerous chemical and physical soil properties, it is important to establish its baseline status in order to be able to monitor its variations over time. It is a source of nutrients and is crucial for agricultural production. (FAO, 2017). Soil organic carbon stocks were investigated in different regions and countries. Spatial distribution of soil organic carbon and SOC sequestration potentials were investigated in the soils of Republic of Serbia. Organic carbon stocks were estimated for soil layers 0-30 cm and 0-100 cm based on the results from a database and using soil and land use maps (Vidojevic *et all*, 2015) . Organic carbon stocks were also estimated for agricultural soils. The mean value of organic carbon up to the depth of 30 cm was found to be 68.99 t ha^{-1}, or 1.58%, which is considered as low (1-2%) (Vidojević *et al.*, 2014). Statistically significant differences in the variations of organic matter content over time can be obtained only when an adequate database is available (Sleutel *et al.*, 2003; Van Meirvenne *et al.*, 1996). This paper presents an assessment of organic carbon stocks in the soils in the Republic of Srpska. The assessment of organic carbon stocks in the soils in the Republic of Srpska was carried out in the period 2014-2017. The result of this research is the first step towards the establishment of SOC monitoring system in the Republic of Srpska.

MATERIAL AND METHODS

On the territory of the Republic of Srpska (RS), in the period 2014 - 2017, the fertility control of arable land was performed in 4125 average samples representing the surface area of 5776 ha. The analyzed area is represented by 23 types of soil (FAO class). An average sample consists of 15 to 25 individual samples taken from top soil (0 - 30 cm). The average tested plot area was 1.4 hectares. All samples are geo-positioned and linked to the SOTER database (land and terain databases). The Republic of Srpska is divided into 262 SOTER units (surfaces which are similar by the geological surface, soil type and geomorfology).

In each soil sample humus was analysed (colorimetric method, wet burning with $K_2Cr_2O_7$ and conc H_2SO_4). Soil organic carbon (SOC) was calculated from humus (% humus x factor 0.58). SOC stock (t ha^{-1}) for each plot were calculated on the basis of the volume mass (mg m^{-3}) of the soil type on which the plot is located, the soil weights up to 30 cm (kg ha^{-1}) and the area of the plot (ha). The assessment of SOC stocks on the total arable land of the Republic of Srpska (RS) was performed using ARCMAP 10.0. Agriculture lands are separated from the LCLU maps of RS 1:100 000 and represented by the following polygons: arable land, meadows, orchards, vineyards and fragmented areas (polygons) on which they dominate arable lands, meadows, orchards and vineyards. Abandoned areas (such as mined areas) and pastures (there are not fertility control on these areas) are not included in the research. The estimation of SOC stocks on agricultural areas (polygons) was obtained by IDW interpolation method of SOC values in 4125 samples. For the estimated SOC stocks content by the soil types, SOTER map of dominant FAO soil types was used. Mean values of the content of organic carbon in the soil and standard deviation were calculated with Statistica Version 8.0 (2007)

RESULTS AND DISCUSSION

The results of SOC content analysis in RS are presented in two levels: measured values and value estimates. The measured values of SOC were obtained on the basis of the results of the SOC analysis in 4125 average soil samples (0-30 cm) collected from 5777 ha of cultivable surfaces (1% of total cultivable area of RS). The estimated values of SOC were obtained by GIS interpolation of measured values on the total cultivable area of Republic of Srpska (578894 ha). The results of the measured SOC values are shown in Table 1. The analyzed area (5777 ha) is represented by 23 types of soil (FAO class).

Table 1. The measured values of SOC and SOC stocks in analyzed cultivable areas shown by the dominant FAO soil types.

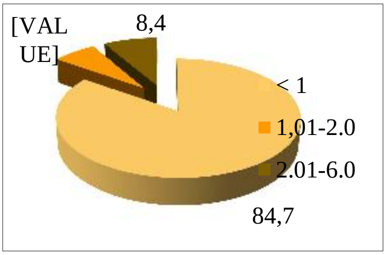
1	2	3	4	5	6	7	8	9	10	11	12
No.	FAO SOIL CLASS	Sample No.	Area ha	Bulk density g cm^{-3}		SOC %	SOC stocks t	SOC content t ha^{-1}			
				min	max			Mean	Min	Max	SD
1.	Stagnic Luvisols	464	826	1.07	1.32	0.6	17521	37.8	0.4	153.9	21.6
2.	Stagnic Podzoluvisols	618	1167	1.11	1.43	0.7	32421	52.5	1.9	157.6	26.0
3.	Chromic Luvisols	102	136	1.08	1.33	0.9	4503	44.0	0.8	110.0	25.7
4.	Eutric Fluvisols	318	435	1.16	1.50	0.9	16352	51.4	8.1	115.1	21.8
5.	Vertic Luvisols	425	544	1.10	1.40	0.9	18501	43.5	0.1	241.2	23.0
6.	Calcaric Fluvisols	272	388	1.11	1.54	1.0	15517	57.0	2.2	163.5	28.2
7.	Eutric Gleysols	631	858	1.21	1.52	1.0	33649	53.3	0.5	303.1	28.1
8.	Eutric Vertisols	222	321	1.03	1.29	1.0	10749	48.4	11.6	158.4	21.3
9.	Ferric Luvisols	189	220	1.19	1.19	1.0	8214	43.5	8.3	121.1	20.1
10.	Calcic Vertisols	57	62	1.05	1.36	1.2	2747	48.2	12.1	98.9	18.2
11.	Ferric Acrisols	34	39	1.34	1.65	1.2	2178	64.1	28.0	123.5	23.4
12.	Haplic Luvisols	104	125	1.21	1.34	1.2	5509	53.0	0.3	170.5	27.1
13.	Mollic Gleysols	51	65	0.54	1.24	1.3	2263	44.4	11.2	120.3	24.1
14.	Eutric Cambisols	97	104	1.02	1.36	1.9	7074	72.9	11.3	254.1	39.2
15.	Dystric Cambisols	48	44	0.99	1.47	2.2	3551	74.0	14.0	146.1	30.6
16.	Ferralic Cambisols	117	105	1.06	1.52	2.4	9848	84.2	18.2	317.1	52.2
17.	Eutric Leptosols	3	4	1.00	1.01	2.5	300	84.8	39.0	143.0	54.0
18.	Vertic Cambisols	65	56	0.98	1.29	2.8	5337	82.1	23.2	177.3	35.6
19.	Humic Cambisols	117	111	0.67	1.15	3.2	9584	81.9	16.0	261.5	39.5
20.	Mollic Leptosols	91	89	0.9	1.23	3.2	9090	99.9	18.8	354.9	54.3
21.	Rendzic Leptosols	54	48	0.71	1.26	3.6	5111	94.6	15.0	226.3	49.5
22.	Umbric Leptosols	15	8	1.16	1.16	4.1	1120	74.7	24.2	114.4	30.4
23.	Calcaric Cambisols	31	22	1.08	1.49	4.7	4030	130.0	36.3	351.4	69.5
Total:		4125	5777	-	-	-	225168	38-130	0,1-39	98,9-354,9	

The SOC stocks (column 8) in the analyzed soil types increases with the increase in the number of analyzed average samples (column 3), as this increases the area of the cultivated land (column 4, an average sample represents an area of 1.4 ha). However, a more realistic situation of SOC is obtained by analyzing % SOC (column 7). Table 2 shows content of SOC by classes of coverage according to Van Ranst *et al.* (1995). Data from Table 2 and Graph 1 show that agricultural production in RS on 91.5% of analyzed areas occurs with very low (84.7%) and low SOC content (6.8%). However, in Table 1, columns 10 and 11, a large variation range between the minimum and maximum SOC content (t ha^{-1}) for all types of soil is observed. For example, the lowest average value of SOC content is established in Stagnic Luvisol and is 37.8 t ha^{-1} or 1.05% (low content) SOC (Table1, number 1, column 9), and variation between minimum and maximum value of SOC is 153.4 t ha^{-1} and ranges from very low content of 0.5 t ha^{-1} to 153.9 t ha^{-1} and 4.3 %, which presents the class of medium SOC content. On this type of land, control of 464 soil samples (about 11% of all samples) was performed.

Table 2. SOC classes according to Van Ranst *et al. (1995)*

SOC Classes		No. of samples	% of samples	Area ha	% Area
Very low	< 1%	3241	78.6	4895	84.7
Low	1.01-2.0	343	8.3	395	6.8
Medium	2.01-6.0	541	13.1	487	8.4
High	> 6.01%	0	-	0	-

Graph 1. Content of SOC (%) in analyzed area



The highest average SOC value of 130 t ha^{-1} and 3.3% (medium content) was found in Calcaric Cambisols (Table 1, number 23, column 9). SOC variations in Calacaric Cambisolu ranged from very low content of 36.3 t ha^{-1} (0.9%) to high content of 651.4 t ha^{-1} or 9.1% OC Such a large variations of SOC is associated with the use of cultivable land and the application of good agricultural practice, i.e. with the structure of plant production. Table 2 shows stocks of SOC depending on the structure of plant production on examined cultivable land.

Table 3. SOC stocks on the analyzed cultivable land depending on the structure of plant production.

1	2	3	4	5	6
No.	Crops and plantings	Area ha	Area %	Average SOC t ha^{-1}	SOC %
1	Grain crops	4098	70.9	32.7	0.9
2	Vegetable	191	3.3	67.9	1.9
3	Orchards and vineyards	423	7.3	46.5	1.3
4	Meadows	1065	18.4	54.8	1.5
	Total:	5777	100.0	-	-

The results in Table 3 show that the analyzed cultivable land is mostly used for grain crops cultivation (71%), but also that the lowest average value of SOC 32.7 t ha^{-1} or 0.9% is found in these soils, which is very low SOC content. The lowest area of cultivable land is used for vegetable growing (3.3%), but in these soils twice the average SOC content of 1.9% (low level) is found.

The reason for this state of OC in the soil, on which vegetables are grown, is because of the intensive production on smaller areas where regular organic fertilizers are applied. When growing cereals, organic fertilizers are used to a lesser extent, mainly mineral fertilizers are used, and therefore the content of OC in these soils decreases. For these reasons, the conclusion is that the content of OC in the agricultural soil, besides the type of land, depends to a large extent on the way of use i.e. the structure of plant production, the regular application of measures for increasing the organic matter in soil and the type of agricultural production (organic, integral ...). Predic *et al. 2016* came to similar conclusions it was found that the results of the basic parameters of soil fertility indicate that it is the soil of different levels of fertility, which is related to the land use and soil type. The average content of OC in meadow areas, permanent crops, i.e. in soils which are occasionally processed, depend to a great extent on the type of land.

For evaluation of SOC stock in soils in RS, GIS charts LC/LU were used, according to which RS agricultural area occupies 1047724 ha (42.5%) (Predić *et al.* 2011). The arable land of 578894 ha, marked out of the agricultural land, are dominated by the following: meadows, orchards, vineyards and fragmented areas (polygons). Currently abandoned arable areas (mine risk ...) are not analyzed in this paper because fertility control on these surfaces was not carried out. Figure 2 shows the spatial distribution of estimated OC content on arable land, and Table 4 shows the distribution percentage of the estimated OC content in agricultural land of RS.

Table 4. Class percentage of the estimated CO content in RS arable land

Class OC		ha	%
Very low	< 1%	469967	81.2
Low	1.01-2.0	100199	17.3
Medium	2.01-6.0	8363	1.4
High	> 6.01%	365	0.1
	Total:	578894	100

On the basis of the data obtained (Table 4), it can be concluded that agricultural production in RS on 81.5% of the arable areas is performed on very low OC soils, and on 17.3% of the low OC content soils which is in total 98.5% or 570166 ha of arable land with insufficient OC content. The estimated SOC stock is shown in Table 5.

Table 5. The estimated SOC stock by FAO soil classes (the total arable land area of RS)

1	2	3	4	5	6	7	8	9	10
No.	FAO SOIL CLASS	Area ha	%	SOC stocks t	SOC %	SOC content t ha^{-1}			
						Mean	Min	Max	SD
1.	Eutric Leptosols	151	0.03	10100	0.03	66.9	13.5	74.7	9.8
2.	Umbric Leptosols	5238	0.9	453610	1.4	86.6	34.6	120.8	16.7
3.	Calcaric Cambisols	5596	1.0	492467	1.5	88.0	33.3	286.3	40.8
4.	Vertic Cambisols	7290	1.3	568609	1.7	78.0	23.2	177.3	26.7
5.	Mollic Gleysols	10899	1.9	573266	1.8	52.6	11.2	145.0	25.7
6.	Dystric Cambisols	12897	2.2	753162	2.3	58.4	14.0	131.9	20.9
7.	Calcic Vertisols	17576	3.0	868257	2.7	49.4	10.5	98.8	10.6
8.	Eutric Fluvisols	18645	3.2	939703	2.9	50.4	8.1	114.6	15.3
9.	Ferric Luvisols	23238	4.0	1036410	3.2	44.6	8.3	121.1	13.0
10.	Ferric Acrisols	23009	4.0	1069916	3.3	46.5	18.3	93.2	11.1
11.	Ferralic Cambisols	14675	2.5	1071304	3.3	73.0	18.2	185.8	35.5
12.	Chromic Luvisols	23886	4.1	1084444	3.3	45.4	0.9	107.1	16.9
13.	Rendzic Leptosols	15552	2.7	1286171	3.9	82.7	19.8	207.0	29.8
14.	Mollic Leptosols	18724	3.2	1421123	4.4	75.9	18.8	278.8	27.0
15.	Haplic Luvisols	27597	4.8	1437804	4.4	52.1	0.3	168.2	16.2
16.	Eutric Vertisols	26155	4.5	1558829	4.8	59.6	12.6	148.8	22.4
17.	Eutric Cambisols	36385	6.3	2252220	6.9	61.9	12.3	254.0	23.5
18.	Humic Cambisols	29228	5.0	2326586	7.1	79.6	16.0	186.5	32.3
19.	Stagnic Podzoluvisols	46012	7.9	2383418	7.3	51.8	2.2	157.4	17.4
20.	Vertic Luvisols	47723	8.2	2510256	7.7	52.6	0.1	241.0	17.7
21.	Eutric Gleysols	46783	8.1	2666629	8.2	57.0	0.5	302.8	17.3
22.	Stagnic Luvisols	70341	12.2	2855860	8.8	40.6	0.4	150.5	13.5
23.	Calcaric Fluvisols	51293	8.9	2964757	9.1	57.8	2.2	163.4	21.3
Total		578894	100.0	32584900	100.0	44.6 - 88.0	0.1 -34.6	74.7-302,8	-

Table 4 shows soil types according to SOC content. The results show that Stagnic Luvisols is the most common type of soil (12.2%) on the arable areas of RS, while the largest SOC stocks are in Calcaric Fluvisol (9.1%). The estimated SOC stock in arable agricultural land of RS is 32584900 t, which is 56.3 t ha^{-1} in average or 1.56% of RS, respectively. Therefore, the arable land in RS is classified as low OC content land by Van Ranst *et al.* (1995). Similar results were obtained in Serbia, where the mean value of SOC was established at 68.99 t ha^{-1} or 1.58% to 30 cm of depth (Vidojević *et al., 2014*).

CONCLUSIONS

The SOC stock in arable agricultural land on 578894 ha in RS is estimated to 32584900 t. Average OC content is 56.3 t ha^{-1} or 1.56% which classifies RS arable land in low OC content land, according to Van Ranst *et al.* (1995). 98.5% or 570166 ha of the arable land in RS is with the insufficient OC content for agricultural production, while in 81.5% of the arable land a very low OC content was determined. OC in the agricultural soil, besides the type of land, depends to a large extent on the way of use i.e. the structure of plant production, the regular application of measures for increasing the organic matter in soil and the type of agricultural production (organic, integral ...). The result of this research is the first step towards the establishment of SOC monitoring system in Republic of Srpska.

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