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Estimating organic carbon in soils modified by technical processes in Kula Municipality (Bulgaria)

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Abstract

The current study focuses on the investigation of soil organic carbon in Technosols in Kula Municipality. It has several aims. There is a need of a provision of more data, regarding carbon sequestration rates in topsoils in plains that are formed in subhumid climatic conditions. Another aim is to check the comparability of the in-profile cultural layer with other ones that are built in different climatic conditions. Objects of the research are contemporary since buried soil horizons play a major part on the provision of essential ecosystem services. The characteristics of soil organic matter are determined by a chemical analysis of six soil samples in the laboratories of the Institute of Soil Science, Agrotechnologies and Plant Protection (ISSAPP) "N. Pushkarov". The total carbon content is determined by the test of Turin and soil color is determined by Munsell Soil Color Charts (1975). Soil organic carbon values in topsoil vary from 670,000 tons/ha to 1,240,000 tons/ha. Organic carbon in the studied sites represents less than 1% of the soil sample. The study may be regarded as the first step in the assessment of Bulgarian Technosols and their role in the global carbon cycle.

Keywords: *technosols, horizons, artifacts, carbon pool, vertisolage process*

Rezumat. Estimarea conținutului de carbon organic din solurile modificate prin procese tehnologice în cadrul municipalității Kula (Bulgaria)

Studiul de față analizează conținutul de carbon organic din cadrul tehnosolurilor din municipalitatea Kula, având mai multe scopuri. Este nevoie de furnizarea mai multor date cu privirea la ratele de izolare a carbonului în straturile superioare de sol din zonele de câmpie care s-au format în condiții climatice subumede. Un alt scop îl reprezintă verificarea comparabilității stratului cultural în profil cu altele care s-au constituit în condiții climatice diferite. Obiectivele lucrării sunt de actualitate întrucât orizonturile îngropate de sol au un rol major pentru asigurarea serviciilor esențiale ecosistemelor. Caracteristicile materiei organice din sol au fost determinate cu ajutorul analizei chimice a șase mostre de sol în laboratoarele Institutului de Științe ale Solului, Agrotehnologii și Protecția Plantelor *N. Pushkarov*. Conținutul total de carbon este determinat cu ajutorul testului Turin, iar culoarea solului cu ajutorul diagramelor Munsell (1975). Valorile pentru conținutul de carbon organic din stratele superioare ale solului variază de la 670 000 t/ha la 1 240 000 t/ha. În cazul siturilor studiate, carbonul organic reprezintă mai puțin de 1% din mostre. Studiul poate fi considerat ca un prim pas în evaluarea tehnosolurilor din Bulgaria și a rolului acestora în ciclul global al carbonului.

Cuvinte-cheie: *tehnosoluri, orizonturi, artifacte, acumulare de carbon, proces de vertisolaj*

Introduction

The International Union for Soil Sciences (IUSS) included a new category in the World Reference Base for Soil Resources (WRB) in 2015, which represents one the most discussed subjects in present day science - soil organic carbon. It was distinguished from anthropogenic organic carbon, which is a product of artifacts, included in the soil profile. Soil organic carbon or humus composition in a soil horizon is among the diagnostic criteria in the World Reference Base for Soil Resources (WRB). It plays a major part in the carbon planetary carbon cycle. As a matter of fact, soils are regarded as the largest reservoir for carbon in the world. Soil organic carbon levels are constantly influenced by a variety of naturally occurring processes. At the same time the anthropogenic pressure also takes its toll and leads to changes that have never been seen before.

Technogenic activities (coming from the Greek word of "technikos") lead to the creation of art, craftsmanship and artifacts that are characterized by well-preserved or changed chemical and mineralogical properties. According to the International Union for Soil Sciences (IUSS) artifacts are created, modified or extracted by man, but with a preserved substance composition in general from the moment of their making. Archaeological soils contain more than 20% artifacts in their horizons. They belong to the group of the Technosols (TC), along with the second group of Anthrosols (AT) that is actually representing intensively managed soils.

In general, carbon sequestration in soils is occurring with a constant speed. The access of oxygen into soil is facilitated by different agricultural activities. This involves movement into the upper horizons of organic and mineral substances, resulting in oxidation and transfer of carbon dioxide to the atmosphere. At the same time soil organic carbon contents decrease. Sowing leads to a balance of carbon storages. According to the diagnostic instructions of the World Reference Base for Soil Resources (WRB), continuous agricultural activities and the presence of artifacts are diagnostic criteria that are recreating the chronology of human presence in certain territories. The differences in the fractions of soil organic substance are a proof for technogenic transformation of the soil and are an indicator for the presence of ancient and contemporary landscapes and villages in Bulgaria.

The present investigation has several aims. The authors focus on the provision of an insight for carbon sequestration rates in topsoils in plains that are formed in subhumid climatic conditions. Another aim is to check the comparability of the in-profile cultural layer with those that are formed in other climatic conditions. Objects of the study are contemporary and buried soil horizons that are providing a series of ecosystem services. The link between the geographical and the cultural and historical landscapes is essential. This intersection has led to a sedentary lifestyle, ritual activities and extraction of materials. We intend to investigate the function "e", of the Soil Functions of the Bulgarian Soil Legislation (2018), namely the preservation of biodiversity, carbon contents and genealogical and archaeological heritage.

There are several studies that should be focused on when it comes to soil research and the investigations of Ghimire et al. (2009), Perez and Garcia (2017), Tcherkezova et al. (2019) and Antonov et al. (2019) are among them. They may act as stepping stones, serving for further investigation. Tipping et al. (2017) focused their research on how atmospheric nitrogen deposition affects soil carbon. The authors of the investigation provided a series of examinations in specially chosen semi-natural landscapes in Britain, focusing on the study of anthropogenic change. They conducted mathematical calculations for the epoch of the Holocene with a focus on British semi-natural soils. Wu et al. (2018) participated in another interesting soil study. The authors worked on different management strategies on Chinese territory, aiming at the reduction of greenhouse gases in the battle against global warming. Their investigation is based on Anthrosols and they were researched for a prolonged period of time. Regardless of the fact that these soils are a part of paddy fields in Southern China they are providing sufficient data from a similar research, as the current one. Another study, aiming at unveiling anthropogenic use levels is conducted by Bhardwaj et al. (2019). Their investigation focuses on alluvial soils in the soil research institute in Karnal, India (the Indo-Gangetic Plain). Their results point out that human interference changes the carbon pool of the soil.

Material and Methods

The sampled areas in the investigated territory represent two archeological sites with mean coordinates 43°52′15.53″ N, 22°29′43.29″ E and 43°50′45.8″ N, 22°33′49.8″ W respectively (Fig. 1). Both areas are completely within the extent of the West part of the Danubian Plain, distanced from each other at about 6.5 km. The mound necropolis near the municipal center (Kula town) is elevated at 218 m above sea level. It is discovered and studied by the team of assistant professor Tanya Hristova (2020), which dates the artifacts from the end of the Late Bronze Age and the transition to the Early Iron Age. The early medieval settlement from the VII-IX century AD, discovered by the team of assistant professor Galina Grozdanova (2020) is located West - Southwest of the village of Kosta Perchevo at 219 m.

The area of Kula Municipality includes three adjacent river basins, which determine the general configuration of its boundaries. The shape of the municipal area is closer to an ideal geometric figure (a rectangle), tilted to the Northeast towards the Danube river. The highest point within the area of interest, with an elevation of 490 m, is part of Vrashka Chuka Ridge. Two distinctive levels can be defined based on elevation values - lowland or floodplain (with elevation up to 200 m) and hilly areas (with elevation exceeding 200 m). The West part of the study area includes hills and ridges (such as Bachia Ridge) which are peripheral units of Fore-Balkan's vicinity. River terraces and the floodplain cover the majority of the Northeast and central parts of the study area. The drainage network is represented by streams with variable discharge, characterized by low flow in spring and autumn, pluvio-nival and karst regimes. Watersheds between Kosta Perchevo village and the town of Kula are overlaid with Pleistocene aeolian, alluvial and deluvial deposits (loess clays). River incisions reveal outcrops of Neogene sands, sandstones, and detrital limestone of the Dimovo Formation (Filipov et al., 1992).

The high amount of clay fraction and the slickensides (vertisolage process) are typical features of soils, covering the lowlands and floodplains in Kula Municipality. The genesis of clays is a result of contemporary and/or previous hydromorphism/hydromorphic stages. The soils in the area of interest were used for agricultural purposes; hence the carbon balance was disturbed. Soil organic matter was subjected to the oxidation and removal of atmospheric CO_2 by plants. According to Zhiyanski (2014) "carbon sequestration in soils" includes both emissions of carbon into the atmosphere and its

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storage in the form of soil organic matter. Therefore, the presented study is inspired by the finding of Zomer et al. (2017 a, b). Their research was focused on the potential of agricultural territories on global scale to sequestrate carbon. The authors aimed at the topsoil layer from 0 cm to 30 cm and provided a map of 250 m resolution. Soil organic carbon storages in tons per hectare are provided per pixel value. In order to receive correct data each value should be multiplied by 100. The research team created another map with data about the future carbon sequestration for the next 20 years.

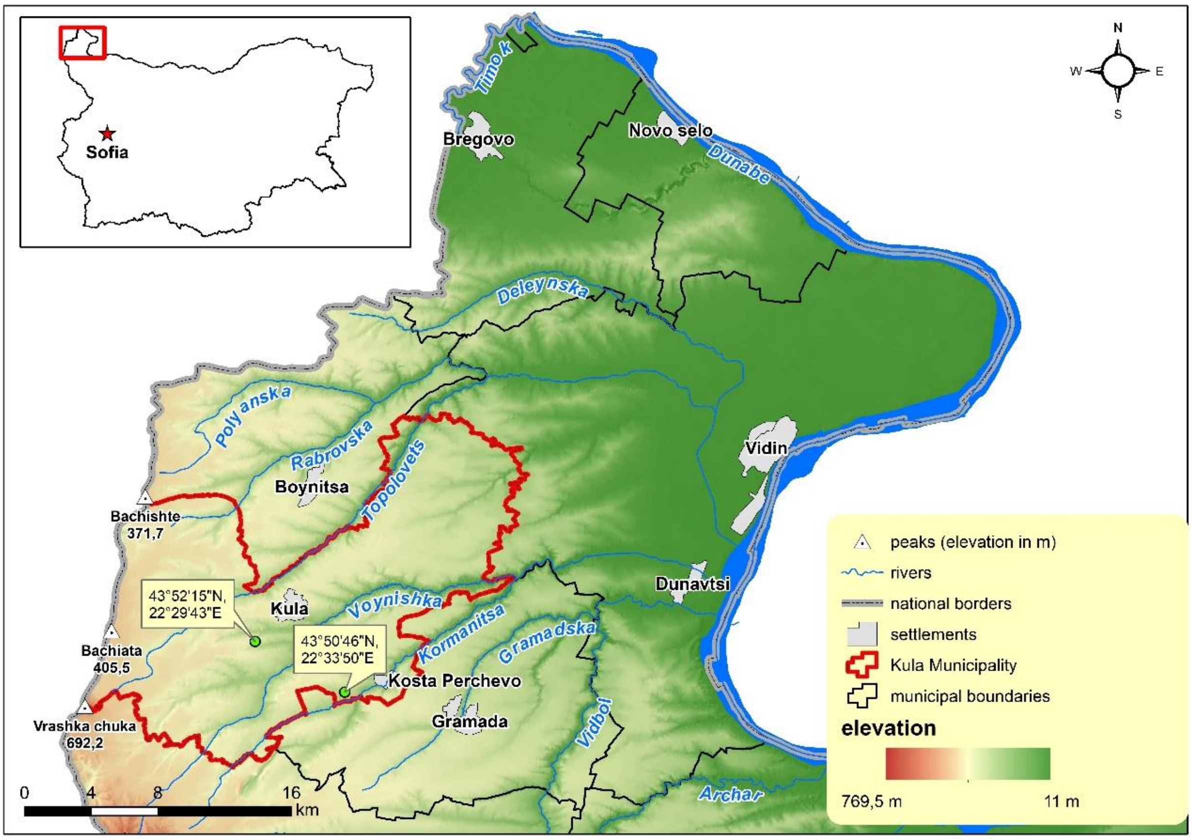

Fig. 1: Study area and sampled soil profiles

The amount and composition of soil organic matter is determined by a chemical analysis of six soil samples. All samples are tested in the laboratories of the Institute of Soil Science, Agrotechnologies and Plant Protection (ISSAPP) "N. Pushkarov", Sofia. The total carbon content is determined by the test of Turin after Kononova (1963) according to the current standards in the country. Thus the humus content is calculated by multiplying the percentage of total carbon by 1.724. Soil profiles in each archeological site are presented by a morphological description and are characterized by grain size analysis. Soil color is determined by Munsell Soil Color Charts (1975).

Results and discussion

Morphological observations

The grain size analyses (Fig. 3) of the morphologically defined three horizons (Fig. 2) shows a similarity between the upper two horizons. The differences are in the large fractions (pebble and sand) that are prevailing in the middle and the lower horizons and another difference is in the amount of silt. The large fractions are most commonly met in the middle horizon (40-80 cm). The presence of clay sized particles in the three horizons is a proof for similar genesis. Thus, the deposits are of an eolic origin, probably mixed with their slow movement down the river, following a creep process.

Gentle slopes and low altitude, the close proximity to a spring that is creating an embrional erosional form and the closeness to constant water flow are among the main reasons for the presence of sedentary lifestyle. The second horizon (Fig. 2) showed a presence of pottery and a furnace that were significantly destroyed. The leading researchers of the excavations (Grozdanova & Koleva, 2020) declared that there is a lack of a typical cultural layer, despite the presence of the ceramics of 4 pots. However, the presence of fragments of iron slag and a tube for oxygen regulation that are moved in zones with anomalies (in the third horizon), as well as the bottoms of the pots that have changed because of the high temperature, are a proves for anthropogenic activities.

Fig. 2: Morphological description of the soil-architectural profile/drilling in Object 5/1004 near Kosta Perchevo Village

- 0-40 (60) cm; black clayey, less gravels; 10YR 3/1 very dark gray; weak reaction with HCl;
- 40 (60) – 80 cm; clayey; lighter in color than the upper layer, less sand and gravel; 10YR 4/3 brown; weak reaction with HCl;
- 80-100 cm; whitish to orange with inclusions and smooth gravels; 10YR 6/6 brownish yellow; reacts with HCl.

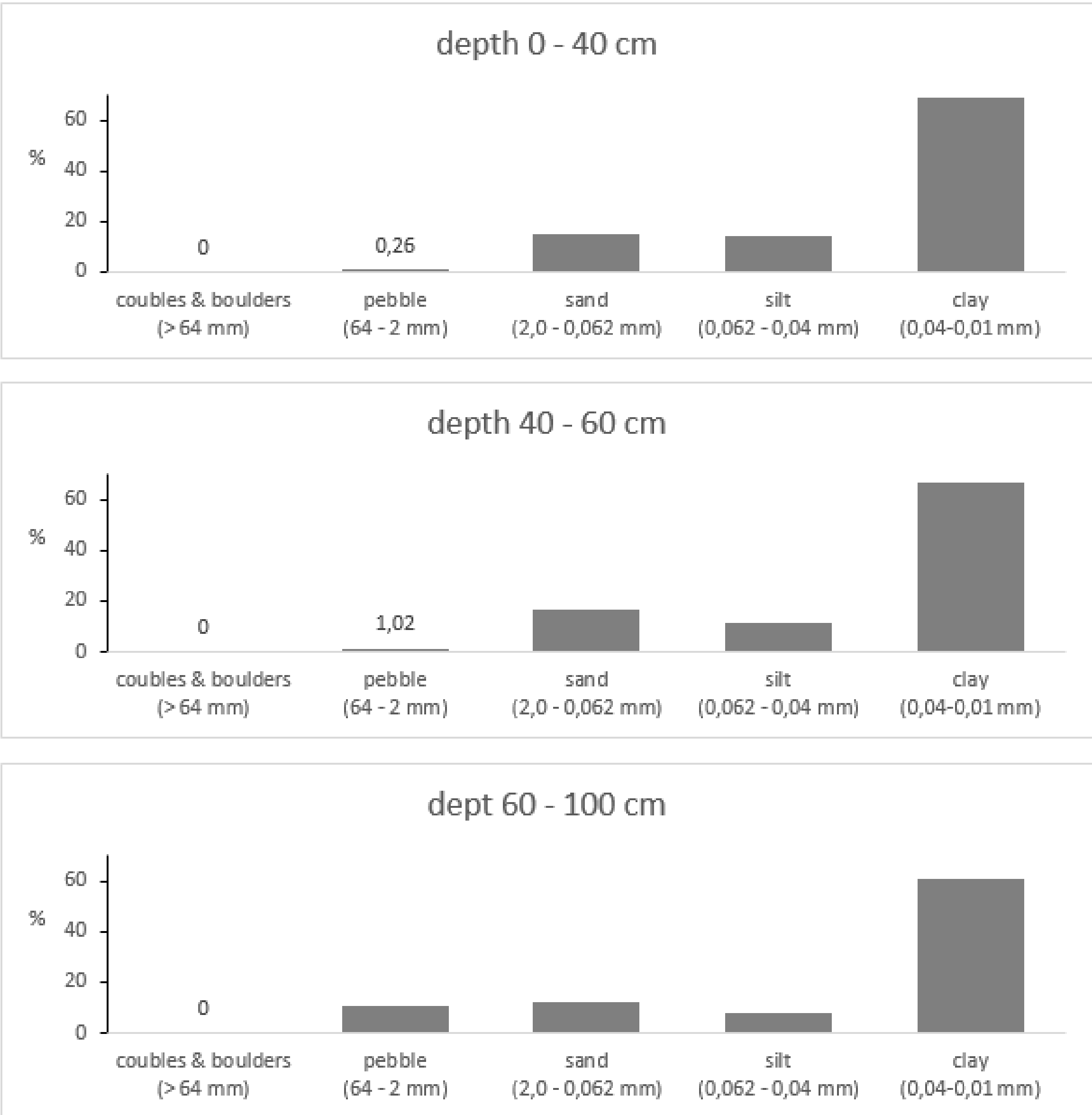

Fig. 3: Results of the grain size analysis

Artifacts also document that the upper horizon of 0-40 cm has developed over the last 10 000 years after the last glacial period. Archaeological structures and the places where urns from the Late Bronze Age necropolis were stored may be associated with the morphological analysis of the third layer (AIII) in Drilling 53 of the object, located near the town of Kula (Fig . 4). It is clear that they were laid in grave pits, leading to a destruction of the AII layer, meaning that it has already been formed in the end of 2nd

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millennium BC (Hristova & Hristov, 2020). This is a period of the Early Bronze Age cryophase. The average values of the climatic elements are as low as 2°C, compared to nowadays - a reason for migration from Northern Europe to the territory of Bulgaria (Baltakov & Kenderova, 2003). Ecological conditions were characterized by lush vegetation and more precipitation. If we take the time span and the cultural layer's depth into account, we may assume that soil accumulation during the Subatlantic period in Choika Area, Kula Municipality is with a low speed 0.0067 cm/year.

Fig. 4: Morphological description of the soil-architectural profile/drilling in Object 4/1003 near the town of Kula

- AI 0–10 cm; very dark gray (10YR 3/1), turfy; heavy sand-clayey, compacted, with trochoid-granular structure, vertical cracks, 5 cm wide; it does not react with HCl; well differentiated boundary with the lower horizon
- AII 11-25 cm; dark grey (10YR 4/1); heavy sand-clayey, heavy compacted; structure with small lumps, vertical cracks, reacts with HCl; gradual transition
- AIII 26-50 cm; very dark gray (10YR 3/1); average sand-clayey; compacted, lump-prismatic structure, reacts with HCl.

Heavy clayeness is typical for the mechanical composition of the soil along with colloid consistency. The vertisolage process is the result of successive shrinkage and expansion of the volume due to over humidity and drying. The glance appearance of prismatic aggregates that are diagnostic classification feature adds weight to this assumption.

FAO defines Vertisols as having weak differentiation of the profile if we look at the mechanical composition. Therefore, the composition is similar in the whole soil profile. Subsurface vertic (vr) horizon, starting from a depth ≤ 100 cm of the soil surface, is typical for zonal soils of the reference group that are characterized by a difficult development of the root systems due to the rotation of humid and dry seasons. Swelling clays are a typical feature of the mineral horizon. According to the diagnostic criteria of the working group of IUSS WRB 2015, the il composition has to be ≥ 30% in an area ≥ 25 cm.

The content of organic carbon (Corg.) in the surface very dark gray (10YR 3/1) AI turf layer, with a depth of 0–10 cm (sample 10 - Table 1) of Vertic Chernozems (FAO, 2014) is relatively less than the Corg. in the carbonate type of chernozems. Carbon content decreases in depth reaching 0.38% in horizon AIII (10YR 3/1 very dark gray). Both topsoil and subsurface layers are shallow and although the surface is covered with tufts of grass, the organic content is low. The number of humic acids (3.82%) in the topsoil exceeds fulvic acids due to the uniformity of the grass vegetation in the sampled site, therefore humate type of humus is formed/observed. Fulvic acids in sample 11 (Table 1) were not found while in both surface and subsurface horizons, 0-10 cm and 11-25 cm respectively, free humic acids and those bound with mobile sesquioxides (R2O3) are missing. Results show absence of leaching of humic substances along the depth of the profile.

Carbon content is shown in Table 1 where underlined value indicates the percentage of organic carbon in the soil sample and the other value represents the proportion of total carbon. The type of humus is defined by the ratio between carbons of humic acids to carbon of fulvic acids – Ch/Cf. This ratio is an indication of climate conditions during the soil formation. The higher amount of Cf indicates a weak process of humification, determined by cold and humid climate and presence of forest vegetation, whereas humic acids predominate under grassy vegetation. Total content of humic and fulvic acids (Cextr) is determined after extraction with a mixed solution of 0.1 M (molar) Na4P2O7 and 0.1 M (molar) NaOH (Table 1).

The humic acid fractional composition includes a first fraction of completely free acids and those bound to R2O3, and a second fraction of humic acids bound to calcium extracted with 0.1 M NaOH. The third extracted fraction is of the most mobile, aggressive fulvic acids. The humic and fulvic acids in both extracts Cextr and C extracted with NaOH were separated by acidifying the solution with 0.5 M H2SO4.

The established quantitative share of humic acids in percentage 0.42% relative to the weight of dry soil as a percentage of the total content of organic carbon - 33.07% in the initial sample (sample 10, Table 1) shows a predominance of fulvic acids due to the abundance of wealth grasses with a dense root system.

Topsoil horizon of Vertic Chernozems near Kosta Perchevo Village is also associated with high humus content, hence high amount of organic carbon ($C_{org.}$). The highest carbon content - 1.47% of all compared samples characterizes the most advanced humification process (sample 26, Table 1). Lower C_h/C_f ratio (2.00) is an indication of fulvate-humate type of humus, whereas the type of humus in sample 10 is considered to be humate type. The portion of aggressive fulvic acids extracted with 0.1 M H_2SO_4 is between 3 and 9% of the total carbon, therefore it is relatively low in both soil profiles. Humic acids in both sampled sites are bounded with calcium.

Pottery was found in the second horizon at a depth between 40 (60) and 80 cm (sample 27, Fig. 2). Fulvic acids are also present in this layer while in the lower layer (80 - 100 cm) archeologists found lots of slag, which is the main reason to classify soil sample 15 as a Technosols. Presence of swamp ore (hydrated iron oxide mixed with vegetation matter) could be explained by a low oxygen environment, such as marshes and peat bog formation. Two marshes near the sampled site represent those conditions that led to deposit of hydrated iron oxides and soil hydromorphism. Results from the analyses of sample 28 (Table 1) from seasonally overmoistured state, are similar.

Table 1: Indicators for content and composition of soil organic matter

Sample	Total carbon(%) / humus (%)	Organic carbon (%) extracted with 0.1 M $Na_2P_2O_7$ + 0.1 M NaOH			C_h/C_f	Organic carbon (%) Fraction of humic acids		Unextracted organic carbon (%) ($C_{remaining}$)	Extracted carbon with 0.1 M H_2SO_4 (%)	$\frac{C_h+C_f}{C_{remaining}}$	Extracted C with 0,1 M NaOH (%)
		Total	Humic acids	Fulvic acids		Free and bound with R_2O_3	Bound with Ca^{2+}				
10	1.27 / 2.18	0.53 41.73	0.42 33.07	0.11 8.66	3.82	0.00	100.00	0.74 58.27	0.05 4.94	0.71	0.08 6.30
11	0.38 / 0.65	0.12 31.58	0.12 31.58	0.00	-	0.00	100.00	0.26 68.42	0.02 5.26	0.46	0.04 10.53
26	1.47/ 2.53	0.60 40.82	0.40 27.21	0.20 13.61	2.00	0.00	100.00	0.87 69.18	0.05 3.40	0.68	0.14 9.52
27	0.55/ 0.94	0.19 34.54	0.12 21.82	0.07 12.72	1.71	0.00	100.00	0.36 65.45	0.05 9.09	0.52	0.11 20.00
15	0.38/ 0.65	0.15 39.47	0.15 39.47	0.00	-	0.00	100.00	0.23 60.53	0.02 5.26	0.65	0.06 15.79
28	0.45/ 0.77	0.21 46.67	0.14 31.11	0.07 15.16	2.00	0.00	100.00	0.24 53.33	0.02 4.44	0.87	0.08 17.78

Soil organic content

The following lines are focused on soil organic carbon content, following Zomer et al. (2017 a, b). The information in the text will be supported by the visual representation of the obtained results, presented by two maps (Fig . 5 and Fig. 6). These maps include several main villages, namely from west to east: Golemanovo, Izvor mahala, Kula, Poletkovtsi, Kosta Perchevo, Chichil, Topolovets and Tsar Petkovo. Their specific geographic location will be used as a marker in the analysis of the allocation of soil organic carbon.

Generally speaking, the lowest values of soil organic carbon in the topsoil are presented with the darker shades (brownish) on the first of the two maps (Fig. 5). They are prevailing within the borders of Kula Municipality, covering the largest territories. Carbon stocks are located mainly near the villages of Topolovets, Kula, Golemanovo and Staropatitsa. The

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values there are in the range of 700,000-750,000 tons/ha with the lowest values to the west of Topolovets – 670,000 tons/ha.

The largest carbon pool with highest values can be discovered in the areas with the lighter colours (yellowish). Carbon contents are ranging from 1,000,000 – 1,110,000 tons/ha near the villages of Golemanovo and Izvor mahala, reaching 1,150,000 - 1,160,000 tons/ha to the north of Kula. The richest carbon pool is located between the villages of Staropatitsa and Poletkovtsi where soil organic carbon stocks in the upper 30 cm are 1,240,000 tons/ha.

There are several blank spots within the map that carry no information, despite that fact they are still an integral part of the cartographic material, providing a specific bunch of data.

Figure 6 presents the expected soil organic carbon contents in the topsoil between 0 cm and 30 cm according to the medium scenario. Zomer et al. (2017 a, b) also provide a high scenario of the carbon pool, but the authors of the current study regard it as a too positive one and decided to omit it from the discussed information. Nevertheless, it should be applied in similar investigations if scientists wish to receive a broader picture of the present day problem with soil organic carbon contents.

Once again areas with lower carbon stocks expectancy are the predominant ones and they are displayed with the darker colors. Carbon contents are reaching 780 000 - 860 000 tons/ha between the villages of Topolovets and Tsar Petrovo to the northeast. At the same time carbon stocks near the villages of Golemanovo, Kula, Poletkovtsi and Izvor mahala to the west are around 880 000 - 920 000 tons/ha. If we focus on the difference between the current situation and the expected within the period of 20 years, it becomes obvious that it is possible to expand the carbon pool with an average of 1 000 000 tons/ha. This would be possible if proper land management techniques are adopted.

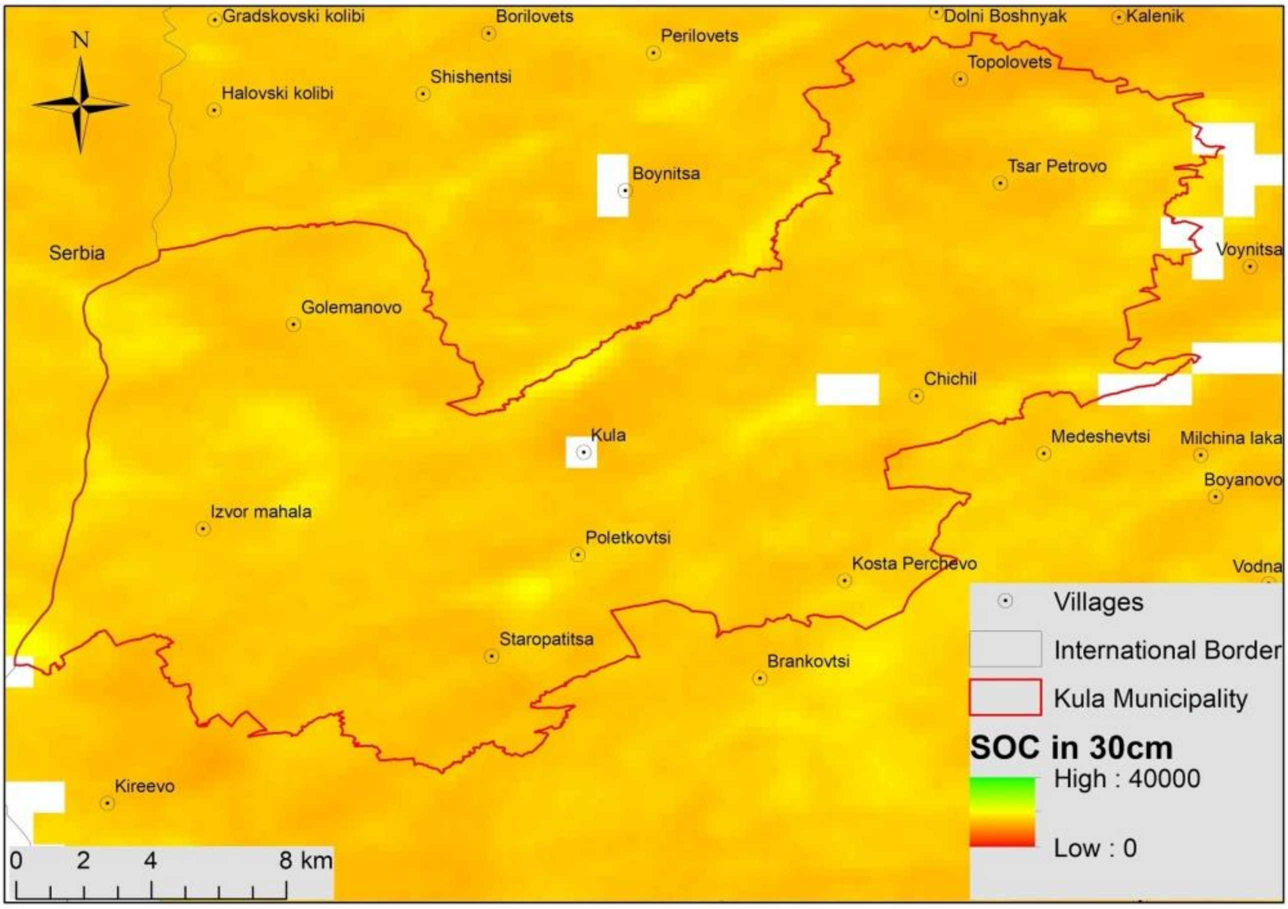

Fig. 5: Soil organic carbon contents in the top 30 cm of the soil in Kula Municipality (according to Zomer et al., 2017 a, b)

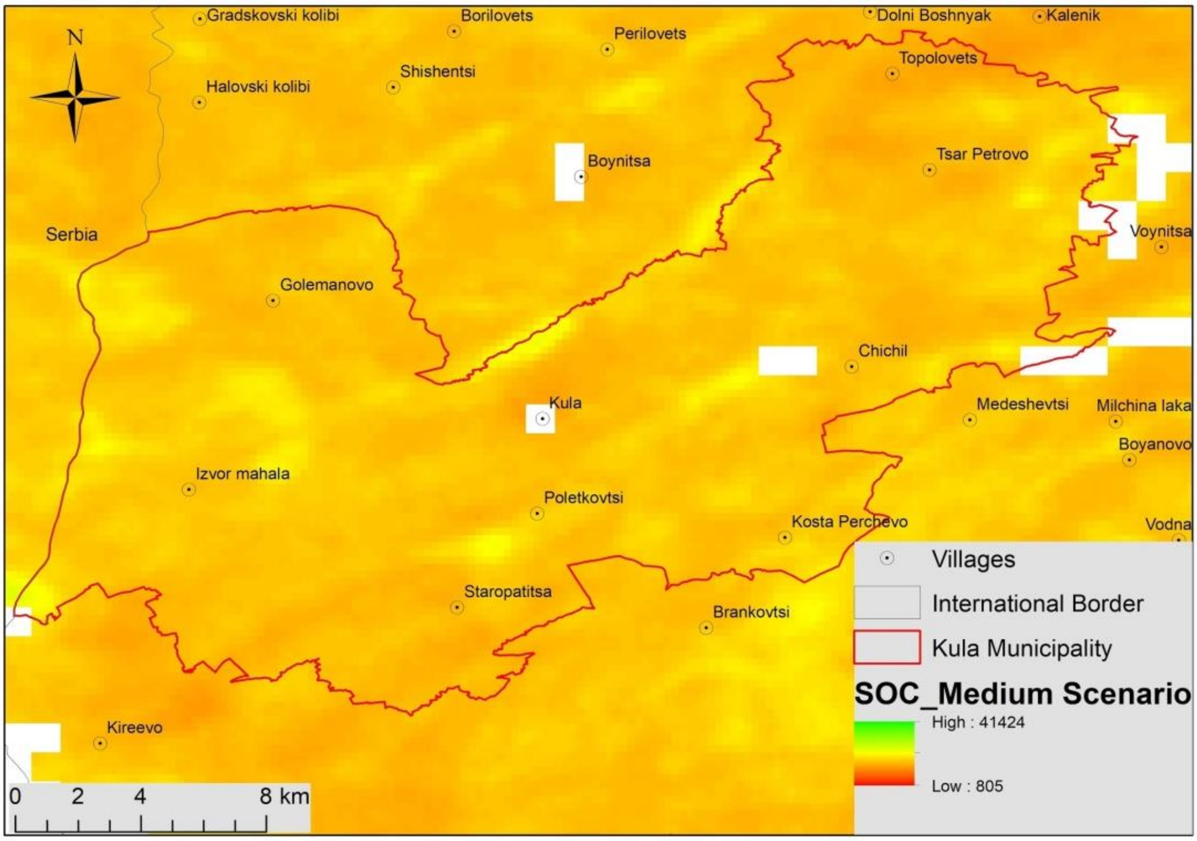

Fig. 6: Soil organic carbon contents in Kula Municipality, as shown in the Medium Scenario. (Following Zomer et al., 2017 a, b)

The medium scenario shows another bunch of data that can be analyzed if we follow the lighter colours on the map. Larger carbon stocks are ranging between 1 100 000 tons/ha and 1 200 000 tons/ha around the villages of Golemanovo and Izvor mahala and over 1 260 000 tons/ha to the west of the settlement of Chichil. The highest values are over 1 350 000 tons/ha to the north of Kula and between the villages of Poletkovtsi and Staropatitsa. Once again an average increase of around 1 000 000 tons/ha may be accomplished if agricultural practices that promote carbon storage are introduced. These results show a typical concordance with some already established rules and they should be referred to by policy makers.

Frank et al. (2018) conducted an investigation that was also aimed at agricultural territories. They calculated that mitigation potentials up to 2050 may be ranging from 10 to 150 $/tCO2eq, which if it multiplied by the expected potential carbon sequestration in the medium scenario, shows a significant amount of money that may be achieved. Another study that is based on cropland areas is the one of Iizumi & Wagai (2019). They are focusing on drought endurance of lands, promoted by the presence of soil organic carbon. Despite Kula Municipality does not fall within the territories that are most susceptible to droughts, like areas in Australia, for example, the expected enhancement of the carbon pool in the medium scenario may play an important part in this matter, as well. Alcántara et al. (2017) investigated a number of sampling territories, including agricultural land in Northern Europe. Their main motivation comes from the expected important role that soil organic carbon sequestration will play in climate change mitigation. They focus mainly on subsoil, unlike our study, in which topsoil is the major player. Fortunately, this does not modify the significance of the soil organic carbon in the first 30 cm of the soil, quite the opposite. Carbon storages in topsoil are as equally important in climate change mitigation and with the expected enlargement of the carbon pool in Kula Municipality; it is going to play an essential role in this process in Northwestern Bulgaria.

A certain measure that may be taken for the improvement of the results of the current research can be the collection of more samples during the terrain observations. The authors agree that the acquisition of data would be a good starting point for even more in-depth analysis. Another road for the perfection of the study is the application of more morphological observations that may add even more value of the successful results.

Conclusion

The current investigation's main focus was on the study of anthropogenic soils in Kula Municipality, Northwestern Bulgaria. As a result of our comparative study on soils modified by technical processes in NW Bulgaria, it was shown that soil horizons and layers had a certain amount of organic carbon in the form of both humic and fulvic acids. Organic carbon in the studied sites represents less than 1% of the soil sample, although it is about 30 to 45% of the total carbon. According to a global model carbon stocks in the study area exceed 1 000 000 tons/ha. The mapped and sampled cultural layer near Kosta Perchevo Village with residues of iron smelting allows us to estimate the organic carbon affected by man-made activity. Therefore, soil is classified as Spolic Tehnosols (form latin spoliare - exploitation) with profile ≥ 20 cm, containing ≥ 20% (by volume) artifacts, of which ≥ 35% are residues from mining, mine dumps sediments after excavation, slag and ash. Cultural layer with artifacts contains indications for soil formation, modified by human technogenic activity. Other two cultural layers are used to date the deposition of artifacts and nowadays represents Urbic Technosols (form latin urbs - city, town) with profile depth ≥ 20 cm, containing ≥ 20% (by volume) artifacts, of which ≥ 35% are building materials and remnants of settlements or sanctuaries in archaeological sites.

The present study, where values of humus, total carbon and soil organic carbon were obtained for spolic (SP) and urbic (UR) horizons, can be considered as the first step in the assessment of Bulgarian Technosols and role in the global carbon cycle. It has displayed some positive outcomes that may be applied in similar studies in the neighboring municipalities and also in other parts of the country.

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Author contribution

Conceptualization and original draft preparation, A.S., P.B. and B.G.; methodology, A.S.; formal analysis, P.B. and B.G.; investigation, A.S.; writing—review and editing, P.B. and B.G. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest:

The authors declare no conflict of interest.

References

Alcántara, V., Don, A., Vesterdal, L., Well, R., & Nieder, R. (2017). Stability of buried carbon in deep-ploughed forest and cropland soils - implications for carbon stocks. *Sci Rep* 7, 5511 https://doi:10.1038/s41598-017-05501-y

Antonov, D., Kotsev, T., Benderev, A., van Meir, N., Gerginov, P., Stoyanova, V., & Tcherkezova, E. (2019). Estimating the moisture regime in variably saturated arsenic contaminated alluvial sediments by using hydrus-1d with daily meteorological data. *European Journal of Geography*. 10 (2) 42–55. http://www.eurogeographyjournal.eu/articles/3_Antonov_etal_EJG_final_07_08_2019.pdf (Accessed 2020-8-8)

Baltakov, G. & Kenderova, R. (2003). Quaternary paleogeography. Varna, Maleo-63. (In Bulgarian).

Bhardwaj, A., Rajwar, D., Mandal, U., Ahamad, S., Kaphaliya, B., Minhas, P., Prabhakar, M., Banyal, R., Singh, R., Chaudhari, S., & Sharma, P. (2019). Impact of carbon inputs on soil carbon fractionation, sequestration and biological responses under major nutrient management practices for rice-wheat cropping systems. *Sci Rep* 9, 9114 https://doi:10.1038/s41598-019-45534-z

Filipov, L., Decheva, A., Koyumdzhieva, E., Popov, N., & Tsankov, T. (1992). Geological Map of Bulgaria on scale 1:50000, Map sheet Vidin. Sofia, Committee of Geology and Mineral Resources (in Bulgarian).

Frank, S., Beach, R., Havlík, P., Valin, H., Herrero, M., Monsier, A., Hasegawa, T., Creason, J., Ragnauth, S., & Obersteiner, M. (2018). Structural change as a key component for agricultural non-CO2 mitigation efforts. *Nat Commun* 9, 1060. https://doi:10.1038/s41467-018-03489-1

Ghimire, R., Basnet, R., Bista, P., & Ranabhat, B. (2009). Soil Quality Cards for Participatory Soil Quality Assessment in Organic and Smallholder Agriculture. *Forum geografic*, VIII (8), 72-76.

Grozdanova, G., & Koleva, R. (2020). Initial archaeological excavations of Object 5/1004 in Kosta Perchevo Village, Kula Municipality. *Archaeological discoveries and excavations 2019. Book II*, NAIM-BAS, 1271-1274 (in Bulgarian).

Gyurov, G., & Artinova, N. (2015). Soil studies. *Intelekspert*, Plovdiv., 259 p.

Hristova, T., & Hristov, M. (2020). Archaeological research of a necropolis of the final phase of the Late Bronze Age in Choika Area, Kula Municipality. *Archaeological discoveries and excavations 2019. Book II*, NAIM-BAS, 399-402 (in Bulgarian).

Iizumi, T., & Wagai, R. (2019). Leveraging drought risk reduction for sustainable food, soil and climate via soil organic carbon sequestration. *Sci Rep* 9, 19744. https://doi.org/10.1038/s41598-019-55835-y

Kononova, M. (1963). Soil Organic Substance. Its Nature, Properties and Research Methods. ASSU, Moscow, p. 314. (in Russian)

Munsell Soil Color Charts. (1975).

Perez, E., & Garcia, P. (2017). Monitoring soil erosion by raster images, from aerial photographs to drone taken pictures. *European Journal of Geography*. 8 (1) 116-128. http://www.eurogeographyjournal.eu/articles/7.Monitoring%20soil%20erosion%20by%20raster%20images,%20from%20aerial%20photographs%20to%20drone%20taken%20pictures.pdf (Accessed 2021-1-1)

Bulgarian Soil Legislation. (2018). (Updated in the State's Newspaper, vol. 89 as of the 6th of November 2007, with amendments in vol. 80 as of the 9th of October 2009, with amendments in vol. 98 as of the 14th of December 2010, with amendments in vol. 92 as of the 22nd of November 2011, with amendments in vol. 66 as of the 26th of July 2013, with amendments in vol. 98 as of the 28th of November 2014, with amendments in vol. 62 as of the 14th of August 2015, with amendments in vol. 58 as of the 18th of July 2017, with amendments in vol. 98 as of the 27th of November 2018).

Tcherkezova, E., Stoyanova, V., & Kotsev, T. (2019). A concept of an integrated geodatabase for surface water, soil and groundwater pollution with arsenic in the upper part of Ogosta Valley, Northwestern Bulgaria. *European Journal of Geography*. 10 (3) 6–23. http://www.eurogeographyjournal.eu/articles/1_Tcherkezova_et_al.pdf (Accessed 2020-4-4)

Tipping, E., Davies, J., Henrys, P., Kirk, G., Lilly, A., Dragosits, U., Carnell, E., Dore, A., Sutton, M., & Tomlinson, S. (2017). Long-term increases in soil carbon due to ecosystem fertilization by atmospheric nitrogen deposition demonstrated by regional-scale modelling and observations. *Sci Rep* 7, 1890 oi:10.1038/s41598-017-02002-w

Wu, X., Wang, W., Xie, X., Yin, C., Hou, H., Yan, W., & Wang, G. (2018). Net global warming potential and greenhouse gas intensity as affected by different water management strategies in Chinese double rice-cropping systems. *Sci Rep* 8, 779 https://doi:10.1038/s41598-017-19110-2

Zhiyanski, M. (2014). Description of general soil organic carbon pools in forest ecosystems, *Forest Science*, No 1/2, 121-138 (in Bulgarian). https://naukazagorata.files.wordpress.com/2015/07/ng_1-2_2014_13.pdf

Zomer, R., Bossio, D., Sommer, R. et al. (2017a). Global Sequestration Potential of Increased Organic Carbon in Cropland Soils. *Sci Rep* 7, 15554 https://doi:10.1038/s41598-017-15794-8

https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/HYFICT

Zomer, R., Bossio, D., Sommer, R., & Verchot, L. (2017b). Replication Data for: Global Sequestration Potential of Increased Organic Carbon in Cropland Soils, https://doi.org/10.7910/DVN/HYFICT, Harvard Dataverse, V1