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Soil organic carbon potential of Bozhurishte municipality: A case study from western Bulgaria

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soil, agricultural areas, organic carbon

Abstract

The current study focuses on the soil organic carbon contents in topsoil (0-30 cm) in Bozhurishte Municipality. The municipality is a part of Sofia Province and it represents a major section of the "Sofia-Bozhurishte Economic Zone". The aim of the investigation is to reveal how soil organic carbon storages may change in the forthcoming 20 years during a medium and a high scenario. The results of the study display several major zones of a large soil organic carbon pool, located to the northeast and the central parts of the municipality. The section, containing the largest soil organic carbon pool, may experience an increase of 376 400 tons/ha for 20 years in the medium scenario and 499 100 tons/ha in the high scenario. The author concludes that promising results may be used as a basis for an expansion of the study in the neighboring municipalities.



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1. INTRODUCTION

The expansion of agricultural areas, considering the fact that more and more food supplies are craved, is inevitable and we should strive to be more aware of this process. Cropland territories are representing a significant carbon sink that deserves as much attention as possible, due to their capability of storing carbon. They are expected to play a major role in global carbon sequestration and climate change mitigation, especially after the adoption of the Paris Climate Agreement and the target of 2°C. Carbon sequestration in agricultural territories is regarded as an effective climate change mitigation measure that has been widely recognized. Croplands are gaining attention and this is proved by the development of a variety of international initiatives, including the "4p1000 Initiative: Soils for Food Security and Climate", aiming at increasing their annual carbon sequestration.

Not only croplands, but also other land cover classes are sustaining a significant carbon pool and they are also discussed in the paper.

Land degradation represents an ongoing issue and every step towards keeping cropland areas undisturbed will help store its carbon pool within them. If carbon is released to the atmosphere, it will surely add weight to the greenhouse effect.

2. BACKGROUND

2.1 Literature review

The investigation of soil organic carbon is not a new scientific field and a number of world studies prove that. Blair et al. (1995) studied agricultural systems and their soil carbon contents. Lal (2001, 2004) focused on global carbon storages in arable croplands. Freibauer et al. (2004) investigated carbon sequestration in agricultural systems in Europe. Olson (2014) aimed at studying agricultural areas in USA. Hoyle et al. (2016) focused on the investigation of agricultural lands in the southwestern parts of Australia. Wiesmeier et al. (2016) built up projections about soil organic carbon dynamics in Bavaria, Germany. Alcántara et al. (2017) investigated experimental territories, including agricultural lands, in Denmark and Germany. Gosling et al. (2017) studied experimental sites in England, observing changes of soil organic carbon contents after the conversion of cropland into grassland. Zhang et al. (2017) combined data from 2473 counties in China, studying soil organic carbon on croplands. Frank et al. (2018) investigated croplands, as greenhouse gases source. Fortier et al. (2019) conducted field experiments, focusing on fine root biomass in Southeastern Canada, in a land that has been agriculturally used and last, but not least Ghimire et al. (2019) laid experimental plots in Oregon, USA studying long-term management effects on soil organic carbon.

Investigations on soil organic carbon contents are not a new experimental field in Bulgaria, as well. Rodeghiero et al. (2011) studied soil carbon contents in Mediterranean ecosystems, including parts from Bulgaria. Tsolova et al. (2014) investigated Technosols near Gabra Village, Western Bulgaria. Zhiyanski et al. (2016, 2017) aimed at studying soil humus and carbon storage in the Western Rhodopes. Menichetti et al. (2017) and Moscatelli et al. (2017) conducted experiments in the areas of Beklemeto and Parangalitsa Reserve. Djukic et al. (2018) aimed at investigating litter decomposition

from sites, including key areas from Bulgaria. Yaneva et al. (2018) assessed and mapped soils in Central Balkan National Park.

There are several other studies focused on soil investigations that deserve attention and among them are those of Perez & Garcia (2017), Tcherkezova et al. (2019) and Antonov et al. (2019).

2.1.1 Theoretical implications

The case study area of Bozhurishte Municipality is located in the western parts of Bulgaria and is a major section of the larger Sofia Province (Fig. 1). The areal extent of the municipality is around 143 km², taking 17th place of the 22 municipalities in Sofia Province. Bozhurishte Municipality is surrounded by several other administrative territorial units. These neighboring municipalities are as following: Slivnitsa Municipality to the northwest, Kostinbrod Municipality to the northeast, Stolichna Municipality and Sofia City Province to the east and to the south, Pernik Municipality and Pernik Province to the southwest and Breznik Municipality to the west.

As for the natural characteristics of Bozhurishte Municipality, the lithology is rather diverse. The main rocks types among the Neogene terrigenous-coalbearing sediments are conglomerates, breccia-conglomerates, sandstones, siltstones, shales, sands, clays and coal and they can be found at the northern and eastern parts of the municipality. The other areas are taken by the Volcanogenic-sedimentary formation in the West Srednogorie-volcanics that includes volcanics - hornblende andesites, trachyandesites, andesitobasalts in extrusive, explosive and subvolcanic facies and sediments - sandstones, siltstones, marls and limestones from the Campanian age of the Late Crateceous epoch.

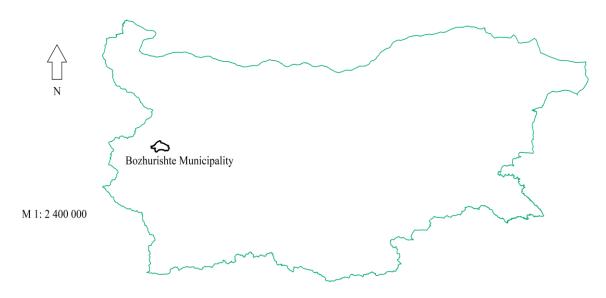


Figure 1. A map of the location of Bozhurishte Municipality

The relief is mainly flat, hilly and the whole investigated area falls within the zone of the low mountainous relief (the zones between 600 m and 1000 m a.s.l). The northeastern section Bozhurishte Municipality is taken by the western parts of Sofia Valley and here the lowest parts of the whole municipality are located, getting as low

as 548 m a.s.l. To the southwest are the mountains of Viskyar and Lyulin. The northern slopes of Lyulin lay between the border areas of Penik Province to the south and the geomorphological landform of the Radui Saddle to the northwest. The highest part of the municipality — Forta Peak, reaching 1024.5 m a.s.l., is situated in a southeastern direction of the village of Mala Rakovitsa. The southernmost parts of Viskyar Mountain are located to the northwest of Radui Saddle.

Bozhurishte Municipality falls within the catchment area of Iskar River, which is the longest river that is springing and flowing in the territory of Bulgaria. If we have to be more specific, the municipality is located within the area of the left tributary of Iskar River – Blato River. Among the other main water arteries are those of the rivers of Herakovska, Kostinbrodska, Tsrna Bara, Malchuganitsa, Gurmazovska and Babin Dol. The municipality is a part of "Sofia-Bozhurishte Economic Zone" and is attracting more and more investments, which is good from economic point of view. Yet, this is resulting in assimilation of territory, including land that is suitable for agriculture and this is one of the main reasons for the choice of that particular municipality, as a case study.

The soil characteristics of the municipality are of a major importance due to the focus of the research in soil organic carbon contents. Bozhurishte Municipality falls within an area with leached and clayey chernozem-smolnitzas (eutric, Vertisols), situated to the eastern section of the investigated territory, where only a small fraction of alluvial and alluvial-meadow, sandy and loamy (eutric, Fluvisols) soils can also be observed. The central and southern parts are taken be by leached cinnamonic forest, heavy loamy to slightly clayey soils (chromic, Luvisols), while the western sections are built up of eroded leached chernozem-smolnitzas (eutric, Vertisols) and a restricted section of leached cinnamonic forest soils (chromic, Luvisols) (Fig. 2).

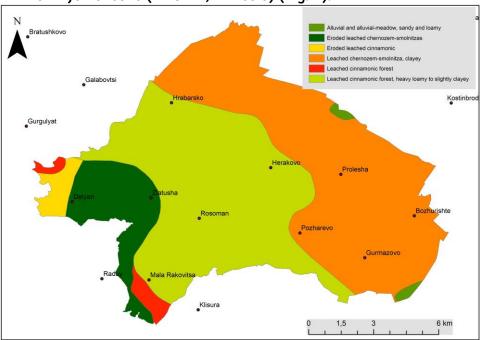


Figure 2. Soil Map of Bozhurishte Municipality.

The importance of the soil organic carbon study in the area of Bozhurishte Municipality is essential from another perspective, as well. No matter that only a tiny fraction of the area falls within Bozhurishte Municipality — more specifically, it is located to the southeastern section, the investigated territory is a part of the Meshtitsa

Site BG0002101 of the NATURA 2000 network in Bulgaria. Therefore, it is a Special Protected Area, included in the Directive 2009/147/EC – a cornerstone and the oldest legislation document, concerning the environment in the territory of the European Union in its former name Directive 79/409/EEC.

The main source of information of the current study is the work of Zomer et al. (2017 a, b) who published a paper, regarding global carbon sequestration potential of croplands and presented replication data. The authors provide a series of datasets aimed at analyzing the potential of the top 30 cm of croplands to sequester carbon. The topsoil layer of 30 cm contains the weighted average of the soil layers of 0-5 cm, 5-15 cm and 15-30 cm. Their 250 m resolution provides values of soil organic carbon per pixel. Data is available for download at the Harvard Dataverse free data repository: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/HYFICT.

The dataset of soil organic carbon on croplands is in 250 m resolution and it was downloaded in order to get a better impression of the soil organic carbon pool of the municipality, which will serve as a basis for the next phase of the investigation. The dataset also shows the soil organic carbon pool in other territories, apart from the agricultural areas. In order to receive information about total tons of carbon per hectare, the value has to be multiplied by 100. After that an analysis was conducted in order to acquire information about the areas of the municipality with highest soil organic carbon contents. The other two datasets that were applied are containing data about the potential soil organic carbon after 20 years in a medium and a high scenario, respectively. They are also providing 250 m pixel resolution in tons per hectare and the value of the pixel also has to be multiplied by 100.

In order to discover some of the reasons behind the presence or the lack of significant proportions of soil organic carbon, another source of information was needed. This is why the study adopted the use of the presented data in the latest CORINE Land Cover datasets (https://land.copernicus.eu/pan-european/corine-land-cover; European Union, Copernicus Land Monitoring Service 2019, European Environment Agency (EEA)) (Table 1).

Table 1. CLC 2018 for Bozhurishte Municipality

Level 3 CLClasses in Bozhurishte Municipality
112 Discontinuous urban fabric
121 Industrial or commercial units
124 Airports
133 Construction sites
142 Sport and leisure facilities
211 Non-irrigated arable land
231 Pastures
242 Complex cultivation patterns
243 Land principally occupied by agriculture, with significant areas of natural vegetation
311 Broad-leaved forests
312 Coniferous forest
313 Mixed forests
321 Natural grasslands
324 Transitional woodland-shrub

Source: Copernicus, Europes's Eyes on Earth - https://land.copernicus.eu/pan-european/corine-landcover

3. ANALYSIS

Soil organic carbon contents in the top layer of 0-30 cm in Bozhurishte Municipality are displayed in Figure 3. A quick view allows discovering several main areas that are containing the largest soil organic carbon pool.

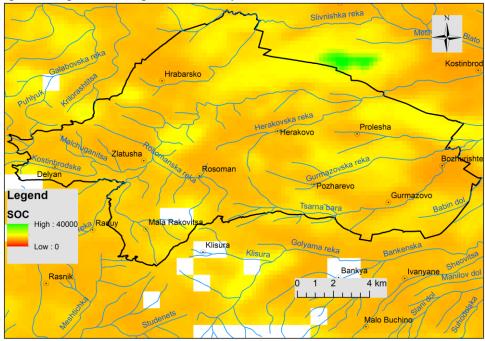


Figure 3. Soil organic carbon contents in Bozhurishte Municipality in topsoil (0-30 cm)

The first area represents a band, located along the northeastern boundary of the municipality and it is following it, stretching from the northwest to the southeast. Values of soil organic carbon in this area reach up to 1 730 000 tons/ha, just to the northeast where the green hotspot is located, containing the largest carbon pool in this map. This is logical enough due to the presence of the fertile soils of Sofia Valley between the rivers of Herakovska and Kostinbrodska, that are containing large quantities of soil organic carbon. This is a non-irrigated arable land (Fig. 4) and the high presence of soil organic carbon there is some good news for farmers.

The second place is taken by the high values that can be found in the triangle that the villages of Zlatusha, Rosoman and Hrabarsko are forming to the west and that area contains sums up to 1 330 000 tons/ha. These three villages are located at the foothills of the mountains of Lyulin and Viskyar. These areas are covered by broad-leaved forests, mixed forests and a small proportion of the also represents a transitional woodland-shrub area, among cropland areas. The particular territory is dominated by the communities of the broad-leaved tree species of Acer campestre L., Quercus cerris L., Quercus frainetto Ten., Quercus dalechampii Ten., Quercus pubescens Willd., Carpinus betulus L., Acer pseudoplatanus L., Fraxinus excelsior, Tilia tomentosa Moench, Tilia cordata Mill. Tilia platyphyllos Scop., and Betula pendula Roth. Mixed forests include several coniferous species, such as Pinus nigra J. F. Arnold, Pinus sylvestris L., Pinus strobus L., Picea abies (L.) H. Karst and Pseudotsuga menziessi (Mirb.) Franco, while the transitional woodland-shrub area consists of the communities of Crataegus monogyna Jacq., Prunus spinosa L., Cornus mas L., Carpinus orientalis Mill and Rosa canina L. A possible explanation of the high values of soil organic carbon in this second section may

within the fact that the broad-leaved forests, mixed forests and the transitional woodland-shrub area are mature enough to be well integrated within the ecosystem and that they participate actively in the flow of matter and energy, leading to the stocking of enough quantity of soil organic carbon.

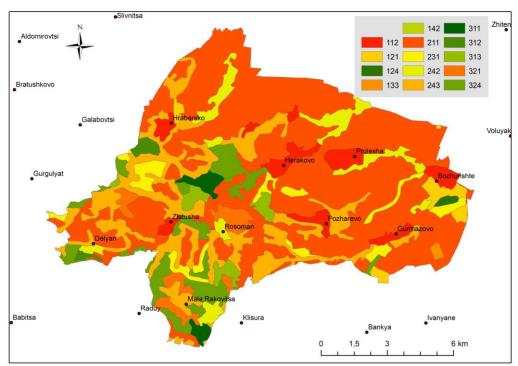


Figure 4. CLC 2018 in Bozhurishte Municipality

The third sector is located within the triangle of Prolesha, Pozharevo and Gurmazovo between the rivers of Tsrna Bara and Herakovska to the east where values reach 1 160 000 tons/ha. This area is occupied by non-irrigated arable land and the high levels of soil organic carbon here may be explained by the application of appropriate agricultural techniques, decreasing the loss of valuable carbon stocks, during the land processing.

Another area, where soil organic carbon contents are reaching higher levels in topsoil between 0 cm and 30 cm, is situated to northeast of the village of Prolesha. Here soil organic carbon stocks reach up to 1 350 000 tons/ha in a non-irrigated arable land. This may be considered as another fine example of the introduction of appropriate skills for agriculture by the local farmers. There is another section with high contents to the southeast of the village of Gurmazovo where values are of 1 030 000 tons/ha – again within non-irrigated arable land. However, a broad section here recently experienced a conversion of status and changed to a construction site, leading to a decrease of soil organic carbon contents with more than 100 000 tons/ha to 920 000 tons/ha. This is negative example how land management leads to a disturbance of the carbon cycle, ending in a loss in the carbon pool.

To the south of the village of Pozharevo soil organic carbon contents are at 1 110 000 tons/ha — another example of exceeding of the 1 million tons/ha boundary. The discussed area falls within the section of the non-irrigated arable land.

Another triangle encompasses an area where soil organic carbon stocks reach 1 080 000 tons/ha. This particular territory is landlocked between the villages of Pozharevo, Rosoman and Herakovo and it is covered by the specific vegetation, included in the mixed forests, typical for Bozhurishte Municipality.

The area that is situated between the villages of Rosoman and Mala Rakovitsa in the southern parts of the investigated municipality contains territories with soil organic carbon contents of 1 190 000 tons/ha. Here, we can observe mixed forests and natural grasslands, as well, that are in a good condition, dominated by the communities of the species of Festuca valesiaca Schleich. ex Gaudin, F. stojanovii (Acht.) Kožuharov, Poa pratensis s.l., F. dalmatica (Hack.) K. Richt., F. rupicola Heuff., Dichanthium ischaemum (L.) Roberty, Molinia caerulea (L.) Moench., Chrysopogon gryllus (L.) Trin., Briza media L., Dactylis glomerata L. and different Thymus spp.

The last major area, where soil organic carbon contents reach high levels, is located to the southwest of the village of Hrabarsko. Here stocks are as high as 1 320 000 tons/ha and they are found under coniferous forests, dominated by different Pine tree taxa. Although coniferous forests are not typical for these low altitudes, this territory represents a good example of a land use technique, adopted for controlling of the erosional processes, that has led to the building up of stable soil organic carbon stocks in topsoil.

Some of the lowest values of soil organic carbon are situated mainly near the villages of Bozhurishte and Prolesha to the east with 610 000 tons/ha and 690 000 tons/ha, respectively. These particular territories are occupied by the classes of the discontinuous urban fabric or they represent industrial or commercial units. That is why it is merely a surprise that the sealing of the soil with concrete is leading to a disruption of it is physical and chemical characteristics, leading to the loss of soil organic carbon.

There is another territory to the northwest around the village of Hrabarsko where soil organic carbon levels are as low as 670 000 tons/ha. The same explanation is valid here as well, where anthropogenic interference in natural processes may be regarded as the main reason for the low stocks of soil organic carbon, due to the disruption of soil quality and quantity.

Another example of low soil organic carbon values may be discovered near the village of Gurmazovo where carbon reaches 610 000 tons/ha. Here, again discontinuous urban fabric territories and industrial and commercial units are represented, proving that when such anthropogenic interventions are at hand, soil organic carbon stocks may be significantly depleted, as the values are almost three times lower than those in the areas where soil organic carbon pool is the richest.

Soil organic carbon levels around the village of Herakovo reach 710 000 tons/ha and those near Pozharevo are in the range of 770 000 tons/ha. Once again the discontinuous urban fabric lands are holding less soil organic carbon contents than those where natural vegetation or well managed arable lands are presented.

Complex cultivation patterns are observed near the village of Rosoman where another area of low soil organic carbon stocks can be found, consisting of 690 000 tons/ha. Here the situation slightly differs, compared to those previously discussed, but the explanation may be, as easy as in the last cases. When agricultural techniques are not led by professionals who know how to keep soil carbon levels in their lands at high levels, agricultural workers may adopt techniques that are leading to carbon loss and this is the case here.

Carbon levels near the village of Mala Rakovitsa 810 000 tons/ha are higher and this may be explained by the fact that here we come across a land principally occupied by agriculture, with significant areas of natural vegetation. Agriculture has led to a decline of carbon levels, but the abandonment of agricultural land due to the processes of depopulation, typical for most parts of rural Bulgaria, and the conversion of this land into pastures and meadows leads to a slight increase in organic carbon contents in topsoil. A similar situation is observed near the village of Delyan where soil organic carbon levels reach 820 000 tons/ha. Here land cover represents a combination between land principally occupied by agriculture, with significant areas of natural vegetation and complex cultivation patterns.

The last case that is going to be discussed is the one of the Zlatusha village where soil organic carbon levels in topsoil are as low as 720 000 tons/ha and the discontinuous urban fabric land cover is the main reason behind this.

A careful observation of the map reveals several white spots to the reader. They are not carrying any information, as they lack such, so they are omitted of the analysis of soil organic carbon contents. Following the correct use and citation of the presented map, they, however, cannot be left aside and this is the reason why the major cartographic rule, saying that there should not be any blank spots within the map, is not obeyed.

The end of discussion of the reasons why there are sections with high soil organic carbon contents in the topsoil of 0-30 cm deserves some valid conclusions that will be presented in the following lines. Bozhurishte Municipality contains several areas of highs and lows. The area with the largest carbon pool represent non-irrigated arable land, proving that when appropriate measures are adopted by land owners that are following prescriptions for maintaining high levels of carbon stocks, agriculture does not lead to the disruption of carbon sequestration. In addition there sectors where soil organic carbon stocks are high, because they are occupied by natural forests (broadleaved, mixed and coniferous), shrubs and grasslands that are in a good condition, allowing for the capturing and preservation of sufficient levels of soil organic carbon. On the opposite site – when agricultural techniques are restricted to those that are not carbon-friendly, there will be less carbon in topsoil. Another reason behind soil organic carbon decrease is the presence of discontinuous urban fabric territories and industrial and commercial units. The expected increase of converted land for the needs of "Sofia-Bozhurishte Economic Zone" would not present any benefits to the soil organic carbon pool, it is quite the opposite. They will have a detrimental effect on it.

As it was previously mentioned, Zomer et al. (2017a) developed two scenarios: a medium scenario and a high scenario of the potential of soils to sequester carbon in the next 20 years. These two scenarios for Bozhurishte Municiality are displayed at fig. 5 and fig. 6, respectively. Both are representing future projections of what might be the picture after two decades, regarding soil organic carbon.

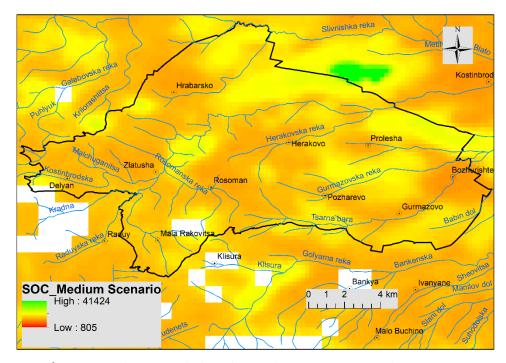


Figure 5. Medium scenario for soil organic carbon contents after 20 years.

Some of the same areas that were discussed in the previous section will be analyzed here in order to get a better impression about the soil organic carbon potential on cropland areas and other land cover areas, as well. Yet, to turn the potential into reality, improved farming practices should be adopted. In addition, soil conservation, water holding capacity and improved fertility have to be enhanced.

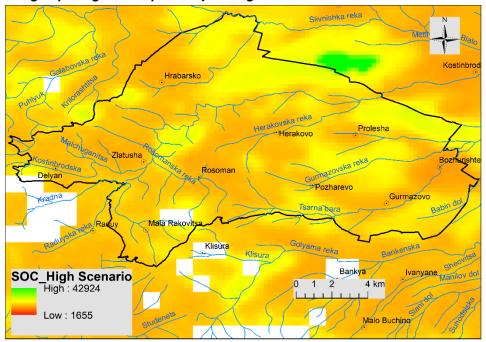


Figure 6. High scenario for soil organic carbon contents after 20 years.

The band, located in the northwestern-southeastern direction contains sums up to 2 106 400 tons/ha, which represents an increase of 376 400 tons/ha for 20 years in the medium scenario and 2 229 100 tons/ha in the high scenario — a raise of 499 100

tons/ha. The section between the villages of Zlatusha, Rosoman and Hrabarsko may experience a change 157 400 tons/ha in its soil organic carbon values, reaching 1 487 400 tons/ha, while the area between the villages of Prolesha, Pozharevo and Gurmazovo may reach sums up to 1 310 900 tons/ha, displaying an increase of 150 900 tons/ha in the medium scenario. If the high scenario is taken into account, the first section can even possibly contain 1 559 400 tons/ha, while the second may contain 1 438 400 tons/ha in twenty years.

On the opposite site are the lowest values of soil organic carbon, but even they may experience an enhancement if appropriate land management practices are adopted. The areas around the villages of Bozhurishte, Prolesha and Hrabarsko that were previously discussed, may increase their carbon pools in twenty years and reach 761 900 tons/ha 869 300 tons/ha, 796 100 tons/ha, respectively during the medium scenario and 890 500 tons/ha, 995 100 tons/ha, 935 900 tons/ha, respectively in the high scenario.

The soil organic carbon medium scenario and the soil organic carbon high scenario are two hypotheses by their very nature. If the first or the second one comes to being a series of measurements have to be implemented if arable land is taken into account. For those territories where agricultural practices were found to be appropriate for sustaining a large soil organic carbon pool (between the rivers of Herakovska and Kostinbrodska in Sofia Valley, along the rivers, in the triangle of the villages of Prolesha, Pozharevo and Gurmazovo, to northeast of the village of Prolesha, to the southeast of the village of Gurmazovo and to the south of the village of Pozharevo), a good advice is to keep on applying the same techniques for agriculture practices. However, other sections would need instant measures if the goal is to sustain sufficient soil organic carbon stocks. Policy makers, as well, should aim at adopting polies, focused on the increase of carbon storages. As for the territories with natural forests, shrubs and grassland, they probably will continue to sustain a good deal of topsoil organic carbon due to their capability to participate in the flows of energy and matter, leading to the creation of more soil organic carbon. Moreover, if policy makers and land owners focus on the preservation of such healthy ecosystems, they will surely benefit from them in the long term, not only by the creation of more soil organic carbon, but also from the countless ecosystem goods and services that stable ecosystems provide.

4. CONCLUSIONS

The current investigation aimed at displaying and analyzing the current trends of soil organic carbon contents in Bozhurishte Municipality and the possibility of their increase in 20 years during a medium and a high scenario. The CORINE Land Cover was also applied in order to make a better analysis. It was proved that large proportions of arable land and healthy ecosystems are sustaining a large carbon pool. Moreover, if appropriate land management practices are applied, soil organic carbon stocks may be increased by 376 400 tons/ha for 20 years in the medium scenario and even 499 100 tons/ha in the high scenario in the richest carbon zone. However, sealed territories are not sustaining large quantities of soil organic carbon. It is difficult to make prognosis about the extent of future financial investments in the territory, which will lead to the loss of more agricultural land and the current paper tried to display the large carbon sequestration capacity of Bozhurishte Municipality nowadays. It is clear that any

financial injection is good for the economy of this part of the country, but the loss of land will have detrimental effect on its ability to sequester carbon and the discussed carbon increases will not only provide local farmers with a higher quality harvest, but may also help mitigate climate change even in from a local point of view.

The hypothetical character of the investigation leaves room for mistakes, but this should not take away from its positive aspects. The author concludes that the present work showed good results that can be used as a basis for similar studies in the neighboring municipalities and it can also be regarded as an example of a case study for the investigation of topsoil organic carbon pool.

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