sciendo

CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

E-ISSN 2450-8594

CEER 2021; 31 (1): 0182-0191
DOI: 10.2478/ceer-2021-0013
Original Research Article

THE LINK BETWEEN HABITATS AND CARBON ACCUMULATION FROM NATURAL FOREST REGROWTH IN BORINO MUNICIPALITY (SOUTHERN BULGARIA)

Borislav GRIGOROV[1]
Faculty of Geology and Geography, University of Sofia "St. Kliment Ohridski", 15 Tzar Osvoboditel Blvd., 1504 Sofia, Bulgaria

A b s t r a c t

Carbon accumulation in forests is an important step towards achieving better climate mitigation levels. The current research aims at uncovering the link between the NATURA 2000 habitats in Borino Municipality, Southern Bulgaria and the expected carbon sequestration from natural forest regrowth for the period 2020-2050. The case study area currently is of a predominantly mountainous character with a number of forests – a prerequisite for enlargement of the carbon pools. Nevertheless, there are also grassland habitats, which participate in this process as well. The results of the research show that the southern parts of the municipality possess a larger potential for carbon accumulation with levels, reaching 1.10 and 1.28Mg C ha^{-1} yr^{-1}. The promising outcomes may be used as an example of an investigation of climate mitigation and may serve as a basis for broadening the geographical range in other municipalities in the region.

Keywords: NATURA 2000, carbon sequestration, forests

[1] Borislav Grigorov: Faculty of Geology and Geography, University of Sofia "St. Kliment Ohridski", 15 Tzar Osvoboditel Blvd., 1504 Sofia, Bulgaria, borislav.g.grigorov@gmail.com, +359 02 9308361

1. INTRODUCTION

Researchers are racing to experiment with any possible measures in order to reach solid ground in the battle with climate change. Carbon accumulation, leading to the enlargement of the carbon pool, plays an important role in mitigating of climate change. This was the main reason behind the initialization of the current study. Different attempts have been made, aiming at acquiring more data about the interactions between different habitat types and the accumulation of carbon within their ecosystems. Habitats are harboring vast quantities of aboveground and belowground biomass, which are playing a vital role for carbon sequestration, especially in the vicinity of forests.

The current study focuses on the investigation of the link between habitats that are part of the NATURA 2000 network and the carbon accumulation potential of their particular areas, with the eyes on natural forest regrowth. A number of articles have been based on modeling and the construction of prognoses with a different time span, regarding the expansion of the carbon pool, as far as forests are concerned. Several studies should not be left aside without at least mentioning them, as they display an enormous amount of data, regarding the potential of forests, as major carbon accumulation agents, and their indispensable participation in climate change mitigation [1,11]. Scientific knowledge is added by the other research, as well [16,18]. Data about carbon density is presented in two papers with Chaturvedi as a leading author [3,4]. A special place in the present study have the investigations by Cook-Patton et al. [6,7], regarding carbon accumulation from natural forest regrowth. The literature review could not be complete without the studies of Burciaga [2], Javadinejad et al. [13] and Fenu & Malloci [10]. Cosic-Flajsig [8] also contribute with some data.

As an addition to the abovementioned researchers, scientists in Bulgaria surely deserve their distinctive place in the academic field of this type of ecosystem research. When it comes to habitat and phytocoenological studies in Bulgaria, a well-deserved place among them are the investigations of several authors [e.g., 19,20]. And these studies [21,22] add more data. There are other important studies that grab the attention for their role in Bulgaria, regarding mountain regions, their forest cover and carbon sequestration [e.g., 9,15]. The following research [23,24] also presents a more in-depth insight of the problem.

As a member country of the European Union (EU), Bulgaria has established and has been developing its NATURA 2000 network since 2002, although it became a part of the EU five years later - in 2007. Nowadays, there are 120 sites in the Birds Directive (Directive 2009/147/EC), covering over 23% of the country and 234 sites, which are included in the Habitats Directive (Directive 92/43/EEC) that are representing more than 30% of the territory of Bulgaria [12,17]. Some of these habitats, included in the Habitats Directive, are participating in the process of

future carbon accumulation in the present study, which aims at showing this connection in particular for a municipality, located in the southern parts of the country.
The article comprises of several structural units: an introduction, a methodological chapter, results, a chapter with a conclusion and evaluation and a reference list in the end of it.
The necessity of the research lies within its main focus, aimed habitat diversity and carbon accumulation. Habitats are key subject for policy making, concerning ecosystems. Their essential role is amplified by their ability to store carbon in huge amounts, making them an important player in climate change mitigation.

2. MATERIALS AND METHODS

The present research is based on available information sources that allow for making analysis. Data about the NATURA 2000 site BG0001030, Rodopi-Zapadni/Western Rhodopes, representing the only site, falling within the area of Borino Municipality, was acquired through the habitat mapping of Bulgaria, provided by the Ministry of Environment and Water [18]. The interpretation and analysis of the habitats was helped by the use of the Interpretation Manual of European Union Habitats [5] and the manual for Bulgarian habitats [14].
Carbon accumulation potential in the study was regarded only within the aboveground forest cover that was formed for the 30-year period between 2020 and 2050, considering natural forest regrowth, excluding any influence of anthropogenic disturbance [6,7]. A model of the possible carbon sequestration is made, regardless of the current land cover in the area. The measurement unit is Mg C ha^{-1} yr^{-1}. The resolution of the map that is presented is 1x1 km.
The case study area of Borino Municipality was chosen, as it consists of a variety of forest habitats that are of a central importance for the investigation. Borino Municipality is located in the southern parts of Bulgaria and it represents one of the smallest of the 10 municipalities in Smolyan Province. To the west it borders with Dospat Municipality, to the north is located Batak Municipality, to the east is Devin Municipality, and to the south is the Hellenic Republic, which is more popular with the name Greece (Fig. 1). The total area of the municipality is around 173 km^2.

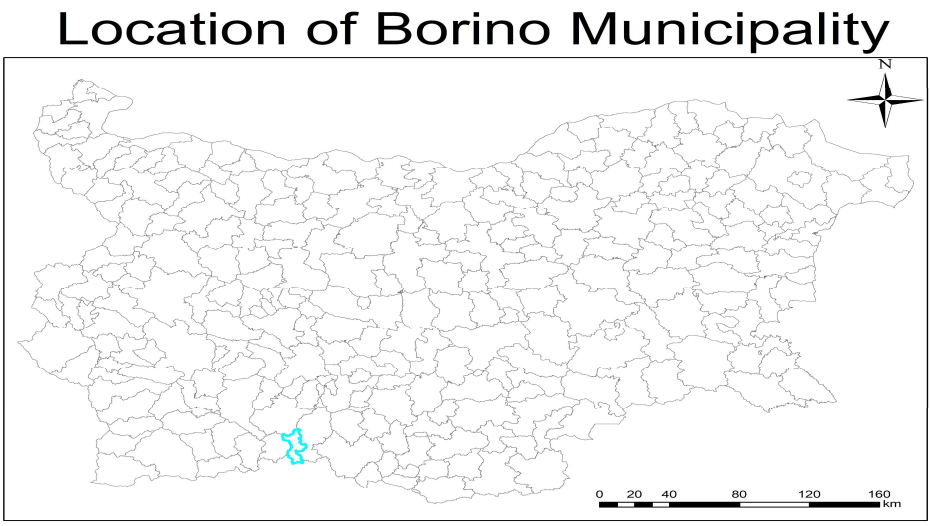

Fig. 1. Location of Borino Municipality in Southern Bulgaria

The lithology of the municipality includes magmatic and metamorphic rocks (granites, gabbro, syenomonzonites, granodiorites, quartzmonzonites, monzonites, marbles, dolomitic marbles, schists and ignimbrites). The relief is mountainous, as the municipality falls within some of the main geomorphological features of the Western Rhodopes Mountain and more specifically – Devinska Planina Mountain to the north and Veliishko-Videnishki Ridge to the south. The main river artery is Vucha River with its left tributary – Buynovska River. Main tributary of it is Chikatdere River, which again flow from the left side. Another river that is large enough is Devinska River, which represents a northern boundary of Borino Municipality. The main soil types of the study region are brown forest soils (*Cambisols*) and brown forest soils with rendzinas.

3. RESULTS

The NATURA 2000 network covers 105.24 km^2 or 60.8% of the whole territory in total. Borino Municipality possesses a wide variety of habitat types (Table 1 and Fig. 2 (left)). It becomes obvious that forest habitats (11 types in total) are more frequently occurring. One of the main reasons for choosing this case study area is their prevalence when compared to non-forest habitats (10 types in total). The forest habitats which were represented in Borino Municipality were carrying the following codes: 9130, 9150, 9170, 9180, 91E0, 91AA, 91BA, 91CA, 9410, 9530 and 9560, while the non-forest ones were: 5130, 6210, 6230, 62A0, 62D0, 6410, 6430, 6520, 7140, 8210. Both, non-forest and forest habitat types are presented in Table 1.

Table 1. Habitat types in Borino Municipality and their areal extent

Non-forest habitat type	**Area (km^2)**
5130 *Juniperus communis* formations on limestone	0.28
6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)	0.35
6230*Species rich *Nardus* grasslands on silicates	5.75
62A0 Eastern sub-mediteranean dry grasslands	0.08
62D0 Oro-Moesian acidophilous grasslands	1.26
6410 *Molinia* meadows on calcareous, peaty or clayey-siltladen soils (*Molinion caeruleae*)	0.67
6430 Hydrophilous tall herb fringe communities of plains and the montane to alpine levels	0.39
6520 Mountain hay meadows	3.72
7140 Transition mires and quaking bogs	0.016
8210 Calcareous rocky slopes with chasmophytic vegetation	0.79
Forest habitat type	
9130 ***Asperulo-Fagetum* beech forests**	1.75
9150 Medio-European limestone beech forests of the *Cephalanthero-Fagion*	1.02
9170 ***Galio-Carpinetum* oak-hornbeam forests**	0.31
9180 * *Tilio-Acerion* forests of slopes, screens and ravines (**a priority habitat type**)	0.023
91E0*Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*)(a priority habitat type)	0.0073
91AA*Eastern white oak woods (**a priority habitat type**)	0.0024
91BA Moesian silver fir forests	3.54
91CA Rhodopide and Balkan Range Scots pine forests	50.43
9410 Acidophilous Picea forests of the montane to alpine levels (*Vaccinio-Piceetea*)	34.48
9530*(Sub-) Mediterranean pine forests with endemic black pines (**a priority habitat type**)	0.35
9560*Endemic forests with *Juniperus* spp (**a priority habitat type**)	0.026

Despite the fact that the habitat types are divided almost equally (11:10), the area that forest habitats were taking was much wider. Two of them: 91CA Rhodopide and Balkan Range Scots pine forests (the most common habitat type in Borino Municipality) and 9410 Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceetea*) are taking 49% of the whole area. They are well-dispersed throughout the whole investigated territory. This is not surprising at all, due to the fact that the Western Rhodopes are particularly famous for their richness of coniferous species (*Pinus sylvestris* L., *Picea abies* (L.) H. Karst, *Abies alba* Mill.).

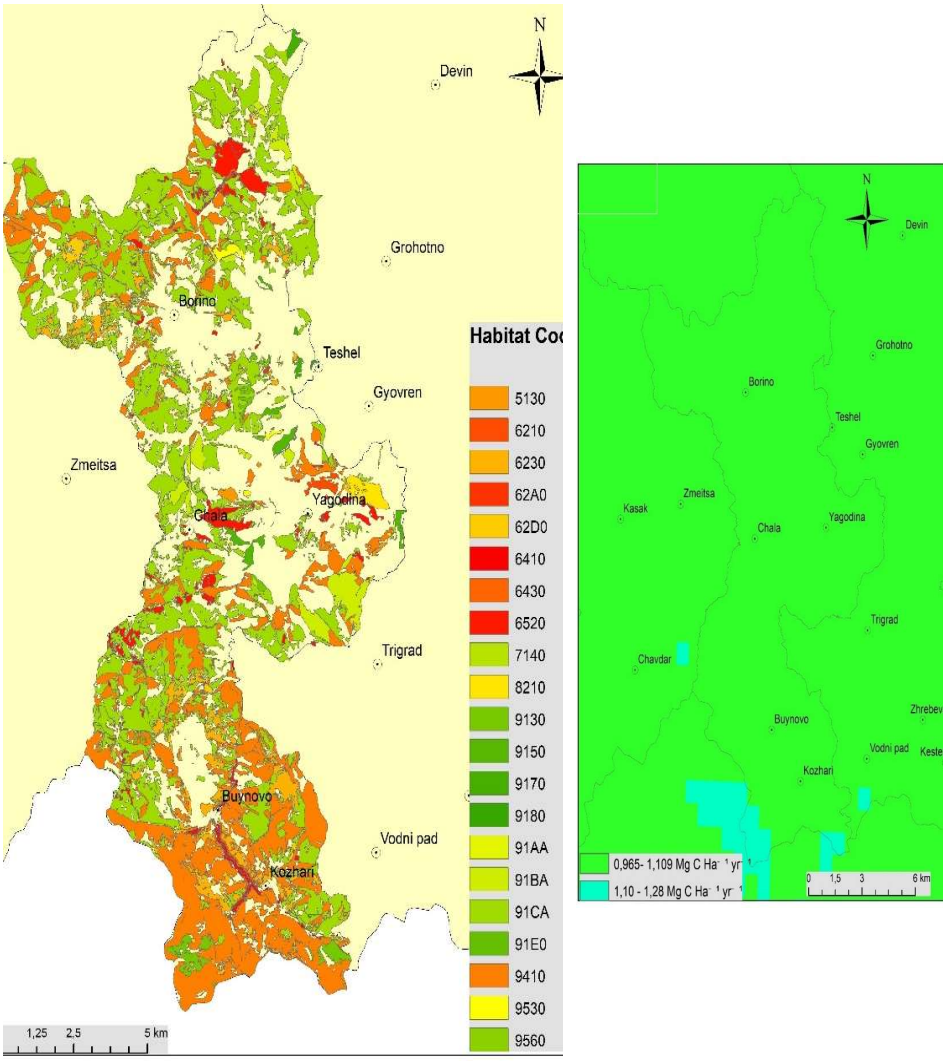

Fig. 2. Habitat map (left) and a map of the potential carbon accumulation (right)

Several of the habitat types are falling within the category of the priority habitat types - they are with a higher degree of protection interest. Among them are habitat types 9180, 91E0, 91AA, 9530 and 9560 (all are examples of forest habitat types). The habitat type 9180 **Tilio-Acerion* forests of slopes, screens and ravines is located near the village of Teshel to the northeast, and 91E0 *Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*) can be found between the villages of Teshel and Yagodina. 91AA *Eastern white oak woods are distributed to the northeast of the village of Chala, almost

the same as the last two types: 9530 *(Sub-) Mediterranean pine forests with endemic black pines and 9560 *Endemic forests with *Juniperus* spp.
The grassland habitat types are represented by several variations, among which 6230 *Species rich *Nardus* grasslands on silicates and 6520 Mountain hay meadows are standing out, taking up to 5% of the whole territory, and representing patches, predominantly in the northern and southern parts of Borino Municipality. They are dominated by the species of *Nardus stricta* L*., Festuca spp.,* and *Alopecurus pratensis* L. The non-forest habitat types are of a particular interest in the current study, regarding the future prediction for carbon accumulation from natural forest regrowth, leading to the assumption that their structure and species richness may become totally different, adding value to the overall carbon pool.
The analysis of the results also incorporates other geographical features of the investigated area. For instance, the Borino Municipality is sparsely populated and with uneven village structure – villages are unevenly distributed. Both remoteness and the lack of anthropogenic pressure in some areas are the reason for natural forest regrowth, leading to more carbon accumulation.
The right section of Fig. 2 shows the potential carbon sequestration rates for the period 2020-2050, originating from natural forest regrowth. The largest proportion of the municipality falls within the range of 0.965 – 1.109 Mg C ha^{-1} yr^{-1}. This is not the case only in Borino Municipality, but in the neighboring municipalities in the Western Rhodopes, as well. Despite the significant habitat diversity, this is not playing a major role in terms of the building up of carbon from natural forest regrowth. Only a small fraction to the extreme southwestern and southeastern parts of the case study area is containing higher levels in the range between 1.10 and 1.28 Mg C ha^{-1} yr^{-1}. This is the territory to the south of the villages of Buynovo and Kozhari. Here, two habitat types can be distinguished: 9130*Asperulo-Fagetum* beech forests and 9410 Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceetea*). Based on observations, a strict line differentiating forest habitats from non-forest habitats in the area in terms of future carbon stocking cannot be drawn, and this may be logical enough, as contemporary land cover is not taken in mind in these prognoses. Overall, the carbon accumulation potential from natural forest regrowth in Borino Municipality is showing consistency with the results for Bulgaria, as the investigated area is not standing out with a wide variety of habitats, allowing for a significant enlargement of the carbon pool in the aboveground biomass. The studied area does not display sharp differences in terms of future carbon stocking, but this does not mean that these potential carbon levels are low and inefficient. On the contrary, they are following the pattern that is typical for this geographic latitude in Europe. It is true that predicted carbon levels may rise up to 6 Mg C ha^{-1} yr^{-1}, but this is an exclusive right of the regions with tropical forests. It may

be assumed that the habitat types in the municipality will play their indispensable role in climate change mitigation in the forthcoming years.

4. CONCLUSION AND EVALUATION

The present research focused on the investigation of the habitats of the NATURA 2000 network in Borino Municipality and their link with the predicted carbon accumulation from natural forest regrowth for the next 30 years. Over 60% of the case study area was covered by a wide variety of habitats, distinguished in this research as forest and non-forest habitats. The first group is the dominant group, both in terms of the total count of the different habitats and the overall territory the group takes, as explained by the geographical pattern. Among the forest habitats, the one that was with the widest territorial extent was 91CA Rhodopide and Balkan Range Scots pine forests, while 6230 *Species rich *Nardus* grasslands on silicates was dominating the other habitats. In terms of the future carbon sequestration, two habitat types are standing out: both 9130 *Asperulo-Fagetum* beech forests and 9410 Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceetea*) were reaching values between 1.10 and 1.28Mg C ha^{-1} yr^{-1}, yet their territorial extent is negligible. The largest proportion of Borino Municipality falls within the 0.965 – 1.109 Mg C ha^{-1} yr^{-1} range, which is consistent with the neighboring municipalities, as well as the overall predictions for Bulgaria, as a whole. While, it is difficult to distinguish forest habitats from non-forest ones, when it comes to future carbon sequestration, still the territories they are currently occupying will play a very important role in the accumulation of carbon in the aboveground biomass.

A weak subject of the research is the lack of terrain research in this area of the author and the fact that it is dealing only with data, based on available resources. A future study in this particular area should include terrain observations, as well as data from relevés. Despite this weak point, the research does possess worthy contributions and this should be considered in other studies on this matter.

The results of the investigation are encouraging and may be used by policy-makers. Moreover, these findings could be employed as a foundation for broadening of the geographic perspective in the adjacent territories, as well as the whole area of the Western Rhodopes.

REFERENCES

1. Anderson-Teixeira, K et al. 2018. ForC: a global database of forest carbon stocks and fluxes. *Ecology* **99**, 1507.
2. Burciaga, U 2020. Sustainability assessment in housing building organizations for the design of strategies against climate change. *HighTech and Innovation Journal* **1 (4)**, 136-147.
3. Chaturvedi, R et al. 2011. Carbon density and accumulation in woody species of tropical dry forest in India. *Forest Ecology and Management* **262 (8)**, 1576-1588.
4. Chaturvedi, R and Raghubanshi, A 2015. Assessment of carbon density and accumulation in mono- and multi-specific stands in Teak and Sal forests of a tropical dry region in India 2015, *Forest Ecology and Management* **339**, 11–21.
5. Commission of the European Communities 2013. Interpretation manual of European Union habitats-EUR 28. DG Environment Nature and Biodiversity. Brussels. Commission of the European Communities. (available from https://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf.
6. Cook-Patton, S, Leavitt, S, Gibbs, D et al. 2020. Mapping carbon accumulation potential from global natural forest regrowth. *Nature* **585**, 545–550. https://doi.org/10.1038/s41586-020-2686-x.
7. Accessed through Global Forest Watch on [30.09.2020]. (www.globalforestwatch.org) Cook-Patton et al. 2020. Uncertainty in carbon accumulation potential from natural forest regrowth in forest and savanna biomes.
8. Cosic-Flajsig, G, Vuckovic, I and Karleusa, B 2020. An innovative holistic approach to an E-flow assessment model. *Civil Engineering Journal* **6(11)**, 2188-2202.
9. Dimitrova, V, Lyubenova, M and Vanguelova, E 2014. Biomass and carbon accumulation in herb layer of representative forest ecosystems in Bulgaria. *Journal of Balkan Ecology* **17 (1)**, 55-71.
10. Fenu, G and Malloci, F 2020. DSS LANDS: A decision support system for agriculture in Sardinia. *HighTech and Innovation Journal* **1(3)**, 129-135.
11. Grassi, G et al. 2017. The key role of forests in meeting climate targets requires science for credible mitigation. *Nat. Clim. Chang.* **7**, 220–226.
12. Information system for protected areas of the ecological network NATURA 2000 in Bulgaria. (retrieved from (http://natura2000.moew.government.bg/).
13. Javadinejad, S, Rebwar, D and Jafary F 2020. Climate Change Scenarios and Effects on Snow-Melt Runoff. *Civil Engineering Journal* **6 (9)**, 1715-1725.

14. Kavrakova, V, Dimova, D, Dimitrov, M, Tzonev, R, Belev, T, Rakovska and K (eds.) 2009 *Manual for Determination of Habitats with European Importance in Bulgaria*. Second Edition. Sofia (WWF–Danube Carpathian Programme & Green Balkan Federation). 131 p. (in Bulgarian).
15. Koulov, B, Ivanova, E, Borisova, B, Assenov, A and Ravnachka, A 2017. GIS-based Valuation of Ecosystem Services in Mountain Regions: A Case Study of the Karlovo Municipality in Bulgaria. *One Ecosystem* **2**: e14062. https://doi.org/10.3897/oneeco.2.e14062.
16. Lewis, S, Wheeler, C, Mitchard, E and Koch, A 2019. Regenerate natural forests to store carbon. *Nature* **568**, 25–28.
17. Ministry of Environment and Water/https://www.moew.government.bg/en/ (Accessed 7.10.2020).
18. Paul, K and Roxburgh, S 2020. Predicting carbon sequestration of woody biomass following land restoration. *For. Ecol. Manage.* **460**: 117838.
19. Tzonev, R, Dimitrov, M and Roussakova, V 2009. Syntaxa according to the Braun-Blanquet approach in Bulgaria. *Phytol. Balc.*,**15 (2)**: 209-233.
20. Vassilev, K, Dajič, Z, Cušterevska, R, Bergmeier, E and Apostolova, I 2012. Balkan Dry Grasslands Database. – In: Dengler, J., Oldeland, J., Jansen, F., Chytrý, M., Ewald, J., Finckh, M., Glöckler, F., Lopez-Gonzalez, G., Peet, R.K., Schaminée, J.H.J. (Eds.) *Vegetation databases for the 21st century*.
21. Vassilev et al. 2016. Balkan vegetation database: Historical background, current status and future perspectives. *Phytocoenologia* **46(1)**:89-95.
22. Velev, N and Vassilev, K 2014. Management regimes within syntaxa of semi-natural grasslands from West Bulgaria. *Hacquetia*, **13/1**: 191-204.
23. Zhiyanski, M, Glushkova, M, Ferezliev, A, Menichetti, L and Leifeld, J 2016. Carbon storage and soil property changes following afforestation in mountain ecosystems of the Western Rhodopes, Bulgaria. *iForest*, **9**, SISEF - Italian Society of Silviculture and Forest Ecology, ISSN:1971-7458, DOI:10.3832/ifor 1866-008, 626-634.
24. Zhiyanski, M 2020. Forest ecosystems in Bulgaria under environmental change – carbon sequestration potential and vulnerability zones. In: *Smart Geography* (eds. S. Nedkov, G. Zhelezov, N. Ilieva, M. Nikolova, B. Koulov, K. Naydenov, S. Dimitrov), 417-441.

Editor received the manuscript: 05.11.2020