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ORGANIC MATTER CONTENT AND HUMUS RESERVES IN NATURAL SOILS OF ROSTOV AGGLOMERATION

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The research aims to study the content of organic matter in typical chernozem, its distribution in the soil profile under herbaceous and wooden phytocenoses. Organic matter plays a key role in the functioning of soils and their stable performance of ecological functions, including – the protection function. This is particularly relevant in the growing urbanization. The research analysis includes 40 full-profile sections of migration-segregated chernozems (typical carbonate) laid on the upland soil of the Rostov agglomeration. We determined organic matter by high-temperature catalytic combustion on a TOC-L CPN Shimadzu in an SSM-5000A solid sample combustion unit. Based on the data obtained, we calculated the organic carbon reserves. Statistical analysis included the calculation of the Mann-Whitney U-test to consider significant differences in the samples of indicators under wooden and herbaceous phytocenoses and descriptive statistics. The research results showed the influence on the organic carbon content of such a widespread type of anthropogenic impact as planting trees in the steppe zone. Comparison of the total organic carbon content values in similar genetic horizons under herbaceous and wooden phytocenoses indicates the spatial heterogeneity of this indicator, associated primarily with the type of land use. The supply of humus for Rostov chernozems under herbaceous phytocenoses was assessed as low and under wooden phytocenoses – as average. In the one-meter layer of natural chernozems of the Rostov agglomeration, humus reserves are 387 t/ha, which corresponds to the average supply level. Thus, the park and recreational zone, where wooden vegetation grows, plays a special ecological role in the city as a place of accumulation of an increased amount of organic matter of natural origin compared to other soils of the Rostov agglomeration.

Keywords: *organic matter; humus; natural soils; migration-segregation chernozems*

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СОДЕРЖАНИЕ ОРГАНИЧЕСКОГО ВЕЩЕСТВА И ЗАПАСЫ ГУМУСА В ЕСТЕСТВЕННЫХ ПОЧВАХ РОСТОВСКОЙ АГЛОМЕРАЦИИ

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Цель – исследование содержания органического вещества в черноземах обыкновенных, его распределение в профиле почв под травянистыми и древесными фитоценозами. Органическому веществу принадлежит ключевая роль в функционировании почв и стабильном выполнении ими экологических функций, в том числе – протекторной функции, что приобретает особую актуальность в условиях растущей урбанизации. Анализ включал 40 полнопрофильных разрезов черноземов миграционно-сегрегационных (обыкновенных карбонатных), заложенных на плакорах Ростовской агломерации. Определяли органическое вещество методом высокотемпературного каталитического сжигания на анализаторе углерода TOC-L CPN Shimadzu в приставке для сухих образцов SSM-5000A. По полученным данным рассчитывали запасы органического углерода. Статистический анализ включал расчет критерия Мана-Уитни, для учета достоверных различий в выборках показателей под древесными и травянистыми фитоценозами, а также описательную статистику. Результаты исследований показали влияние на содержание органического углерода такого распространенного вида антропогенного воздействия, как посадка деревьев в степной зоне. Сравнение величин содержания общего органического углерода в аналогичных генетических горизонтах под травянистыми и древесными фитоценозами указывает на пространственную неоднородность данного показателя, связанную, в первую очередь, с типом землепользования. Обеспеченность гумусом для чернозёмов Большого Ростова под травянистыми фитоценозами оценивается как низкая, а под древесными фитоценозами – как средняя. В метровой толще естественных черноземов Ростовской агломерации запасы гумуса составляют 387 т/га, что соответствует среднему уровню обеспеченности. Таким образом, парково-рекреационная зона, где произрастает древесная растительность, выполняет особую экологическую роль в городе, являясь местом аккумуляции повышенного количества органических веществ природного происхождения по сравнению с иными почвами Ростовской агломерации.

Ключевые слова: *органическое вещество; гумус; естественные почвы; черноземы миграционно-сегрегационные*

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Introduction

Many scientific works of national and foreign scientists are devoted to the study of the organic matter of urban soils [3; 6; 7; 12; 22; 25]. However, there are not enough studies considering the carbon profile of soils under human-made forests. This lack does not allow one to fully assess the processes of transformation and migration of soil organic matter associated with changes in the quantity and quality of litter and, as a consequence, humification conditions [5; 18]. One of the leading components in the process of soil degradation in urban landscapes is the dehumification of urban soils; it is reflected in a decrease in organic matter in buried humus-accumulative horizons. Simultaneously, the role of human-made forests in the ecology of cities, especially the steppe zone, is very important. They optimize microclimatic conditions by creating a windbreak around the city, and to some extent regulating the air temperature. This is also evidenced in our studies by showing an increase in the humus content in the surface layer of soils under forest vegetation. Urban cultivated forests in Rostov-on-Don act as “compensating territories” not only from the point of creating microclimatic conditions but from the point of forming special environmental-forming territories. In the light of residential and industrial areas of the city, these territories are characterized by a different redistribution of matter in the plant-soil system. The presence of forest cover and the formation of a dense grassy ground cover protected from summer burnout by tree crowns represent a rich energy material that enriches the soil with organic forms of carbon. Thus, in an urban environment with highly degraded soils that lose their protective functions, soils under tree plantations develop; they are representing zones of a more intensive circulation of elements with increased humus content.

Organic matter – one of the main constituents of the soil. On the one hand, it can respond to environmental changes. On the other hand, it is a fairly “conservative” part of the soil, capable of withstanding anthropogenic impact and maintaining its ecological condition. The planting of wooden vegetation on chernozems and the change due to this biological cycle of substances affect not only the accumulation of humus in the surface horizon [5] but also its composition. In city conditions, the species composition of intrazonal wooden rather than zonal herbaceous vegetation affects the accumulation of soil organic matter [1; 11; 13].

Materials and methods

When considering the content and reserves of humus, its distribution in the soil profile under herbaceous and wooden phytocenoses in natural soils of the Rostov agglomeration, we solved the following tasks:

- Based on previous studies of the Rostov agglomeration, selected the research objects, considering their spatial position, the degree of anthropogenic influence exerted on them, and the peculiarities of the floristic composition;
- Determined the content and profile distribution of soil organic carbon under laboratory conditions;
- Systematized data using descriptive statistics (data aggregation, coefficient of variation calculation, and Mann-Whitney U-test calculation);
- Estimate the humus reserves in the studied chernozems by the amount of accumulated carbon.

The research object was the soils of the Rostov agglomeration – its core of “Big Rostov” and adjacent agrogenic territories.

The studied natural soils are defined as migration-segregated chernozems [4] or typical carbonate chernozems [8; 14]. Full-profile sections were laid in the park and recreational zones of the city. Fallow chernozems of the exposition “Priazovskaya step” at the Botanical Garden of the Southern Federal University (sections 1609 and 2001) were used as a reference. In total, more than 40 sections in total were laid from 2012 to 2020.

The organic carbon content was determined by high-temperature catalytic combustion on a TOC-L CPN Shimadzu in an SSM-5000A solid sample combustion unit. This method is based on high-temperature catalytic combustion of the sample and subsequent detection of the evolved carbon dioxide. The sample is analyzed in two stages: the total amount of carbon is determined by burning the sample at a temperature of 900 C° and the inorganic sample – of 200 C° (with the phosphoric acid). Organic carbon is determined by subtracting the inorganic carbon from the total. The advantage of this method is that the “side” result of the analysis is the determination of the inorganic carbon amount in a dry sample [27]. We calculated the reserves of soil organic matter (OM) based on the data obtained in the laboratory analyzes according to the following formula:

$$\text{OM stocks kg/ha} = C * H * d * 1000, \quad (1)$$

where: C – is OM content, %;

d – is the thickness of the horizon (layer), cm;

H – is the soil density, g/cm^3.

The statistical analysis included a Mann-Whitney U-test calculation used to assess the differences between two independent samples. The processing and systematization of empirical data are presented in graphs and tables by the data aggregation method.

Results

The study of the organic matter content in soils is the most important task of the current comprehensive research due to its key role in the soil functioning and stable performance of its ecological functions [16; 20; 21; 24].

Table 1 shows the content and profile distribution of organic matter in the most typical representatives of the group of natural soils of the Rostov agglomeration that we selected.

Table 1.

Content and profile distribution of organic matter in the migration-segregation chernozems of the Rostov agglomeration

Horizon	Selection depth	With OM, %	Humus, %	Horizon	Selection depth	With OM, %	Humus, %
Section 1609, deposit				**Section 1601, forest park**			
AU rz	0–15	2.27	3.91	AU rz	0–5	4.05	6.98
AJ	15–50	1.87	3.22	AJ	5–50	1.87	3.22
AJ lc	50–65	1.63	2.81	AJ lc	50–70	1.15	1.98
AJ lc	65–90	1.10	1.90	AJ lc	70–90	0.78	1.34
BCA nc	90–110	0.53	0.91	BCA nc	90–130	0.43	0.74
C ca	110–150	0.25	0.43	C ca	130–150	0.3	0.52
Section 2001, deposit				**Section 1603, forest park**			
AU rz	0–10	2.47	4.26	AU rz	0–15	3.41	5.88
AJ	10–15	2.35	4.06	AJ	20–30	2.67	4.6
AJ	15–35	1.89	3.26	AJ	50–60	2.27	3.91
AJ lc	35–60	1.48	2.55	AJ lc	70–95	1.48	2.55
AJ lc	60–75	1.00	1.72	AJ lc	95–120	0.93	1.6
BCA nc	75–95	0.70	1.21	BCA nc	120–145	0.56	0.97
C ca	95–135	0.27	0.46	C ca	145–160	0.34	0.59

The content of organic matter decreases with depth. This is natural for migration-segregated chernozems. The highest content is observed in the surface sod horizons with an average thickness of about 10 centimeters, where the bulk of the dead plant remains falls. It is important to note that in chernozems developing under wooden vegetation, more organic matter accumulates in the surface 10-centimeter layer than in the same chernozems of virgin or fallow areas.

It can be explained by the fact that there is an increased supply of plant litter to the soil surface in forest parks, both due to the annually discharged foliage of deciduous wooden plants and the well-developed herbaceous vegetation under the canopy of the first and second arboreal layers (not only its terrestrial part but also powerful root system) [19; 23]. The latter, protected by tree crowns from intensive evaporation of moisture, in summer could vegetate for a longer time than the vegetation of the steppe massifs [15].

Comparing the obtained values with Table 1 of soil humus supply, we conclude that for fallow areas, the humus content in the surface (most active) layer can be estimated as the following:

- Low (2%–4%) in chernozems under herbaceous vegetation;
- Medium (4%–6%);
- Increased (6%–8%) under the canopy of trees in forest parks.

Fig. 1 shows the horizontal results of the average statistical content of organic matter in a sample of 15 soil sections.

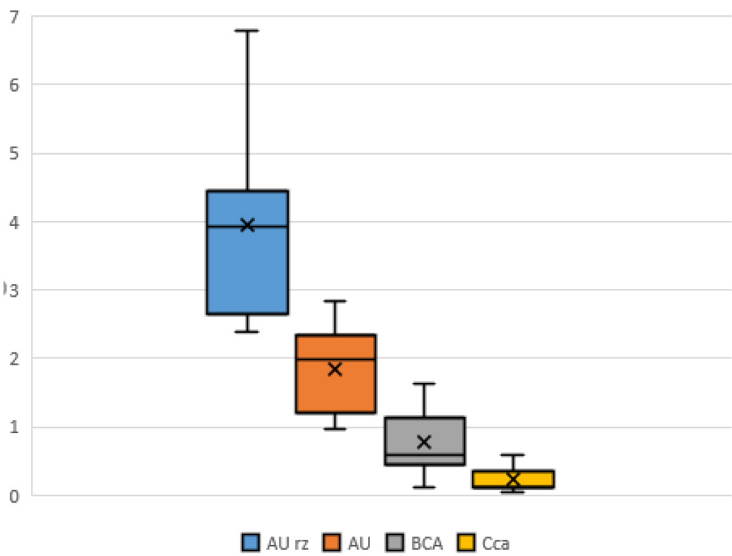

Fig. 1. Box-and-whiskers diagram – diagram of the organic matter content (%) in the samples of the natural soils horizons of the Rostov agglomeration.

In the sod horizon AU rz (which is the richest in organic carbon), we observe the greatest variation of this indicator. The coefficient of variation is 34%, which indicates the heterogeneity of the sample. It is due not only to the rate of organic carbon input and its transformation but also to the floristic composition of the territories where this chernozem was formed. Despite the minimum values of organic matter in the horizon of white-eye C ca accumulation (0.29% on average), the coefficient of variation here is maximum – 60%. The AU horizon is characterized by the smallest value of the coefficient of variation (28%). This indicates a significant variability of the features in the cumulo layer but the homogeneity of the sample. The total organic carbon content in chernozems of urban landscapes can be considered a rather dynamic indicator. At the same time, the coefficient of variation does not exceed 10% in chernozems of the same subtype of agricultural territories [2]. It indicates a slight variability of the trait and its diagnostic significance.

During the current research, we also investigated organic carbon density and determined the readings of humus reserves in 50 centimeters and one-meter soil layers (270 t/ha and 387 t/ha, respectively). For a one-meter thickness, such indicators are estimated as average.

Discussion

Studies show [7; 22] that forest vegetation affects several factors: the temperature and hydrological regime of the soil, its microbiological activity, and the floristic composition of the herbaceous cover [17; 26]. This ultimately leads to a change in some soil properties. At the same time, the soil evolution process under the forest and, as the rich experience of afforestation accumulated in the 50s–70s shows, this indicates noticeable changes in soil properties in general and in the humus content in particular. A notable feature is the influence of physical and geographical conditions on the species composition of plants and, as a result, on the accumulation of organic matter in the soil. Thus, in the biogeocenoses of the forest zone, where birch dominates in the tree layer, there is a greater accumulation of humus compared to forests, where the dominants are oak, aspen, or pine. The opposite picture can be observed in the forest-steppe zone [7; 10].

Analysis of the humus condition of natural soils in Rostov-on-Don allows us to conclude that the content features and distribution of organic matter along the profile of these soils are associated with the type of land use. Thus, the statistical processing of the data presented in the work of S. A. Zakharov [9] showed that the average humus content in the surface 10-centimeter layer of the Northern Azov chernozems of arable land (now called migration-segregated chernozems) is 5.7%, with fluctuations from 4.4% to 7.6% [3]. Studies of chernozems in the Rostov-on-Don forest park zone indicate an increased humus content of these soils: the average humus content in the surface layer is 7.3%, with fluctuations from 6.5% to 10% [5]. Similar processes are observed in Moscow, where an increase in organic carbon content in soils under tree vegetation was also noted [12].

Conclusion

The humus content in the chernozems of "Big Rostov" is estimated as low (fallow areas under herbaceous vegetation), medium, or increased (chernozems of the park-recreational zone). Comparison of the values of the total organic carbon content of similar genetic horizons of natural soils indicates the spatial heterogeneity of this indicator associated with the type of land use. In the one-meter layer of natural chernozems of the Rostov agglomeration, humus reserves are 387 t/ha, which corresponds to the average supply level. Thus, the soils of the park-recreational zone of the Rostov agglomeration are areas of increased accumulation of organic matter of natural origin compared to the soils of other functional zones. Due to the ability of humus to bind heavy metals, it provides a complete fulfillment of the ecological (protective) role of the soils.

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References

1. Akhtyrtsev B. P. *Seryye lesnyye pochvy Tsentral'noy Rossii* [Gray Forest Soils of Central Russia]. Voronezh, Voronezh State University, 1979, 233 p. https://search.rsl.ru/ru/record/01007742803
2. Bezuglova O. S. *Gumusovoye sostoyaniye pochv Yuga Rossii* [Humus State of Soils in the South of Russia]. Rostov-on-Don, Severo-Kavkazskiy Nauchny Tsentr Vysshey Shkoly, 2001, 228 p.
3. Bezuglova O.S., Gorbov S.N., Privalenko V.V. Sozdaniye gumusovogo profilya i mikroelementnogo sostava pochv rekreatsionnykh territoriy g. Rostova-na-Donu [Creation of humus profile and microelement composition of soils of rec-

reational territories in Rostov-on-Don]. *Pochvovedeniye* [Soil Science], 2000, vol. 9, pp. 1142-1148.
4. Vysotskiy G.N. *Izbrannyye proizvedeniya, t. 1-2* [Selected Works, vols 1-2]. Moscow, USSR Academy of Sciences Publishing House, 1962, 2 V. URL: https://search.rsl.ru/ru/record/01005595439
5. Gorbov S.N., Bezuglova O.S. Spetsifika organicheskogo veshchestva pochv Rostova-na-Donu [Specificity of soil organic matter in Rostov-on-Don]. *Pochvovedeniye* [Soil Science], 2014, vol. 8, pp. 963. https://doi.org/10.7868/S0032180X14080048
6. Gorbov S. N., Bezuglova O. S. Elementnyy sostav guminovykh kislot v pochvakh urbanizirovannykh territoriy (na primere g. Rostova-na-Donu) [Elemental composition of humic acids in soils of urbanized territories (on the example of Rostov-on-Don)]. *Pochvovedeniye* [Soil Science], 2013, vol. 11, 1316-1324.
7. Demakov Yu. P., Isaev A. V., Chernykh V. L. Ekologo-resursnyy potentsial drevostoyev lesoobrazuyushchikh porod Srednego Povolzh'ya [Ecological-resource potential of forest stands of forest-forming species of the Middle Volga region]. *Vestnik Povolzhskogo gosudarstvennogo tekhnologicheskogo universiteta. Seriya Ekologiya lesa Prirodopol'zovaniye* [Vestnik of Volga State University of Technology. Series Forest Ecology Nature Management], 2014, vol. 4, no. 24, pp. 5-20. URL: http://vestnik.volgatech.net/index.php/forest/article/view/65
8. Egorov V. V., Ivanova E. N., Friedland V. M. *Klassifikatsiya i diagnostika pochv SSSR*. [Classification and Diagnostics of Soils in the USSR], Moscow, Kolos, 1977, 225 p. URL: https://www.geokniga.org/books/3460
9. Zakharov S. A. *Pochvy Rostovskoy oblasti i ikh agronomicheskaya kharakteristika.* [Soils of the Rostov Region and Their Agronomic Characteristics], Rostov-on-Don, Rostizdat, 1946, 123 p. URL: https://search.rsl.ru/ru/record/01005797523
10. Karpachevskiy L. O. *Les i lesnyye pochvy* pForest and Forest Soils]. Moscow, Lesnaya promyshlennost, 1981, 264 p. URL: https://search.rsl.ru/ru/record/01001037959
11. Ponomareva V.V., Plotnikova T.A. *Gumus i pochvoobrazovaniye* [Humus and Soil Formation]. Leningrad, Nauka, 1980, 221 p. URL: https://search.rsl.ru/ru/record/01000991840
12. Prokofieva T.V., Rozanova M.S., Poputnikov V. Nekotoryye osobennosti organicheskogo veshchestva pochv parkov i prilegayushchikh k nim selitebnykh territoriy g. Moskvy [Some features of soil organic matter in parks and adjacent residential areas of Moscow]. *Pochvovedeniye* [Soil Science], 2013, vol. 3, p. 302. http://dx.doi.org/10.7868/S0032180X13030076

13. Rusanov A. M. Vliyaniye lesov na sostav i svoystva organicheskogo veshchestva stepnykh chernozemov v sopredel'nykh biogeotsenozakh [The influence of forests on the composition and properties of organic matter of steppe chernozems in adjacent biogeocenoses]. *Ekologiya* [Ecology], 2012, vol. 1, pp. 36-42 URL: https://naukarus.com/vliyanie-lesa-na-sostav-i-svoystva-organicheskogo-veschestva-stepnyh-chernozemov-prilegayuschih-biogeotsenozov
14. Shishov L. L., Tonkonogov V. D. Lebedeva I. I. *Klassifikatsiya i diagnostika pochv Rossii* [Classification and Diagnostics of Russian Soils]. Smolensk, Ojkumena, 2004, 341 p. URL: https://obuchalka.org/20180819103171/klassifikaciya-i-diagnostika-pochv-rossii-shishov-l-l-tonkonogov-v-d-lebedeva-i-i-2004.html
15. Cao J., He X., Chen Y., Chen Y., Zhang Y., Yu S., Zhou L., Liu Z., Zhang C., Fu S. Leaf litter contributes more to soil organic carbon than fine roots in two 10-year-old subtropical plantations. *Science of the Total Environment*, 2020, vol. 704, e135341. https://doi.org/10.1016/j.scitotenv.2019.135341
16. Colombini G., Auclerc A., Watteau F, Techno-moder: A proposal for a new morpho-functional humus form developing on Technosols revealed by micromorphology. *Geoderma*, 2020, vol. 375, e114526. https://doi.org/10.1016/j.geoderma.2020.114526
17. Dean C., Kirkpatrick J. B., Doyle R. B., Osborn J., Fitzgerald N. B., Roxburgh S. H. The overlooked soil carbon under large, old trees. *Geoderma*, 2020, vol. 376, e114541. https://doi.org/10.1016/j.geoderma.2020.114541
18. Gorbov S. N., Bezuglova O. S. Specific Features of Organic Matter in Urban Soils of Rostov-on-Don. *Eurasian Soil Science*, 2014, vol. 47, no. 8, pp. 792–800.
19. Guimarães D. V., Gonzaga M. I. S., da Silva T. O., da Silva T. L., da Silva Dias N., Matias M. I. S. Soil organic matter pools and carbon fractions in soil under different land uses. *Soil and Tillage Research*, 2013, vol. 126, pp. 177-182. https://doi.org/10.1016/j.still.2012.07.010
20. Korkina I. N., Vorobeichik E. L. Non-typical degraded and regraded humus forms in metal-contaminated areas, or there and back again. *Geoderma*, 2021, vol. 404, e115390. https://doi.org/10.1016/j.geoderma.2021.115390
21. Lemanowicz J., Haddad S. A., Bartkowiak A., Lamparski R., Wojewódzki P. The role of an urban park's tree stand in shaping the enzymatic activity, glomalin content and physicochemical properties of soil. *Science of the Total Environment*, 2020, vol. 741, e140446. https://doi.org/10.1016/j.scitotenv.2020.140446
22. Lorenz K., Kandeler E. Biochemical characterization of urban soil profiles from Stuttgart, Germany. *Soil Biology & Biochemistry*, 2005, vol. 37, pp. 1373-1385. https://doi.org/10.1016/j.soilbio.2004.12.009

23. Mora J. L., Molina-Clerencia M., Girona-García A., Martí-Dalmau C., Badía-Villas D. Factors controlling the buildup of humus and particulate organic matter in European beech and Scots pine stands at their southernmost distribution limits (Moncayo Massif, Spain). *Geoderma*, 2021, vol. 401, e115211. https://doi.org/10.1016/j.geoderma.2021.115211
24. Ouédraogo R. A. Chartin C., Kambiré F. C., Wesemael B., Delvaux B., Milogo H., Bielders C. L. Short and long-term impact of urban gardening on soil organic carbon fractions in Lixisols (Burkina Faso). *Geoderma*, 2020, vol. 362, 114110. https://doi.org/10.1016/j.geoderma.2019.114110
25. Pouyat R., Groffman P., Yesilonis I., Hernandezd L. Soil carbon pools and fluxes in urban ecosystems. *Environmental Pollution*, 2002, vol. 116, pp. 107-118. https://doi.org/10.1016/S0269-7491(01)00263-9
26. Sokołowska J., Józefowska A., Zaleski T. Humus horizon development during natural forest succession process in the Polish Carpathians. *Journal of Mountain Science*, 2022, vol. 19, no 3, pp. 647-661. https://link.springer.com/content/pdf/10.1007/s11629-021-6836-x.pdf
27. Tagiverdiev S. S. Gorbov S. N. Bezuglova O. S. Skripnikov P. N. The content and distribution of various forms of carbon in urban soils of southern Russia on the example of Rostov agglomeration. *Geoderma Regional*, 2020, vol. 21, e00266. https://doi.org/10.1016/j.geodrs.2020.e00266

Список литературы

1. Ахтырцев Б. П. Серые лесные почвы Центральной России. В.: Воронежский государственный университет, 1979, 233 с. URL: https://search.rsl.ru/ru/record/01007742803
2. Безуглова О. С. Гумусное состояние почв юга России. Р.: Южный федеральный университет, 2001, 228 с.
3. Безуглова О. С., Горбов С. Н., Приваленко В. В. Гумусовый профиль и микроэлементный состав почв рекреационных территорий г. Ростов-на-Дону // Почвоведение. 2000. № 9. С. 1142-1148.
4. Высоцкий Г. Н. Избранные сочинения, тома 1-2. М.: Издательство Академии Наук СССР, 1962, 2 т. URL: https://search.rsl.ru/ru/record/01005595439
5. Горбов С. Н., Безуглова О. С. Специфика органического вещества почв Ростова-на-Дону // Почвоведение. 2014. № 8. С. 953. https://doi.org/10.7868/S0032180X14080048
6. Горбов С. Н., Безуглова О. С. Элементный состав гуминовых кислот почв урбанизированных территорий (на примере Ростова-на-Дону) // Почвоведение. 2013. № 11. С. 1316-1324.

7. Демаков Ю. П., Исаев А. В., Черных В. Л. Эколого-ресурсный потенциал древостоев лесообразующих пород среднего Поволжья // Вестник Поволжского государственного технологического университета. Серия: Лес. Экология. Природопользование. 2014. Т. 4. № 24. С. 5-20. URL: http://vestnik.volgatech.net/index.php/forest/article/view/65
8. Егоров В. В., Иванова Е. Н., Фридланд В. М. Классификация и диагностика почв СССР. М.: Колос, 1977, 225 с. URL: https://www.geokniga.org/books/3460
9. Захаров С. А. Почвы Ростовской области и их агрономическая характеристика. Р.: Ростиздат, 1946, 123 с. URL: https://search.rsl.ru/ru/record/01005797523
10. Карпачевский Л. О. Лес и лесные почвы. М.: Лесная промышленность, 1981, 264 с. URL: https://search.rsl.ru/ru/record/01001037959
11. Пономарева В. В., Плотникова Т. А. Гумус и почвообразование. Л.: Наука, 1980, 221 с. URL: https://search.rsl.ru/ru/record/01000991840
12. Прокофьева Т. В., Розанова М. С., Попутников В. О. Некоторые особенности органического вещества почв на территориях парков и прилегающих жилых кварталов Москвы // Почвоведение. 2013. № 3. С. 302. http://dx.doi.org/10.7868/S0032180X13030076
13. Русанов А. М. Влияние леса на состав и свойства органического вещества степных черноземов прилегающих биогеоценозов // Экология. 2012. № 1. С. 36-42. URL: https://naukarus.com/vliyanie-lesa-na-sostav-i-svoystva-organicheskogo-veschestva-stepnyh-chernozemov-prilegayuschih-biogeotsenozov
14. Шишов Л., Тонконогов В., Лебедева И. И. Классификация и диагностика почв России. С.: Ойкумена, 2004, 341 с. URL: https://obuchalka.org/20180819103171/klassifikaciya-i-diagnostika-pochv-rossii-shishov-l-l-tonkonogov-v-d-lebedeva-i-i-2004.html
15. Cao J., He X., Chen Y., Chen Y., Zhang Y., Yu S., Zhou L., Liu Z., Zhang C., Fu S. Leaf litter contributes more to soil organic carbon than fine roots in two 10-year-old subtropical plantations // Science of the Total Environment, 2020, vol. 704, e135341. https://doi.org/10.1016/j.scitotenv.2019.135341
16. Colombini G., Auclerc A., Watteau F, Techno-moder: A proposal for a new morpho-functional humus form developing on Technosols revealed by micromorphology // Geoderma, 2020, vol. 375, e114526. https://doi.org/10.1016/j.geoderma.2020.114526
17. Dean C., Kirkpatrick J. B., Doyle R. B., Osborn J., Fitzgerald N. B., Roxburgh S. H. The overlooked soil carbon under large, old trees // Geoderma, 2020, vol. 376, e114541. https://doi.org/10.1016/j.geoderma.2020.114541

18. Gorbov S. N., Bezuglova O. S. Specific Features of Organic Matter in Urban Soils of Rostov-on-Don // Eurasian Soil Science, 2014, vol. 47, no. 8, pp. 792–800.
19. Guimarães D. V., Gonzaga M. I. S., da Silva T. O., da Silva T. L., da Silva Dias N., Matias M. I. S. Soil organic matter pools and carbon fractions in soil under different land uses // Soil and Tillage Research, 2013, vol. 126, pp. 177-182. https://doi.org/10.1016/j.still.2012.07.010
20. Korkina I. N., Vorobeichik E. L. Non-typical degraded and regraded humus forms in metal-contaminated areas, or there and back again // Geoderma, 2021, vol. 404, e115390. https://doi.org/10.1016/j.geoderma.2021.115390
21. Lemanowicz J., Haddad S. A., Bartkowiak A., Lamparski R., Wojewódzki P. The role of an urban park's tree stand in shaping the enzymatic activity, glomalin content and physicochemical properties of soil // Science of the Total Environment, 2020, vol. 741, e140446. https://doi.org/10.1016/j.scitotenv.2020.140446
22. Lorenz K., Kandeler E. Biochemical characterization of urban soil profiles from Stuttgart, Germany // Soil Biology & Biochemistry, 2005, vol. 37, pp. 1373-1385. https://doi.org/10.1016/j.soilbio.2004.12.009
23. Mora J. L., Molina-Clerencia M., Girona-García A., Martí-Dalmau C., Badía-Villas D. Factors controlling the buildup of humus and particulate organic matter in European beech and Scots pine stands at their southernmost distribution limits (Moncayo Massif, Spain) // Geoderma, 2021, vol. 401, e115211. https://doi.org/10.1016/j.geoderma.2021.115211
24. Ouédraogo R. A. Chartin C., Kambiré F. C., Wesemael B., Delvaux B., Milogo H., Bielders C. L. Short and long-term impact of urban gardening on soil organic carbon fractions in Lixisols (Burkina Faso) // Geoderma, 2020, vol. 362, 114110. https://doi.org/10.1016/j.geoderma.2019.114110
25. Pouyat R., Groffman P., Yesilonis I., Hernandezd L. Soil carbon pools and fluxes in urban ecosystems // Environmental Pollution, 2002, vol. 116, pp. 107-118. https://doi.org/10.1016/S0269-7491(01)00263-9
26. Sokołowska J., Józefowska A., Zaleski T. Humus horizon development during natural forest succession process in the Polish Carpathians // Journal of Mountain Science, 2022, vol. 19, no 3, pp. 647-661. https://link.springer.com/content/pdf/10.1007/s11629-021-6836-x.pdf
27. Tagiverdiev S. S. Gorbov S. N. Bezuglova O. S. Skripnikov P. N. The content and distribution of various forms of carbon in urban soils of southern Russia on the example of Rostov agglomeration // Geoderma Regional, 2020, vol. 21, e00266. https://doi.org/10.1016/j.geodrs.2020.e00266

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Скрипников П.Н.: Подготовка текста, участие в полевых и лабораторных исследованиях, переписка с редакцией.

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