Atlantis Highlights in Material Sciences and Technology (AHMST), volume 1
International Symposium "Engineering and Earth Sciences: Applied and Fundamental Research" (ISEES 2019)

Characteristics of the Assimilation Potential of Tree Vegetation in Carbon Dioxide Absorption by PAs in Moscow

Sorokina A.A.
Department of Technosphere Safety and Ecology
Russian State Social University
Moscow, Russia
soroka612@yandex.ru

Zubkova V.M.
Department of Technosphere Safety and Ecology
Russian State Social University
Moscow, Russia
vmzubkova@yandex.ru

Gaponenko A.V.
Department of Technosphere Safety and Ecology
Russian State Social University
Moscow, Russia
gaponenko69@mail.ru

Belozubova N.Yu.
Department of Technosphere Safety and Ecology
Russian State Social University
Moscow, Russia
gerlinger_natali@mail.ru

Soshenko M.V.
Department of Technosphere Safety and Ecology
Russian State Social University
Moscow, Russia
soshenkomv@mail.ru

***Abstract* – The paper presents a comparative assessment of the contribution of forest tree vegetation of the natural sanctuary Serebryany Bor and the Natural-Historical Park Bitsevsky Forest to carbon dioxide absorption. It is found that the amount of carbon dioxide absorption depends on both the composition of tree species and the area occupied by these species. The research revealed that the assimilation potential of hardwood plantations exceeds the assimilation potential of softwood plantations. The data obtained on the assimilation potential of the tree vegetation of Serebryany Bor and Bitsevsky Forest show that forest plantations of these specially protected natural areas absorb more than 8% of pollutants emitted per year by the road transport in Moscow. The area occupied by these plantations makes up no more than 1% of the area of the entire city of Moscow, and this confirms the value of specially protected natural areas and their importance in a large city.**

Keywords – PA; natural historical park; nature monument; assimilation potential; carbon dioxide; tree vegetation.

I. INTRODUCTION

The territory of Moscow includes more than 120 specially protected natural areas (PAs). Their total area is more than 270 km^2, which is about 10.5% of the total area of the city [1].

The significant role in the life of the city (purification of air from dust and pollutants, enrichment with oxygen and reduction of carbon dioxide, urban noise reduction and general creation of comfortable human environment) and a small area of these areas necessitate their very careful protection [2, 3].

The tree vegetation of PAs optimizes the carbon dioxide and oxygen balance in the air. Plantings absorb CO_2 emitted by industrial sources of pollution only after its transition into an available form, and this process depends on the level of illumination and lasts on average from 2–2.5 hours to 5 days. The ability to absorb pollutants depends on thickness, average yield class, their age, the assimilation surface of the tree crown, and the length of the growing season [4–6].

An optimal range of trees and shrubs helps to effectively improve the environment, and green areas and suburban areas should be considered not so much in terms of recreation and agricultural production, but from in terms of "ecological donation" of clean air, water and soil [7].

The study aims to assess the tree vegetation of the natural-historical park Bitsevsky Forest and the natural sanctuary of regional significance Serebryany Bor by prevailing species and the assimilation potential of tree vegetation by carbon dioxide absorption.

II. METHODS AND MATERIALS

The study used data from priority projects for preservation, development and reproduction of plantations, projects for preservation, development and reproduction of plantations in the area, specialized surveys and taxation descriptions of the

studied protected areas, and the study of the tree flora conducted in 2017–2019 by route method.

The assimilation potential by carbon dioxide absorption was assessed based on the methodology developed by G.E. Mekush [8] and E.A. Unruh [9].

The assimilation potential (AP) of tree vegetation was calculated using formula 1:

AP forest = AP softwood + AP hardwood (1)

AP softwood = (X – X mature and overmature)*Vn*0,5 (2)

AP hardwood = (F mature and overmature)*Vn*0,3 (3)

where AP softwood is assimilation potential of softwood forests,

AP hardwood is assimilation potential of hardwood plantations,

X is growing stock with predominance of softwood species,

X mature and overmature is stock of mature and overmature softwood species,

F is growing stock with predominance of hardwood species,

F mature and overmature is stock of mature and overmature hardwood species,

Vn is the volume of carbon dioxide absorbed by specific tree spices from 1 ha of the forest belt per year, kg,

0.3 is coefficient of absorption, assimilation of carbon dioxide for hardwood species;

0.5 is coefficient of absorption, assimilation of carbon dioxide for softwood species; [8].

Natural sanctuary of regional significance Serebryany Bor (NS Serebryany Bor) is located in the north-western administrative district of Moscow. Its total area is 328.6 hectares, of which 202 hectares is a protected area. Green areas on the PAs occupy 144.18 ha (71%), which include 112.27 ha covered with tree vegetation [10].

The natural-historical park Bitsevsky Forest (NHP Bitsevsky Forest) is located in the south-west of Moscow, and it is the second largest protected natural area in the city. The total area of the forest park is 2208.4 hectares. Most of the protected areas are covered with vegetation – 1,891.7 hectares (86.7%), which include forest stands of 1,550.5 hectares (71.06%). Softwood species are predominant in the forest plantations of the natural-historical park Bitsevsky Forest. The distribution of forest plantations in the natural-historical park by age groups is characterized by predominance of mature and overmature tree stands (45.7%) and an insignificant proportion of young stands (1.2%). The average age of tree stands in the protected areas is 74 years. The average class of the average yield class in the forest plantations of the park is 1.57. In conditions of increased recreational load, these values are optimal for normal growth and development of plantations [11].

Over 33.7 km, the border of the natural history park runs along major highways with high traffic intensity. From the north, the forest park is bounded by Balaklavsky Avenue, from the north-west by Sevastopolsky Avenue; from the west and east by Profsoyuznaya street, Varshavskoye Highway, etc.; in the southern part intersected by MKAD. Residential areas of Yasenevo, Teply Stan, Konkovo, Cheryomushki, Zyuzino and Chertanovo are adjacent to the borders of the forest park from all sides. Near the forest park, there are large industrial areas of Vorontsovo (Special alloys plant, Krasny Proletary plant, numerous motor transportation enterprises) and Teply Stan dominated by motor transportation enterprises, vehicle bases, service stations, and warehouses; thermal power plants: TPP-26, RTS Yuzhnoye Butovo, RTS Krasny Stroitel, RTS Chertanovo, RTS Volkhonka-ZIL, RTS Teply Stan. A small area of the forest park is separated from the mainland by Sevastopolsky Prospect. Practically all the areas adjacent to the forest park are sources of negative anthropogenic impact on its natural complexes: roads (vehicle emissions, stormwater runoff, salt aerosols), residential districts (recreation followed by grass trampling, soil compaction, mechanical damage to trees, flowering grass collection, fires, littering, etc.). Despite this, the area where the forest park is located is one of most sustainable in Moscow in terms of comprehensive assessment of the environment al status, which includes the level of air pollution, the degree of surface water pollution, total soil pollution, etc. This is caused by the following factors: distance from the city center; the absence of powerful sources of environmental pollution in the south-west of the capital and in the south-west Moscow region; relatively high forest cover of the south-western suburbs; favorable direction of the prevailing winds (western transfer prevails).

III. RESULTS

Comparative characteristics of forest plantations show that the predominant species in the forest plantations of the NS Serebryany Bor are softwood species, in particular, Scotch pine. Forest distribution by age groups is as follows: young stands – 15.8%; middle-aged – 40.5%; maturing – 13.4%; mature and overmature – 38.63%. The age structure of the stands in the natural sanctuary is distinguished by diversity in pine plantations only. The majority of pine plantations is represented by trees aged from 90 to 260 years, the age of some specimens is more than three hundred years. The average age of a pine tree in the natural sanctuary is 187 years. The average yield class for all species growing in the natural sanctuary is defined as 1.9 [2]. In Bitsevsky Forest, softwood species are prevailing. The age distribution of forest plantations in the natural-historical park exhibits predominance of mature and overmature trees (45.7%) and an insignificant proportion of young stands (1.2%). The average age of tree stands in specially protected natural areas is 74 years. The average yield class for forest plantations of the natural-historical park is 1.57. In conditions of increased recreational load, these values are optimal for normal growth and development of plantations [11].

Comparative characteristics of the forest plantations in Serebryany Bor and Bitsevsky Forest are presented in Tables 1 and 2.

TABLE I. SPECIES COMPOSITION AND AREAS OF FOREST TREE PLANTATIONS IN NS SEREBRYANY BOR AND NHP BITSEVSKY FOREST

	Pine, ha	**Larch, ha**	**Oak, ha**	**Birch, ha**	**Linden, ha**	**Willow, ha**	**Other, ha**
NS Serebryany Bor	66,84 (61,67%)	1,04 (0,96%)	2,02 (1,87%)	5,47 (5,04%)	3,93 (3,62%)	24,15 (22,28%)	4,97 (4,56%)
NHP Bitsevsky Forest	70,46 (4,93%)	17,2 (1,11%)	205,07 (13,23%)	584, 17 (37, 67%)	473,87 (30,56%)	12,85 (0,83%)	167,18 (10,78%)

TABLE II. RATIO OF AREAS COVERED BY SOFTWOOD AND HARDWOOD PLANTATIONS

S, ha	**With softwood species dominating**	**With hardwood species dominating**	**Total**
NS Serebryany Bor	74,21	38,06	112,27
NHP Bitsevsky Forest	158,94	1391,65	1550,59

In addition to the recreational function, specially protected natural areas perform a protective function. This function implies capture of harmful substances and reduction of the adverse effects of technogenic and other harmful factors. Thus, tree vegetation of specially protected natural territories assimilates carbon dioxide, which is found in large quantities in the air of large cities and megalopolises, in particular, in Moscow due to a large number of vehicles. According to the official data of the Open Data Portal of the Government of Moscow for 2017, the emission of pollutants into the atmospheric air from road transport amounted to more than 845.1 thousand tons [8, 12].

Table 3 presents the total ratio of the stock of wood, and separately softwood and hardwood species growing in the natural sanctuary of regional significance Serebryany Bor and the natural-historical park Bitsevsky Forest.

TABLE III. THE RATIO OF THE STOCK OF WOOD.

V, m³	**With softwood species dominating**		**With hardwood species dominating**		**Total stock of wood**
	Total	***Including ripe and overripe***	***Total***	***Including ripe and overripe***	
NS Serebryany Bor	1292	484	1972	859	3264
NHP Bitsevsky Forest	46548	12932	337143	177576	383691

When calculating the assimilation potential, it is necessary to take into account that an annual increase in biomass of trees and fallen leaves on the forest soil contribute to binding of carbon by the forest ecosystem. Young stands absorb more carbon dioxide increasing their biomass during growth and development. As the ecosystem age increases, the amount of organic matter in the soil increases and the amount of carbon dioxide absorption grows up. Once the ecosystem becomes mature, its ability to absorb carbon dioxide decreases. Mature and overmature forests no longer absorb carbon dioxide, and therefore they are not taken into account in the calculation of the assimilation potential of the forest stands [9, 13].

Data on the absorption capacity of forest-forming species obtained by G.E. Mekush method are presented in Table 4 [9]. Despite the fact that the data are obtained for the forests in Kemerovo region, they can be used to assess the assimilation potential of forests in other regions.

TABLE IV. THE AMOUNT OF CARBON DIOXIDE ABSORBED BY FOREST-FORMING SPECIES.

Forest-forming species	**The amount of CO_2 absorbed, kg/m³**
Pine	750
Spruce	700
Fir	700
Larch	700
Cedar	750
Birch	1600
Aspen	880
Poplar	880
Willow	880

Table 4 presents the amount of carbon dioxide absorbed by the tree during the whole life. Data on the age of wood cutting can be used to calculate the average amount of carbon dioxide absorbed by forest-forming species per year.

The average age of cuttings used in calculations [14]:

- pine – 110 years;
- spruce – 110 years;
- larch – 110 years;
- tall pedunculate oak – 130 years;
- ash – 130 years;
- birch – 75 years;

- common alder – 75 years;
- linden – 75 years;
- low pedunculate oak – 75 years;
- poplar – 55 years;
- aspen – 55 years;
- speckled alder – 55 years.

The calculations revealed that the carbon dioxide absorption capacity of softwood species growing in Serebryany Bor is 330 tons per year, and that of hardwood species amounts to 306 tons per year, which in total gives 636 tons of assimilation potential of tree vegetation.

The assimilation potential of tree vegetation of Bitsevsky Forest in carbon dioxide absorption averages 67715.27 tons per year, of which 12606 tons are assimilated by softwood species and 55109.27 tons are assimilated by hardwood species. Table 5 provides the comparative data.

TABLE V. ASSIMILATION POTENTIAL OF TREE VEGETATION PER YEAR

	Softwood species, tons	**Hardwood species, tons**	**Total, tons**
NS Serebryany Bor	330	306	636
NHP Bitsevsky Forest	12606	55109,27	67715,27

According to the Open Data Portal of the Government of Moscow for 2017, 845.1 thousand tons of pollutants from road transport were emitted into the atmosphere. Based on data on the assimilation potential of tree vegetation of Serebryany Bor and Bitsevsky Forest, which amount to 68,351.27 tons per year, it was calculated that these forest plantations assimilate more than 8% of pollutants per year that are emitted into the atmosphere by transport in Moscow. Moreover, both plantations occupy about 1% (25.36 km^2) of the entire city of Moscow (Bitsevsky Forest – 22.08 km^2, Serebryany Bor – 3.28 km^2), which confirms the value of these specially protected natural territories and their significance for the megapolis [15].

Table 6 shows the absorption of CO_2 per unit area in Serebryany Bor equal to 567.8 t/km^2 and that in Bitsevsky Forest equal to 4368.7 t/km^2.

TABLE VI. ASSIMILATION POTENTIAL OF FOREST PLANTATIONS PER KM^2.

S, km^2	**Total area of specially protected areas, km^2**	**Area covered by forest plantations, km^2**	**Assimilation potential per 1 km^2**
NS Serebryany Bor	3,28	1,12	567,8
NHP Bitsevsky Forest	22,08	15,5	4368,7

IV. CONCLUSION

The assessed assimilation potential of the forest plantations of the natural sanctuary Serebryany Bor and the natural-historical park Bitsevsky Forest is of significant practical value for creation of further strategy for ecological development of the city of Moscow. In addition, this can be used to implement the projects for conservation and development of specially protected natural areas and other natural objects in the territory of a large city.

References

[1] Federal law of 14.03.1995 No. 33-FZ “On specially protected natural territories”.

[2] Department of nature management and environmental protection: nature Monument of regional significance “Serebryany Bor”. Retrieved from: http://www.dpioos.ru/eco/ru/oopt/o_79 (date of application: 13.02.2018).

[3] A.G. Serebryakov, Textbook for the protection of the environment and natural resources. MP Rover, 1999.

[4] B.V. Krasuckii, “Integration of approaches to the study of the assimilation capacity of forest ecosystems in relation to carbon dioxide and its assessment for the Chelyabinsk region”, Problems of geography of the urals and adjacent territories, pp. 221–228, September, 2018 [Problems of geography of the urals and adjacent territories, 296, 2018].

[5] V.V. Kuzmichev, Regularities of forest stand dynamics: principles and models. Novosibirsk: Science, 2013.

[6] S.L. Rysin, Dynamics and stability of recreational forests. Moscow: From-in scientific editions of KMK, 2006.

[7] L.A. Anisimova, V.M. Zubkova, “The Use of woody vegetation in the monitoring of the quality of the environment by the example of natural-historical Park "Bittsevsky wood"”, Environmental problems of technolgoical and ways of solution: materials of the research.-prakt. Conf. masters of FAC. ecology and technosphere. safety RGSU, dedicated. year of ecology in Russia, pp. 5–11, January 2017.

[8] G.E. Mekush, “Experience with evaluation of the carrying capacity of the forests of the Kemerovo region”. On the way to sustainable development of Russia, vol. 51, pp. 43–48, 2010.

[9] E.A. Unruh, “Economic evaluation of the assimilation potential of forests of the Chelyabinsk region for the absorption of carbon dioxide”, Student scientific forum-2013, Chelyabinsk state University, pp. 10–16, 2013.

[10] Resolution of the government of Moscow of September 19, 1995, no. 783 “On integrated development and management system of the territory «Silver Forest»”.

[11] L.A. Anisimova, V.M. Zubkova, “Assessment of the assimilation potential of forest woody vegetation of the natural-historical Park "Bitsevsky forest" for the absorption of carbon dioxide”, Academy of pedagogical ideas "NOVATION", pp. 4–12, 2017.

[12] I.V. Kashin, “Natural resources as part of the national wealth of Russia”, Use and protection of natural resources in Russia, vol. 5, pp. 3–7, 2009.

[13] K.S. Vanina, “Comparative assessment of the assimilation potential of the natural environment of the regions”, Science of the future – youth science, pp. 13–15, September, 2017 [III All-russian scientific forum "Science of the future – youth science", 331 p., 2017].

[14] About establishment of age of cabins: the order of Rosleskhoz of 09.04.2015 no. 105.

[15] Open data portal of the government of Moscow: Dynamics of emissions of pollutants into the air from road transport. Retrieved from: https://data.mos.ru/opendata/7704221753-vybrosy-naibolee-rasprostranennyh-zagryaznyayushchih-atmosferu-veshchestv/row/889001880 (date of application: 13.02.2018).