The recreational and economic role of the suburban landscaped territories in Voronezh

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Abstract. The applicability of the topic is conditioned by the increase the share of the recreational forests and the development of the urban agglomeration. The purpose of the study was to determine the recreational capacity of natural green areas, followed by an ecological and economic assessment. In the work, recreational and sanitary-hygienic assessments were carried out, the stages of digression, the classes of stability of plantings were determined, followed by an ecological and economic assessment of suburban green areas. The weighted average value of the ecological recreational capacity is determined. In plantations with a predominance of oak or pine in the existing types of forest growing conditions, the specific value of the ecological recreational capacity is the same, therefore, approaches to the development of these forests may be the same. To assess the ecological potential of plantings, the content of carbon, absorbed carbon dioxide, and oxygen released by them were calculated. The results of the calculations show that the maximum amount of C2 is observed in mixed stands with a predominance of oak, the minimum-in pure pine stands. Obtained results of the investigation let to realize the forest planning, taking into consideration the results of the eco-economic estimate.

1. Introduction

Urban growth, the proportion of urban populations and an increase in their well-being entail an increase in the recreational impact on urban green spaces and suburban forests. A city with a population of more than one million inhabitants is considered unfavorable in terms of the ecological state of the environment. To improve it, it is necessary to preserve and increase landscaping facilities, which must have significant recreational resources. The intensity and environmental friendliness of the use of these objects are different. This depends on the demand of the population and the degree of regulation of recreational exposure. In the suburban forests, a social form of recreation prevails in the form of mass amateur recreation. Green and forest plantations with their unregulated recreational use reduce recreational qualities and the degree of vitality. Unfavorable changes in forests or deviations in the recreational environment are ubiquitous. Since forests simultaneously perform many functions and the resulting effect manifests itself in different ways over time, it becomes obvious how difficult this object is for economic assessment. In foreign literature on the organization of the recreational use of forests, considerable attention is paid to scientifically grounded zoning of territories for a more rational and integrated use of resources [1,2]. Much work is being done to improve recreational forest management in Germany, Hungary, the Czech Republic and Poland. Such works include - How Much Is the Abandonment of Forest Management in Private Forests Worth? A Case of Poland, Assessing the
Cooling Effect of Four Urban Parks of Different Sizes in a Temperate Continental Climate Zone: Wroclaw (Poland) [1,3,4].

The main function of green infrastructure is to minimize the impact of the anthropogenic factor and enhance its positive impact on the urban environment [3-6]. One of the main tasks of the management of recreational forests is the preservation of nature in such a state in which forest resources do not lose their ability to reproduce. This problem is solved by determining the maximum permissible values of recreational loads, that is, the ecological recreational capacity of each homogeneous landscape area subject to this type of impact. The relevance of the topic is due to the increasing recreational load on suburban forests, the need to organize forest recreation with the condition of preserving the environment and identifying an economic assessment that shows the effectiveness of these forests not only in terms of products, but also in terms of recreational ones. Activities. Therefore, the study of suburban forests is necessary in order to improve their condition, ensure the regulation of recreational impact within the framework of the ecological recreational capacity of forest areas, and ensure effective and high-quality management of territories. The studies presented in the work partially overlap with scientists from many countries, referring to issues of ecology and ecological and economic assessment of plantings.

The purpose of this work was to study natural plantings with the subsequent determination of the recreational capacity of suburban green spaces, with an ecological and economic assessment of the studied plantings with the implementation of their carbon storage and oxygen-producing functions.

2. Methods and material

The object of the study was the northern part of the forest territory of the green zone of the city of Voronezh, adjacent to the Voronezh reservoir in the east, occupying the southern part of the Pravoberezhnoye forestry quarters, which is in greatest demand among the population, population, as it is directly adjacent to the northern part of the city massifs. The object of the study with an area of 102.9 hectares is included in the city limits, but is located on the lands of the forest fund, therefore, the forests cannot be called urban.

The object of study on urban planning zoning refers to the recreational zone and includes forests, the territory of which is located between the M4 highway and the Voronezh reservoir. In addition, these are land plots of an agricultural university and municipal land. The coordinates of the location of the experimental areas: 51.740020 - 39.2244130 - 51.7791670 39.2170160. In addition, these are land plots of an agricultural university and municipal land.

The research object is within walking distance – less than an hour's walk, has good transport accessibility. The main forest-forming species of the object are English oak and Scots pine, which have a significant impact on the ecology of the city, improving sanitary and hygienic and aesthetic conditions.

The maximum permissible and actual recreational loads were found according to the standards developed by Lviv scientists [4], but taking into account the prevailing forms of recreation and landscape accessibility of natural complexes. The stability class of plantings is determined depending on the prevailing breed and the type of forest growing conditions. The degree of change in the forest environment under the influence of recreational use is determined by the stage of recreational digression.

The elements of biological productivity, which are expressed in units of dry matter weight [6], are the initial indicators for the quantitative assessment of oxygen yield and carbon content and the energy invested in the primary production of forest stands.

Using the taxation characteristics of the investigated forest area, dividing the indicator of wood stock by the age of the stand, the average growth of the stand was obtained. Multiplying by the indicator of the conditional density of wood (depending on the type of wood) (oak -0.550, birch - 0.500), we calculate the indicator of dry matter mass.

The mass of leaves was determined using the average statistical data on the proportion of fractions 10-15% of the total stock of phytomass. The area of the leaves is the product of the norm by the mass of the leaves. To calculate environmental indicators, it is necessary to add up the total stock of phytomass and wood, multiplied by the standards of environmental indicators.
3. Results and discussion

Forests have significant recreational value, characterized by the following indicators: content and form of a stand, predominating species, existence of glades and margins, water bodies, natural and cultural monuments, elements of redevelopment, pollution, passability, diversion of land forms and deficiency of forests. To reveal the influence of the recreational impact, the resistance class with the consideration of predominating species and type of forest site were defined. Taking into account predominating forms of the recreation and landscape accessibility of natural complexes, maximum allowable and actual recreational load was found (table 1).

| Stage of digression | Resistance class |
|---------------------|------------------|
|                     | 1                |
|                     | 2                |
|                     | 3                |
|                     | 4                |
|                     | 5                |
| 1                   | 1.5              |
| 0-3.0               |
| 0-2.0               |
| 0-1.2               |
| 0-0.7               |
| 0-0.3               |
| 2                   | 3.0              |
| 0-4.0               |
| 2.5-5.0             |
| 1.0-2.0             |
| 0.7-1.4             |
| 0.5-1.0             |
| 3                   | 6.0-10.0         |
| 2.5-5.0             |
| 1.0-2.5             |
| 0.7-1.4             |
| 0.5-1.0             |
| 4                   | 17.8-35.5        |
| 12.0-23.8           |
| 7.5-15.0            |
| 4.0-8.0             |
| 2.5-4.0             |
| 2                   | 26.6             |
| 17.9                |
| 11.2                |
| 6.5                 |
| 3.1                 |
| 5                   | 47.1             |
| 31.7                |
| 20.0                |
| 11.5                |
| 5.5                 |
| 3                  | 35.5-58.8        |
| 23.8-39.6           |
| 15.0-25.0           |
| 8.7-14.4            |
| 4.2-6.8             |

*Note: the average value of the recreational load in the off-road form of recreation for a certain stage of digression, in the denominator – the range of changes in these loads in the process of constant and continuous impact on natural complexes.

The stages of recreational digression violation of the environment) of the forest environment were also identified, the first stage is characterized as an undisturbed environment with normal growth and development of trees and shrubs, with mossy and grass cover typical for this type of forest. A further increase of the digression stage leads to changes in the forest environment, which degrades, reaching the fifth stage.

The object of the investigation gas the following types of forest site: fresh subor (S2), fresh hardwood forest type (H2), transient type of forest sites (SD2) – sudubrava, oakwood (O2). At the same time, there are areas with a predominance of both pedunculate oak and Scots pine. During the investigation, it was determined that the stands had resistance classes 2, 3 and 4 and reached the first three stages of recreational digression. Based on the values of the stability class and the digression stage, the actual recreational load was determined. The form of recreation and the coefficient of landscape accessibility were also taken into account. The predominant type of recreational use of the object's forests is public recreation in the form of mass amateur recreation [6-8], the accessibility coefficient was 1.0.

The maximum permissible recreational load for the second resistance class was 12.0 people-day/ha, for the third class – 7.5 people-day/ha, for the fourth class – 4.4 people-day/ha of the roadless form of recreation for oak and pine stands (table 1). For a more complete study of the recreational impact, the arithmetic mean values of the load in people-days/ha and the weighted average indicators, taking into account the area of allotments, were compared (table 2).
Table 2. Indicators of ecological recreational capacity and actual load in the off-road form of recreation in different types of forest-growing conditions and full landscape accessibility of people-days/ha.

| Indexes                     | Type of the forest site | Predominant species | On the object of the investigation |
|-----------------------------|-------------------------|---------------------|-----------------------------------|
|                             | O₂ H₂ S₂ SD₂            | oak     | pine     | o₂ H₂ S₂ SD₂                     |
| Arithmetic mean values      |                         |         |          |                                  |
| of the actual recreational  | 6.98 3.5 3.9 0.6        | 2.78    | 3.6      | 3.2                              |
| load                        | 4.4-9.5 2.1-4.9 2.2-5.8 | 1.66-3.9 | 2.1-5.38 | 1.9-4.5                          |
| Ecological recreational     |                         |         |          |                                  |
| capacity                    | 12 7.7 6.7 7.5          | 7.8     | 7.8      | 8.4                              |
| Weighted average values     |                         |         |          |                                  |
| of the actual recreational  | 4.8 2.8 2.7 0.6         | 3.6     | 2.4      | 2.7                              |
| load                        | 3.2-6.4 1.8-3.9 1.7-3.9 | 2.1-4.5 | 1.5-3.5 | 1.7-3.7                          |

The results of table 2 show that plantings in the type of forest growing conditions D₂ (oak forests) are exposed to greater recreational effects, since the arithmetic mean value of the actual load is 2 times higher than in the conditions of snowdrifts, 1.8 times higher than in fresh suborns, and 11 times higher than in sudubrava. Also, the ecological recreational capacity and the actual recreational load in D₂ exceeds these indicators in other conditions [9-12].

The recreational estimate of the territory of the object of the investigation was 64 points out of 110 maximally possible, therefore, there are opportunities for its improvement.

The obtained results allow us to approach the environmental and economic estimate. The cost of recreational forests, as well as any other natural resources, should directly depend on the quality of their main functions, in this case – recreational and sanitary-hygienic.

The next stage was the ecological and economic estimate of the studied suburban landscaped territories. The ecological and economic estimate of urban forests was based on the estimate of the carbon-retention and oxygen-disengagement functions of stands. To determine the carbon content in the components of the stand, the stock of phytomass is determined. After determining the stock of phytomass using the coefficients of the carbon content in the absolutely dry substance of phytomass, phytomass in each component of the stand, including the grass cover, was calculated.

The initial data for assessing the oxygen-disengagement and carbon-retention functions in forest ecosystems are the elements of biological productivity, which are expressed in weight units of absolutely dry substance (table 3). Changes in the carbon-retention and oxygen-disengagement functions of the stand depend on the age dynamics of the phytomass of the stand (table 4).

In the investigated suburban forests, the maximum amount of carbon in phytomass of the stand is noted in compartment 45, subcompartment 2 – 7538 t/ha, the minimum 18 t/ha – in the pure stands of Scots pine (compartment 42, subcompartment 26). Thus, pure stands have the lowest carbon retention, which affects the content, growth and productivity of the stands. Regardless of the species composition and age of the stands, carbon is redistributed in the components of phytomass. Most of it is contained in the stem part (57%), in the branches of the crown – 33%, about 7% – in the roots, and in the leaves – about 3%.
Table 3. Absolutely dry mass of the stands.

| No. quart/s | Composition | Age, years | T, F, S | Stock m³/ha/annual increment/nominal density, t/m³ | Phytomass, t/ha |
|-------------|-------------|------------|---------|-------------------------------------------------|-----------------|
|             | Object of the investigation | stem | c. branches | roots | leaves | total |
| 55/2        | 6O2A1Mp1Ln  | 78 | O₂ | 260/3.33/2.17 | 565 | 113 | 85 | 23 | 786 |
| 54/44       | 802MpALn   | 120 | H₂ | 200/1.66/1.63 | 326 | 65 | 48 | 13 | 453 |
| 54/34       | 100AmpLn   | 120 | 2S₂ | 40/0.53/0.55 | 22 | 13 | 4 | 1 | 31 |
| 54/46       | 100MpLn    | 120 | H₂ | 80/0.66/0.55 | 44 | 9 | 7 | 2 | 61 |
| 54/36       | 100MpLn    | 120 | 2S₂ | 40/0.33/0.55 | 22 | 4 | 3 | 1 | 31 |
| 54/30       | 100ALnMp   | 120 | S₂ | 100/0.83/0.55 | 55 | 11 | 8 | 2 | 76 |
| 55/5        | 100ALn     | 130 | H₂ | 40/0.30/0.55 | 22 | 4 | 3 | 1 | 31 |
| 52/26       | 4O4Ln1Mp   | 130 | SD₂ | 210/1.61/1.63 | 342 | 68 | 51 | 14 | 476 |
| 50/72       | 802An+B    | 100 | H₂ | 110/1.1/1.71 | 188 | 37 | 28 | 8 | 261 |
| 51/22       | 10O        | 130 | H₂ | 120/0.92/0.55 | 66 | 13 | 10 | 3 | 92 |
| 51/29       | 901ALnMp   | 110 | SD₂ | 390/3.54/1.63 | 636 | 127 | 95 | 25 | 884 |
| 49/19       | 502A2Ln 1Mp | 130 | S₂ | 460/3.53/2.17 | 1000 | 200 | 150 | 40 | 1390 |
| 46/6        | 7O2An1LnB Mp | 110 | S₂ | 170/1.54/2.79 | 474 | 94 | 71 | 18 | 659 |
| 47/2        | 7O2Ln1AMp  | 110 | H₂ | 450/4.09/2.17 | 978 | 195 | 146 | 39 | 1359 |
| 48/23       | 7O2An1Ln   | 130 | S₂ | 140/2.22/1.59 | 222 | 44 | 33 | 8 | 309 |
| 44/10       | 901B      | 100 | O₂ | 480/4.8/1.2 | 576 | 115 | 86 | 23 | 800 |
| 46/9        | 7O2An1LnB  | 110 | H₂ | 1100/10/2.24 | 2464 | 492 | 369 | 98 | 3424 |
| 44/30       | 901B+An   | 100 | O₂ | 320/3.2/1.71 | 547 | 109 | 82 | 21 | 760 |
| 45/2        | 404Ln2MpAA n | 110 | O₂ | 2300/20.90/2.14 | 4926 | 985 | 738 | 197 | 6847 |
| 43/4        | 6O2Ln2MpA | 110 | O₂ | 730/6.63/2.17 | 1587 | 317 | 238 | 63 | 2205 |
| 46/21       | 9O1AnLnMp  | 110 | S₂ | 270/2.45/2.14 | 578 | 115 | 86 | 23 | 803 |
| 46/8        | 8P2O+B    | 110 | S₂ | 420/3.81/1.6 | 672 | 134 | 100 | 26 | 934 |
| 48/22       | 5O4An1Ln,P,B | 67 | S₂ | 150/2.23/2.64 | 396 | 79 | 59 | 15 | 550 |
| 42/19       | 10P        | 33 | H₂ | 70/2.12/0.40 | 28 | 5 | 4 | 1 | 38 |
| 42/26       | 10P        | 65 | H₂ | 30/0.46/0.4 | 12 | 2 | 2 | 1 | 16 |
| 42/12       | 8P1B1O    | 90 | H₂ | 490/5.44/1.6 | 784 | 156 | 117 | 31 | 1089 |
| 42/32       | 6O4An     | 73 | H₂ | 60/0.82/1.06 | 63 | 13 | 9 | 3 | 88 |
| 43/7        | 9O1B+Ln   | 110 | H₂ | 600/5.45/1.59 | 954 | 190 | 143 | 38 | 1326 |
| 43/24       | 4O3B1A1LnMp+An | 110 | H₂ | 370/3.36/3.33 | 1233 | 8 | 246 | 185 | 49 | 1714 |
| 47/4        | 7O1A1Mp1Ln | 110 | H₂ | 350/3.18/2.17 | 760 | 152 | 114 | 30 | 1057 |

*Note: O – oak, A – ash, Mp – maple, Ln – linden, An – aspen, B – birch, P – pine*
According to the oxygen content in phytomass of the stand of the object of the investigation, it is also noted in compartment 45, subcompartment 2 – 20,741 t/ha. The minimum accumulation of oxygen is in 42 compartment, and subcompartment 26 – 51 t/ha. Carbon dioxide emissions from the phytomass of the investigated plantations are shown in table 5.
Table 5. CO₂ disengagement from phytomass of the stands.

| No. comp./ No. subcomp. | CO₂ disengagement from phytomass, t/ha |
|-------------------------|----------------------------------------|
|                         | stem | crown | branches | roots | leaves | total  |
| 55/2                    | 1904 | 1017  |          | 203   | 153    | 3279   |
| 54/44                   | 1099 | 587   |          | 117   | 88     | 1893   |
| 54/34                   | 74   | 39    |          | 7     | 5      | 127    |
| 54/46                   | 148  | 79    |          | 15    | 11     | 255    |
| 54/36                   | 74   | 39    |          | 7     | 5      | 127    |
| 54/30                   | 185  | 99    |          | 19    | 14     | 319    |
| 55/5                    | 74   | 39    |          | 7     | 5      | 127    |
| 52/26                   | 1154 | 616   |          | 123   | 93     | 1988   |
| 50/72                   | 633  | 338   |          | 67    | 51     | 1091   |
| 51/22                   | 222  | 118   |          | 23    | 17     | 382    |
| 51/29                   | 2144 | 1145  |          | 229   | 173    | 3692   |
| 49/19                   | 3370 | 1800  |          | 360   | 272    | 5802   |
| 46/6                    | 1599 | 854   |          | 170   | 129    | 2753   |
| 47/2                    | 3296 | 1760  |          | 352   | 266    | 5676   |
| 48/23                   | 750  | 400   |          | 80    | 60     | 1291   |
| 44/10                   | 1941 | 1036  |          | 207   | 156    | 3341   |
| 46/9                    | 8303 | 4435  |          | 887   | 670    | 14,296 |
| 44/30                   | 1844 | 984   |          | 196   | 148    | 3174   |
| 45/2                    | 16602| 8867  |          | 1773  | 1340   | 28,584 |
| 43/4                    | 5348 | 2856  |          | 571   | 431    | 9207   |
| 46/21                   | 1949 | 1041  |          | 208   | 157    | 3355   |
| 46/8                    | 2264 | 1209  |          | 241   | 182    | 3898   |
| 48/22                   | 1334 | 712   |          | 142   | 107    | 2297   |
| 42/19                   | 94   | 50    |          | 10    | 7      | 162    |
| 42/26                   | 40   | 21    |          | 4     | 3      | 69     |
| 42/12                   | 2642 | 1411  |          | 282   | 213    | 4548   |
| 42/32                   | 214  | 114   |          | 22    | 17     | 369    |
| 43/7                    | 3214 | 1717  |          | 343   | 259    | 5535   |
| 43/24                   | 4157 | 2220  |          | 444   | 335    | 7157   |
| 47/4                    | 2564 | 1369  |          | 273   | 206    | 4414   |

Carbon-retention is accompanied by carbon dioxide absorption and oxygen disengagement. The maximum amount of carbon dioxide is also absorbed in compartment 45, subcompartment 2 – 28584 t/ha. The minimum amount is absorbed in compartment 42, subcompartment 26 – only 70 t/ha. The obtained results allow us to estimate the annual absorption of carbon dioxide and disengagement of oxygen in the researching stands [13-15]. To estimate stands from an economic point of view, the assessment of urban forests began with the determination of stocks of non-wood forest products. Reference and normative sources for the Voronezh Region were used for the assessment [16]. The stock of non-wood forest products was determined using inventorial descriptions. The amount of leaves was calculated using reference and normative material per 1 m³ of stem wood. Multiplying the stock of stem wood by subcompartments by the corresponding standard, we got a stock of resources. The yield of
leaves, tannic bark is calculated similarly, through the stock of stands. After determining the stock of non-wood forest products, the mass of leaves was calculated.

Dust retention is nothing more than the product of the leaf area by the standard of the main species in the composition (oak – 12, pine – 6).

O2 and bioactive substances disengagement was determined by multiplying the corresponding standards of each species (oak disengages oxygen per 1 ton of dry substance, 1400 kg, pine disengages 1390 kg, oak disengages 20 kg of bioactive substances with 1 kg of leaf mass, pine disengages 40 kg) as part of the stands in subcompartment by phytomass. On the territory of urban forests of the Right-Bank Forestry of the Voronezh region, on an area of 102.9 hectares, 39,967 kg of O2 can be disengaged, 571 tons of bioactive substances, and the dust retention will be 12,108 kg.

Further, using the rates of payment per unit volume of forest resources taken from the resolution of the Voronezh Region Administration of 27.05.2008 No. 436, we calculated the total cost of non-wood forest products (pine paw) – 42,076 rubles.

After determining the cost of non-wood forest products, an economic estimate of forest land was made, taking into account the predominating type of the forest, type of the forest site in which the stands grow and the differential rent. The economic value of land is equal to the product of the average increase in stands by the present rent. The differential rent is measured in rubles per 1 m³ and depends on the type of forest site in which the stands grow (D₂, C₂), the average growth (3.4 and 2.9). The economic value of the land is 4872.6 thousand rubles.

The rate of payment per unit area of a forest plot, to perform research activities, educational activities on the territory of the Right-Bank Forestry on an area of 102.9 hectares (1.07 rubles per hectare per year) will be 110,103 rubles per year. ‘Performing recreational activities’ involves investing and receiving direct income. The social form of recreation in the form of mass amateur recreation does not apply to the implementation of activities. This is the use of forests with an indirect effect in the field of production.

For recreational use, the rate of payment per unit area of a forest plot per year is 1,009,644 rubles per year.

4. Conclusion
The study is intended to determine ecological capacities and assess the actual recreational loads, as well as to determine the economic estimate, taking into account the prevailing type of forest, forest site.

Regulation of recreational use is a land relationship that should be performed considering the biological properties of forest-forming species – oak and pine, ecological recreational capacity of territories and the characteristics of types and forms of recreation.

The efficiency of carbon-retention and oxygen-disengagement functions of stands is directly dependent on their phytomass. At the age of 33 to 130 years, the stands perform their ecological functions quite well, which is due to the more intensive production of phytomass.

The economic estimate demonstrated that in the studied suburban green areas of Voronezh, with an area of 102.9 hectares, the stands are able to disengage 39,967,093 tons of O₂, 571 tons of bioactive substances, and the dust retention is 12,108 kg.

On the territory of the object of the investigation, it is possible to harvest one type of non-wood forest products – pine paw, which costs 42,076 rubles.

The economic estimate of the forest lands of the object of the investigation, taking into account the predominating type of forest, type of forest site and differential rent, will be 4872.6 thousand rubles.

On the territory of the object of the investigation, it is possible to perform research activities, educational activities, the rent will be 110,103 rubles per year. For recreational use, the rate of payment per unit area of the forest plot is 1,009,644 rubles per year.
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