Environmental assessment of recreational value on pine biogeocenoses in Somovsky forest (Voronezh region, Russia)

D Timashchuk
Faculty of Forestry, Voronezh State University of Forestry and Technologies named after G.F. Morozov, 8 Timiryazeva Street, Voronezh, 394087, Russian Federation
E-mail: timashchuk90@mail.ru

Abstract. Currently, recreation is the most common use of natural areas. Silvicultural assessment of the state and stability of pine biogeocenoses has been used for conducting a systematic analysis of the recreational potential of forest areas exposed to recreational impact. Functional recreational zones in various categories of recreational landscape are highlighted. The results show that species diversity of underwood trees decreases, projective cover of the ground cover and proportion of forest species increases, specific resistance of the upper soil layer grows with an increase in the recreational load. Specific resistivity is 20.5 kg/cm² at a depth of 20-25 cm while approximately equal resistance is already observed at a depth of 3-5 cm in the fifth type section (forest road). Unsatisfactory organization of landscape structure has led to a decrease in sustainability in forest ecosystems of the Somovsky forest district. The chosen forest landscape category occupies 6,262 ha on the territory of the Somovsky forest district, forest-park area – 2,912 ha, the subzone of "Organized Mass Leisure" – 46.5 ha, the subzone of “Beach recreation” – 113.5 ha, the subzone of “Mass flashpacking recreation” – 2,752 ha. The obtained data indicate the necessity to introduce the regulation modes for recreational use of Somovsky forest district territory.

1. Introduction
Recreational use of natural territories is increasing around the world [1]. However, recreational activities and infrastructure provided to them can also have a negative environmental impact if they are not designed and managed effectively. Despite rapid worldwide urbanization, environmental studies of the impact of recreational activities in natural areas are behind the similar studies in protected areas [1]. Recreational load causes decrease in vegetation cover, change in its species composition as a result of trampling [2], changes in soil compaction [3], appearance of many types of weeds and pathogenic microorganisms [4], and disturbance of forest ecosystems [5].

The aim of the study is to conduct a systematic analysis of the recreational potential of forest areas exposed to recreational impact.

2. Material and methods
The objects of our research are located in natural and artificial pine stands of suburb forests of Voronezh city (Somovsky forest of the Voronezh region, Russia), which are popular recreation areas for citizens, that is, these forests perform recreational functions.

Test plots were laid in Scots pine plantations with a small admixture of birch in the summer of 2013 in Borovoe natural boundary (geographical coordinates 51°65′ N, 39°32′ E) and Maklok natural boundary (geographical coordinates 51°77′ N and 39°34′ E). In the summer of 2014, natural and artificial
pine stands of this forestry, growing on the territory of Lesnaya Skazka (51°53' N, 39°22' E) and Kominternovets (51°49' N, 39°23' E) tourist bases were taken as an object of the research.

Taxation indicators were determined (table 1) in 10 permanent sample plots (PRP) in accordance with generally accepted forestry methods [6]. Recreational loads were calculated, forest renewal process was studied, living ground cover was investigated and recreational potential was assessed. A soil density research (when determining the degree of recreational load influence on forest biogeocenosis) was carried out by Revyakin hardness-testing machine using the technique by S.M. Matveev [7].

**Table 1. Taxation characteristics of test plots of Scots pine in Somovsky forest (Voronezh region).**

| Quarter / Stratum | Stage of recreation al digression | Composition of tree species, % | Age, years | Growth class | $h^*$, m | $dbh^*$, cm | f |
|-------------------|---------------------------------|-------------------------------|------------|--------------|----------|-------------|---|
| 12/6              | I,5                             | 100%                          | 100        | I            | 27       | 38          | 0.73 |
| 7/30              | III                             | 100%                          | 100        | II           | 25       | 37          | 0.61 |
| 7/30              | IV                              | 100%                          | 100        | II           | 25       | 36          | 0.52 |
| 28/23             | I,5                             | 100%                          | 64         | I*           | 27       | 28          | 0.60 |
| 28/23             | III                             | 100%                          | 70         | I            | 24       | 25          | 0.57 |
| 172/3             | III,5                           | 100%                          | 50         | I*           | 23       | 26          | 0.51 |
| 172/3             | IV                              | 100%                          | 52         | I*           | 24       | 27          | 0.60 |
| 26/15             | III                             | 100%                          | 100        | II           | 26       | 28          | 0.50 |
| 26/15             | IV                              | 100%                          | 100        | II           | 25       | 28          | 0.63 |
| 26/17             | I,5                             | 100%                          | 100        | I            | 26       | 32          | 0.70 |

*Note: $h^*$ – mean height; $dbh^*$ – mean quadratic breast height diameter; $f$ – density of tree placement in the PRP (corresponds to the canopy density).

Recreational assessment of forest resources was carried out according to 25 indicators, which were combined into three main groups: forest attractiveness, comfort for recreation and resistance to recreational identification. All the indicators are evaluated on a 5-point system [8]. A differentiated assessment of recreational potential of research objects has been carried out. All recreational potential parameters were divided into eight groups, characterized by the physical quantities:

$$ RP = \sum_{i=1}^{5} CP + \sum_{i=2}^{3} FR + \sum_{i=1}^{4} Wt + \sum_{i=1}^{1} FAGR + \sum_{i=1}^{2} W + \sum_{i=1}^{2} BL + \sum_{i=1}^{2} SPL + \sum_{i=1}^{4} R $$  \hspace{1cm} (1)

where, $RP$ – recreational potential of natural landscape; $CP$ – climate-forcing parameters; $FR$ – recreational capacity of forests; $Wt$ – water resources; $FAGR$ – forest-agrarian landscapes; $W$ – wild animals; $BL$ – balneological resources; $SPL$ - speleological resources; and $R$ – relief. These indicators are taken as diagnostic signs. The scores point was calculated by the equation (2):

$$ P = \frac{Pa \times 100}{Ps} $$  \hspace{1cm} (2)

where, $P$ – score point; $Pa$ – the actual value of the score point of estimated stand; $Ps$ – the value of the same indicator; taken as the standard (the maximum (optimal) value is taken as the standard).

In the frames of differentiated approach, the total estimated score point was determined as the weighted average of the correlation coefficient between the diagnostic parameters of individual indicators:

$$ Ps = \frac{b_1 r_1 + b_2 r_2 + \cdots + b_n r_n}{r_1 + r_2 + \cdots + r_n} $$  \hspace{1cm} (3)
where, $P_s$ – total estimated score point; $b_1, b_2, b_n$ – points of individual indicators of plantations; and $r_1, r_2, r_n$ – correlation coefficients.

This method of allocating points made it possible to take into account the participation share of each diagnostic indicator of the stands in the formation of the ecological productivity. The sum of all indicators was taken for 100 points according to which the recreational potential was determined at their maximum value [8].

The research of recreational loads on natural forest complexes was carried out on functional zones and stages of forest stand digression according to 56-100-95 Industrial Standard [9]. Evaluation of recreational loads was carried out according to the tables of S.A. Gensiruk, M.S. Nizhnik, R.R. Wozniak [10] based on the stability of natural complexes in the lowland conditions. Allocation of functional areas was carried out according to the method of M.T. Serikov [11] in keeping with the organizational and economic activities in various categories of the recreational landscape of green areas. The cartographic diagram of functional zones was built using MapInfo Profession program. [17].

3. Results and discussion

One stage of recreational digression predominates within each test plot; and the stages from I to IV are examined. If different stages of digression took place on the territory of one forest-taxation section, then it was further divided into homogeneous landscape areas according to this feature, in which test plots were laid. At the same time, I and II stages of digression (minor violations of forest environment) were not territorially separated.

The analysis of sanitary condition of trees on test plots at different stages of recreational digression has showed that the weighted average of the state category of tree stands increases from I to IV stage of digression and reaches III, 5. Respectively, the stands at this stage fall into the category of “severely weakened”. There is a decrease in stock of I category (with no signs of weakening) with increasing recreational effects. The variability coefficient of the number of trees of different state categories (C) at stage IV of digression reaches 30%, which shows the uneven distribution of the number of trees by categories of state. When analyzing the reliability of the data by the Student’s criterion (t), the actual values (tact) were obtained for each stage of digression exceeding the standard $t_{st}$ value. I.e. mean values of state categories are determined reliably. Significant differences between stages of recreational digression are essential.

From 4,500 to 10,000 units/ha of viable undergrowth of different ages (figure 1) are observed at stage I of digression (undisturbed stands), and there are from 6 to 10 species of trees and shrubs (European hazel (Corylus avellana L.), wartybark euonymus (Euonymus verrucosus Scop.), mountain ash (Sorbus aucuparia L.) etc.) in undergrowth composition; understory and undergrowth are evenly distributed over the area, the ground cover mainly consists of forest species (May lily (Convallaria majalis L.), hedge strawberry (Fragaria vesca L.), lady fern (Athýrium fílix-fémina L.) etc). Meadow and weed species are at sites of all the stages of recreational digression, but their share increases with increasing recreational load. Understory is absent at IV stage of digression, undergrowth is located in clumps and the number of species which are poorly resistant to compaction reduces significantly (European hazel (Corylus avellana L.), wartybark euonymus (Euonymus verrucosus Scop.), weed and gramineous vegetation prevails: greater celandine (Chelidónium május L.), common dandelion (Taráxacum officinále Wigg.), sedge (Carex pilosa Scop.), and bush grass (Calamagróstis epigéios L.). Cole [13] assesses the response of vegetation to trampling, based on the dominant influence in the vegetation type of gramineous weeds. Therefore, access to recreants is an important factor for monitoring, especially in the areas with a high recreational load. The percentage ratio (by area) of five types of plots is determined within each test area in accordance with the classification developed by S.M. Matveev [7]. An increase in the specific resistance of the upper soil layers from type 1a (undisturbed area, near-stem part) to type 5 (forest road) at any depth (within the limits of measurements) was revealed. The difference in soil resistivity in subtypes: a) (near-stem part) and b) (intertree part) in type 1 (undisturbed area) is small and disappears at the depth of 20-25 cm. In type 2 (weakly broken area) this difference is higher, in type 3 (heavily disturbed area) the difference between the subtypes is significant. The soil resistivity ($S_r$) in
type 1 reaches 20.5 kg/cm² at the depth of 20-25 cm. In type 5 (forest road), Sᵣ is 20.5 kg/cm² at the depth of 3-5 cm.

Restoration of areas varies significantly depending on the nature of the impact and the type of ecosystem, but in general, deterioration occurs much faster than restoration. Residual trampling effects were observed 30 years later at Glacier National Park, MT [14] and over 42 years at Rocky Mountain National Park, CO [15]. However, Marion and Cole [16] report irrefutable evidence of vegetation disturbances and significant soil compaction in the areas in the eastern United States only after six years, although the composition and condition of the vegetation remained quite different from the undisturbed control plots. As a field of study, recreation includes the impact of recreation activities on forest ecosystems in general. The two main references in this area, Hammitt and Cole [18] and Liddle [19], describe recreation as a study of the effects of recreation activities on natural environment.

Estimation of recreational value coefficient (RVC) is determined by three indicators: forest attractiveness (FA), comfort for tourists (CT) and resistance to recreational impact (RRI). It indicates the average quality of landscapes state of Somovsky forest in the Voronezh region (table 2).

| Quarter Stratum | Area, ha | Forest attractiveness | Comfort for tourists | Resistance to recreational impact |
|-----------------|---------|----------------------|----------------------|----------------------------------|
| 7               | 0.5     | 0.42±0.012           | 0.56±0.017           | 0.50±0.015                       |
| 30              | 1.0     | 0.38±0.019           | 0.56±0.018           | 0.44±0.013                       |
| 12              | 1.0     | 0.68±0.020           | 0.65±0.007           | 0.67±0.018                       |
| 6               | 0.5     | 0.70±0.022           | 0.72±0.005           | 0.50±0.020                       |
| 172             | 1.0     | 0.48±0.009           | 0.55±0.036           | 0.58±0.008                       |
| 3               | 1.0     | 0.47±0.007           | 0.57±0.042           | 0.60±0.005                       |
| 26              | 0.5     | 0.54±0.013           | 0.60±0.044           | 0.51±0.002                       |
| 15              | 1.0     | 0.50±0.015           | 0.61±0.021           | 0.42±0.011                       |
| 26              | 1.0     | 0.72±0.013           | 0.73±0.018           | 0.67±0.019                       |
| Average         |         | 0.52                 | 0.63                 | 0.53                             |

The calculated coefficients are in the range of 0.38-0.72. It was revealed that the class of sanitary-hygienic assessment of plantings decreases to the second stage in the places visited by recreants (II-IV stage of digression), the result of which is the littered territory. High values of coefficients are typical for areas which are not subjected to intensive recreational load. Lower coefficients of recreational value at IV stage of digression are caused by the sanitary condition of the trees, the lack of undergrowth, and the prevalence of weeds and gramineous vegetation. The third class of resistance to recreational loads prevails on the whole territory of the object, as pine grows mainly under B₂ conditions. The forest-park category of recreational landscape is characterized by a weak intensity of recreant visits due to the lack of a road-path network. Leisure activities which are natural for "picking" form of recreation (fishing, pick berries and mushrooms in the forest, etc.) prevail.

Test plots in the forest-park category of recreational landscape were divided into several subzones: "Organized mass leisure", "Mass flashpacking recreation" and "Beach recreation". The objects of our research in Maklok natural boundary are included in the functional subzone "Mass flashpacking recreation." Forest areas with the III and IV stages of digression, located in the zone of recreational impact of Lesnaya Skazka and Kominternovets camp sites, are included in the functional subzone "Organized Mass Leisure". Their plots with stages I and II of digression are assigned to the subzone of "Mass flashpacking recreation", as well as all the objects of research of Borovoe natural boundary. The forest category of the landscape is 6,262 ha (68.3%), and the forest-park category is
2,912 ha (31.7%), “Organized mass leisure” subzone takes 46.5 ha (0.5%), “Beach recreation”- 113.5 ha (1.2%), “Mass flashpacking recreation”- 2,752 ha (30%).

Table 3. Quantitative assessment of the actual use of recreational potential of Scots pine in Somovsky forest, Voronezh region (forest-park landscape category (subzones of mass organized and mass flashpacking recreation, selectively) with a predominance of a picnic form of recreation, E = 7).

| Quarter | Stratum | Area, ha | Species composition | Recreation digression stage | max allowable per 1 ha | per plot | actual per 1 ha | per plot |
|---------|---------|----------|----------------------|-----------------------------|------------------------|----------|----------------|----------|
| 7       | 30      | 0.5      | 100%                 | III                         | 7.5                    | 0.5      | 5.0            | 0.4      |
|         |         |          |                      |                             | 2.5-7.5                | 0.2-0.5  |
|         |         | 1.0      | 100%                 | IV                          | 7.5                    | 1.1      | 11.2           | 1.6      |
|         |         |          |                      |                             | 7.5-15.0               | 1.1-2.1  |
| 12      | 6       | 1.0      | 100%                 | I,5                         | 7.5                    | 1.1      | 12             | 0.2      |
|         |         |          |                      |                             | 0.6-1.8                | 0.1-0.2  |
| 28      | 23      | 1.0      | 100%                 | I,5                         | 7.5                    | 1.1      | 12             | 0.2      |
|         |         |          |                      |                             | 0.6-1.8                | 0.1-0.2  |
| 172     | 3       | 1.0      | 100%                 | III,5                       | 7.5                    | 1.1      | 11.2           | 1.6      |
|         |         |          |                      |                             | 7.5-15.0               | 1.1-2.1  |
| 26      | 15      | 0.5      | 100%                 | III                         | 7.5                    | 0.5      | 5.0            | 0.4      |
|         |         |          |                      |                             | 2.5-7.5                | 0.2-0.5  |
| 26      | 17      | 1.0      | 100%                 | I,5                         | 7.5                    | 1.1      | 12             | 0.2      |
|         |         |          |                      |                             | 0.6-1.8                | 0.1-0.2  |
| Total   |         | 10.0     |                      | 9.2                         |                        | 7.8      | 4.8-10.0       |

Note: Recreational load: the numerator - the average value, the denominator - the limits of value variation; per 1 hectare - for roadless (basic) form of recreation, per plot - taking into account the prevailing form of recreation.

When calculating the ecological recreational capacity of the forest areas studied, the following indicators were taken into account: the coefficient of landscape accessibility, the resistance class to recreational loads, the coefficient of environmental impact, depending on the prevailing forms of recreation. As a result, it was possible to calculate the values of the maximum permissible and actual recreational loads (by stages of recreational digression) for the forest category of the recreational landscape as a whole and for each plot of the forest-park category (table 3).

Thus, the total maximum permissible recreational load on 10 hectares of sample plots laid selectively in the natural part of the functional zone “Forest-Park Category of Recreational Landscape”, taking into account the prevailing picnic form of recreation, was 9.2 man-day with an average actual recreational load of 7.8 (varies from 4.8 to 10.0) man-day. Consequently, actual recreational load (on average) does not exceed the value of the ecological recreational capacity. The situation is aggravated by the fact that the fourth stage of recreational digression, i.e. the onset of degradation of the natural complexes (quarter 7, stratum 30; quarter 172, stratum 3; quarter 26, stratum 15) is seen on three plots with a total area of 3 hectares. In some areas the load exceeds the maximum permissible norms during the peak of the
recreational season. Strict regulation of the recreational use of the forests is required in this functional zone, up to a temporary complete elimination of sites with IV stage of digression from recreation process and carrying out restoration activities.

The maximum permissible recreational load for the entire functional zone “Forest-park category of the recreational landscape”, taking into account the prevailing "picking" form of recreation, amounted to 23,484 man-day with an average actual recreational load of 3,757 (with fluctuations from 1,879 to 5,636) man-days. Consequently, the actual recreational load does not exceed the value of the ecological recreational capacity even during the peak of the recreational season in this functional zone, that is, there is a significant supply of unused recreational potential – 17,848 man-days (23,484 – 5,636) of "picking" recreation forms or 5,100 man-days of, for example, picnic forms of recreation. Indicators of recreational use of forests are presented in Figure 1.

![Figure 1. Indicators of recreational use of forests.](image)

A table of attributive information was created [17] in MapInfo Profession geographic information system, containing information on the belonging of forest allocation units to one or another territorial functional difference. Creation of a thematic map (figure 2) illustrates the distribution of Somovsky forest by categories of recreational landscape and predominant forms of recreational forest use, which formed the basis of functional recreational zoning of this territory. Despite the fact that the actual recreational load does not exceed the value of its ecological recreational capacity in the surveyed area of Somovsky forest, that is, there is a reserve of unused recreational resources, it is necessary to introduce regulation modes for recreational use of this territory, as there are local manifestations of the onset of forest degradation, and there is underutilization of the recreational resource in “Forest-park category of recreational landscape”. It is recommended to redistribute the flow of holidaymakers without restricting citizens' access to forests and reducing the environmental aggressiveness of the prevailing types of recreation by increasing the share of road form of recreation due to improvement, as well as strengthening supervision. These tasks are needed to be addressed in conjunction with the expansion of the functional recreational zone “Forest-park category of recreational landscape”.

![Figure 2. Thematic map illustrating the distribution of Somovsky forest.](image)
4. Summary

Species diversity of underwood trees, projective cover of the ground cover and proportion of forest species decreases with an increase in recreational load. At the IV-th stage of digression, weed and grass vegetation prevails. Evaluation of the recreational value of the research object indicates the average quality of the state of forest plantations in Somovsky forest, Voronezh region. The calculated coefficients of recreational value are within 0.38-0.72, the average value of the coefficients exceeds 0.53. The actual recreational load on the surveyed territory of Somovsky forest does not exceed the value of its ecological recreational capacity. However, it is necessary to introduce regulation modes for the recreational use of this territory.

Figure 2. Functional recreational zoning of Somovsky forest.
References

[1] Neda A, Seyed E, Asghar F, Kamran A and Hamid A 2015 Estimation of conservation value of myrtle (Myrtus communis) using a contingent valuation method: a case study in a Dooreh forest area, *Lorestan Province Iran Forest Ecosystems*, 2 30 https://doi.org/10.1186/s40663-015-0051-6

[2] Dudek T 2016 Needs of the local population related to development of forests for recreational purposes: example of south-eastern Poland *J. For. Sci.* 62 35 https://doi.org/10.17221/99/2015-JFS

[3] Hlaváčková P and Šafařík D 2016 Quantification of the utility value of the recreational function of forests from the aspect of valuation practice *J. For. Sci.* 62 345 https://doi.org/10.17221/50/2016-JFS

[4] Pirikiya M, Amirnejad H, Oladi J and Ataie Solout K 2016 Determining the recreational value of forest park by travel cost method and defining its effective factors *J. For. Sci.* 62 399 https://doi.org/10.17221/12/2016-JFS

[5] Rolfe John and Windle Jill 2015 Multifunctional recreation and nouveau heritage values in plantation forests *J. Forest Econ.* 21 131 https://doi.org/10.1016/j.jfe.2015.06.001

[6] Industrial standard 56–69–83 *Square Trial Forest Inventory Methods Bookmark* [in Russian] (Introduced 01 January 1984) p 59

[7] Matveev S M 1996 Bioindication of anthropogenic changes in suburban forests as a method for assessing their condition *Proc. 1rst Russ. Conf. Voronezh Development of Small Towns of TSRC* (Voronezh: VSU) [in Russian] p 88

[8] Sultanova R R, Khairetdinov A F and Martynova M V 2015 *Optimization of Management in Recreational Forests*: teaching guide [in Russian] (Ufa: BSAU) p 255

[9] RF Industrial standard 56–100–95 *Industry Standards of Methods and units for measuring the recreational load on forest natural complexes* [in Russian] Introduced on January 09, 95 p 12

[10] Gensyruk S A, Nizhnik M S and Wozniak R R 1987 *Recreational Use of Forests* [in Russian] (Kyiv: Urozhai) p 247

[11] Serikov M T 2011 *Basics of Recreational Forest Management*: Laboratory Course for Students Majoring 250203 - Landscape Gardening and Architecture [in Russian] (Voronezh: VSUFT) p 95

[12] Farris E, Pisanu S, Ceccherelli G and Filigheddu R 2014 Human trampling effects on Mediterranean coastal dune plants *Plant Biosystems* 147(4) 1043 doi: 10.1080/11263504.2013.861540

[13] Cole D N 2005 Computer simulation modeling of recreation use: current status, case studies and future directions Generaltechnical report RMRS-GTR-143 USDA Forest Service Rocky Mountain Research Station, Ogden, p 41

[14] Hartley E 1999 Visitor impacts at Logan Pass, Glacier National Park: a thirty-year vegetation study. In: Harmon D (ed) *Proc. 10th Conf. On thefrontiers of conservation*, (Hancock: The George Wright Society) p 297

[15] Willard B E, Cooper D J and Forbes B C 2007 Natural regeneration of alpine tundra vegetation after human trampling: a 42-year dataset from Rocky Mountain National Park, Colorado, USA, *Arct. Antarct. Alp. Res.* 39 177

[16] Marion J L and Cole D N 1996 Spatial and temporal variation in soil and vegetation impacts on campsites: Delaware Water Gap National Recreation Area *Ecol. Appl.* 6 520

[17] MapInfo Professional (Russian version) User manual MapInfo Corporation Troy New York p 392

[18] Hammitt W E and Cole D N 1998 *Wild Land Recreation: Ecology and Management* 2nd ed. (New York: John Wiley) p 398

[19] Liddle M J 1997 *Recreation Ecology: the Ecological Impact of Outdoor Recreation and Ecotourism* (London: Chapman and Hall) p 421