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ANALYSIS OF THE RECREATIONAL IMPACT ON TAXONOMIC INDICATORS AND THE CONDITION OF PINE STANDS IN THE STATE FOREST NATURE RESERVE "SEMEI ORMANY"

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Abstract: The aim of this work is to analyze the impact of recreational impact on the taxation indicators and the condition of pine stands of the Semey Ormany State Forest Reserve. Taxation indicators and the vital condition of pine stands in field studies conducted in 2024. As a result of the study, stages of recreational degeneration were determined for different recreational use zones, and taxonomic indicators of pine trees were analyzed. The research revealed that the recreational use zone I is in a relatively degraded state. There is a general trend of increased damage indicators and a decrease in the condition index by 11-22% for the quantity and size of stands in the zone of active visitation compared to the zone of moderate visitation.

Keywords: forest, recreational degeneration, taxonomic indicators, condition assessment, SFNR "Semei Ormany"

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INTRODUCTION

The modern period is characterized by very intensive natural resource use in all its aspects. Among these, recreational use of forests occupies a special place. This process, among various directions of natural resource use, is becoming one of the foremost. New forest areas are increasingly falling into the realm of recreation, and recreational loads are rising, leading to a deterioration in the quality of forest stands and, in some cases, complete degradation that excludes natural recovery.

Recreational forest use is a collection of phenomena arising from the exploitation of forests for tourism and recreation, characterized by a bidirectional relationship: the impact of the forest on visitors and the impact of visitors on the forest (Tudoran et al., 2022; Riccioli et al., 2019; Mohd Kher, 2014; Patricia et al., 2019; Miller et al., 2022).

The beneficial effects of forests are primarily explained by their microclimatic features (specific temperature regimes, solar radiation, air phytocidicity, ionization, oxygen release into the atmosphere, dust and noise absorption, retention of radioactive particles, reduction of wind speed), as well as their aesthetic functions and landscape properties, etc. (Ferrenberg et al., 2016; Greiser et al., 2018; Menge et al., 2023; Ballantyne et al., 2018).

Environmental pollution, lack of oxygen, increased mental and reduced physical stress, industrial and domestic noise, and confinement negatively impact the human body (Xu et al., 2023; Abad López et al., 2023; Siddiqua et al., 2022; Manisalidis et al., 2020). Under the influence of favorable natural factors, the functions of various bodily systems are altered (Addas, 2023; Butt et al., 2020; Yuan et al., 2020; Bateman and Fleming, 2017). Active recreation can reduce the incidence of cardiovascular diseases by 50%, respiratory organs by nearly 40%, and nervous and musculoskeletal systems by 30%. The constant increase in population, development of infrastructure and transportation lead to the progressive urbanization of natural landscapes, deteriorating conditions of urban and suburban forests, forest parks, and green spaces (Meixia Lin et al., 2020; Xu et al., 2020; Wang et al., 2022, Wan et al., 2024). The benefits of forest recreation and its positive effects on restoring psychological balance and physical strength result in an increased influx of recreational users, which, in turn, raises the load on forest ecosystems and weakens their resilience

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(Ozgeldinova et al., 2023; Marasinghe et al., 2020; Ozgeldinova et al., 2022). Recreational use of forest plantations leads to adverse changes (such as reduced stand density, increased number of sick and damaged trees, destruction of the forest floor, soil compaction, and the death of undergrowth and saplings), which can pose risks to the continued natural development of ecological components. In some cases, these changes can result in complete, naturally irreversible degradation (Haris et al., 2020; Sanzheev and Namdakov, 2023; Scherbina et al., 2022).

Recreational forest use usually causes negative changes in forest ecosystems, referred to in recreational forestry as recreational degeneration. This term describes complex changes in various elements of forest ecosystems, primarily affecting nutrient exchange, energy flow, and interactions between plant and animal species (Dertien et al., 2021; Rasputina et al., 2019). In assessing the degree of recreational degeneration, it is common to distinguish between 3 and 4 stages (IS 56-84-85; Komarova and Komarov, 2013; Dancheva and Zalesov, 2014; Timashchuk, 2015), less frequently 5 stages (Dyukova and Serikov, 2012; Zakamsky and Musin, 2013), and sometimes 6 stages (Gorshkova et al., 2012) of forest degeneration. The resilience of a forest stand to recreational load is determined by its degree of degeneration (Babushkina, 2011). In most cases, the boundary of forest resilience lies between the III and IV stages of degeneration.

Indicators of recreational degeneration include the magnitude of recreational loads, quantitative and qualitative indicators of the forest floor, live ground cover, saplings, undergrowth, soil, the projected cover of epiphytic lichens on tree trunks, the area of trampled territory, the condition of the stand, etc. (Tokarieva et al., 2022; Rasputina et al., 2019; Scherbina et al., 2022). The forests of SFNR (State Forest Nature Reserve) "Semei Ormany" are characterized by their uniqueness and favorable conditions for tourism and various forms of recreation. However, uncontrolled visitation often leads to exceeding recreational loads, which affects the ecological condition of the forest system and its components, potentially leading to complete degradation. The aim of this work is to analyze the influence of recreational impact on the taxation indicators and condition of pine stands of the «Semei Ormany» state forest nature reserve.

MATERIALS AND METHODS

Research was conducted in 2024 on sample plots (SP) in SFNR "Semei Ormany". The subjects of the research were natural and artificial pine forests of SFNR "Semei Ormany". In SFNR "Semei Ormany", pine plantations are located near recreation centers and children's sanatoriums (Figure 1). SFNR "Semei Ormany", located in the Abai region, covers an area of 654,179.8 hectares. Geographically, the reserve is situated within the Irtysh Plain, the Kokpekti-Charsk small mountain range, and the Chinggis Tau Mountains. The ribbon forests are located in the northwestern part of the East Kazakhstan region. The territories of the Begenevsky, Borodulikha, Bukebayevsky, Dolonsky (excluding floodplain forests), Zhanasemeisky, Kanonersky, Morozovsky, Novoshulbinsky, and Semipalatinsk (excluding floodplain forests) branches fall into the steppe latitudinal-geographical zone. The territory of the Zharminsky branch falls into the desert latitudinal-geographical zone. According to botanical-geographical classification, the territory occupied by the ribbon forests of the Irtysh region belongs to the Euroasian Steppe Region, the Volga-Kazakhstan Province, the Eastern Kazakhstan Steppe Subprovince, and the zone of dry fescue-feather grass steppes on chestnut soils.

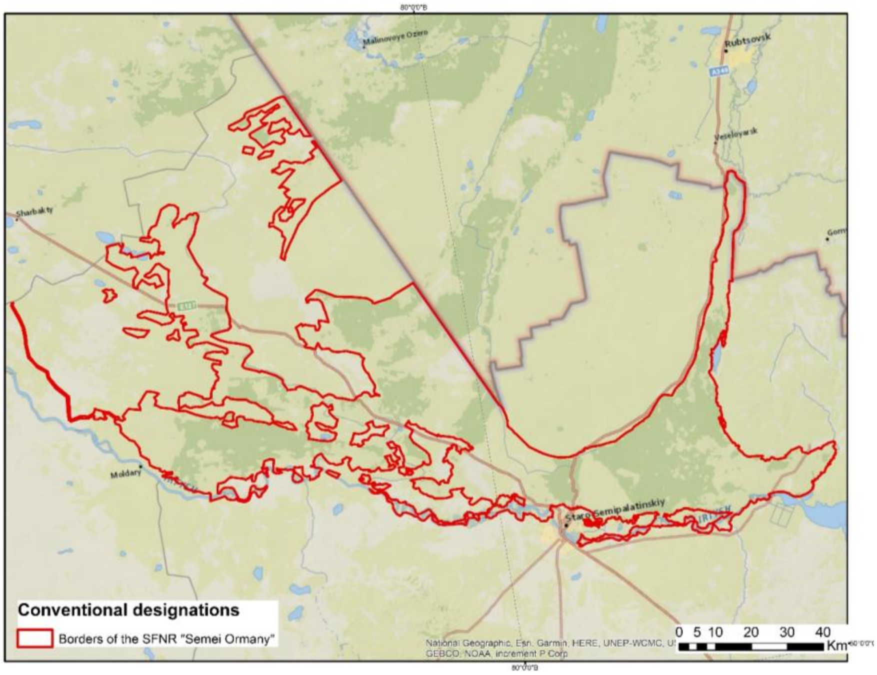

Figure 1. SFNR "Semei Ormany"(Source: Created by the authors in ArcGIS 10.8 using the "National Geographic World Map")

The area is characterized by a unique combination of vegetation types: steppe, forest, desert, shrub, meadow, and swamp. The flora of higher plants in the ribbon forests of the Irtysh region is represented by 344 species from 201 genera and 61 families. The core of the flora consists of angiosperms – 340 species, including dicotyledons – 80.59% (274 species) and monocotyledons – 19.41% (66 species) (https://www.oopt.kz/categories/view/semey_ormany/).

Steppe communities with a dominance of xerophytic, cold-resistant bunch grasses occupied significant areas before extensive plowing. In sandy areas, along with pine forests, there are psammophyte-mixed-grass-fescue-feather grass (Stipa pennata, Festuca valesiaca, Agropyron fragile, Gypsophylla paniculata) steppes. Common accompanying species include Cleistogenes squarrosa, Centaurea sibirica, Helichrysum arenarium, and Ephedra distachya.

Forest Vegetation Type: A unique feature of this area is the presence of forest stands in the steppe zone, consisting of pine, birch, and aspen forests. The existence of forests in the steppe zone has significant water protection and aesthetic value. The forests here occur under specific conditions: on sandy soils and with a close occurrence of groundwater. The typical landscape of such areas is characterized by a mix of pine or aspen-birch forests and sandy steppes. The main forest-forming species are Scots pine (Pinus sylvestris), silver birch (Betula pendula), and aspen (Populus tremula). In the herbaceous layer, the dominant grasses are feather grass (Stipa pennata), previously known as John’s feather grass (Stipa joannis), and fescue (Festuca pseudoovina, F. valesiaca), as well as Marshall's wormwood (Artemisia marschalliana), previously field wormwood (Artemisia campestris) (https://www.oopt.kz/categories/view/semey_ormany/). In SFNR "Semei Ormany", pine forests are represented by dry (C2) and moist (C3) forest types. The natural pine forests of SFNR "Semei Ormany" are characterized by a V age class. The bonitet class is V. The studied plantations are classified as medium-dense (P=0.5-0.6). The establishment of sample plots (SP) and the determination of forest-taxa parameters of stands were carried out in accordance with widely accepted forestry methodologies (Dancheva and Zalesov, 2015).

The issue of rational use of recreational forests should be addressed against the backdrop of proper organization of forest park areas, conducting scientifically-based zoning, and developing architectural and planning solutions for each zone (Dertien Stern et al., 2022; Miller et al., 2023; Lukoseviciute et al., 2022). The classification of pine plantations by usage form was based on earlier studies (Portyanko and Zholdybaeva, 2011). The main criterion for distinguishing recreational use zones (RUZ) was the distance from areas of mass recreation. The authors identified three RUZ:

RUZ-I – zone of intensive visitation, where forest plantations experience maximum recreational load.

RUZ-II – zone of moderate visitation. This zone includes forest areas with average visitation and those directly adjacent to the intensive visitation zone.

RUZ-III – zone of low visitation. It encompasses areas far from convenient transportation routes, inaccessible for pedestrian visits, or lacking attractive landscape elements.

The above method for distinguishing recreational use zones of pine plantations for "Semei Ormany" recreational purposes was based on the principle of distance from mass recreation areas. Our goal was to achieve a more accurate recreational zoning of pine plantations using not only the distance from recreation sites but also additional quantitative indicators, including the magnitude of recreational loads. For measuring recreational load, a registration-measurement method (OST 56-100-95) was used, based on recording visitors and their time spent at sample plots.

The number of visitors was recorded three times a day on calendar dates – in the morning (9:00 AM - 12:00 PM), at lunchtime (12:00 PM - 3:00 PM), and in the evening (3:00 PM - 6:00 PM). Attendance was monitored on both working and non-working days under comfortable and uncomfortable weather conditions (OST-56-100-95). Determining the average annual one-time recreational load would be inaccurate, as the use of the studied pine plantations for recreation and tourism is primarily seasonal. The peak visitation of recreational pine forests in the ribbon forest (SFNR "Semei Ormany") occurs from June to August, so in our studies, the recreational season here and elsewhere will be the aforementioned period, which totals 92 days. In addition to determining recreational loads by recreational zones, the stages of recreational degeneration of pine plantations were assessed. The research was conducted in the pine forests of SFNR "Semei Ormany". For this, all roads, trails, and trampled areas were recorded according to the methodology of Gensiruk et al. (1987). All areas with clear signs of trampling, where the forest floor was absent or in a trampled state, were marked on the map.

The stages of recreational degeneration in the studied sample plots were determined by the ratio of the area of trampling to the mineral horizon of the surface to the total area of the surveyed site (OST 56-100-95): the first (I) stage – up to 1.0%, the second (II) – 1.1-5.0%, the third (III) – 5.1-10.0%, the fourth (IV) – 10.1-25.0%, the fifth (V) – more than 25.0%.

Assessment of the vitality of trees (VST), indices of tree condition by quantity (Ln) and size (Lv), as well as the damage to stands (Dv) were carried out according to the methodology of Alekseev (1989). At 100-80%, the stand was assessed as "healthy", at 79-50% – damaged (weakened), at 49-20% – severely damaged (severely weakened), at 19% and below – completely destroyed. The damage to the stand (Dv) was determined by the formula (Alekseev, 1990):

$$D_v = \frac{30\times M_2 + 60\times M_3 + 95\times M_4 + 100\times M_5}{\sum M}, \ \% \qquad (1)$$

where, M2, M3, M4, M5 – volume of timber of damaged (weakened), severely damaged, dying trees, and deadwood on the sample plot or per hectare, m³; 30, 60, 95, and 100 – coefficients representing the damage levels of different tree categories, %; ΣM – total timber volume on the sample plot, m³/ha (including the volume of healthy trees).

When the damage indicator DvDvDv is less than 20%, the stand can be considered "healthy" (Dv = 11-19% indicates initial weakening of the stand); at 20-49% – "damaged"; at 50-79% – severely damaged; and at 80% or more – "destroyed". The calculation of the stand condition index by the number of trees (Ln) was performed using the formula (Alekseev, 1990):

$$Ln = \frac{(100\times N_1 + 70\times N_2 + 40\times N_3 + 5\times N_4)}{N}, \qquad \% \qquad (2)$$

where, N1 – number of healthy trees, N2 – weakened trees, N3 – severely weakened trees, N4 – dying trees on the sample plot (or per hectare, units); N – total number of trees (including dead trees) on the sample plot or per hectare, units.

The Growth Intensity Coefficient (GIC) of the studied pine stands was determined using the methodology by Gustova and Terekhina (2007):

$$КОП = \frac{H \times 100}{G_{1,3}}, \quad см/см^2 \qquad (3)$$

where, H – average height of the stand, m; G1,3 – cross-sectional area of the average tree at a height of 1.3 m, cm².

For pine stands of I site quality class, the value of the Growth Intensity Coefficient (GIC) is 4.0 cm/cm² at 20 years of age, 3.5 cm/cm² at 30-70 years, and 2.0 cm/cm² at 100 years (Shulga et al., 2007; Shulga, 2012). For normal pine stands, the GIC values are 20.6 cm/cm² for 20-year-old stands, 12.3 cm/cm² at 30 years, 6.8 cm/cm² at 50 years, 4.8 cm/cm² at 70 years, and 3.4 cm/cm² at 100 years. Recreational load was measured using recreational density (Rd) and recreational attendance (Re), calculated using the formula (OST 56-100-95):

$$R_e = R_d \times T^{-1} \times t, \qquad (4)$$

where, Re – recreational attendance, people/ha/day (in our studies, people/ha/day); T – duration of the measurement period (in our case, T = 180 minutes or 3 hours); t – duration of a single visit (in our studies, in the active use zone (RUZ-I), on average, t = 10 minutes or 0.17 hours; for the moderate use zone (RUZ-II) and the control zone (RUZ-III), t = 5 minutes or 0.08 hours).

$$R_d = N \times S^{-1}, \qquad (5)$$

where, Rd – recreational density, people/ha; N – number of visitors, people; S – area, ha. One of the important features is the crown. Kraft, using these characteristics, classifies all trees into 5 classes (Morozov, 2004) (Figure 2).

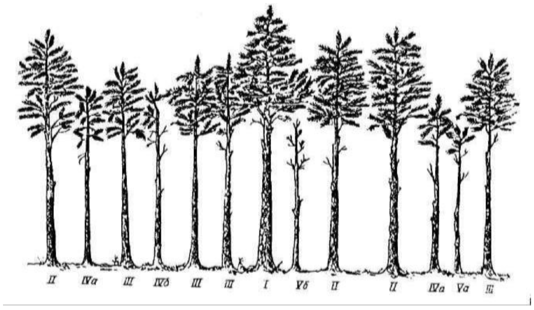

Figure 2. Classification of forest trees

- Class I – Dominant Trees: These trees have a strong, well-developed crown and large height and diameter trunks, standing out from the general canopy. They make up up to 8% by density and up to 20% by volume.
- Class II – Co-dominant Trees: These trees make up the upper part of the tree canopy. They account for 15 to 35% of the total and constitute 40-80% by volume. The maximum number of such trees is found in mature stands, and in immature stands, they appear after thinning.
- Class III – Sub-dominant Trees: These trees are part of the general canopy with the trees of the first two classes but are suppressed by them, as indicated by their narrow crowns. They are shorter in height and vary in number: from 10% in mature managed stands to half of the total in young stands.
- Class IV – Suppressed Trees: These trees make up 5 to 30% by density. They are divided into two subclasses: IVa – trees with symmetrical crowns growing in gaps, and IVb – trees with flag-like one-sided crowns, partially under the crowns of other trees.
- Class V – Shaded Trees: These trees make up 1 to 30% by density. They are also divided into two subclasses: Va – trees with viable crowns and Vb – trees with dying or dead crowns.

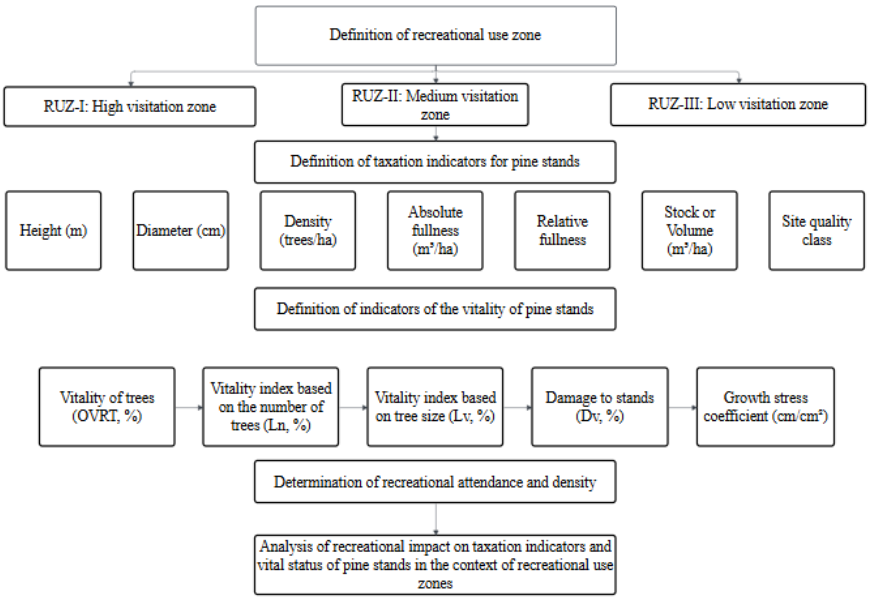

Figure 2. analysis of recreational impact on the taxation indicators and vital status of pine stands of the SFNR "Semei Ormany"

The reasons for tree differentiation include: hereditary traits; soil fertility heterogeneity; the differentiation process is more intense in denser natural stands and where trees grow faster. Tree growth can be weakened by pests, diseases, wind, snow, and other factors. The block diagram of the conducted analysis of recreational impact on the taxation indicators and vital status of pine stands of the SFNR "Semei Ormany" is shown in Figure 2.

RESULTS AND DISCUSSION

According to our research, the pine stands in the SFNR "Semey Ormany" in RUZ-I are at stages IV-V of recreational degeneration. The proportion of trampled areas down to the mineral soil layer averages 50.0%, with variation in this indicator across monitoring plots (PP) ranging from 11.2% to 91.0%. Stands in RUZ-II are characterized by stages II-III of recreational degeneration, with the average proportion of trampled surface in this functional zone being 6.1%.

In RUZ-III, no trampled areas down to the mineral soil layer were found, so the pine stands in this zone can be classified as stage I of recreational degeneration. Since, according to OST 56-100-95, the third stage of recreational degeneration is defined as the maximum allowable for forest natural complexes, the values for recreational density (Rd) and recreational attendance (Re) are also considered the maximum allowable. In our research, the maximum values for Rd and Re are those corresponding to RUZ-II. Therefore, for the studied pine stands, the maximum allowable values for recreational density (Rd) are 110-160 people/ha, and for recreational attendance (Re) are 3-10 people/ha/day. The allowable average seasonal value for recreational attendance (Re) is 3.4 people/ha/day. The obtained data allow for some changes and additions to the previously developed recreational use zones (Portyanko and Zholdybaeva, 2011; Dancheva, 2018), extending them to all pine stands in "Semey Ormany":

- RUZ-I – Active Use Zone: This includes pine stands directly adjacent to mass recreation areas, etc. Recreational attendance is 12 or more people/ha/day. The stand is characterized by stages IV and V of recreational degeneration (Figure 3).

-RUZ-II – Moderate Use Zone: This includes areas of pine stands with average attendance, directly adjacent to the active use zone. Recreational attendance is 3-10 people/ha/day. The stand is characterized by stages II-III of degeneration.

-RUZ-III – Low Use Zone (conditionally control): This includes pine stands that are distant from convenient transportation routes, inaccessible for pedestrian visits, or lacking attractive landscape elements.

Figure 3. Medium-dense pine forests of the SFNR "Semey Ormany" in the active use zone (RUZ-I) (Source: Authors, 2024)

Recreational attendance is 0.5-1 people/ha/day. The stand is characterized by stage I of recreational degeneration. As a result of the conducted research, it has been established that with increasing recreational impact, there is an increase in the average diameter and height of high-density pine stands (Table 1). The values of these indicators in the active use zone (RUZ-I) increase by 1.1-1.3 times compared to the corresponding values in the moderate (RUZ-II) and low (conditionally control) (RUZ-III) use zones.

Table 1. Inventory indicators of medium-dense pine stands in the SFNR "Semey Ormany" (Source: Author, 2024)

Recreational Use Zone	Height, m	Diameter, cm	Density, ind./ha	Absolute fullness, m²/ha	Relative fullness	Stock, m³/ha	Bonitet class	Growth area, m²
I	17,6±0,4	29,6±1,1	247	21,8	0,6	176	IV	38,4
II	16,7±0,4	28,2±1,2	278	20,9	0,6	163	IV	35,7
III	15,2±0,5	23,4±1,1	365	21,1	0,5	168	IV	22,6

In all the high-density pine forests of "Semey Ormany" examined, an increase in recreational impact is associated with a decrease in stand density (Table 1). This effect is most pronounced in very dry and dry pine forests. For instance, in RUZ-II, the density is 278 trees/ha, which is 1.2-1.5 times lower compared to RUZ-III, while in RUZ-I, the density is 247 trees/ha, which is 2-2.5 times lower than in RUZ-III. The average density in the active use zone (RUZ-I) of fresh and wet growing conditions is 1.2-1.4 times lower compared to the control zone (RUZ-III).

Along with the decrease in stand density, there is an increase in the growth area of trees. In medium-dense stands, stand density increases by 1.1-1.8 times as one moves away from RUZ-I (Table 1). With increasing recreational impact, there is an increase in the number of trees classified as Kraft classes I-II (Figure 4).

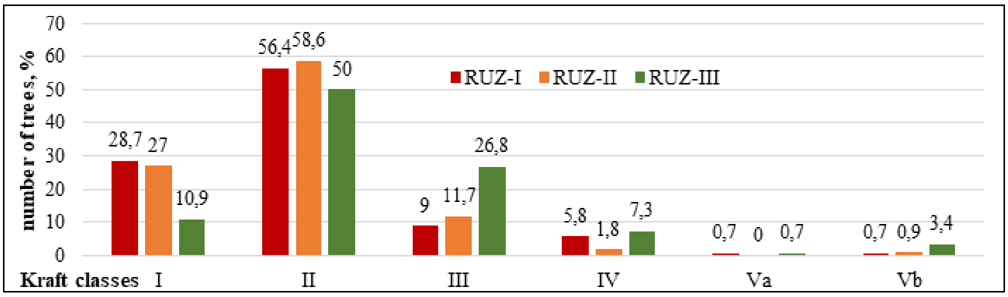

Figure 4. Distribution of pine trees by Kraft classes in medium-dense pine forests of the SFNR "Semey Ormany" (Source: Author, 2024)

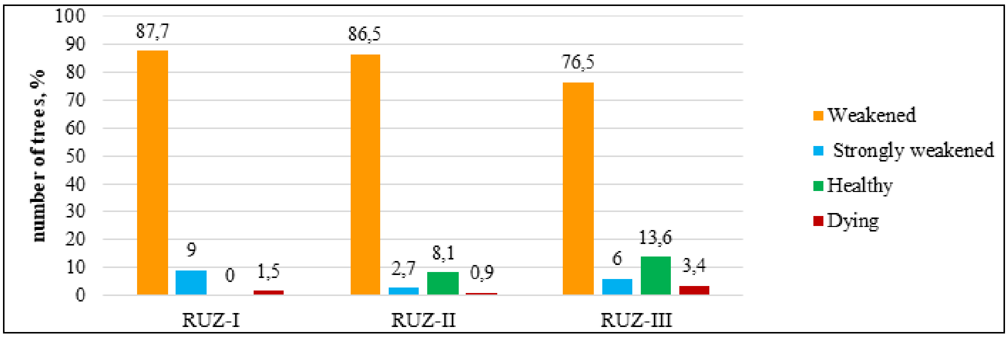

Figure 5. Distribution of trees by vitality categories in medium-dense pine forests of the SFNR "Semey Ormany" (Source: Author, 2024)

In the active use zone (RUZ-I), the proportion of trees classified as Kraft classes I and II is 1.2-1.4 times higher compared to the control zone (RUZ-III). In pine forests, a sharp increase in the number of trees classified as Kraft classes III-IV is noted when recreational impact decreases across all considered forest type groups (Figure 5). In the moderate use zone (RUZ-II) and control zone (RUZ-III) of both dry and fresh pine forests, the number of trees in Kraft classes III-IV is 1.3-2.3 times lower compared to the active use zone (RUZ-I). Deadwood (Kraft class Vb) is mostly present only in the moderate use zone (RUZ-II) and control zone (RUZ-III). The proportion of deadwood in high-density pine stands is 5-10%, while in medium-dense pine stands, it is 1-6% of the total density on monitoring plots (PP). The absence of deadwood in RUZ-I is explained by its timely removal during selective sanitary cutting. One of the main indicators characterizing stand condition is the relative vitality index (RVI). According to Figure 5.13, the RVI of medium-dense pine forests in all functional zones of the considered forest type groups ranges from 54% to 76%, which classifies them as "weakened." An increase in recreational impact leads to a decrease in the vitality index in medium-dense dry pine forests by 15-22%. The differences in RVI values between RUZ-I and RUZ-II, as well as between RUZ-I and RUZ-III, are statistically significant in stands of all forest type groups. With decreasing moisture levels, there is a slight increase in RVI in RUZ-I within medium-dense pine forests. The analysis of the data in Figure 5 indicates that in all RUZs, both high-density and medium-dense pine stands predominantly consist of trees classified as "weakened" – up to 90% of the total number.

As the intensity of recreational impact increases, there is a rise in the number of "weakened" trees and a decrease in the number of "healthy" trees. For example, in medium-dense pine forests in dry growing conditions, the number of "strongly weakened" trees in the active use zone (RUZ-I) is 0.9 times higher compared to the moderate use zone (RUZ-II). The correlation between the increase in the number of "weakened" trees and the decrease in "healthy" trees with increased recreational impact is less pronounced in dry pine forests. The number of trees categorized as "dying" in medium-dense pine stands varies significantly across each of the considered forest type groups. In the active use zone (RUZ-I), their number is 0.6 times higher compared to the moderate use zone (RUZ-II). The analysis of the data in Table 2 indicates a general trend of increasing damage (Dv), and decreasing vitality index by quantity (Ln) and size (Lv) of stands in the active use zone (RUZ-I) compared to the moderate use zone (RUZ-II) and control (RUZ-III).

Table 2. Vitality indicators of medium-dense pine stands in the SFNR "Semey Ormany"(Source: Author, 2024)

№	1-19C	2-19C	3-19C	4-19C	5-19C
RUZ	I	II	I	II	III
RVI, %	54,3±1,9	66,6±1,5	63,1±0,6	66,8±1,3	64,9±3,0
L_n, %	61,5	69,7	68,5	74,1	69,5
L_v	67,3	71,5	70,3	72,6	75,3
D_v, %	33,8	29,8	31,7	28,4	23,6
GSC, $^{cm/cm^2}$	3,4±0,3	3,2±0,3	2,8±0,1	3,4±0,4	4,4±0,3

The methods currently used to assess the vitality (Alekseev, 1989) and sanitary condition (Rules for Logging in State Forest Fund Areas, 2015) of forest stands are based on visual evaluation of healthy, weakened, strongly weakened trees, as well as deadwood, according to various indicators, one of which is the condition of the crown and photosynthetic apparatus. Therefore, these methods are subjective, depending on the opinion of the specific researcher. For an objective assessment of tree vitality categories, it is advisable to use additional quantitative indicators that should be technological, i.e., easily and accurately measurable (Shevelina et al., 2010). For the studied pine stands, the growth stress coefficient (GSC) (Gustova and Terekhina, 2007) was used for the first time. The data in Table 2 show that the GSC values in medium-dense pine forests range from 2.8 to 4.4 cm/cm², which is optimal for this age category (Shulga et al., 2007). In other words, the pine forests are characterized as biologically stable. The distribution of GSC values by vitality categories presented in Table 2 indicates that in medium-dense pine stands, the lowest GSC values are associated with trees categorized as "healthy" and also with "weakened" trees having an average GSC value. The lowest values of the growth stress coefficient (GSC) across all considered condition categories are found in medium-dense pine stands.

A general pattern is observed where the value of the growth stress coefficient (GSC) increases as the vitality of the trees decreases. Significant differences in GSC values are most often noted between all categories of tree vitality. The conducted research has established a close relationship between the vitality index and the growth stress coefficient (GSC). In the medium-dense mature pine forests of the SFNR "Semey Ormany," across all RUZs, trees classified as "healthy" have GSC values ranging from 3.0±0.1 to 5.0±0.5 cm/cm². The GSC values for "weakened" trees range from 2.8±0.2 to 4.1±0.4 cm/cm². Trees classified as "strongly weakened" and "dying" have GSC values of 5.0±0.7 cm/cm² and above (Table 3).

Table 3. Average GSC values for medium-dense pine forests of the SFNR "Semey Ormany" by vitality categories, cm/cm² (Source: Author, 2024)

№	1-19C	2-19C	3-19C	4-19C	5-19C
RUZ	I	II	I	II	III
Categories of condition					
healthy	–	3,0±0,1	–	4,1±0,3	5,0±0,5
weak	2,8±0,2	2,9±0,1	2,9±0,1	3,3±0,3	4,1±0,4
Severely weak	6,4±0,7	9,8±0,8	3,6±0,1	4,1	8,7±0,7
dying	5,0±0,7	10,4	–	–	8,5±0,7

CONCLUSION

Recreational loads exceeding the maximum allowable values contribute to soil surface compaction, trampling of moss-lichen and grass cover, compression of the litter, mechanical damage to the forest stand, destruction of undergrowth and shrubs, changes in insect fauna, and the creation of conditions where restoration processes do not keep pace with destruction processes and the introduction of components of a more stable and capable biogeocoenosis that can exist under higher recreational loads – ruderal biogeocoenosis (Musin et al., 2020; Scherbina et al., 2022; Ozgeldinova et al., 2023). Thus, according to the zoning of recreational use, the pine forests of "Semey Ormany" are divided into 3 zones: active use zone (RUZ-I), moderate use zone (RUZ-II), and low use zone (RUZ-III). The intensity of recreational impact on pine forests varies significantly across these zones. Pine forests in the RUZ-I zone experience the highest recreational load – up to 83 people/ha/day. In comparison, this indicator increases 12-19 and 59-69 times in RUZ-II and RUZ-III, respectively. In the active use zone (RUZ-I), mass recreation such as picnics, beach outings, and walks around sanatoriums and rest houses predominates, whereas in RUZ-II and RUZ-III, recreational activities are more focused on gathering (e.g., mushroom and berry picking). Recreational visitation and density sharply increase on non-working days across all functional zones. The highest recreational loads are observed in RUZ-I during morning and evening hours, in RUZ-II during morning and midday hours, and in RUZ-III during morning hours.

Pine forests in the active use zone (RUZ-I) are characterized by IV and V stages of recreational degradation, while those in the moderate use zone (RUZ-II) are in II-III stages, and those in the control zone (RUZ-III) are in the I stage of recreational degradation. The level of recreational visitation in RUZ-II is the maximum allowable for the pine forests of the studied regions and is equal to 3-10 people/ha/day. The permissible mid-season level of recreational visitation is 3.4 people/ha/day. As recreational loads increase, there is a decrease in tree density and an increase in the growth area of trees by 1.3-2.4 times. This pattern is more pronounced in dry growing conditions (forest type group C2) than in fresh conditions (forest type group C3). Increased recreational loads accelerate the process of natural thinning of the forest stand, which explains the increase in the number of trees of I-II class and the decrease in trees of IV-V class according to Kraft by 1.3-1.8 times in RUZ-I compared to RUZ-II and RUZ-III. On most monitoring plots (PP), according to indicators of condition (damage (Dv), vitality index by quantity (Ln) and size (Lv)), the pine forests are characterized as "weakened."

There is a general trend of increasing damage (Dv) and decreasing vitality index by quantity (Ln) and size (Lv) of stands in the active use zone (RUZ-I) by 11-22% compared to the moderate use zone (RUZ-II) and control (RUZ-III).

It has been established that the growth stress coefficient (GSC) is a reliable indicator of biological stability both of the entire stand and of the separately considered tree groups. A close relationship has been identified between the vitality index (VI) and the growth stress coefficient (GSC) with tree size. As tree size increases, there is an increase in VI and a decrease in GSC. Forest recreation and tourism, including ecological tourism, is a complex and multifaceted economic sector, requiring not only investment but also a balanced infrastructure for the three main elements of sustainable territorial development – economic, ecological, and social (Winter et al., 2019; Tudoran et al., 2022). Recreational forest use is increasingly becoming an important area of joint activities between people and forestry agencies providing forest areas for recreation and tourism (Zigern-Korn et al., 2020; Riccioli, 2019; Miller et al., 2022). Consequently, it is necessary to establish an economic basis for such relationships, where forestry incurs certain costs from public visits to forest areas, while the population gains social benefits such as improved health, treatment of various diseases, and so on. However, currently, the economic assessment of recreational potential is complex and underdeveloped both methodologically and technically. There is no unified and universally accepted method for evaluating these resources either in Kazakhstan or abroad.

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REFERENCES

Abad López, A**.,** Trilleras, J**.,** Arana, V**.,** Garcia-Alzate, L., & Grande-Tovar, C. (2023). *Atmospheric microplastics: exposure, toxicity, and detrimental health effects.* RSC Advances., 13, 7468–7489. https://doi.org/ 10.1039/d2ra07098g

Addas, A. (2023). *Impact of forestry on environment and human health: an evidence-based investigation.* Frontiers in Public Health, 11, 1-12. https://doi.org/10.3389/fpubh.2023.1260519

Alekseev, V. A. (1989). *Diagnosis of the Vital State of Trees and Stands.* Foresrty, (4), 51-57, (in Russian).

Alekseev, V.A. (1990). *Diagnostics of damage to trees and forest stands due to atmospheric pollution and assessment of their vital state*. Forest ecosystems and atmospheric pollution. Leningrad: Nauka, 38-53, (in Russian).

Babushkina, O. G. (2011). *The Importance of the Ecosystem Method of Forest Management for Designing Rational, Environmentally Safe, and Economically Effective Development of Recreational Forests.* ForestryJournal, (3), 41-47, (in Russian).

Ballantyne, R., Hughes, K., Lee, J., Packer, J., & Sneddon, J. (2018). *Visitors' values and environmental learning outcomes at wildlife attractions: Implications for interpretive practice.* Tourism Management, 64, 190-201. https://doi.org/10.1016/j.tourman.2017.07.015

Bateman Philip, W., & Fleming Patricia, A. (2017). *Are negative effects of tourist activities on wildlife over-reported? A review of assessment methods and empirical results.* Biological Conservation, 211, Part A, 10-19. https://doi.org/10.1016/j.biocon.2017.05.003

Butt, E., Conibear, L., Reddington, C., Darbyshire, E., Morgan, W., Coe, H., Artaxo, P., Brito, J., Knote, C., & Spracklen, D. (2020). *Large air quality and human health impacts due to amazon forest and vegetation fires.* Environmental Research Communications, 2(9), 1-18. https://doi.org/10.1088/2515-7620/abb0db

Dancheva, A. V. (2018). *Increasing Recreational Stability and Attractiveness of Pine Forests in Kazakhstan*: Doctoral Dissertation in Agricultural Sciences, Specialty 06.03.02. Yekaterinburg: UGLTU. 515 p. (in Russian).

Dancheva, A. V., & Zalesov, S. V. (2014). *Changes in the Properties and Stocks of Forest Litter in Pine Stands under the Influence of Recreational Factors*. In *Proceedings of the IV International Scientific and Practical Conference "Innovations and Technologies in Forestry" ITF-2014, May 27-28, 2014. St. Petersburg: St. Petersburg Scientific Research Institute of Forestry, 41, (in Russian).

Dancheva, A. V., & Zalesov, S. V. (2015). *Ecological Monitoring of Recreational Forest Stands: A Study Guide.* Yekaterinburg: Ural State Forest Engineering University, 152 p. (in Russian).

Dertien, J., Larson, C., & Sarah, E.(2021). *Reed Recreation effects on wildlife: a review of potential quantitative thresholds.* Nature Conservation, 44, 51-68. https://doi.org/10.3897/natureconservation.44.63270

Dyukova, L. A., & Serikov, M. T. (2012). *Determination of Recreational Capacity and Actual Use of Park Territories of the Foros Sanatorium Complex (Ukraine)*. Modern Problems of Science and Education, (2), 363-369, (in Russian).

Dertien, Stern M., Blahna D., & Stein T. (2022). *Recreation as a transformative experience: Synthesizing the literature on outdoor recreation and recreation ecosystem services into a systems framework.* Journal of Outdoor Recreation and Tourism, 38.1-9. https://doi.org/10.1016/j.jort.2022.100492

Ferrenberg, S. (2016*). Landscape Features and Processes Influencing Forest Pest Dynamics.* Current Landscape Ecology Reports 1, 19–29. https://doi.org/10.1007/s40823-016-0005-x

Gensiruk, S. A., Nizhnik, M. S., & Voznyak, R. R. (1987). *Recreational Use of Forest*. Kyiv: Urozhay. 346 p. (in Russian).

Gorshkova, T. A., Khukalenko, E. S., Pavlova, N. N., Amosova, N. V., & Rasskazova, M. M. (2012). *Analysis of Changes in the Composition and Structure of Forest Plant Associations in the Gradient of Recreational Load*. Scientific Bulletin of Belgorod State University. Series: Natural Sciences, 18(3), 105-113, (in Russian).

Greiser, C, Meineri E., Luoto M., Ehrlén J., Hylander K. (2018). *Monthly microclimate models in a managed boreal forest landscape.* Agricultural and Forest Meteorology, 250–251, 147-158. https://doi.org/10.1016/j.agrformet.2017.12.252

Gustova, A. I., & Terekhina, D. K. (2007). *Assessment of Hydro-Physical Characteristics of Wood for Justifying Silvicultural Treatments in Protective Afforestation*. Agrarian Bulletin of the Urals, 5(41), 55-59, (in Russian).

Komarova, N. A., Komarov, Y. E. (2013). *Impact of Recreational Loads on Natural Communities of the "Tsey" Tourist Complex.* Samara Luka: Problems of Regional and Global Ecology, 22(4), 154-160, (in Russian).

Lin M., Lin T., Jones L., Liu X., Xing L., Sui J., Zhang J., Ye H., Liu Y., Zhang G., & Lu X. (2021). *Quantitatively Assessing Ecological Stress of Urbanization on Natural Ecosystems by Using a Landscape-Adjacency Index.* Remote Sensing,13(7), 1-16. https://doi.org/10.3390/rs13071352

Lukoseviciute, G., Pereira, L., Panagopoulos, T., Fedeli, G., Ramsey, E., Madden, K., & Condell, J. (2023). *Recreational trail development within different geographical contexts as a determinant of income multiplier and local economic impact.* Tourism Management Perspectives, 46, 1-16. https://doi.org/10.1016/j.tmp.2023.101090

Manisalidis, I., Stavropou, lou E., Stavropoulos, A., & Bezirtzoglou, E. (2020). *Environmental and Health Impacts of Air Pollution*. A Review. Frontiers in Public Health, 8 (14), 1-14. https://doi.org/10.3389/fpubh.2020.00014

Marasinghe, S., Simpson, G., Newsome, D., & Perera, P. (2020). *Scoping recreational disturbance of shorebirds to inform the agenda for research and management in tropical asia*. Tropical Life Sciences Research, 31(2), 51-78. https://doi.org/10.21315/tlsr2020.31.2.4

Miller, A., Blahna, D., & Morse, W. (2022). *From recreation ecology to a recreation ecosystem: A framework accounting for social-ecological systems.* Journal of Outdoor Recreation and Tourism, 38, 1-8. https:// doi.org/10.1016/j.jort.2021.100455

Menge, J., Magdon, P., & Wöllauer, S. (2023). *Impacts of forest management on stand and landscape-level microclimate heterogeneity of European beech forests*. Landscape Ecology, 38(4), 903-917. https://doi.org/ 10.1007/s10980-023-01596-z

Miller Anna, B., Blahna Dale, J., Morse Wayde, C., & Leung Yu-Fai. (2022). *Rowland Mary M. From recreation ecology to a recreation ecosystem: A framework accounting for social-ecological systems. Journal of Outdoor Recreation and Tourism,* 38, 100455. https://doi.org/10.1016/j.jort.2021.100455

Morozov, G. F. (2004). *Selected Works. Russian Society of Foresters. M.: VNIILM, 415.*

Mohd Kher, H. (2014). *Sustainability of three recreational forest landscape management in Selangor*, Malaysia. *Journal of Design and Built Environment,*14(2), 1-16. https://www.researchgate.net/publication/270280721_Sustainability_of_Three_Recreational_Forest

Musin, H., Denisov, S., Khalilov, I., & Gafiyatov, R. (2020). *Assessment of recreational forests by stages of recreational digression.* International Scientific-Practical Conference “Agriculture and Food Security: Technology, Innovation, Markets, Human Resources” (FIES 2019), 17, 1-4. https://doi.org/10.1051/bioconf/20201700221

Ozgeldinova, Z., Bektemirova, A., Mukayev, Z., Zhanguzhina, A., & Mussagaliyeva, A. (2023). *Assessment of recreational load on forest landscapes of the Kostanay region in the Republic of Kazakhstan. Geojournal of Tourism and Geosites*, 47(2), 632-638. https://doi.org/10.30892/gtg.47231-1063

Ozgeldinova, Z., Bektemirova, A., Mukayev, Z., Tursynova, T., & Yerzhanova, Z. (2022). *Natural and recreational potential of landscapes of the Tobol river basin within the Kostanay region*. GeoJournal of Tourism and Geosites, 43(3), 907–911. https://doi.org/10.30892/gtg.43309-903

Portyanko, A. V., & Zholdybaeva, M. K. (2011). *Classification of Forest Massifs by Landscape Categories and Their Morphometric Indicators.* Bulletin of Agricultural Science of Kazakhstan, (4), 40-43, (in Russian).

Rules for Logging in State Forest Fund Areas [Internet resource], 2015. (in Russian) http://adilet.zan.kz/rus/docs/V1500011894

Rasputina, E., Tsygankova, M., Bilichenko, I., Korolkova, E., Sofronov, A., & Bardash, A. (2019). *Landscapes of the central ecological zone of the Baikal natural territory within the Buryat republic and their resistance to recreational load: Evaluation and mapping.* Geodezia i Kartografia, 952(10), 21-33, (In Russian). https:// doi.org/10.22389/0016-7126-2019-952-10-21-33

Riccioli, F., Marone, E., Boncinelli, F., Tattoni, C., Rocchini, D., & Fratini, R. (2019). *The recreational value of forests under different management systems*. New Forests, 50(2), 345-360. https://doi.org/10.1007/s11056-018-9663-3

Sanzheev, E., & Namdakov, M. (2023). *Recreational Forest Use in the Regions of Northern Asia (for example of the Republic of Buryatia.* University news. North-Caucasian region. Natural sciences series. 2 (218), 103-114. https://doi.org/10.18522/1026-2237-2023-2-103-114

Scherbina, V. (2022). *Allelopathic Soil Regime After a One-Time Recreational Load in the Forest Ecosystems of the Sochi Black Sea Region.* University news. North-Caucasian region. Natural sciences series.1 (213), 96-106. https:// doi.org 10.18522/1026-2237-2022-1-96-106

Shulga, V. D., Terekhina, D. K., Gustova, A. I., & Kuzenko, A. N. (2012). *The Role of Intensive Thinning in Realizing the Potential of Timber Species.* Proceedings of the Lower Volga Agro-University Complex, 3(27), 1-5, (in Russian).

Shulga, V. D., Gustova, A. I., & Terekhina, D. K. (2007). *Justification of the Obligation for Intensive Silvicultural Treatments for Recreational Stands in Arid Zones.* Arid Ecosystems, 13, 33-34, 81, (in Russian).

Shevelina, I. V., Korostelyov, I. F., Plotnikova, O. A., Roslyakov, A. N., & Grigoriev, V. V. (2010). *Taxation Features of Pine Stands at Different Stages of Recreational Degradation*. Forestry Journal, (5), 30-35, (in Russian).

Siddiqua, A., Hahladakis, J., & Al-Attiya, W. (2022). *An overview of the environmental pollution and health effects associated with waste landfilling and open dumping.* Environmental Science and Pollution Research, 29, 58514–58536 https://doi.org/10.1007/s11356-022-21578-z

Timashchuk, D. A. (2015). *Condition and Stability of Pine Stands under Anthropogenic Impact (Case Study of the "Lesnaya Skazka" Tourist Base).* Lesotechnical Journal, (3), 102-115, (in Russian).

Tudoran, G. M., Cicșa, A., Cicșa (Boroeanu) M., & Dobre, A. C. (2022). *Management of Recreational Forests in the Romanian Carpathians Forests*, 13(9), 1-18. https://doi.org/10.3390/f13091369

Tokarieva, O., PuRUZna, N., & Vorotynskyi, O. (2022). *Pyrological Characteristics of Forest Edges under Intensive Recreational Loads.* Ukrainian Journal of Forest and Wood Science, 13(2), 51-57. https://doi.org/10.31548/forest.13(2).2022.51-57

Wang, Q., Liu, S., Liu, Y., Wang, F., Liu, H., & Yu, L. (2022). *Effects of urban agglomeration and expansion on landscape connectivity in the river valley region, Qinghai-Tibet Plateau.* Global Ecology and Conservation, 34, 1-4. https://doi.org/10.1016/j.gecco.2022.e02004

Wan R., Wan R., & Qiu Q. (2024). *Progress and Prospects of Research on the Impact of Forest Therapy on Mental Health: A Bibliometric Analysis.* Forests, 15(6), 1013. https://doi.org/10.3390/f15061013

Winter P. L., Selin S., Cerveny L., & Bricker K. (2019). *Outdoor Recreation, Nature-Based Tourism, and, and sustainability.* Sustainability (Switzerland), 12(1), 81. https://doi.org/10.3390/su12010081

Xu, H., Jia, Y., Sun, Z., Su, J., Liu, Q., Zhou, Q., & Jiang, G. (2022). *Environmental pollution, a hidden culprit for health issues.* Eco-Environment & Health, 1(1), 31-45. https://doi.org/ 10.1016/j.eehl.2022.04.003

Xu, M., Luo, T., & Wang, Z. (2020). *Urbanization diverges residents' landscape preferences but towards a more natural landscape: case to complement landsenses ecology from the lens of landscape perception*. International Journal of Sustainable Development and World Ecology, 27(3, 250-260. https://doi.org/10.1080/13504509.2020.1727989

Yuan, X., Li, H., & Zhao, J. (2020). *Impact of Environmental Pollution on Health—Evidence from Cities in China.* Social Work in Public Health, 35(6), 413-430. https://doi.org/10.1080/19371918.2020.1805084

Zakamsky, V. A., & Musin, K. G. (2013). *Assessment of Forest Areas for Mass Recreation by Stages of Recreational Degradation*. Bulletin of the PGTU, (2), 20-29, (in Russian).

Zigern-Korn, N., & Solomina, Z. (2020). *Spatial organization of tourist and recreational activities in the reserve: The conservation and touristic imperatives*. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management (SGEM), 20, 731-738. https://doi.org/10.5593/sgem2020/5.1/s20.092

***IS 56-84-85 – 1987. *Use of Forests for Recreational Purposes: Terms and Definitions*. Moscow, 1987, 5 p. (in Russian).

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