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ASSESSMENT OF RECREATIONAL DISTURBANCE IN THE FOREST MASSIFS OF KOSTANAY REGION

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Abstract: The article discusses the results of assessing the recreational disturbance of forest massifs within the Kostanay region. The objective of this research is to assess the recreational disturbance of forests in the Kostanay region based on field data utilizing GIS. In the first stage of the work, evaluation indicators and observation points were selected in each forest massif. Recreational disturbance was assessed using ArcGIS 10.8 software and by introducing weighted coefficients for individual indicators. The research indicated that the natural environment near the "Sosnovy Bor" sanatorium, located in an area with high visitor traffic, is in a relatively disturbed condition.

Keywords: forest massifs, recreational disturbance, recreational degradation, integrated assessment, Kostanay region

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INTRODUCTION

Recreation is considered as one of the anthropogenic factors of influence on the components of the natural environment, leading to its qualitative change (Winter et al., 2020; Miller et al., 2022; Zhang and Smith, 2023). Recreation is recreation outside the dwelling for the purpose of restoring health and ability to work, taking place in the bosom of nature, or during a tourist trip associated with visiting places of interest (Morse et al., 2022).

Disturbed recreational areas - lands that have lost their original natural and economic value due to recreational activities and, as a rule, represent a source of negative impact on the environment (Galdin et al., 2021).

The accumulated domestic and foreign experience shows that the negative consequences of tourism and recreational use of natural areas can be minimized under the condition of scientifically sound planning, monitoring of the ecological state of the object and regulation of tourism and recreational activities (Zigern-Korn and Solomina, 2020; Zaburaeva et al., 2018). A review of the works of the last decades in the field of recreational ecology and geography showed that most of the scientific research is devoted to the assessment of the condition of vegetation and soils changing under the action of intensive trampling (Miller et al., 2022). At the same time, researchers paid special attention to trails, picnic meadows, areas near viewpoints and objects of excursion display (Haris et al., 2020; Lukoseviciute et al., 2023).

The natural landscape, with forests as an integral part, fulfills recreational functions. These functions arise from the need to satisfy the population's demand for rest, restoration of vitality (physical, emotional, and spiritual), and health improvement in a forest environment. However, these natural complexes inevitably experience negative impacts, causing damage to the reserves and quality of biota, reducing the resilience of forest systems, which in turn diminishes the forests' capacity to fulfill their recreational functions. Therefore, humans directly utilize a certain natural (forest, landscape) recreational resource, which can recover if the magnitude of impact is limited. According to the ecological classification of natural resources, it is considered an exhaustible but renewable resource, provided that natural systems are maintained in a

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stable state (Wang, 2021). Moreover, this resource can be artificially enhanced by humans, though such enhancement will no longer be natural. The objective of this research is to assess the recreational disturbance of forests in the Kostanay region based on field data utilizing GIS. Currently, various forms of forest recreation have become a significant factor of anthropogenic impact on forests. The forests of the Kostanay region are characterized by their uniqueness and favorable conditions for tourism and the organization of various forms of leisure. However, uncontrolled visits to forest massifs often lead to exceeding recreational capacities, which affects the ecological condition of forest systems and their components, potentially leading to complete degradation (Tokarieva et al., 2022).

Since natural resources are the means of human existence, the degree of their exploitation is naturally increasing, and the degree of forest use for recreational purposes is also increasing. Man, satisfying his recreational needs by staying in the forest environment, directly consumes or destroys some stocks of wood and non-wood products in the course of mining and other, more aggressive forms of recreation. In addition, the very presence of people in the forest, even if the road form of recreation prevails, causes various damages to ecosystems due to trampling of the ground cover, compaction of the upper layer of soil, etc. All this together causes digression of the forest environment. All this together causes degradation of the forest environment, critical values of which cause degradation of biogeocenosis. This occurs, more often than not, gradually, as environmental disturbances accumulate (increasing stages of recreational digression). Moreover, forest natural systems and plant communities are resistant to recreational loads, i.e. at permissible values of anthropogenic impact the composition, structure and internal interrelationships of ecosystems are preserved (restored). These possibilities are different for different natural systems, however, the presence of any stock of their stability creates prerequisites for managing the process of recreational use of forests in order to ensure its environmental friendliness.

In this regard, it should be emphasized that determining the stages of recreational degradation of the forest environment solely based on the "percentage of area trampled down to the mineral horizon of the ground cover" is unacceptable, as the condition of all elements of the phytocenosis and the forest environment must be assessed. This method may be applicable for determining the stages of recreational degradation in non-forest areas and lands not covered by forest vegetation, but with adjustments for the overall condition of the ground cover, its composition, and the degree of soil compaction (Winter et al., 2019). Recreational loads are classified into safe, which includes both low and maximum permissible loads, dangerous, critical, and catastrophic (Scherbina, 2022). A load can be considered safe if it does not cause irreversible changes in the natural complex. The impact of such loads on a natural complex leads to the 2nd or 3rd stage of degradation. The load corresponding to the 2nd stage is conventionally called "low," as the natural complex can withstand a greater load without losing its restorative ability. The maximum permissible recreational load brings the natural complex to the 3rd stage of degradation.

When a natural complex moves from the 3rd to the 4th stage of degradation, crossing the threshold of resilience, the recreational loads affecting it are considered dangerous. Critical loads correspond to the 4th stage of degradation. Finally, catastrophic loads are those that bring the natural complex to the 5th stage of degradation, where connections between both natural components and their constituent parts are disrupted (Terent'eva et al., 2023). The stages of vegetation community changes are used as indicators of degradation, with general characteristics of these stages provided in related works (Musin et al., 2020). At the beginning of the degradation process, while the impact of recreation is still low, only biotic components: vegetation and fauna undergo noticeable changes. These changes can be considered reversible, because if the external impact is stopped, the natural complex will eventually return to its original state through self-recovery. The process of restoration of the original natural complex after the removal of recreational pressure can be called reversion of digression, and the process of digression of the natural complex can be considered reversible. The essence of the process of digression consists in the change of the entire natural complex as a result of gradual accumulation of changes not only in its biota, but also, more significantly, in the geomagnetic environment, as a result of which by the 4th stage of digression it reaches a state in which the phytocenosis loses its ability to regenerate stands. Thus, on the territory experiencing high recreational load, there is a change in the species composition of fauna and flora. This can lead to partial or complete changes in the biocenosis and ecosystem as a whole (Asmelash and Kumar, 2019). One of the tasks of complex determination of geo-ecological state of recreational objects of Kostanay region was the assessment of recreational loads on their components. The state forest fund of Kostanay region is 1 million 146 087 ha (Mayor Office of Kostanay Region).

MATERIALS AND METHODS

The research was conducted between 2023 and 2024 at sampling points in the forested areas of the study region. Five sampling points were identified within the forest areas, for each of which recreational disturbance was calculated. Based on the objectives of the study and taking into account the peculiarities of the study area, indicators were identified and calculated for each forest area. Most of the forest areas in the study area are covered with pine trees and shrubs. Pine and birch forests of recreational use ("Borovskoye", "Amankaragai", "Arakaragai", "Kazanbasy", "Naurzum Colony Forest") were selected as the object of the study (Figure 1) "Borovskoye". According to the data of the Borovskoye Forestry Institution, the area of the Borovskoye woodland occupies 93 hectares. The surface of the forest massif is composed of uvals interspersed with sandy hills composed of ancient alluvial deposits. The forest area is characterized by mixed forests (pine, birch, aspen), where the dominant species are mainly light coniferous forests. Pine forests are confined to gentle slopes of high sand hills and to depressions between them. The most common phytocenoses are phytocenoses including herbaceous, early sap-sedge, horsetail, lichen, eagle and other pine forests. "Amankaragai". The Amankaragai pine forest with a length of about 320 km² geomorphologically represents a larger ancient dune forest massif, predominantly with pine forests. This massif is characterized by the predominance of hilly uplifts and high emplacement of Paleogene sediments. The crests and slopes of sand ridges and dunes are occupied by pine forests with communities of rare steppe grasses and

lichens and sand herbs. In interdune hollows there are grassy, often slightly waterlogged birch and aspen-birch stands on maltings. On lowered lake terraces one can notice the predominance of halophytic meadows (barley, beskilnitsa, wheatgrass, etc.), which are replaced by birch forests at the foot of sand dunes (Kropinova et al., 2023).

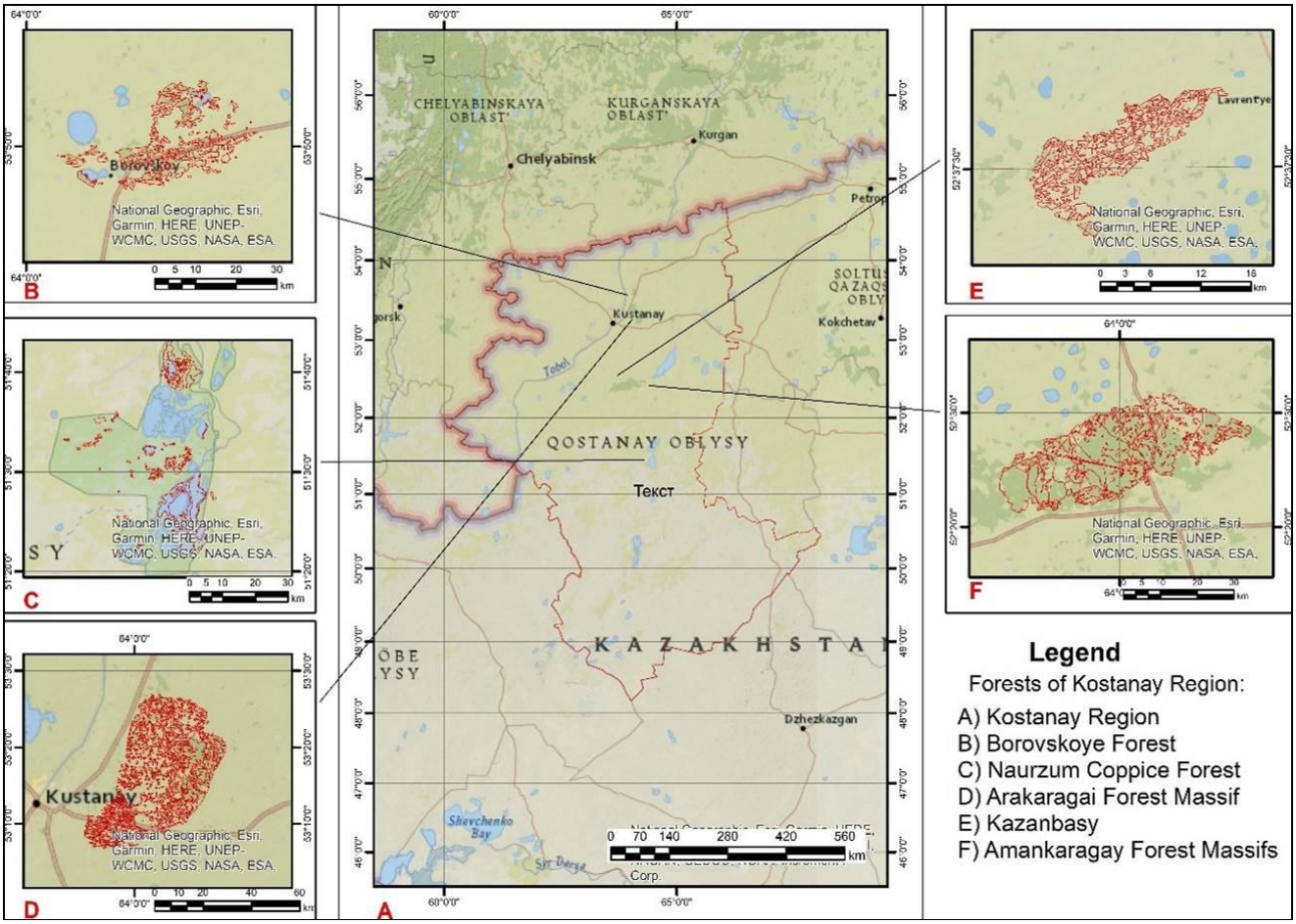

Figure 1. Forests of Kostanay Region (Source: Created by the authors using ArcGIS 10.8 with the "National Geographic World Map"): A) Kostanay Region, B) Borovskoye Forest, C) Naurzum Coppice Forest, D) Arakaragai Forest Massif, E) Kazanbasy, F) Amankaragay Forest Massifs

The most productive plantations from phytocenoses of formerly sedge, reed-vein-grass, birch horsetail-bone and mixed-grass-ground-vegetable pine forests occupy areas with shallow groundwater table (Ozgeldinova et al., 2022).

"Arakaragai". The Arakaragai pine forest with a length of 616 km^2 is located in the central part of the Tobol-Obagan interfluve and is composed of the Lower Pliocene-quaternary strata of alluvial sandy sediments with traces of ancient aeolian processes. Forest plantations are represented by middle-aged and young birch forests of the colony type, which are widespread in the western low-lying part of the interfluve. Pine forests grow in the eastern part of the interfluve on sandy hills of the Arakaragai massif. Phytocenoses of early-sedge, early-sedge-ground-veinaceous, spirea-cherry, mixed-grass-ground-veinaceous and fescue-lichen pine forests are widespread. Herbaceous steppe and mossy-grass pine forests are found in places, and they are characterized by rare undergrowth of cherry and briar. Pine forests in the Arakaragai boron are not represented as a continuous massif, but consist of separate islets (Chazdon et al., 2016; Cutler et al., 2018; Tokpanov et al., 2021). Naurzum Coppice Forest. The Naurzum coppice forest, part of the Naurzum Reserve, is located at a latitude of 51° North, 100 kilometers north of the semi-desert boundaries. The forest is situated in the Turgai Depression between the Sarymoin and Aksuat lakes, covering no more than 5% of the total area of the drifting sands.

At the western and eastern edges, the forest has a park-like character. It is predominantly composed of dune and gently rolling ridge pine forests. In the interdune depressions and on the lake terraces, there are grassy associations, birch forests with thickets of rosehip, meadowsweet, and hawthorn. The pine forest in this area is park-like, with pine forest coverage amounting to 934 hectares. Pine stands are more commonly found on the slopes of sandy dunes and relatively flat areas, and less frequently on high sandy dunes. There are also fescue and fine fescue, sand grass, mixed herbaceous, and other age-diverse pine forests, as well as areas with hanging and Kyrgyz birch.

Kazanbasy Forest Massif. The Kazanbasy forest massif is a sandy, isolated area stretching in a northeast direction in the northwestern part of the Amankarağay pine forest. It differs from the Amankarağay massif in its lower absolute elevations, predominantly ranging from 205 to 210 meters. The forest areas within the Kazanbasy massif are characterized by their sparse distribution and significant deforestation. Around the edges of the Kazanbasy pine massif, especially near settlements, there are areas of blown sand that are devoid of vegetation due to anthropogenic impacts. Within the Kazanbasy massif, among the stabilized ancient dune sands, there are lakes, most of which are dry. In the northeastern part

of the massif, fresh lakes are predominant, while in the southwestern part, the lakes are saline. Assessment of recreational disturbance (Figure 1) in forested areas based on ArcGIS 10.8 software consists of the following steps:

- selection of recreational disturbance indicators;
- determination of actual values of the selected indicators;
- development of the evaluation scale of the selected indicators for the studied territory;
- calculation of the integral indicator of recreational disturbance and determination of the stages of recreational digression;
- analyzing the manifestation of recreational disturbance in different forest areas (Figure 2).

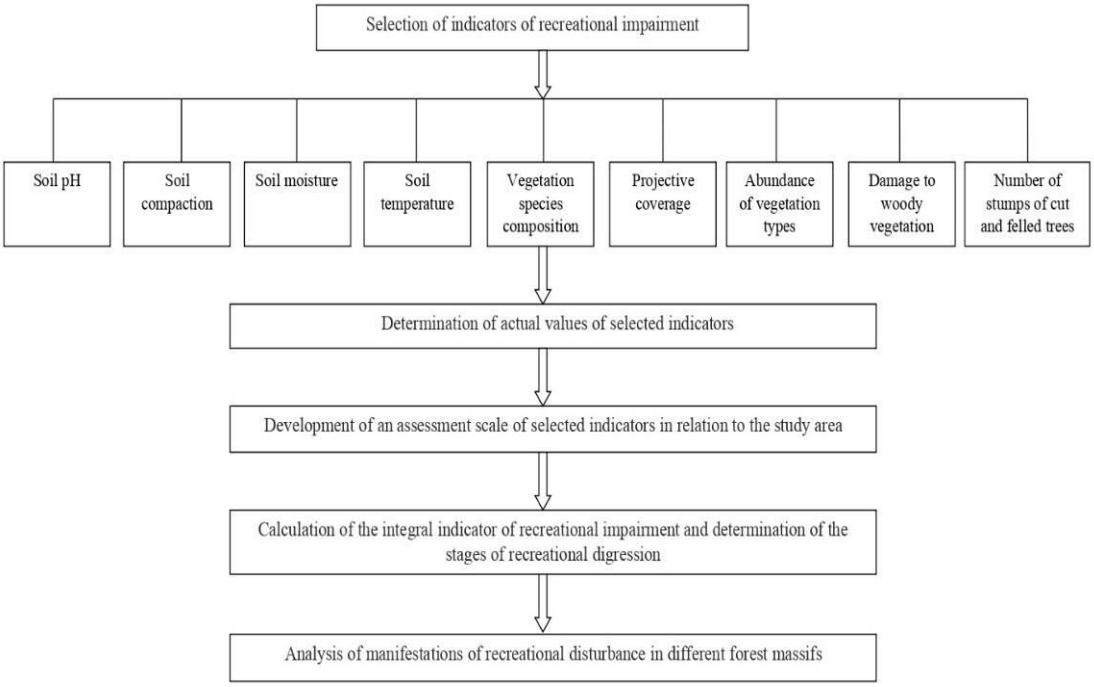

Figure 2. Block diagram "Assessment of recreational disturbance of forested areas" (Source: Authors)

To assess recreational disturbance, the following parameters were recorded at each forested area:

1. Soil pH (SDT-60 soil pH meter);
2. Soil compaction (TYD-2 soil hardness type determination, kg/cm^2);
3. Soil moisture (determination of soil moisture with portable soil tensiometer TEN-120, Bar);
4. Soil temperature (determination of soil temperature index with digital temperature meter TRS-II);
5. Vegetation species composition. Share of area (%) occupied by secondary vegetation groups with predominance of trampling-resistant, mainly ruderal herbaceous species (dandelion (Taraxacum officinale Wigg. s. l.), plantain (Plantago major L.), creeping clover (Trifolium repens L.), common glade (Agrostis capillaris L.), annual bluegrass (Poa annua L.), fragrant lepidotheca (Lepidotheca suaveolens (Pursh) Nutt.), slender grass (Juncus tenuis Willd.);
6. Projective coverage (in %);
7. Vegetation species abundance (1 per m^2);
8. Damage to woody vegetation (% of damaged trees out of their total number);
9. Number of stumps of cut and felled trees (pcs./ha);

The source data for mapping recreational disturbance indicators in the study region come from field data collected in 2023-2024. During the cartographic process, various interpolation methods were used to represent the indicators of recreational disturbance (Pintilii, 2022). One of the primary interpolation methods applied was the "Spline" option in the Spatial Analyst module of ArcGIS 10.8. The advantage of this interpolation method is that it calculates point values based on a mathematical function that adjusts to the surface conditions, resulting in a smooth surface that passes through all measurement points. The Geostatistical Analyst module was used to interpolate values by examining the relationships between all reference (control) points and to create a continuous surface for the distribution of the selected indicators. This module allows for the construction of an interpolation model and the assessment of the quality of the work performed. It provides final statistical results from the point of interpolation method selection, which helps in evaluating and analyzing the expected quality of the model obtained during the work. The integral assessment of recreational disturbance is conducted using standard tools in ArcGIS 10.8 (Figure 3). Weighted coefficients

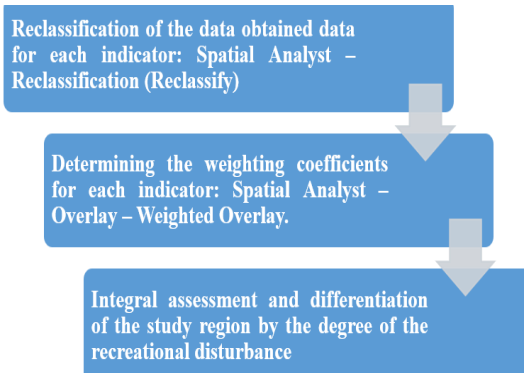

Figure 3. Algorithm of integral assessment of recreational disturbance of forest areas using ArcGIS 10.8 software

are established through an expert method based on the differentiation of indicators according to their impact on the overall indicator. The value characterizing these indicators became the basis for differentiation of the territory by the degree of recreational disturbance. The obtained values of the integral indicator of recreational disturbance were ranked by 4 stages:

I - low-disturbed state: trampling is not observed even in the form of a weakly expressed trail network; recreational impact is reduced to cutting of trees, the diameter of which (meaning the diameter at the level of cutting or felling) rarely exceeds 10-15 cm, and the appearance of sporadic campfires; secondary vegetation is practically absent.

II - disturbed condition: there is a clearly defined trail network with an area not exceeding 10%; single campfires occur; ruderal plant species are present on trails and old campfires.

III - highly disturbed condition: stand is poorly closed, groups of trees are limited by paths, roads and glades; trampled contour area up to 50%; increased density of campfires (up to 100 pieces/ha); greater proportion of damaged trees (up to 50%); secondary groups of plants occupy a noticeable area.

IV - degradation of vegetation cover: trampling of the original vegetation ground cover up to 100 %; the area of secondary plant groupings often exceeds 50 %; undergrowth is almost completely absent; undergrowth is preserved in a small number of clumps; the number of damaged trees reaches 100 %, tree roots are often exposed; abundance of fire pits, with more than 100 pieces/ha (Haris et al., 2020).

RESULTS AND DISCUSSION

As a result of this work, a cartographic representation of the integral assessment of recreational disturbance was created (Figure 4) and the following pattern was revealed. Excessive recreational pressures on forest systems lead to degradation and destruction of forest litter and plant ground cover, undergrowth and undergrowth.

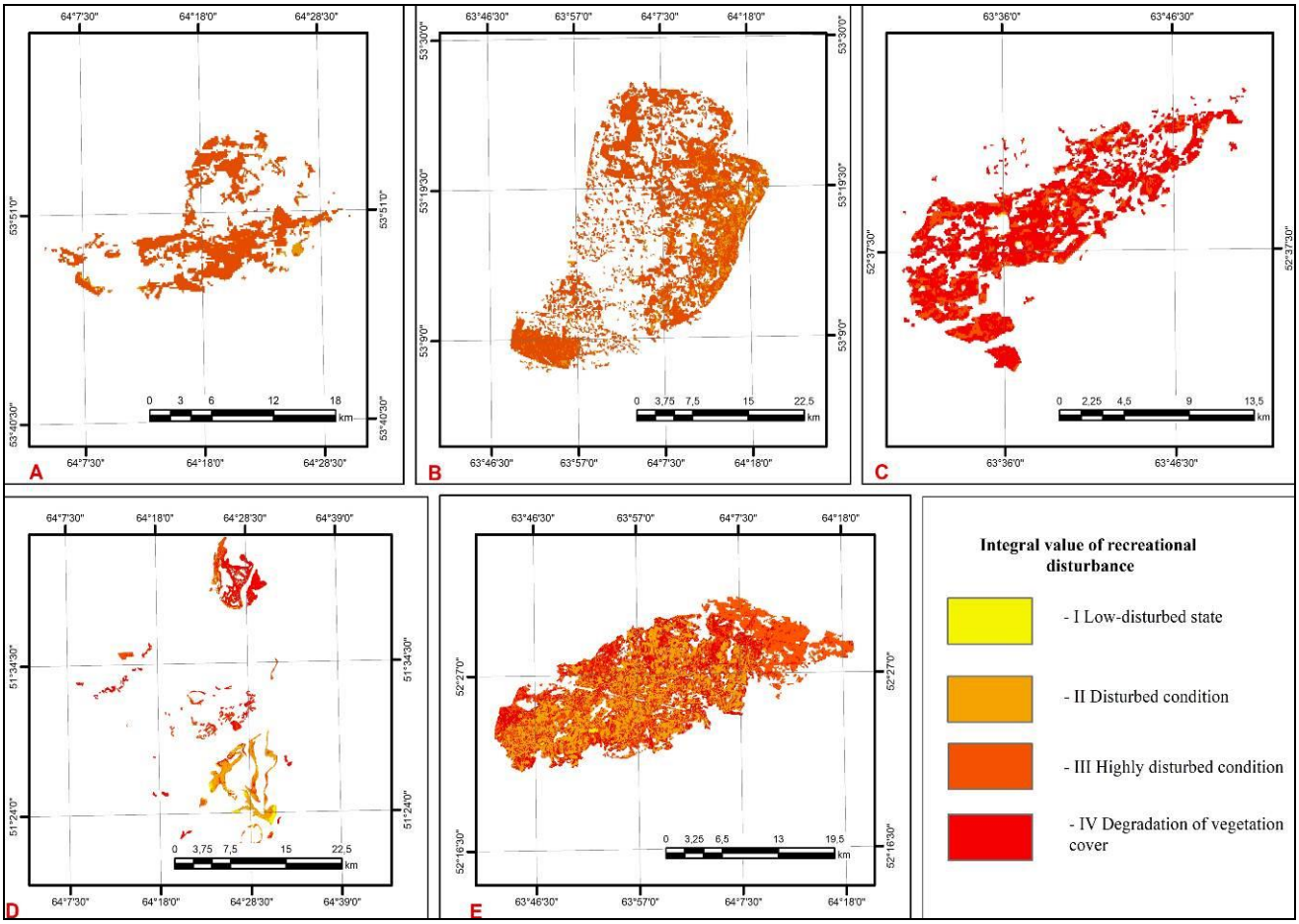

Figure 4. Integral value of recreational disturbance of Forest Massifs of Kostanay Region: A) Borovskoye Forest, B) Arakaragai Forest Massif, C) Kazanbasy Forest Massif, D) Naurzum Coppice Forest, E) Amankaragay Forest Massifs

Forest plants respond differently to trampling. Soil disturbance and changes in light conditions in recreational forests often result in the ruderalization of cenoses and the introduction of weedy meadow species under the canopy. The existing parcellar structure of forest biogeocenoses is destroyed and a "network" structure with an alternation of disturbed and undisturbed forest areas is formed. The most extensive damage to soil cover and vegetation in the forest is observed on and along trails. In recreational forest plantations a polygonal road-trail network is gradually formed, consisting of trails 0.3-3.5 m wide. Forest litter is partially or completely absent on them, in some cases there are disturbances of soil composition and loss of the upper mineral horizon.

The study was conducted in 2023-2024 on the forest massifs of the research region (Figure 5).

Figure 5. Field measurement work, 2023: a) SDT-60 soil pH meter b) Soil hardness tester TYD-2; c) digital temperature meter TRS-II

Within the key area, five selection points were identified, for each of which recreational disturbance was calculated. Based on the research objectives and considering the characteristics of the study area, indicators were established for each forest massif, and calculations were performed. All the aforementioned indicators were taken into account, and the resulting data were recorded. Thus, a set of recreational load indicators was obtained for each key site (Table 1).

Table 1. Recreational pressure indicators for key sites (Source: Authors)

№ selection points	soil pH	Soil compaction, kg/cm2	Soil moisture, Bar	Soil temperature	Species composition of vegetation	Projective coverage%	Vegetation species abundance, 1 per m^2	Damage to woody vegetation, %	Number of stumps of cut and felled trees, pcs./ha
«Amankaragai» forest massif									
1	3.8	9	0.5	20	25	83	51	1	6
2	4.1	11	0.4	16	8	85	55	-	-
3	4.5	8	0.6	18	5	89	58	2	9
4	3.9	19	0.9	14	17	84	59	-	7
5	4.2	8	0.5	19	4	83	54	1	10
«Borovskoye» forest massif									
1	5.1	9	0.5	12	32	80	57	3	8
2	4.8	11	0.6	15	10	79	49	5	-
3	3.5	13	0.7	18	8	85	58	-	3
4	3.9	15	0.4	15	25	89	59	-	5
5	4.1	7	0.4	12	5	82	54	-	-
«Arakaragai» («Sosnovy Bor «) forest massif									
1	5.5	17	0.5	19	30	75	48	15	2
2	5.8	21	0.9	21	25	89	35	8	-
3	4.9	19	0.7	15	35	80	47	7	8
4	6	10	0.5	18	38	77	34	10	3
5	3.9	15	0.5	15	31	81	36	17	7
«Kazanbasy» forest massif									
1	5.1	9	0.4	20	28	90	50	-	5
2	5.2	11	0.5	19	29	95	58	7	-
3	4.8	9	0.5	17	22	92	55	-	1
4	3.2	10	0.7	18	30	98	49	3	-
5	3.1	8	0.3	15	32	93	60	2	7
«Naurzum Colony Forest forest massif									
1	4.7	7	0.2	16	27	91	61	-	1
2	4.6	8	0.5	19	25	89	60	5	-
3	4.9	6	0.3	14	32	92	55	-	8
4	3.8	9	0.3	11	38	93	58	-	-
5	3.6	9	0.7	16	25	94	59	1	10

The pine and birch forests we surveyed are located in a high-visitor area and are characterized by stages II, III, and IV of degradation. The survey of the Arakaragai forest massif's pine stands revealed that the visitation of sample plots significantly exceeds the norm, and the forest massif has a very dense network of trails. The stages of recreational degradation in the pine forests range from III to IV, where due to trampling, the live ground cover is almost completely absent. The natural mosaic of the live ground cover is heavily transformed due to recreational loads (Bozena et al., 2021).

As the distance from the recreation centers increases, the degree of disturbance decreases, with communities being less disturbed at distances of 400-500 meters from the recreation centers. Areas of severe damage are the trail networks. On the trails, plants mainly from the grass family are found (annual bluegrass Poa annua L., narrow-leaved bluegrass Poa angustifolia L.), as well as some other species (broad-leaved plantain Plantago major L., birdweed Polygonum aviculare L.). At a distance of 1.5 meters from the trails, the number of species in the herbaceous layer increases, and typical forest species appear. Increased light on the trails and adjacent areas leads to the vigorous development of non-forest species whose seeds are present in the forest soils. In recreational areas, continuous trampling of the herbaceous layer and the absence of a litter layer create favorable conditions for the germination of meadow grasses present in the soil (Simkin et al., 2020).

In permanent picnic areas, and especially on children's and sports grounds and trails, there is a significant change in the morphological properties of soil, not only in the surface but also in the underlying horizons of the profile. As an example, it is possible to compare morphological characteristics of profiles laid in an oak plantation on a trail about 2.5 m wide and on an undisturbed area 3.2 m from the trail. The horizontal structure of the live ground cover consists of alternating areas with varying degrees of disturbance and undisturbed sections. The vegetation cover is characterized by various herbaceous groupings with a significant proportion of weed species. Recent studies have shown that the total area of trails and trampled areas in pine forests is directly related to the visitation levels of these forests (Köse, 2022).

In the Amankaragay and Borovskoye forests, stages III and IV of recreational degradation have been identified. Additionally, these forest massifs are used as dumping grounds for domestic and construction waste.

The territory of "Borovsky" and "Amankaragai" is characterized by a relatively dense network of trails (projective coverage from 79% to 89%), light-loving species predominate in the herbaceous cover, meadow grasses begin to appear, litter thickness decreases, forest regeneration still continues, satisfactory in extratropical areas. On the trail in its middle part, the litter is completely absent. Falling leaves are largely removed from the soil surface due to the passage of recreants and wind action, and partially pressed into the upper soil horizon.

Soil morphological changes, mainly observed in the upper part of the profile, indicate signs of degradation gleying under the action of periodically changing redox conditions in the soil, minerals are gradually destroyed and products are transported outside the profile with in-soil runoff. In addition, the increase in surface runoff along the buried and over-compacted trail bed leads to mechanical destruction of the upper soil horizon, removal of soil material and development of erosion phenomena. In case of excessive moisture entering the soil surface, trails turn into temporary channels of surface runoff, as evidenced by the formation of mini-rolls of twigs, bark fragments, leaves, and other plant remains on trails after precipitation, which we have repeatedly diagnosed. Thus, it is the trails united in a polygonal transit network structure that, under high recreational loads, can become centers of soil degradation in the forest.

It was found that on all trial plots soil failure on trails, paths and platforms leads to an increase in the volume weight of the upper horizons to the values limiting for plant root systems. Earlier model experiments, in the course of which new bypass trails were organized on trial areas, showed high dynamics of soil compaction on them. The forest areas "Kazanbasy", "Naurzum colony forest" are not disturbed recreationally. As a result of the survey of these forest areas it was found that the attendance rate of the sample plots is comparatively lower, the forest area has not a very dense network of paths (Figure 6). Stages I and II of recreational digression were identified in Kazanbasy and Naurzumsky forests. The projective cover varies from 89% to 98%, the abundance of vegetation species, 1 per m^2 reaches up to 61 specimens.

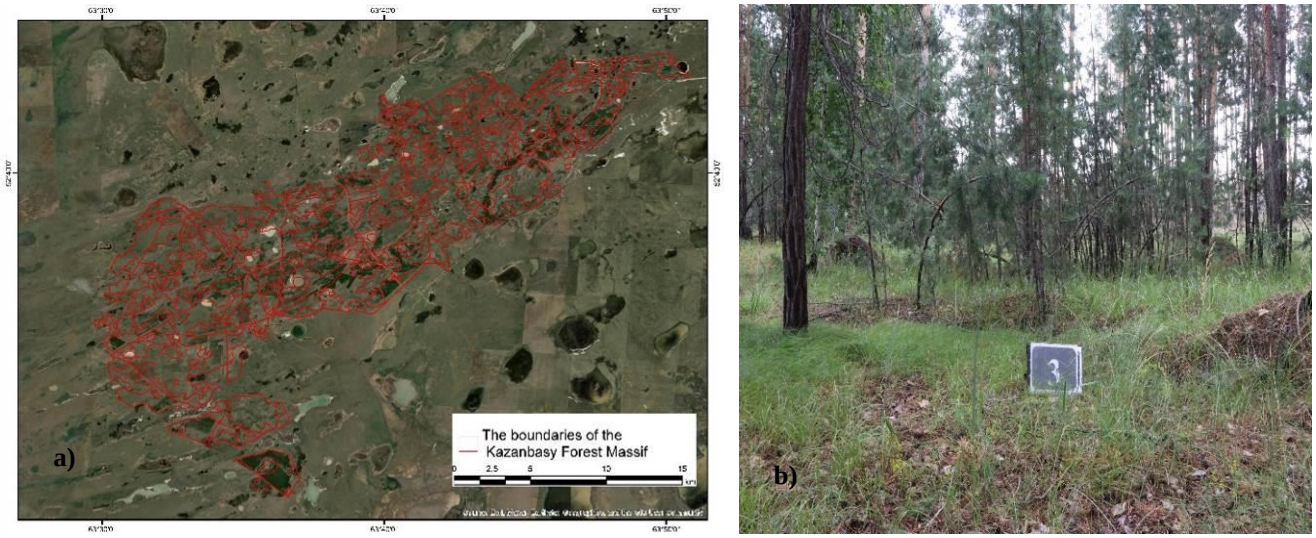

Figure 6. a) Kazanbasy Forest Massif (Source: Created by authors in ArcGIS.10.8 program using "National Geographic World Map")
b) The key site № 3 Kazanbasy Forest Massif (Source: research conducted by authors in "Kazanbasy", 2024).

CONCLUSION

Based on the above, it can be stated that forest landscapes of Kostanay region are under the influence of recreational activities, which every year is growing and leads to the transformation of the natural environment. Pine and birch plantations for a long time are subjected not only to recreational loads, but also to strong anthropogenic influence. With

increasing recreational loads, the species composition of both pine and birch forests changes, which definitely affects both the productivity of the herbaceous-shrub layer as a whole and the productivity of individual species of herbaceous plants. Under the influence of recreational impact not only the species composition of the living ground cover, but also the projective cover and productivity of the lower tiers of vegetation change. In pine forests under significant recreational loads, mosses degrade first of all in the composition of the ground cover, therefore they can be used as indicators of the state of vegetation cover of recreationally and technogenically disturbed areas. With a continuous increase in the demand for "near" recreation and, accordingly, recreational flows within forest areas, it is necessary to conduct continuous monitoring of the state of landscapes of recreational areas, primarily forest landscapes. Further strengthening of the conjugate impact of these pressures without a set of environmental protection measures in plantations can lead to weakening of their environment-forming and protective functions and their degradation.

The recreational disturbance assessment scale for forest areas allowed us to assess the state of the natural environment in places with no recreational load and in places with intensive recreational load. Based on the assessment using this scale, it was revealed that the studied communities in places of mass recreation are strongly modified. This occurs under the influence of recreational loads. The results of the research showed that recreational pressure leads to an increase in the area of trails and glades, a decrease in stand closure, and consequently to a change in microclimate, an increase in solar radiation intensity and temperature amplitude, a decrease in air humidity, and a deterioration in the water-physical properties of soils. As a result, there is a gradual replacement of diverse indigenous communities by homotypic derivatives. The grass cover under the forest canopy acquires the features of meadowization.

At a certain stage there is an increase in the number of species due to the introduction of meadow and weedy species uncharacteristic of the original forest growing conditions. Then communities simplify in terms of the number of species and specimens, in other words, biodiversity decreases. The following conclusion can be made on the basis of the conducted research: the ground cover, which is one of the main components of biogeocenosis, serves as an indicator of the state of environmental conditions. Thus, the impact of recreational factors strongly changes the trends of natural dynamics of forest communities of Kostanay region.

To effectively manage recreational pressure on forested areas, it is recommended to comprehensively employ administrative, economic, and informational regulatory instruments. The management strategy should include the following key directions: reducing recreational pressure on the area, particularly during the summer season, and enforcing compliance with environmental protection laws by recreationists. Within the framework of reducing recreational pressure on the area, the following measures are recommended:

- develop a network of ecological trails, actively incorporating them into tourist routes, and encourage guests at resorts to visit these eco-trails.
- differentiate parking fees based on favorable weather conditions: increase the cost of parking on hot, sunny days.
- disperse tourist flows by promoting recreational use of areas adjacent to the forest.
- concentrate and limit recreational pressure on specially equipped sites along ecological trails.
- equip a designated beach area.
- construct a network of paved pedestrian pathways.

To ensure compliance with environmental protection laws by visitors, it is essential to first communicate the specific characteristics of the area they are visiting:

Install informational boards in visible locations outlining the requirements dictated by the environmental protection status of the area.

Erect prohibitory road signs.

Place visible directional markers.

Impose administrative penalties for non-compliance with environmental regulations.

The increasing impact of recreation on fundamental soil processes and regimes ultimately leads to a weakening and death of forest vegetation, making it one of the most detrimental anthropogenic factors for natural areas. The results obtained allow for a new assessment of the intensity and scale of recreational impact on the soil cover of forested areas.

1. Selected indicators of recreational disturbance—pH, soil compaction, moisture and temperature, species composition of vegetation, projective cover, species abundance, damage to woody vegetation, and the number of stumps from cut and felled trees—have been determined through field observations at specific points.

2. Within the study areas, stages of recreational degradation have been identified and used to assess the degree of recreational disturbance in various forested areas.

3. For each forest area studied in the Kostanay region, an integrated indicator of recreational disturbance has been calculated, and the stages of recreational degradation have been identified. The Arakaragai pine plantations, with their particularly dense network of trails, experience especially high levels of pressure.

4. As a result of the research, recommendations for the restoration of damaged areas have been developed for each stage of recreational degradation in forest landscapes.

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