Recreational loading as a factor of changes in the process of moisture ground soil in protected natural territories of the Black Sea coast of Russia

O V Khalikova, R R Isyanyulova and S I Muftakhova
Federal State Budget Educational Institution of Higher Education Bashkir State Agrarian University, 34 50th October anniversary street, Ufa 450000, Russia
E-mail: khalikova_o.v@mail.ru

Abstract. The article presents the results of studies on how the unsystematic impact of recreational loads leads to deterioration in the soil cover of the Black Sea coast. The impact of anthropogenic factors leads to severe degradation of the soil cover and greatly changes the level of soil moisture reserve. The objectives of the study included studying the composition of soils in the forest territories of the Novorossiysk, Gelendzhiks, Abinsky, Afipsky forestry, analysis of the properties and condition of soils, and the assessment of various indicators as a result of the impact of recreation. The main problem in the conditions of recreation is the decrease in thickness and fertile layer in forest soils of the Black Sea coast due to trampling and degradation of the litter. The main quantitative indicators of damage to the soil cover during recreation affects the dynamics of soil moisture are presented in the tables 1 and 2, where the soils in the pine and rock oak formations (the main forest-forming species of the Krasnodar Territory). The scientific novelty of the work lies in the fact that studies of the state of forest soils under conditions of increasing recreational loads are rarely carried out. Scientists and forestry workers study the soil as a biological source for the growth of woody plants in various types of soils. Novelty is that the study of soils is carried out not only under conditions of recreational stress, but also in mountainous terrain.

1. Introduction
Krasnodar Territory is the most economically developed territory in Russia. It is in this region of the country that a large number of unique, relict and introduced species of woody plants grow on forested areas. A favorable climate and natural conditions, as well as a high content of humus and nutrients in the soil are the main sources of such biological diversity. For their intended purpose, all the forests of the Black Sea coast of Russia belong to the protective ones; clear felling and unsystematic economic and recreational activities are prohibited here [1]. Over the years, the forests of the studied region have formed a large productive ecosystem; a powerful litter under the forest canopy has enriched the soil with nutrients and made it more fertile, improving the water-air regime of the soil. The soils of the Black Sea coast of Russia and the Krasnodar Territory are mainly represented by black soils, and they are the most fertile in Russia. The thickness of soils and their humus layer exceeds 120 cm. Before the research, the existing problem was traced and clearly posed. Over the past 30 years, recreational activities and intensive economic development of forest areas have made adjustments to biogeocenoses and soil conditions. Trampling has led to the transformation of forest litter, which has greatly reduced the physical and mechanical properties of soils. As a result, tree-shrub plants cannot normally grow in
damaged and degraded soil, which results in their death [2]. This, in turn, leads to poor natural regeneration of unique species of woody plants and a further decrease in the biological productivity of forests as a whole. The global problem that arises from these consequences of forest recreation and economic development is the deterioration of the ecological situation in the region.

Over the past 3-4 years, a number of scientists have studied the soils of the Black Sea coast and the Krasnodar Territory. The authors of research have studied and assessed the resistance of different types of soils to chemical pollution and the presence of heavy metals in forest soils of the Northern Caucasus [3]. The biological activity of forest soils of the Black Sea coast of Russia was studied by D. V. Strukova [4]; this work was the topic of her dissertation for the degree. The transformation of the phosphate regime of brown soils of the Black Sea coast of Russia was studied by V. V. Kerimzade [5]. Analysis of agrogenic changes in the brown forest soils of the Black Sea coast of Russia and their diagnosis was carried out by D. V. Strukova [4]. Studies on the content of nitrogen and carbon in the soil of the Black Sea coast under conditions of pyrogenic exposure were carried out by V. O. Pyrkin [6]. L. S. Malyukova and N. V. Kozlova [7] focused their works on the factors of soil-forming processes in the subtropical zone of Russia. The influence of various types of recreation was studied in the USA [8]. The issue of soil compaction and suppression of the vital activity of the roots of tree-shrub rests has been considered in detail in the works by many authors [9].

This literature review confirms the fact that soil research in this region should not stop; research should give specific goals for improving the soil and vegetation cover of the forest territories of the Black Sea coast. Based on existing problems, this work aims to identify a direct pattern of how recreation leads to global environmental problems, starting with the deterioration and pollution of forest soils of the Black Sea coast of Russia. The scientific novelty of the work is that in recent years, the dynamics of soil moisture and the study of the moisture content of the soil in these forestries have not been carried out. The work also aims to propose effective measures for the restoration of soil resources in the studied region.

2. Materials and methods

Studies of woody plants and soil moisture in the trial plots were carried out from April 20, 2018 to September 27, 2018. During the study the plantation taxation of the forest stands of Gelendzhigsky, Abinsk, Afipsky, Novorossiysky, Dzhubga and Mikhailovsky forestry were studied. Permanent trial plots were laid in 2017 and were limited instrumentally with measuring angles and sides with cutting along the boundary lines (width 0.3-0.5 m); the total size of one trial plot was 0.25 ha. At the corners of the permanent trial plots in the studied forestries, the posts were set according to All-Union Standards 56-69-83 with the year, area and purpose of the establishment. On the permanent test plots in these forestries, the sanitary condition of woody and shrub plants was assessed. To assess the vital state of woody plants and shrubs, the method by V. A. Alekseeva [9] on a 5-point system was used. Also, the state of the grass and living ground cover was assessed on the test plots. The degree of disturbance of these objects of study is usually expressed through the stages of digression, which correspond to different levels of disturbance of parts of forest communities. For the first time, such a differentiation was proposed by R. Karpisonova [10]. It is this technique that we have used. Due to the fact that trampling of the grass cover is associated with compaction of the upper soil horizon and a change in its chemical composition, the degree of trampledness of the grass cover was assessed at the test sites. For this, the dosed trampling technique was used [9]. During the study, early data on attendance accounting at trial plots with varying degrees of recreational loads were studied and new data were compiled. Attendance on trial plots in forestries was assessed by taking into account vacationers to determine the degree of intensity of use of the study area. By the method by A. S. Khairedinov and S. I. Konashova [11], the size of the recreational load (the number of vacationers per specific area unit) was determined.

Attendance was determined by the formula:

\[
\text{Att.} (\text{un.}) = K_1 \frac{\text{The total area}}{K_2}
\]

After that, comparative measures were taken of the study results in places with one or another intensity of recreational loads in order to identify the causes of soil cover degradation in connection with
the above factor. In 2018, during the survey work, the annual dynamics of the sanitary and forest pathological state was determined; the work was also focused on the study of the soils of these areas, and the soil properties (moisture, bulk density, acidity) were evaluated. During the study, the soils of the foothills, mountain, slope and mid-mountain were studied. The study of the soil cover of meadow and alpine zones will continue in 2019-2020. During research with scientists, a hand drill and a shovel were used to collect soil samples. Research methods were chosen taking into account the tasks set. Soil sampling was carried out on the basis of State All-Union Standard 17.4.4.02-84. On permanent test plots, plots (10 pieces) were created; in the center of each of them, soil cuts to a depth of 1.5 m were made using a hand drill and a shovel. After that, the samples were taken for research and the sections were filled in. To determine the soil acidity, we used universal indicator papers for pH tests and a portable pH meter for soil, which allows us to determine the level of soil acidity (12 levels) and soil moisture (5 levels). Acidity and humidity were determined by sticking a pH meter probe into the samples, which reflected the level of the test reaction. To study the moisture content of the soil and determine the volumetric weight, the thermostatic-weight method was used. To calculate the dynamics of soil moisture at constant sample plots, a generally accepted scheme was used which allows one to calculate the soil moisture reserve in a meter layer. For this, the formula is used:

\[ W_{k+1} = W_k + (F_0(\ast 0 - W_{\text{Low}(k)})T, W(0) = PF_0 \]  

(2)

Statistical analysis was carried out using the sampling method, the method of static observations, as well as the method of summarizing and grouping materials of static observation.

The soil cover in the forests of the Black Sea coast is distinguished by its great diversity due to the complex bioclimatic conditions of the region. The soils here are distinguished by their friability and clay composition. The thickness of the soils in the forests of the Black Sea coast depends on the type of relief and soil-forming factors. So, on the test areas, which were laid in places with the greatest steepness of the slope, the soil power was minimal. The soil formation process in forests is affected by various biological factors and the state of vegetation. The main soil type in the study area is brown mountain forest soils, which were formed under beech (Fagus) and oak (Quercus) forests, which are the main forest-forming species in the study area. In pure oak (Quercus) formations in these territories, sod-carbonate and humus-carbonate mountain-forest soils prevail, usually located in the northern part of the Caucasus Mountains. The content of organic substances in the second case is fixed in the upper parts of the soil, which indicates an increased content of humus and soil fertility.

During the studies, regularity was revealed of how the degree of recreational load affects the humus content in the soil and, as a consequence, its fertility. In recent years, soil fertility in the forests of the Black Sea coast has decreased by 20%. Currently, trends in forest soil fertility deterioration due to the impact of recreation, especially black soils persist. The area of black soils is reduced due to soil degradation that occurs as a result of trampling. The negative consequence of recreation in forest soils in the study area is erosion. Water erosion is clearly visible on the slopes. During the research, it was revealed that due to a decrease in organic matter in the soil as a result of human activity and because of the rare vegetation and rain cover, the topsoil is washed out. Potholes and ravines are formed. In addition to recreational impacts, the climate of the Krasnodar Territory, as well as the relief and geological structure, also lead to soil erosion.

The thickness of soils in the North Caucasus reaches a mark of 50 cm, since there is more flat terrain and altitude does not rise above a mark of 600 m. Significant reduction in the power of the soil can be seen in southern areas of the Caucasian mountains, where the ridges have a steep slope, rather than in the north; the soil power here does not exceed 20 cm. The study shows that the impact of recreation makes adjustments to the structure of the soil. In places of increased recreational load (Sochi National Park, Bolshoi Utrish Wildlife Refuge, Caucasus State Natural Biosphere Reserve), the soil is overly compacted, there is a significant deterioration in the water regime (decrease in moisture content) of the soil as a result of recreation [4]. Figures 1 and 2 show the indicators of the dynamics of the soil cover and the presence of sedate recreational loads (April-September 2018) with varying degrees of damage to the soil and varying degrees of recreational load.
Figure 1. Analysis of the dynamics of soil moisture in the stands of rocky oak (*Quercus petraea*) in the trial plots.

Figure 2. Analysis of the dynamics of soil moisture in the plantings of Pitsunda pine (*Pinus brutia var. Pityusa*) in the trial plots.

In figure 1, the data of six-month observations of the dynamics of soil moisture in especially valuable stands of rock oak (*Quercus petraea*) in the trial plots allow us to note the trend of deteriorating water regime in the soil due to the effects of recreation in this area. An analysis of the dynamics of moisture reserve in the soil in figure 2 in the plantings of Pitsunda pine (*Pinus brutia var. Pityusa*) for the entire growing season shows that the moisture in the soil directly depends on the degree of recreational loads and the degree of soil damage. The sharp fluctuations in the moisture reserves can be explained by the fact that the litter and topsoil are severely disturbed in this territory. In areas with a high degree of recreation, these fluctuations reach significant sizes.

The entire diversity of soil cover in the forests of the Black Sea coast depends not only on climatic conditions, but also on the unique structure of the Caucasus Mountains. Soils in the forests of the Black Sea coast were formed at different heights above the sea level, with different slope steepness indicators and the influence of altitudinal zoning. They can be divided into 6 large categories by zones: meadow, soils of the foothills, mountain, mid-mountain, slope and high mountain. In the study area, there are all 6 categories of soils; this vertical zonality determines their diversity and uniqueness.
The Mediterranean climate of the Krasnodar Territory and the presence of Colchis type forests have led to the formation of mountain brown soils. This type of soil can be found in such forestries of the Krasnodar Territory as Gelendzhiksky, Abinsky, Afipsky and Dzhubgsky, where such low-productive plantations as the Caucasian hornbeam (*Carpinus betulus*) and fluffy oak (*Quercus pubescens*) grow. Under their canopy, mountain brown soils were formed.

The oak (*Quercus*) forests of the study areas are found in the same gray forest soils. In the watersheds of the North Caucasus (Pshadskoye, Mikhailovskoye local forestry - the valleys of the Zhane, Pshada, Aderba, Mezib rivers), mountain chernozems prevail which are distinguished by their fertility and good structure. It is in these places of the North Caucasus that tourists randomly visit forests and nature monuments of various profiles, as well as illegal logging of woody plants occurs. These factors are negative and reduce the quality of the soil, its water performance and properties. It is in these forests that the undergrowth of forest-forming species is absent and there is a strong degradation not only of the soil cover, but also of the entire plant community.

Studies of the South Caucasus territories (areas of Tuapse, Sochi, Adler and closer to the border with Abkhazia) showed the presence of high mountain soil types. On slopes of different steepness and high elevations above the sea level, soddy mountain-forest soils and sod-peat soils are formed here.

The study of foothill zones and mountain zones was carried out at an altitude of 500-600 m above the sea level (hereinafter – HASL). Here, the highest indicators of soil moisture are observed due to indicators of mixed zoning. Soils change depending on these conditions.

An analysis of the dark gray forest soils of the Black Sea coast shows high humus content in the upper soil layer and an average thickness (25-30 cm). The soils here are heavily loamy. The impact of anthropogenic factors has led to soil compaction and erosion [7].

Also, on the studied height in such foresties as Gelendzhikskoye and Dzhubgskoye brown mountain soils were revealed that formed in mountainous terrain with a maximum slope of 30º, a HASL of 700 m and a thickness of 30 cm. The vegetation in this area is represented by plantations of eastern beech (*Fagus orientalis*) and Caucasian hornbeam (*Carpinus betulus*) with an almost complete absence of grass cover. In places where recreation does not do much harm to the soil, they are characterized by normal indicators of moisture and water permeability. Soil compaction and a decrease in moisture content occur in places with increased recreational load.

Within the Afipsky and Abinskksky forestry, gray forest-steppe soils of medium thickness (20 cm), HASL of 200-450 m prevail, the steepness of the slope is 15-20º. This type of soil is characterized by a difference in horizontal zones. Also, in the study area, there are gray forest soils at an altitude of 300-400 m above the sea level with different exposure and slope steepness. As a rule, they are formed under the canopy of the formations of fluffy oak (*Quercus pubescens*), rocky (*Quercus petraea*) and petiole (*Quercus robur*) as well as undergrowth of the Caucasian hornbeam (*Carpinus betulus*) and oriental beech (*Fagus orientalis*). Due to the low humus content, soils do not differ in high fertility. Due to the large number of nature monuments and protected areas in these forestries, recreation flourishes here; a large number of paths, trampled grass and oppressed undergrowth are observed on the territory.

Everywhere at an altitude of 400-700 m above the sea level sod-carbonate (typical, podzolized and leached) soils are represented. There are such forestries on the Gelendzhik-Tuapse segment within the boundaries of protected areas: Gelendzhiksky, Mikhailovsky, Dzhubgsky, Afipsky, Abinsky and Tuapse laziness. This type of soil is formed under the canopy of broad-leaved forests of the Black Sea coast in especially valuable forests of fluffy oak (*Quercus pubescens*), rocky (*Quercus petraea*), oriental beech (*Fagus orientalis*), seed chestnut (*Castanea sativa*), Caucasian hornbeam (*Carpinus betulus*). On the territory of forestry, mixed forests with a mixture of pine Pitsunda (*Pinus brutia var. pityusa*) and Caucasian fir (*Abies nordmanniana*) can be found [11]. Soddy carbonate soils in the studied forest districts are distinguished by their mechanical composition; high rockiness is observed. Despite the small steepness of the slopes, where sod-carbonate soils are represented, the thickness here is not great – 20 cm. Soils do not differ in high fertility. PH in sod-carbonate soils in these forestries ranges from 7-8.2, which indicates a slightly alkaline environment. The pH of sod-carbonated leached varies from 6-7. Due to the fact that a large number of nature monuments of various profiles are located within the
forestries (for example, Mount “Thab” and “Monasteries”), a high degree of recreational load is here. A lot of tourist routes pass along the borders of the protected areas and invade the natural places of growth of especially valuable forests. In this connection, the water regime in soils is severely disturbed here. Soil compaction causes low moisture content in its upper layers; plants has unsatisfactory growth, and undergrowth becomes unviable.

Yellow earth soils can also be found in Dzhubgs ky, Abinsky and Afipsky forestry. Because the forests of these forestries are of Colchis type, here the stands are represented by Caucasian hornbeam (*Carpinus betulus*), planting chestnut (*Castanea sativa*) and horse chestnut (*Aesculus*); the undergrowth consists of fern (*Polypodióphyta*) and blackberry (*Rubus*). Soils up to 1 m thick are acidic (pH 4). Soil moisture is low; soils are heavily loamy due to which there is low water permeability.

In the Anapa forestry in the “Bolshoi Utrish” nature reserve, where recreation has destroyed almost all relict plantations of Crimean pine (*Pinus pallasiana*) and Pitsunda pine (*Pinus brutia var. Pityusa*), brown soils were revealed. HASL is 300-400 m, steepness of slopes is 30°. Soils here are subject to water erosion due to the fact that they are located on the slopes. Of the vegetation not destroyed by tourists, there are junipers (*Juniperus*), rare specimens of dumifolia pistachios (*Pistacia atlantica*), Caucasian hornbeam (*Carpinus betulus*) and oriental beech (*Fagus orientalis*); you can find young growth of rock oak (*Quercus petraea*) and fluffy (*Quercus pubescens*). Soil moisture is not high, because rains in summer are rare (maximum peak in July).

The soils of the midlands and slope zones are represented at an altitude of 600-800 m above the sea level on slopes of various steepness. Here, sod-carbonate, black soil and brown forest soils were investigated. Sod-carbonate soils here are powerful (on gentle and sloping slopes of different exposures), reaching a mark of 70 m. An alkaline environment prevails in the soil; an indicator paper of the pH test showed a result of 7.5–8. As in the previously studied territories, the water regime of the soil is poor; the physical properties are also unfavorable.

Brown forest soils, as well as sod-carbonate, are present in the Sochi National Park and on the section from Tuapse to Adler. Soils are medium-power, acidic. Humidity is 20%. Due to the impact of recreation, the mid-mountain soil in the studied territories is re-compacted, but at the present time, constant measures are being taken to restore the soil cover due to the impact of recreation. However, illegal logging, illegal passage of sightseeing cars exacerbate the situation, and recovery measures do not improve the situation [12]. On the territory, there is a large number of paths and potholes. At present, visits to the borders of protected areas are unregulated, and forest ecosystems are severely affected. The black soils in this section are moist, fertility is low. Excessive effects of recreation on forest biogeocenoses are also observed.

Another factor in the degradation of soil cover in the studied areas in forestries is illegal logging of woody plants. Almost all the forests of the Black Sea coast are home to relict species of woody plants. Therefore, a large number of areas and forests are protected here; clear cutting and cutting of high intensity are prohibited here. However, on the territory, there are also production forests. Unfortunately, deforestation is not limited to the legal way; valuable specimens of vegetation for personal use are destroyed everywhere. Unique and relict species of trees are highly productive; their wood is of high quality and, therefore, illegal logging takes place for delivery to the “black market”.

Another factor of illegal logging is the direct proximity of villages and private houses to the borders of forestries, where specially protected natural areas are located, so residents cut down trees for their own needs, without thinking about their environmental value and the functions they perform. All this significantly affects the physical properties of the soil and the state of its surface. According to the category of state of damage to the soil cover, the studied territories belong to stages 2 and 3. Lack of litter, over-compacted soil, degradation of undergrowth – all these are consequences of illegal logging and recreation [12]. Due to the economic development of forests in this region, natural regeneration has greatly decreased, the area of damaged surfaces is increasing annually, soil water regime is deteriorating due to felling, and the fertile layer is decreasing. Because of this, erosion processes of the soil occur in mountainous terrain. All this leads to a decrease in the water-regulating function in the mountain forests of the study area.
3. Results and discussion

Soil is an integral part of natural forest complexes of the Black Sea coast. The research results show that economic activity penetrates deeper into forest ecosystems, causing irreparable damage not only to vegetation, but also to the soil cover. Due to the low water permeability and low moisture content of the soil shown in diagrams 1 and 2, it becomes unable to withstand various external factors, in particular, pollution and erosion. The soil has a decrease in its functions. The degradation of the forest landscapes of the Black Sea coast revealed during research is everywhere greatly worsening the environmental situation in the entire region of the Krasnodar Territory [13]. Transformation of soil and vegetation is the result of unresolved utilization of forest areas, illegal logging, and resulting diseases and pest infections. We have revealed that since the introduction of specially protected natural areas, it does not fully protect forest biogeocenoses from the impact of anthropogenic factors. Sochi National Park, the reserve “Big Utrish”, the Caucasian State Nature Biosphere Reserve over the past decades have lost their pristine appearance. Tourism development, jeeping, illegal logging and fires have caused enormous damage to the soil cover of these territories. Even taking into account the fact that the influx of tourists in these parts is seasonal (May-October), it is not possible to make up and repair the damage caused during the summer period. In figures 3–4, we give an example of how recreation damages the surface of the soil cover at four permanent trial plots in the Gelendzhik forestry (the trial plot number in the table is designated as TP-1, TP-2, TP-3 and TP-4).

![Figure 3](image3.png)

**Figure 3.** The effects of recreation on damage to the surface of soil cover by the example of pine Pitsunda formations (*Pinus brutia var. Pityusa (Steven) Silba*) in the Pshadsky district forestry (Gelendzhik), %.

![Figure 4](image4.png)

**Figure 4.** The effects of recreation on damage to the surface of soil cover by the example of rock oak formations (*Quercus petraea (Matt.) Liebl.*) in the Pshadsky district forestry (Gelendzhik), %.

Our studies show a tendency to deteriorate the water regime of the soil; the decrease in moisture content directly depends on the fact that trampling the grass cover leads to soil compaction and the
violation of its water-air properties. Like a number of other scientists in this field have already shown, it has been proved that the recreation and economic development of the forest territories of the Black Sea coast leads to a violation of the ecological functions of soils [3], to a decrease in biological indicators depending on the degree of anthropogenic disturbance [4], and to a decrease in important nutrients in the fertile soil layer [6]. The ecological potential of the unique landscapes of the Caucasus Mountains is declining. Forest communities cannot fully fulfill their environmental functions. Therefore, research and monitoring of the current situation in the region should not stop. The vegetation and soil cover in the region are the least resistant to mechanical damage, because they are sensitive to all types of anthropogenic impact, in particular, to recreation.

4. Conclusion
According to a study conducted in the summer of 2018, it can be judged that the situation in the forests of the Black Sea coast worsens annually. The intensive recompaction of soil within the boundaries of specially protected natural areas in forests is caused by the impact of recreation. There is a decrease in the content of humus in the soil, due to the destruction of the litter; the soil is exposed, which makes it less resistant to mechanical damage. The moisture content of the soil is becoming less; water permeability due to overconsolidation is reduced. As a result, the death and drying of woody plants and a weak renewal process occur. There is widespread degradation of soil cover in areas with a high degree of recreation, despite the environmental status of the studied territories. Our comprehensive assessment of the soil cover shows a tendency toward a deterioration of the water regime of soils in forests due to anthropogenic impact. To solve this problem, constant biotechnological and restoration measures, fencing and isolation of some groups of stands, better forest pathological measures and introduction of a visit regime in specially protected natural areas are required. The authors consider it necessary to completely exclude recreational and economic activities for carrying out complex measures to restore territories in the “Bolshoi Utrish” reserve and in some parts of the Sochi National Park.

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