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Decade-long soil changes after the clear felling in forests of the North-Western Caucasus mountains

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ABSTRACT

Clear-fell harvesting significantly alters ecosystem attributes at multiple spatial scales. The results of a study of the dynamics of changes in Rendzik Leptosol and Greyic Phaeozem Vertic forests in the middle mountains of the North-Western Caucasus after clear-cutting in 2010-2020 are presented. Immediately after clearing the forest, areas with varying degrees of disturbance of the soil and vegetation cover were identified in the clearings, from maximum disturbance in the central part of the clearing to slight disturbance on their periphery at different elevations of 540-1600 meters above sea level (masl). The soil covering is represented with Rendzik Leptosol and Greyic Phaeozem Vertic. Among used metrics were temperature, humidity, texture density, penetration resistance, structural and aggregate composition, and other soil parameters. On felling areas, increased temperatures and decreased soil humidity were recorded. The temperature of Rendzik Leptosol at a depth of 10-30 cm changes within the range of 1-15°C in the period 2018-2020. The terrain elevation affects the soil due to the temperature gradient significantly. Rendzik Leptosol is much colder at an elevation 1640 meters above sea level than at 1200 meters above sea level. The temperature of Phaeozem (540 meters above sea level) reaches 20°C during the summer months at a depth of 10 cm. Soils in felling have differences in structural and aggregate composition and water resistance of aggregates. The study results can be used in assessing damage to ecosystems after deforestation and developing methods for accelerating the restoration of soil properties after deforestation. The result of the study can be applied to assess the change in the state of ecosystems after forest degradation. The most informative diagnostic indicators for assessing the state of ecosystems after forest degradation are discussed in the article.

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1. INTRODUCTION

In many parts of the world, forest ecosystems are increasingly subject to degradation, so more attention to productive landscapes is needed to preserve the natural ecosystem. The forest felling drastically alters natural ecosystems (Dymov, 2017). Soil is critical to maintaining the productivity and sustainability of forest ecosystems. On the one hand, soil physically supports trees and is a source of moisture and nutrients for tree growth; when trees grow a great deal of litter is generated, returning nutrients to soil to improve its fertility through decomposition.

The ecological condition of forest soils changes significantly at forest felling that leads to soil cover degradation as a result of erosion processes and other kinds of processes under conditions of mountain relief and plenty of precipitates (Ivonin & Terteryan, 2015; Teng et al., 2019). Progressive successions after the forest felling lead to significant changes in the vegetation and soils (Kuznetsova et al., 2019; Zhang et al., 2020). In postforest ecosystems, not only the degradation can be noted but also the so-called ecotone effect, also known as marginal, or edge effect. The ecotone effect appears not only concerning the vegetation but also the other groups of organisms. The actuality of research of the marginal effect is determined by the possibility to use the received data for predicting the condition of contiguous ecosystems and the estimation of their mutual influence, as well as for examining ecotones as specific wildlife habitual areas where rare species can remain.

Far-reaching consequences of forest harvesting operations are the change of soil morphology and the compression of the upper soil layer, leading to decreased porosity with negative consequences for the soil ecology and forest productivity (Cambi et al., 2015). The firming of soil arising as a result of the work of the heavy equipment used in forest harvesting operations can limit forest productivity seriously for a long time. The impact of the compression on the fertility and the ecological condition of soils was studied extensively, but less information is well known about the recovery of soil properties over time (Azarenko et al., 2020; Kazeev et al., 2020). The recovery of the physical properties of Luvisol and Podzol was shown before, within 54 and 70 years (Mohieddinne et al., 2019).

In the southern part of European Russia, large areas of undisturbed forests remained only in the Caucasus Mountains. They cover a significant part of the territory here, under submontane and mountain conditions. Forest areas have appreciated value due to the wide variety of flora and fauna, environment-forming, and nature protection functions. The West Caucasus Mountains' Forests are among Russia's most varied and productive natural ecosystems. Firry forests and firry and beech forests call for special attention at the forest management in the Krasnodar region and Adygeya because they are disturbed due to the human intervention least of all can be considered to be as reference forests. However, these forests undergo a significant anthropogenic impact now that is connected with the increasing recreational pressure, construction of recreation facilities, roads, power transmission lines, etc.

The problem of the recovery of soils disturbed by fellings up to reference values is studied insufficiently, and no single-valued answer exists within which time limit the soil recovers, and if it recovers at all. That's why the question of soil recovery and the period necessary for it remains actual up to the present.

The work's goal was to determine regularities of the dynamics of the soil changing in felling areas of the West Caucasus Mountains depending on their genesis and the stage of disturbing at the forest felling.

2. MATERIALS AND METHODS

2.1. The study area and soil sampling

The examined territory belongs to the Maykop District of the North-Western Caucasus Mountains (Fig. 1). The western part of the Caucasus Mountains belongs to low-mountain relief and the area of medium-altitude Mountains. Peculiarities of the mountain relief, the altitude differentiation of the climate, and the long-term geologic history of the territory of the Western Caucasus Mountains determined a wide landscape and biologic variety. In the Belaya River basin, the upper mountain belt's natural vegetation is generally formed by two formations involving dark coniferous forest trees: the firry forest and beech and firry forest. At that, the latter prevails. Main forest forming species are Caucasian fir *Abies nordmanniana* (Steven) Spac and oriental beech *Fagus orientalis Lipsky*. The mean forest stand diameter of the fir is from 24 cm to 80 cm (average value 44.4 cm), the diameter of the beech is from 8 cm to 44 cm (average value 28.2 cm). The mean bushiness value is 665 trees per 1 ha. The mean reserve of the phytomass carbon for forests of the North Caucasus Mountains is equal to 70 tons ha^{-1} which is 60 % higher than the similar value (44 kg ha^{-1}) for forests in Russia, in general (Zamolodchikov et al., 2019).

The researched soils of forests of the Western Caucasus Mountains belong to Rendzik Leptosol that is present in many geographic areas across the globe. These soils are especially characterized by their soil-forming material containing calcium; this material is formed on limestones, dolomites, and milestones. In the southern part of European Russia in forest zones of the Northern Caucasus Mountains, Rendzik Leptosol soils with different genesis are widespread on a significant area – more than 1.2 million hectares (Konyushkov et al., 2019). The granulometric composition of these soils is mainly loamy and heavy-loamy clay-silt fraction. In typical and leached subtypes, silt is contained more in surface horizons. Downwards along the soil profile, the lowering of the humus content and the weathering intensity, the silt content in the soil is lowering. The humus content in the surface bed of forest Rendzik Leptosol soils can exceed 10% and more. In underlying beds, its amount is decreasing, but even in the soil-forming material, it amounts to 2% approximately (Kazeev et al., 2012).

The reaction of the soil medium in humus beds of Leptosol is neutral and alkalescent. In lower beds of soil, the alkalinity increases up to the alkalescent reaction of the medium due to the increased number of calcium carbonates. Leached Rendzik Leptosol is distinguished by the reaction of the medium that contains more acid in upper beds (pH = 6.3-7.6), and the alkalescent reaction in lower ones (pH = 7.6-8.1) (Kazeev et al., 2021).

The content of carbonates in surface beds of typical rendzina soils is high (5-25%), and the amount of carbonates in lower beds exceeds 50%. In leached rendzina soils, carbonates can be present only in the lower part of the soil body and the soil-forming material (Kazeev et al., 2012).

The examined territory is located at 10 km far from the Guzerripl township (Adygeya Republik) at elevation 1640 meters above sea level. The observations were carried out yearly from 2010 until 2019. The felling area is a cleared area of the upper part of the slope that doesn't contain any vegetation. The soil surface on the felling site is terrifically disturbed with heavy equipment. For such highly disturbed soils, a new taxonomic definition of detrital turbated soils on mechanically disturbed plots on felling areas was proposed (Dymov, 2017). The research was conducted on felling plots with different degrees of soil cover damage. For this, plots with weak, mean, heavy, and very heavy levels of anthropogenic soil damage were allocated. The criteria for emphasizing were surface and degree of damage estimated-

Map of felling areas

Felling areas No.1 Felling areas No.2 Felling areas No.3

Figure 1. Surveyed areas, photo from an elevation 100 masl, June 2022

based on the force of soil scalping, soil mixing, and burial as a result of heavy equipment work. In most cases, the degree of damage decreased from the road (very strong) to the border of the felling area (weak). Data on soil properties for medium and low damage begins after 24 months of the study. At first two years of the study, differentiation of sites according to the degree of impact did not occur because the idea to divide the sites according to the degree of effects arose later. As a reference area, a plot of the beech and fir forest was taken that borders on the felling area. The soil on the plot is Rendzik Leptosol.

The researched felling areas are situated at several kilometers from each other. The sample taking was carried out on areas with different degrees of soil and plant cover damage. The differences in research plots were estimated based on the depth of the soil scalping, the degree of mixing, and the burial of the heavy equipment working. Plots with weak, mean, and heavy levels of soil damage were allocated in proportion to the distance from the forest to the road.

The first felling area is situated in the vicinity of the Partisan meadow, at the distance of 15 km from the Guzeripl township; geographical coordinates are 44°0.310' of the north latitude and 40°0.585' of the east longitude. Plots of this felling area differed based on the degree of the impact onto the soil (from the B1 plot with heavy damage to the B5 reference plot). On the B1 plot – on the natural soil road – heavy damage was observed: glabrate territory with the extremely intense erosion and this-sown plants. At several meters, the B2 plot with the mean damage is situated which is covered with high-grass meadow vegetation with the weak understory of young regeneration. On the soil surface, many vegetables remain present as rags. The B3 plot with the weak damage is situated at 20 m from the road; on this territory, the margin (ecotone) effect is observed; the vegetation is the same as on the previous plot. On the soil surface, the solid bed of peaty plant remains with the thickness of 1-2 cm is present. The B5 reference plot is situated 50 meters from the road and represents the hornbeam, fir, and maple forest with fern and grass cover.

The second clean felling area is 9 km from the Guzeripl township, at approximately 1200 meters above sea level; geographical coordinates are 44°01.135’ of the north latitude and 40°03.769’ of the east longitude. Here, on B6 plot, the heavy damage of the territory is recorded. This plot can be characterized as a cleared territory on which erosion processes are extremely intense. On the territory of this plot, depositions, grey pebbles, and fragments of white limestone with singular herbage plants were observed. At 10-15 m from this plot, the B7 territory with the mean degree of damage is situated. On this plot, the high-grass meadow cereal vegetation rich in herbs is observed, with the weak understory of young regeneration of alder. To this area, a B8 plot adjoins that has a weak degree of damage and is covered with thick shrubby alder brushwood and high-grass meadow vegetation. As a reference area, the B9 plot was present here where beech, maple, and fir forests are present with the underbrush from the fern, blackberry, and miscellaneous herbs.

The researched territory with the Greyic Phaeozem Vertic soil is near Dakhovskaya Cossack village, Adygeya Republic. The researched soil is characterized by the high content of the organic substance in the upper bed – 7.3 %, neutral reaction of the medium – pH = 7.3, heavy-loamy granulometric composition, and mean biological activity.

The reference area of the aspen and oak forest with the subtle understory of young regeneration of the forest islocated at 540 meters above sea level. The plot is divided into 2 areas: the reference area (forest) and the clear-felling area. Afterward, in 2019, the repeated clear-felling of grown trees was carried out at the felling area. As a result, the felling area was differentiated into 2 plots: the overgrown felling area and the repeated felling area. The species composition of the flora on the felling plot is represented with forest and shrub vegetation (height of 8-10 m) with the cover from the meadow cereal vegetation rich in herbs with the height of 50-100 cm and 100-percent foliage cover. In 2019, on the part of the overgrown felling area, the understory of young regeneration was felled repeatedly. That's why the vegetation was represented here by the meadow cereal motley grasses. Three soil samples from the soil upper layer (0-10 cm) were selected on each investigated plot.

2.2. Determination of soil properties

The soil temperature was defined layer-by-layer with a HANNA CHECTEMP electronic thermometer. Besides, the DT-810 "CEM" pyrometer in 10-fold replication was used to determine the soil surface temperature. The temperature dynamics from 2018 to 2020 were researched using Thermochron DS1921 temperature sensors at a depth of 10, 20, and 30 cm, with the measurement's periodicity from 3 to 6 hours. The soil humidity was determined afield using the Fieldscout TDR 100 humidimeter in 10-fold replication. The soil bulk density was determined using the volume-weight method using steel rings with a volume of 135 cm^3 in 3-fold replication. The soil hardness (penetration resistance, soil structure strength) was investigated afield using the EIJKELKAMP penetrometer at a depth of 50 cm at an interval of 5 cm in 10-fold replication.

The structural and aggregate analysis of the soil was carried out using the method of N.I. Savvinov consists of the soil's dry sieving through the sieve column with cell dimensions from 10 mm to 0.25 mm. The water stability of structure aggregates was determined by taking into account aggregates that crumbled in the slack water within a certain period.

Combining several parameters is a method used to determine the integral parameter of the soil's biological state (IPBS) (Kazeev et al., 2003). This method allowed the evaluation of the biological parameters set. For this, the value of each parameter in the control soil was taken as 100%—this parameter value was expressed as a percentage in relation to it as Equation [1].

$$B_1 = \frac{B_x}{B_c} \times 100\% \quad [1]$$

where B1 is the relative score of the parameter, Bx is the actual value of the parameter in the post-fire soil, Bc is the value of the parameter in the control soil.

After that, the average estimated score of the studied parameters for the sample was calculated. The absolute values cannot be summed since they have different units of measurement (mg, %, etc.). The integral parameter of the biological status of the soil was calculated according to the Equation [2].

$$IPBS = \frac{B_a}{B_{a.c}} \times 100\% \quad [2]$$

where Ba – the average estimated score of all parameters in post-fire soil, Ba.c – estimated score of all parameters under control. Indicators for calculating IPBS: humus, active carbon, catalase, dehydrogenases, invertase, urease, phosphatase, microbial biomass, and number of bacteria.

2.3. Statistical analysis

The statistical processing of data was carried out using Statistica 10.0 software. When discussing the results, statistically significant differences with a significance level of 5% ($p < 0.05$) were taken into account ($p < 0.05$).

3. RESULTS

The dynamics of the flora and vegetation varied on felling areas. After one year, carpet plants appeared on the felling area, decreasing of damages (tracing ruts, furrows, et al.) caused by heavy equipment work was noted. On the reference area in the forest, the species composition counted approximately 40 species with the prevalence of *Abies nordmanniana*, *Fagus orientalis*, and *Acer trautvetteri* Medw. The rarefied crown cover and good moisture conditions create favorable conditions for the development of the herbaceous layer. Common species with foliage cover up to 50% are *Milium effusum L.*, *Polygonatum verticillatum* (L.) All., *Galium odoratum* (L.) Scop., *Dryopteris filixmas* (L.) Schott, *Poa longifolia* Trin. Afterward, after several years, the species composition of the flora on felling areas with the mean and especially weak damage exceeded the biological diversity in reference areas of the forest significantly. This is connected with the edge (margin) effect. The meadow high-grass vegetation with a height up to 150-200 cm covered the surface of the felling area on these plots completely. Only plots with severe damage to the soil cover due to severe erosion are characterized by weak variety and rarefied grass cover (Kazeev et al., 2021).

3.1. Temperature

In felling plots with the high anthropogenic load, high temperature and low humidity were recorded compared to reference values under the forest cover. This is connected with the low-grade foliage cover of the vegetation on plots with severe damage. The minimal temperature and the maximal humidity were recorded in reference areas of the forest that prevented the soil surface insolation to a considerable extent.

Temperature conditions of Leptosol are presented in Figure 2. Generally, it is noted that the soil temperature during the year changes from 1 to 15°C. The soil temperature under the forest, near the felling area number 1 changes significantly in summer and winter at different depths. In transition months, soil temperature differences at different depths are less essential. It should be noted that a thick covering of snow lies here during the significant part of the year, and it preserves the soil against frost penetration, but low temperatures persist from November until May.

Comparative studies of the temperature conditions of researched plots showed a significant discrepancy of values

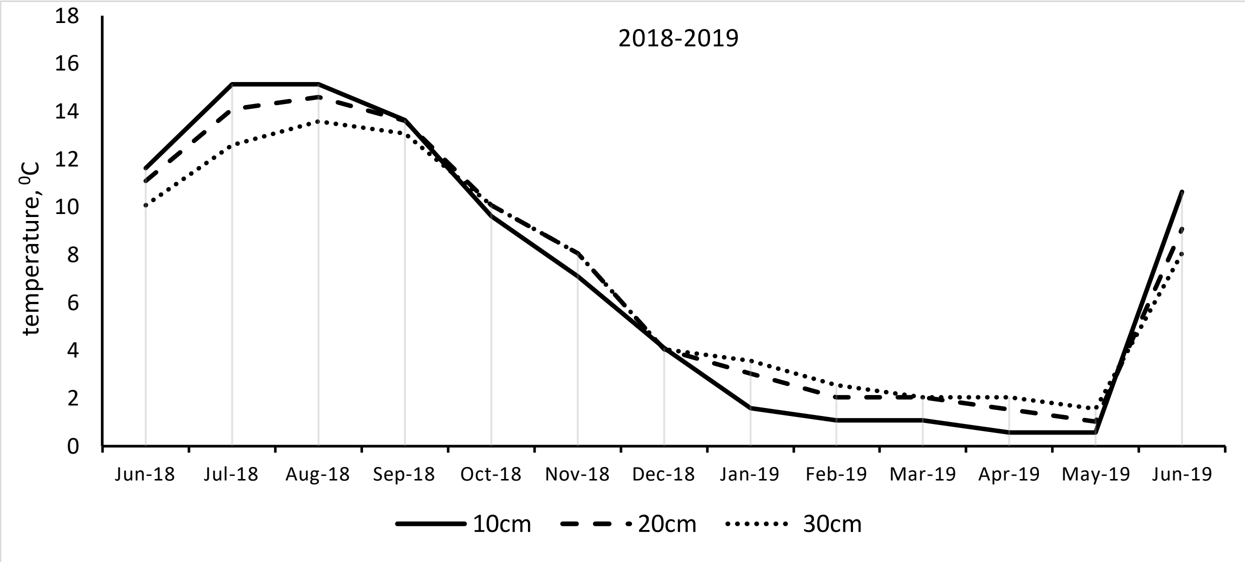

Figure 2. Dynamics of soil temperature in the control plot of forest felling No.1, 2018-2019

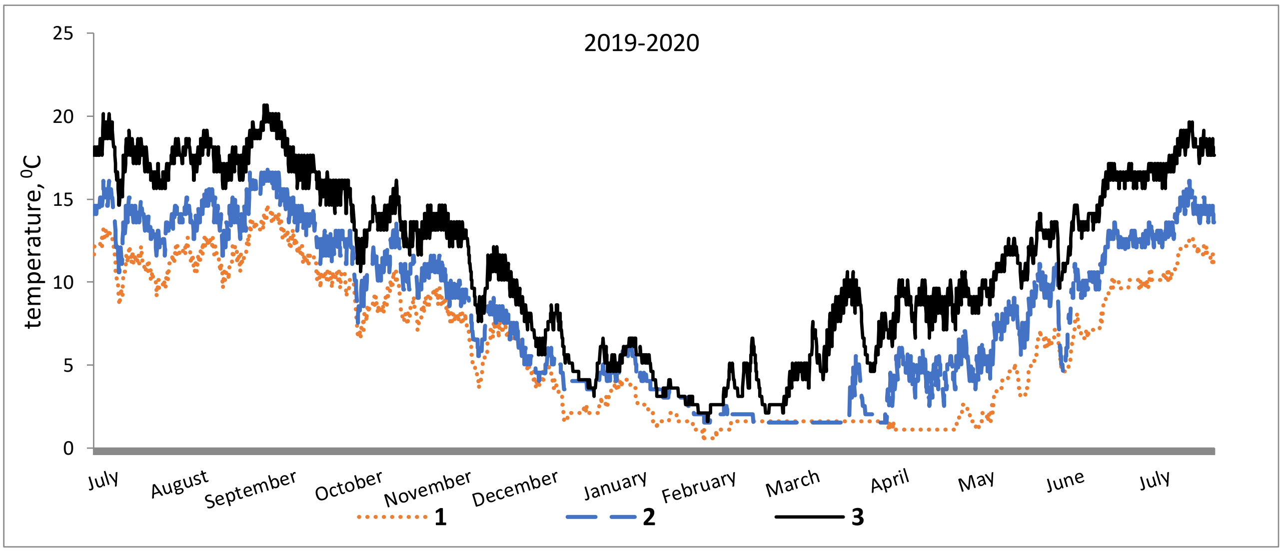

Figure 3. Soil temperature dynamics at a depth of 10 cm in control forest plots at different terrain heights, 2019-2020: 1) 1640 m; 2) 1200 m, 3) 540 m

depending on the height above sea level. The terrain elevation affects the soil temperature dynamics due to under conditions of the medium-altitude mountains (Fig. 3). Thus, soils of felling area No.1 at 1635 masl are colder than the similar soil of felling area No.2 at 1200 masl. The felling area No.3 on the Phaeozem soil is distinguished by warmer conditions because of its location at 540 masl. The soil temperature at a depth of 10 cm reaches 20°C here during the summer months. No freezing of the soil has been detected on all three felling areas.

3.2. Dynamics of physical properties of soils after the forest felling

The physical properties of soils on felling areas were disturbed significantly after the anthropogenic damage. During the first years after the forest felling, a significant excess of the soil texture density was recorded compared to the forest soils metrics. The density values increase was connected closely with the degree of soil surface damage at forest felling and trawling. The pot values increase with severe damage until the high level 1.43-1.45 g/cm^3 (Fig. 4).

The highest level of anthropogenic impact was increased the soil density (Fig. 5). After three years, the soil texture density on the felling plots with the mean and high degree of degradation was higher (0.8-1.3 g cm^{-3}) than on the reference plot (0.8 g cm^{-3}). At the same time, on the plot with moderate damage, the soil texture density became lower than in the reference area.

The soil consolidation on the felling area also leads to the change of hardness measured based on the ingress (penetration) resistance. Due to conducted studies, the increase of the metric values was detected on damaged plots of the felling area (Fig.6). On the first year of studies, inversions of the profile distribution of the soil hardness were detected on the felling area; these inversions are detected with damages to the soil's natural texture.

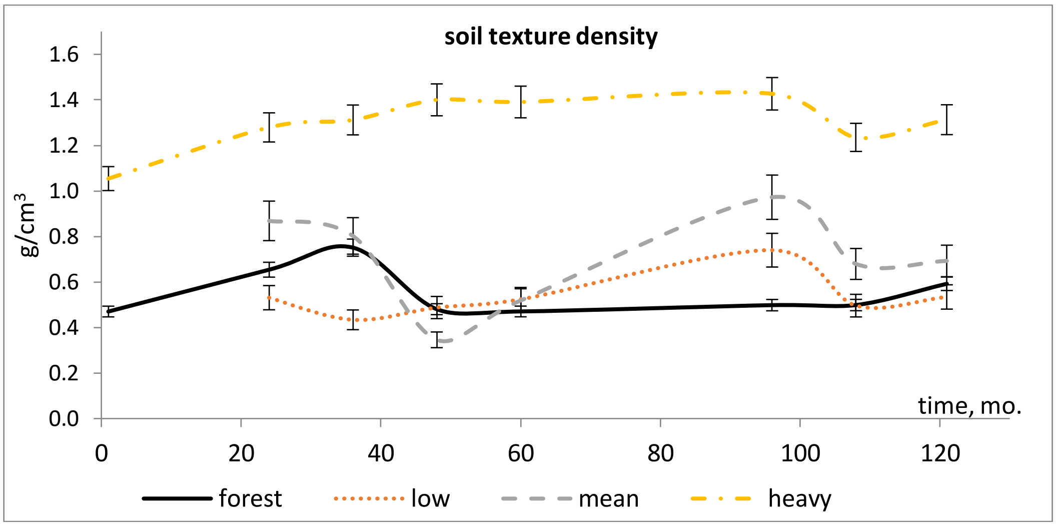

Figure 4. Dynamics of the Rendzik Leptosol composition bulk density in the felling areas with various disturbances of the soil cover, 2010-2020

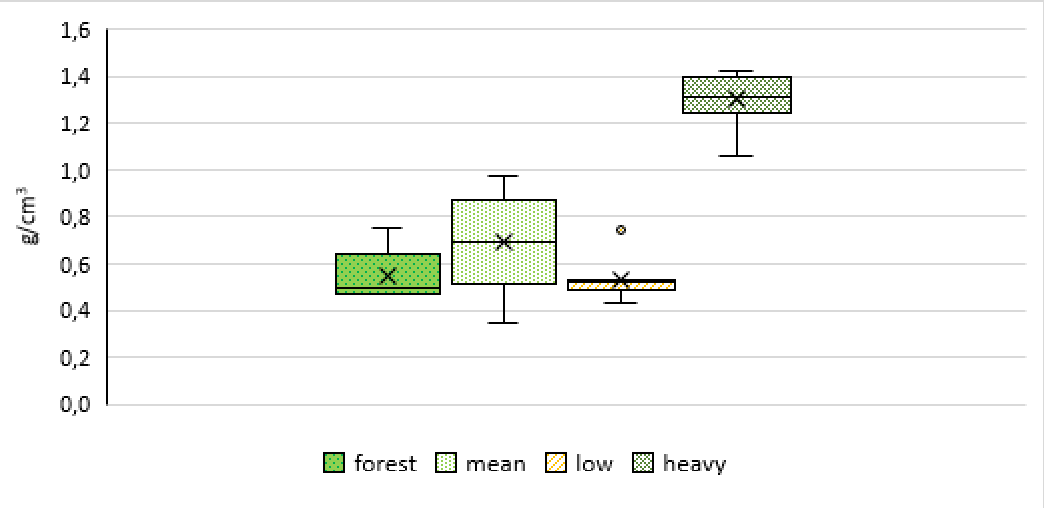

Figure 5. Density of Rendzik Leptosol in different felling areas, average values for 2010-2020

The aggregate content with the dimensions 10 - 0.25 mm in Rendzik Leptosol decreases from 60-70% under the forest to 33-45% on plots with severe damage. The water resistance of aggregates also decreases 98-100% to 33-45%. However, in some cases, especially on plots with a low degree of damage of the soil and vegetation cover on edges of felling areas, no changes of these parameters may occur. The result is connected with the intensification of the sod-forming process under the grassland vegetation in the early succession stages.

On the plot with the Greyic Phaeozem Vertic soil, at 540 meters above sea level, no significant differences in the texture density were recorded during the first years after the forest felling. In 2014, a moderate increase by 10-15% was noted compared to reference values. The same as for felling areas with Leptosol soil, the higher soil temperatures on the felling plot were connected with the increased insolation in the absence of the high forest crop. Ten years after the forest felling, the physical parameters of the soil practically recovered and achieved reference values. The texture density was optimal for plants in all areas (0.87-0.95 g cm^{-3}). The number of valuable soil aggregates in the reference soil was much higher from 2019 until 2020 (by 61-76%) than on felling plots (24-37%). At that, the water stability of aggregates practically did not differ at a high level (89-99%).

As reflected in the IPBS, the total changes in biological activity decreased by 23 and 2% from two sites of severe damage by logging in 2019, and in 2020 by 22% for Greyic Phaeozem Vertic soil. For Rendzik Leptosol, the total change in biological activity decreased by 74, 40, 48% from three sites of severe logging damage in 2019. Figure 7 shows that in 2020 for Rendzik Leptosol there was a 51, 36, 40% decrease.

4. DISCUSSION

The dynamics of the flora and vegetation vary on felling areas. After one year, carpet plants appeared on the felling area, decreasing of damages (tracing ruts, furrows, et al.) caused by heavy equipment work was noted. On the reference area in the forest, the species composition counted approximately 40 species with the prevalence of *Abies nordmanniana*, *Fagus orientalis*, and *Acer trautvetteri* Medw. The rarefied crown cover, as well as good moisture conditions, create favorable conditions for the development

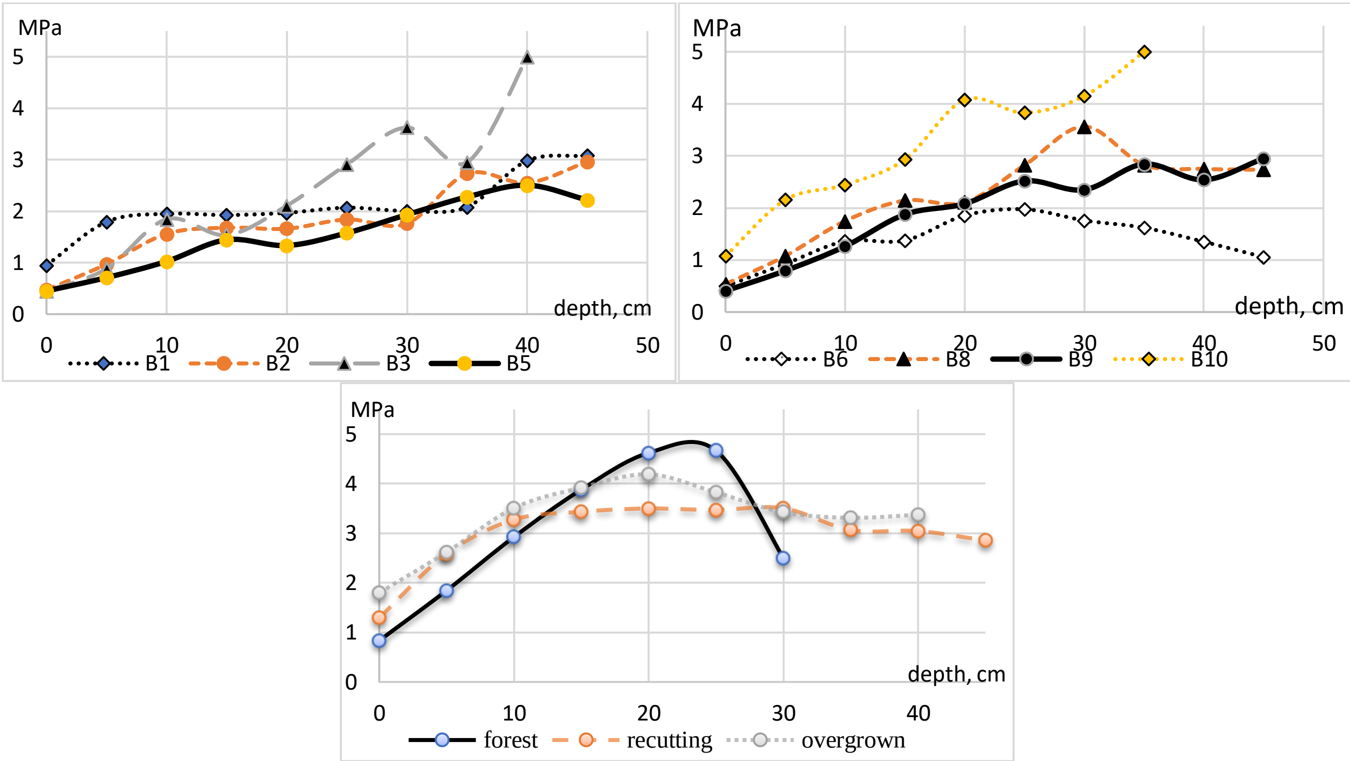

Figure 6. Soil penetration resistance in different felling areas, 2020

of the herbaceous layer. Common species with up to 50% foliage cover are *Milium effusum L.*, *Polygonatum verticillatum* (L.) All., *Galium odoratum* (L.) Scop., *Dryopteris filixmas* (L.) Schott, *Poa longifolia* Trin. Afterward, after several years, the species composition of the flora on felling areas with the mean and especially weak damage exceeded the biological diversity in reference areas of the forest significantly. This is connected with the edge (margin) effect. The meadow high-grass vegetation with a height up to 150-200 cm covered the surface of the felling area on these plots completely. Only plots with severe damage to the soil cover due to severe erosion are characterized by weak variety and rarefied grass cover (Kazeev et al., 2021).

In broad-leaved and cool-temperate dark-coniferous forests, changes in species diversity follow the parabolic trajectory during restorative successions at clear-cutting sites; in other words, the diversity initially increases and then decreases during the progress of the succession. This is caused by introducing invasive synanthropic species during the early stages of the succession (Shirokikh et al., 2018).

In felling plots with the high anthropogenic load, high temperature and low humidity were recorded compared to reference values under the forest cover. This is connected with the low-grade foliage cover of the vegetation on plots with severe damage. The minimal temperature and the maximal humidity were recorded in reference areas of the forest that prevented the soil surface insolation to a considerable extent.

Significant changes in hydrothermal conditions in fellings in the middle mountains with Rendzik Leptosol are associated with thinning of the forest stand, which leads to a greater influx of precipitation into this area, but the holding capacity decreases. Also, due to the lack of shading, the soil is heated, resulting in a decrease in air humidity, and this in turn leads to an increase in water evaporation. The reserves of soil moisture in the areas subjected to felling are greater than under the forest canopy, this is also associated with a large amount of precipitation entering the soil surface. Compared to the forest, the felling area receives 19% more precipitation (Kazeev et al., 2012). In addition, the subsoil forest microclimate contrasts sharply with the climate outside the forest due to the presence of trees and shrubs. The microclimate changes due to the forest's thinning stand persist for several years after the felling of trees. Forests have a microclimate regulated by the forest canopy, the top layer of the forest. When gaps in the forest canopy occur, for example due to harvesting, the regulating influence of the forest canopy diminishes as more sunlight penetrates the canopy and reaches the forest floor. This leads to physical changes in the forest climate (den Ouden & Mohren, 2020).

Changing the temperature conditions of Rendzik Leptosol from 1 to 15°C doesn't promote the intense execution of biological processes in the soil during the major part of the year. That's why organic remains can be preserved for a long time, and the forest cover appears on the soil surface; as well as the peaty layer of the mortmass of plants (rags) appears on felling areas. However, this layer doesn't reach higher values and can disappear by the end of the summer almost completely; it is mineralized or humified.

Areas of timber-loading plots and runways are often compacted too much. The soil compaction is directly correlated with the number of passes of the harvesting equipment (Rubinskaya et al., 2016). On runways, the density is higher by 59% five years from the felling whilst the density on bee-gardens was within normal limits (Ilintsev et al., 2019).

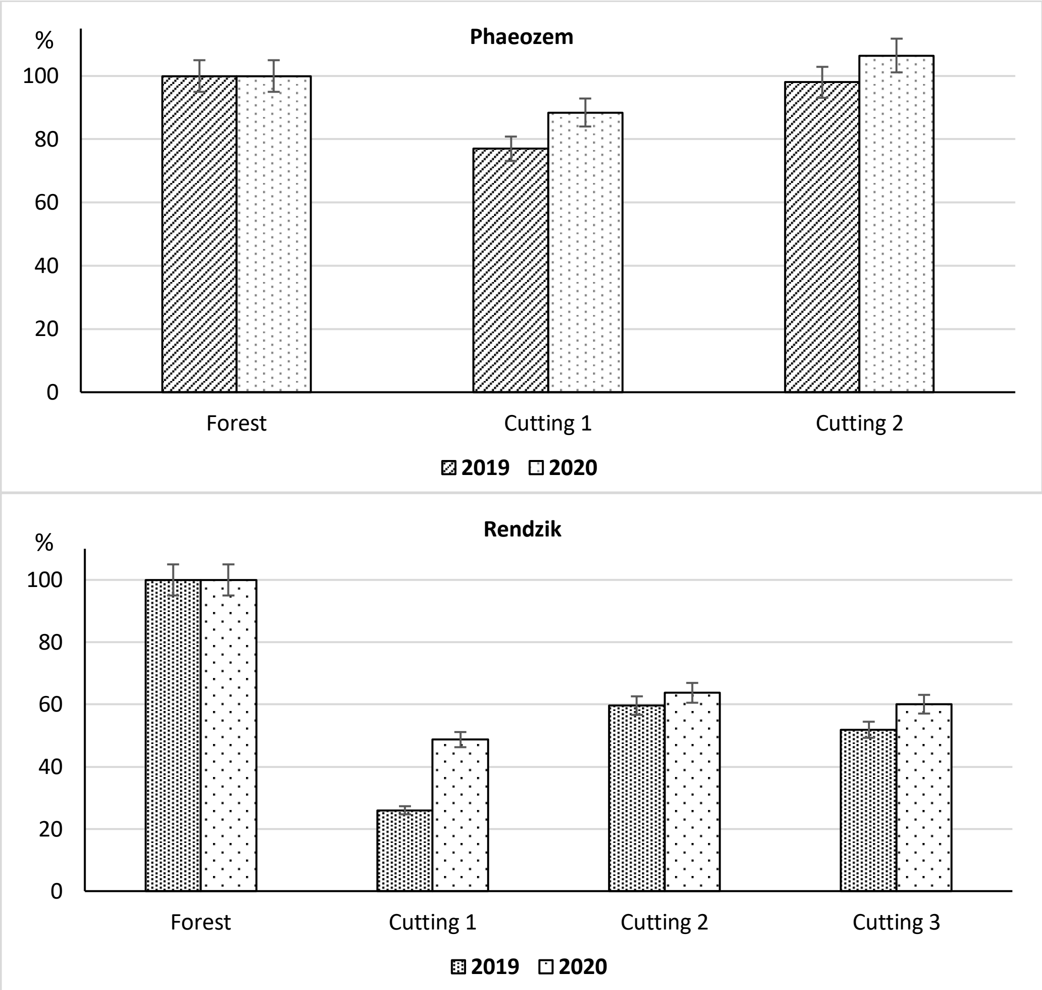

Figure 7. Integral index of biological activity of Greyic Phaeozem Vertic and Rendzik Leptosol at plots with heavy damage, 2019 and 2020

The compaction of the upper soil layer and soil morphology changes are important direct consequences of forest harvesting operations carried out using heavy equipment. The soil compaction leads to the decrease of porosity that implies restrictions of the oxygen and water entry for soil microorganisms and plants; this negatively impacts to the soil ecology and forest productivity. In compacted soils, forest regeneration can be hindered or even terminated for a long time (Cambi et al., 2015).

The reason for this was the damage of the texture of surface beds and the general soil consolidation at works using powerful heavy equipment. Afterward, erosion processes washed upper unconsolidated beds of soil out. The soil density variation because of the forest felling persists within the whole time of observation. The degree of soil density increase depended upon the level of the load on the researched territory.

The soil bulk density decrease in the slight disturbance area is associated with the increase of entry of plant remains into the soil because of the formation of the high-grass flora at the better sun lighting at the periphery of the felling area. That's why the thicker organogenic bed is formed here, and in connection with the plentiful growth of grassland vegetation, the larger soil volume is penetrated with roots. According to the integral parameter of the biological state (IPBS) data, a high resistance of Phaeozem against Rendzik Leptosol to logging was established. On average, the total indicator of biological activity for Phaeozem after deforestation is closer to control values than Rendzik Leptosol.

5. CONCLUSIONS

As a result of the forest felling, significant changes take place in the soil cover during 10 years from the appearance of damages. The significant increase of the soil texture density takes place in felling areas, in comparison with reference forest soils. The more the soil surface was damaged at the forest felling and trawling, the higher the soil texture density is. This metric characterizes the degree of soil degradation well has been disturbed at the forest felling, and it persists after the termination of the impact for a long time. Ecological conditions (terrain elevation, climatic variables, relief conditions, forest type, etc.) significantly impact the evolution of Rendzik Leptosol soils in medium-altitude mountains in Adygeya that contain the dark humus where the soil is disturbed due to felling. The properties of Phaeozem soils of low-mountain relief of the West Caucasus on plots with different vegetation types are characterized by lower differences. Therefore, these soils are more resistant to the forest felling than Rendzik Leptosol soils of areas of medium-altitude mountains of the West Caucasus.

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Declaration of Competing Interest

The authors declare that no competing financial or personal interests that may appear and influence the work reported in this paper.

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