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Original article

REFORESTATION AT LARGE BURNT AREAS IN MIDDLE TAIGA OF THE WESTERN SIBERIA

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Abstract

Background. In forested regions of Russia, hundreds of thousands of hectares of forest are destroyed by wildfires every year. As a result, the success of natural forest regeneration in large-scale fire-affected areas is a relevant issue. In addition, our task was to examine how various forest types respond to wildfire and the regeneration patterns in the region.

Purpose. The study was to examine forest restoration in the middle taiga of the West Siberian Plain.

Material and methods. This study was carried out in the Nizhnevartovsk district of the Khanty-Mansi Autonomous Okrug (KhMAO-Yugra). 20 large-scale fire-affected areas were surveyed six years after the wildfires, covering a total area of 105.29 thousand hectares. The data for this study were collected by field surveys of fire-affected areas in pine and stone pine forests, representing the main variants of pre-fire forest growth conditions (groups of forest types).

Results. The study showed that among conifers, *Pinus sylvestris* L. regenerates better. In productive pine forest types (lingonberry, green-moss, long-moss), the number of pine seedlings ranges from 11.8 to 23.4 thousand/ha. In extreme dry (lichen) and wet (sphagnum) forest types, pine regeneration is unsatisfactory. *Pinus sibirica* Du Tour colonizes the burnt areas primarily through the *Nucifraga caryocatactes* L. and the *Eutamias sibiricus* Laxmann. This study provided significant insights into the ecological recovery of different forest types. Stone pine regeneration can only be considered successful in green-moss stone pine forests (2.8 thousand/ha). The regeneration of deciduous trees - *Betula pubescens* Ehrh. and *Populus tremula* L. is significantly more numerous than conifers in all fire-affected areas (except for lichen types). Its quantity in productive forest types reaches 40 thousand/ha.

Conclusion. In general, forest restoration is proceeding successfully in most of the surveyed fire-affected areas; more than 90% of the surveyed area can be considered forest-covered.

Keywords: Western Siberia; burnt areas; pine forests; Siberian stone; natural reforestation; undergrowth

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Научная статья

ЛЕСОВОЗОБНОВЛЕНИЕ НА КРУПНЫХ ГАРЯХ В СРЕДНЕЙ ТАЙГЕ ЗАПАДНОЙ СИБИРИ

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Аннотация

Обоснование. В многолесных регионах России ежегодно выгорают сотни тысяч гектаров леса. В связи с этим актуальным является вопрос успешности естественного возобновления леса на крупноплощадных гарях.

Цель. Изучить лесовосстановление в средней тайге Западно-Сибирской равнины, на территории Нижневартовского района Ханты-Мансийского автономного округа (ХМАО–Югра).

Материалы и методы. Обследовано 20 крупноплощадных гарей через 6 лет после лесных пожаров на общей площади 105,29 тыс. га. Объектами исследований послужили гари в сосновых и кедровых лесах, представленные основными вариантами допожарных лесорастительных условий (групп типов леса).

Результаты. Из хвойных лучше возобновляется сосна обыкновенная (*Pinus sylvestris* L.). На гарях продуктивных типов сосняков (брусничные, зеленомошные, долгомошные) количество соснового подростка составляет от 11,8 до 23,4 тыс. шт./га, в крайних сухих (лишайниковые) и сырых (сфагновые) типах леса возобновление сосны неудовлетворительное. Заселение гарей кедром сибирским (*Pinus sibirica* Du Tour) осуществляется в основном кедровой (*Nucifraga caryocatactes* L.) и бурундуком (*Eutamias sibiricus* Laxmann).

Возобновление кедра может считаться успешным только в зеленомшных кедровниках (2,8 тыс. шт./га). Подрост лиственных деревьев – березы (*Betula pubescens* Ehrh.) и осины (*Populus tremula* L.) на всех гарях (кроме лишайниковых), значительно более многочисленный, чем хвойный. Его количество в продуктивных типах леса достигает 40 тыс. шт./га.

Заключение. В целом восстановление леса на большей части обследованных гарей идет успешно; более 90% от площади обследования может считаться лесопокрытой.

Ключевые слова: Западная Сибирь; гарь; сосняки; кедровники; естественное возобновление леса; древесный подрост

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Introduction

Forest fires have an ambivalent meaning for nature and human economic activity. On one hand, they are an integral part of the evolution of forest ecosystems and the current state of the Earth's forest cover [16], but on the other hand, they lead to significant environmental, economic and social losses.

Current global climate changes are accompanied by more frequent weather anomalies – hot and dry seasons occur more frequently. This also affects the forest fire situation – the intensity of fires and the size of the burnt areas increase [12; 18; 21; 24; 27]. According to FBI «RCFH», approximately 10-35 thousand forest fires are recorded annually in Russia, and the average amount of caused damage is estimated at about 20 billion rubles [13]. The increase in the number of forest fires is also affected by the prolongation of the fire danger period (early spring – late autumn) and a significantly increased number of fires caused by dry thunderstorms [7; 9; 19]. The destruction and transformation of the forest cover during fires as well as under other impacts, and during long-term recovery successions are accompanied by changes in the composition, biological productivity, sanitary-physiological state and phenology of forest-forming species both in Russia and abroad [2; 4; 10; 20; 22; 25].

The Khanty-Mansi Autonomous Okrug (KHAMAO-Yugra), located in the central part of the West Siberian Plain is among the most fire-hazardous regions of Russia. The forest resources of the KHAMAO-Yugra consist of 50 million hectares of forests and almost 30 thousand hectares of forest burn out annually

on average. As a result, individual burnt areas can amount to the area of more than 1-5 thousand hectares.

Materials and methods

The research was conducted on the territory of the Nizhnevartovsk administrative district of KhMAO-Yugra (Fig. 1). According to geobotanical zoning, the surveyed area is located in the middle taiga subzone of the West Siberian Plain. This territory is characterized by the predominance of dark coniferous (spruce-stone pine) and pine forests and derivative communities.

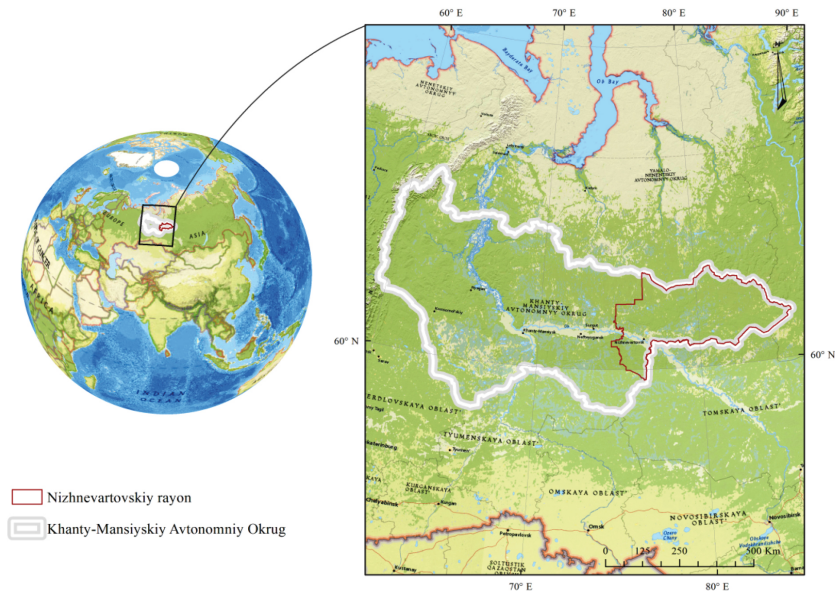


Fig. 1. Surveyed area

Nizhnevartovsk district contains almost a quarter of the forest resources of the Khanty-Mansi Autonomous Okrug-Yugra – 11.7 million hectares; 60% of them are forested. The main forest-forming species are conifers; 58% of the forests are pine forests, 23% are Siberian pine forests. Coniferous forests generally have a complex structure. In addition to Siberian pine and Scots pine, Siberian spruce *Picea obovata* Ledeb., deciduous tree species (birch, aspen), sometimes fir, and in the northern regions – larch *Larix sibirica* Ledeb. are also present in different proportions.

Judging by observation data from the nearby Laryak weather station, the global warming is very prominent in this area (Fig. 2). During the 1936-2023 period the growth rate of average annual air temperature (per century) amounted to $+2.5\text{ }^{\circ}\text{C}$, and it especially intensified in recent years, reaching $+9.1\text{ }^{\circ}\text{C}$ in the 2000-2023 period.

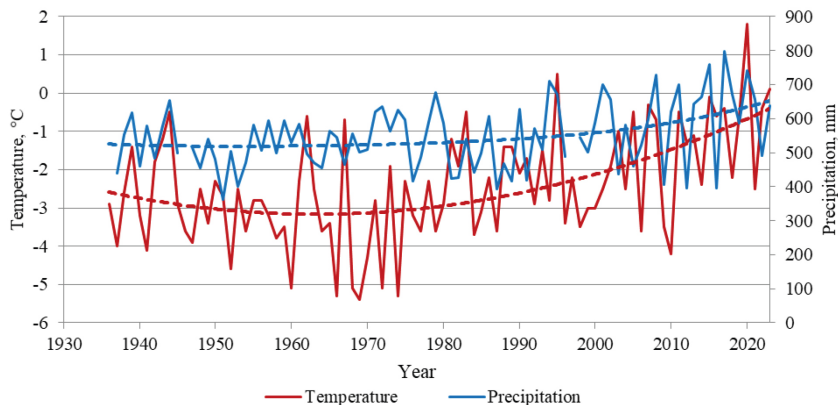


Fig. 2. Changes in the annual average air temperature and annual precipitation in the surveyed area according to the observation data from Laryak weather station (with a polynomial trendline)

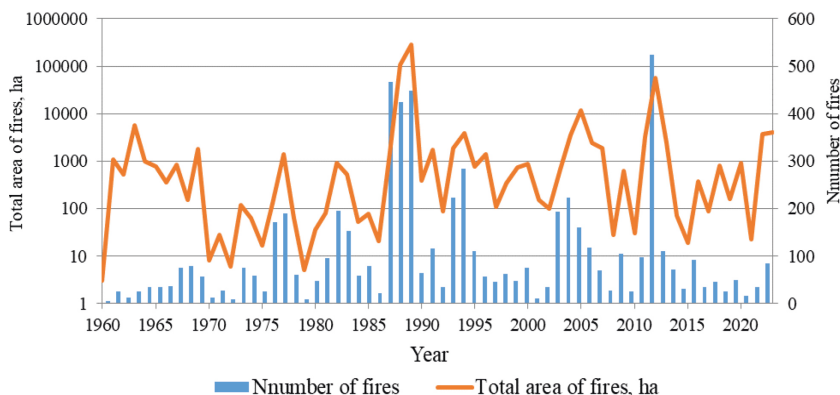


Fig. 3. Number and area of forest fires in the Nizhnevartovsk district, 1960–2023

Due to such climate changes, the coniferous forest-forming trees in Nizhnevartovsk district also show the signs of deterioration in their ecological and physiological state [23], which also reduces their fire resistance.

According to long-term data, an average of 103 forest fires occur per year in Nizhnevartovsk district [19]. Forest fires have a certain cyclicity, determined by the weather and climate characteristics of fire hazard seasons (Fig. 3). The most severe period in terms of forest fires over the past 60 years was the 1988-1989 period, when more than 160 thousand hectares of local forests have been burnt, with most of the burnt areas being results of large fires with an area of more than 1000 hectares.

Six years after these events, in August 1995, we carried out research to assess the success rate of natural reforestation in 20 large burnt areas of the Nizhnevartovsk district, with a total area of 105.29 thousand hectares. The length of reconnaissance routes for selecting areas for research was: covered by land transport – about 300 km, by water – about 80 km and by air – more than 710 km.

During the research we studied the main forest formations (pine, Siberian pine) and types of forest growth conditions (groups of forest types) present in the burnt areas of the middle taiga of Western Siberia. The distribution of the surveyed burnt area by source formations and forest types is shown in Table 1.

Table 1.

Distribution of the surveyed burnt area by source formations and forest type groups.

Formations	Forest type group					
	Lichen	Lingon-berry	Green moss	Long moss	Grass-marsh	Sphagnum
Siberian pine forests	–	–	30 775	35 918	5 850	–
Pine forests	1 098	1 800	9 827	16 250	–	3 772

Research work to assess the natural reforestation in burnt areas was conducted via a selective enumeration method, by laying transects and census plots. The transects were arranged perpendicular to the main border of the burnt area and covered areas that were at least 2 km long and 100 meters wide. On transects, we assessed the number of seed trees that have remained unharmed after the fire – as individual trees or tree groups. At each burnt area, at least 4 transects were laid, oriented to all cardinal directions. Along the transects, the 2x2m-sized census plots were distributed evenly, where we have been counting tree shoots and specimens of viable undergrowth that were up to 150 cm high. At least 20 census plots were arranged on each transect. The obtained data was then recalculated per hectare. A total of 57 transects were surveyed with a total length of 114 km, containing more than 1,140 census sites.

To assess the range of seed dispersal, we selected individual trees located more than 100 m apart from each other, groups of other trees and forest edges. From these trees, a transect was laid with census plots located 10 m apart from one another. The length of the transect was determined by the distance where the undergrowth and tree shoots of post-fire origin ceased to occur.

Snap-traps were used to catch small animals in surveyed area, in order to assess the species composition and abundance of small mammals that serve both as important seed spreaders and seed predators in burnt areas. Trap lines of 50 traps each were set and then checked daily.

Specimens of the Sciuridae family (*Sciurus vulgaris* L. and *Eutamias sibiricus* Laxmann) and nutcrackers (*Nucifraga caryocatactes* L.) were visually observed on transects, made for the observation of natural reforestation in burnt areas.

Results

Our research confirms the opinion of A.D. Vakurov [26] that in the northern forest zone, low- and medium-intensity fires are a rare occurrence (especially in terms of affected area). Out of the 20 surveyed burnt areas, only one had a few significant areas (about 10%) with partially living stone pine stands, but the amount of pre-fire Siberian stone pine undergrowth here was so large (up to 10 thousand pcs/ha) that the role of the surviving trees as seed trees was negligible. In most cases, the tree stand is completely destroyed when a forest area is burnt out. The only exceptions are few practically unburnt areas belonging to swamps and landscape lowerings (sphagnum and grass-marsh groups of forests), which form tree groups or forest edges that split huge burnt areas into parts and can be considered as potential sources of seeds. These areas are mistakenly included into the burnt area and are counted as unforested.

The composition and nature of reforestation in burnt areas depend on many factors. These include the initial composition of the primary tree stand and the degree of its damage caused by fire, the physicochemical (as well as biological) properties of the soil and the changes of those properties caused by fire, the terrain of the burned area and weather conditions in the post-fire period [29].

Another important factor is the presence or absence of animals who destroy the tree seeds or, on the contrary, contribute to their spreading [15; 17].

Nucifraga caryocatactes were encountered along the entire length of survey transects from the forest edges into the depths of the burnt area in equal numbers, which may indicate the possibility that it can spread seeds, for example, that of Siberian pine, over a distance of 2 km or even more.

The results of trapping small mammals in burnt areas of *Pinus sibirica* are given in Table 2.

Table 2.

The results of trapping small mammals in burnt areas (pcs.).

Small Mammal Species	Burnt area of Siberian pine forest (long moss type)	Burnt area of Siberian pine forest (green moss type, with sanitary loggings)	Burnt area of Siberian pine forest (green moss type, without sanitary loggings)
<i>Sorex araneus</i> L.	18	8	0
<i>Sorex caecutiens</i> Lax.	2	0	0
<i>Clethrionomys rutilus</i> Pall.	2	20	56
<i>Clethrionomys glareolus</i> Schreber	0	2	4
<i>Microtus oeconomus</i> Pall.	22	0	0
<i>Microtus agrestis</i> L.	0	18	4
Total	44	48	64

Species composition reforestation is largely determined by the conditions that existed in the pre-fire forest stand, with different levels of moisture and soil mechanical composition. Table 3 shows the success rate of woody plant regeneration in different groups of forest types according to survey results.

Table 3.

Average amount of viable undergrowth of the main woody plant species in burnt areas of different forest types

Forest type group	Soil mechanical composition	Amount of undergrowth 50-150 cm, thsd. pcs. / ha				
		pine	Siberian stone pine	Spruce, fir	birch	aspen
Pine forests						
Lichen	sand	2,100	0,00	0,00	0,00	0,00
Lingonberry	sandy loam	23,40	0,00	0,00	35,15	3,80
Green moss	sandy loam	17,44	1,18	0,00	21,73	11,02
Long moss	light loam	11,80	1,33	0,00	29,00	13,75
Grassmarsh	medium loam	1,25	0,00	0,00	7,00	0,00
Sphagnum	heavy loam	0,01	0,00	0,00	2,50	0,00
Siberian pine forests						
Green moss (with inclusion of pine)	light loam	8,60	1,46	0,64	43,20	14,85

Green moss (without pine)	medium loam	0,58	2,80	0,61	35,92	11,00
Long moss (with inclusion of pine)	medium loam	3,16	0,65	0,15	17,46	5,41
Long moss (without pine)	heavy loam	0,96	0,43	0,11	24,43	6,38
Grassmarsh (without pine)	heavy loam	0,48	0,20	0,00	13,23	0,42

Discussion

In the pine burnt areas that we examined, only pine and, to a lesser extent, Siberian stone pine were present among the coniferous undergrowth; in one of the areas, solitary larch shoots were also observed.

We should mention that the amount of spruce or fir burnt areas is very scarce. This is primarily due to the higher humidity of habitats of these forest formations, which prevents the large spread of fire.

Received data on the natural post-fire spruce regeneration confirms the opinion of most authors who studied the subject that the part of spruce in northern forests in the overall composition of undergrowth is relatively small [26]. The best spruce regeneration was registered in green moss Siberian pine forests, where it can act as “pioneer” tree in open areas. Dead-wood, as well as stumps and herbaceous vegetation can have a similar effect on spruce in the initial post-fire years, and in later years the protective effect can be granted by the undergrowth of deciduous trees.

Post-fire regeneration of Siberian pine is most successful on light and medium loams in green moss and long-moss groups of forest types, and not only in Siberian pine forests, but also in pine forests. This is explained by the zoochoric nature of its seed spread (primarily by the nutcracker), when its seeds are carried considerable distances from the original seed tree forests [28]. Though the satisfactory level of Siberian stone pine regeneration was only observed in green moss pine forests (without any pines in the pre-fire forest stand) and in the long-moss pine forest.

Among the coniferous species, pine shows the widest range of conditions for good natural regeneration. Moreover, with the exception of extreme dry (lichen pine forests) and extreme damp (sphagnum and grass-marsh pine and Siberian pine forests) habitats, pine regeneration can be considered satisfactory, and in lingonberry and green moss pine forests its regeneration is so abundant that with an average height of undergrowth of about 50 cm, 6 years after the fire, the territory could already be transferred to the category of young-aged forest-

ed areas based on pine alone. The areas of green moss and long-moss Siberian pine forests without pines in the pre-fire forest stands are a different case: the regeneration of pine in these areas only happens due to the spread of seeds from neighboring areas and is, in general, very small.

Low rate of natural reforestation is typical for pine in extremely damp forest conditions (sphagnum pine forests). But these areas generally barely burn out during fires and usually remain forested with almost all of the pre-fire undergrowth remaining viable. In extremely dry habitats (lichen pine forest), reforestation occurs almost exclusively due to pine regeneration. If its regeneration is poor, it may lead to forming of sandy heathlands with areas covered by sod-forming grasses. At the same time, it has been reported, that in the north, in lichen pine forests affected by ground fires, from 15–20 to 70–80 thousand specimens of pine shoots and undergrowth per 1 hectare have been observed some 20–30 years after the fire [26], and the amount of self-seeding was inversely proportional to the amount of remaining forest stand.

Among the deciduous species, birch shows the widest range of conditions for good natural regeneration as well as the biggest amount of undergrowth. It does not regenerate only in lichen pine forests. The natural regeneration of birch is most successful in the green-moss and long-moss groups of forest types with soils ranging from sandy loam to heavy loam.

Aspen regenerates relatively well in Siberian pine and pine forests on slightly moist and moist soils, but it does not form independent stands of young trees. In extremely dry and damp habitats, natural regeneration of aspen may be completely absent.

In general, the relatively high rates of natural regeneration of deciduous species in burnt areas is explained by their ability to regrow not only by seed spreading, but vegetatively as well, thus giving them some advantage in the very first stages of regrowth in burnt areas, since they outgrow the post-fire herbaceous vegetation.

The effect of sanitary loggings on the natural reforestation of burnt areas is of much interest to researchers. The movement of tracked vehicles and the removal of logs contributes to soil mineralization creating better conditions for seed germination and having a beneficial effect on the course of natural reforestation [26]. Our research confirms it as well. Pine shows better levels of natural regeneration in cleared burnt areas in all forest growing conditions (Table 4), which is explained by its higher requirements for light and substrate mineralization necessary for seed germination.

Table 4.

The influence of sanitary loggings on the natural regeneration of the main tree species in burnt areas in various growth conditions

Forest type group, tree maintenance	Soil me- chanical composition	Amount of undergrowth, thsd. pcs. / ha				
		Pine	Siberian stone pine	Spruce	Birch	Aspen
Pine forests						
Lichen - with sanitary loggings - without sanitary loggings	sand	2,5 1,7	- -	- -	- -	- -
Green moss - with sanitary loggings - without sanitary loggings	sandy loam	16,1 5,3	0,2 0,3	- -	8,5 0,4	5,2 1,5
Long moss - with sanitary loggings - without sanitary loggings	light loam	17,3 12,3	1,8 1,9	- -	29,2 51,0	19,6 9,8
Siberian pine forests						
Green moss - with sanitary loggings - without sanitary loggings	medium loam	7,6 4,9	3,1 0,7	0,0 0,1	14,7 41,2	10,7 9,8
Long moss - with sanitary loggings - without sanitary loggings	medium loam	0,3 0,1	0,6 0,4	- -	55,9 42,8	9,2 8,4
Long moss - with sanitary loggings - without sanitary loggings	heavy loam	3,6 0,8	0,2 0,1	- -	28,5 7,9	17,5 5,1

Distinctive features of the fauna of small mammals – the main predators of stone pine seeds in large burnt areas, recorded in the process of their captures on trapping lines, are presented in Table 5.

Our data indicates that the reserves of small mammals (rodents and, to a lesser extent, insectivores) who act as seed predators in extensive Siberian pine burnt areas 9 years after the fire are no lesser than those of natural unburned stands (even in the most productive of them) (Table. 5). It contradicts some sources [17], but on the other hand, M. Stewart [23] reports even lower relative abundance of micromammals in unburned plots comparing to those burned annually, thus supporting our results.

Moreover, in burnt green-moss Siberian pine forests, the relative abundance of small mammals is 1.1 times (with sanitary logging conducted after the fire) and 1.5 times (without logging) higher than that in untouched green-moss Siberian pine forests. At the same time, the total food supply for predatory animals, consisting of rodents, in burnt areas as a whole (4.7 kg/ha) is almost 2 times

higher than the food supply in general for Siberian pine forests in the studied region. The share of the dominant species, *Clethrionomys rutilus*, in the total abundance of small mammals varies greatly in different biotopes, increasing from wet to drier and from areas with less debris to those containing more debris. In humid biotopes, representatives of the genus *Sorex* and the species *Microtus oeconomus* are found, which are practically absent in drier groups of forest types (especially without any loggings conducted), where, however, *Clethrionomys glareolus* and *Microtus agrestis* are being spotted among the micromammal population.

Table 5.

Fauna of small mammals on large burnt areas of Siberian pine in the middle taiga zone of the Middle Ob region

Parameters	Burnt Siberian pine forest, long moss type	Burnt Siberian pine forest, green moss type (with sanitary loggings)	Burnt Siberian pine forest, green moss type (without sanitary loggings)
Number of species (pcs.)	4	4	3
Species of small mammals:	<i>Sorex araneus</i> L. <i>Sorex caecutiens</i> Lax. <i>Clethrionomys rutilus</i> Pall. <i>Microtus oeconomus</i> Pall.	<i>Sorex araneus</i> L. <i>Clethrionomys rutilus</i> Pall. <i>Clethrionomys glareolus</i> Schreber <i>Microtus agrestis</i> L.	<i>Clethrionomys rutilus</i> Pall. <i>Clethrionomys glareolus</i> Schreber <i>Microtus agrestis</i> L.
Relative abundance of small mammals (spec./100 trap-days)	44,0	48,0	64,0
Share of rodents, %	54,5	83,3	100,0
Relative abundance of rodents (spec./100 trap-days)	24,0	40,0	64,0
Absolute abundance of rodents (spec./ha)	79,2	132,0	211,2
Rodent biomass (kg/ha)	2,2	3,6	5,8
Share of <i>Clethrionomys rutilus</i> (%)	8,3	50,0	87,5

Animals, primarily the nutcracker (and a number of rodents), play a very important role in reforestation processes within large burnt areas, where the role of wind seed dispersal for pine seeds is relatively limited (even over snow crust), and the seed dispersal has an almost exclusively zoochoric nature [5; 6]. This makes the role of squirrels *Sciurus vulgaris* and Siberian chipmunks *Eutamias*

sibiricus especially important, since they are the most reliable seed spreaders among mammals, being able to transport Siberian pine seeds hundreds of meters from the nearest seed trees, while making their seed caches for the winter. And the number of chipmunks, as we established earlier [8], grows in recovering burnt areas also because of the favorable food conditions occurring due to the growth of prickly rose *Rosa acicularis* Lindl., rowan *Sorbus aucuparia* L. and other berry bushes on burnt areas.

The nutcracker, unlike rodents, cannot reach the soil surface through the debris of trunks and branches formed after the destruction and collapse of trees. We should also mention, that the nutcracker prefers soft substrates – like hummocks of moss, rotten stumps, etc. for burying Siberian pine seeds [28]. Operation of tracked vehicles during loggings create a large number of such substrates – upturned heaps of soil, parts of forest floor, crushed stumps or rotting dead wood. Our research shows that the shoots of Siberian pine are most often observed in such areas.

We also observed a clear positive reaction of aspen undergrowth to sanitary loggings in burnt areas, most strongly expressed on the lightest and heaviest of soils – which are less favorable for its natural regeneration.

Birch showed ambiguous reaction to sanitary loggings depending on different forest conditions. In burnt areas with extreme levels of soil moisture and mechanical composition, more abundant natural regeneration was observed after the loggings, than in burnt areas not affected by logging. Under optimal moisture conditions, the opposite picture can be observed: the amount of birch undergrowth in cleared areas is two or more times less than in areas that did not undergo logging.

The limited data on natural regeneration of spruce indicates that it is more successful in uncleared areas, which confirms the previously expressed idea about the positive effect of moderate amounts of wood debris on spruce regeneration.

Sparse herbs and shrubs contribute to the regeneration of some tree species, in particular spruce, protecting its sprouts from frost. The competitive impact of living ground cover on the self-seeding of woody plants starts to show 2-3 years after the fire and intensifies as the density of herbaceous plants and mosses increases [11].

Conducted research showed that the influence of herbaceous vegetation differs from that of mosses (primarily Polytrichopsida). Moreover, the latter have different effects on the natural regeneration of the main coniferous species: pine and Siberian pine. A strong negative correlation was determined between the

pine undergrowth and the total projective cover (TPC) of grasses, which was growing stronger as the growing conditions being surveyed became more humid (Table 6). The same picture was observed for mosses, but the correlation coefficients were lower. Among the herbs, reed grasses (*Calamagrostis epigeios* (L.) Roth, *C. langsдорffii* (Link) Trin.) and fireweed (*Chamaenerion angustifolium* (L.) Scop.) have the greatest negative effect on the natural regeneration of pine, while shorter forest grasses have almost no effect on its success.

Table 6.

Correlation coefficients between the abundance of pine and Siberian pine undergrowth and the total projective cover (TPC) of herbs and mosses

Compared options	$R \pm m$					
	Pine forests			Siberian pine forests		
Pine undergrowth and herbs TPC	-0,07±0,17	-0,75±0,15	-0,79±0,11	-0,80±0,14	-0,90±0,10	-
Pine undergrowth and mosses TPC	-0,04±0,17	-0,21±0,23	-0,50±0,20	-0,61±0,17	-0,70±0,15	-
Siberian pine undergrowth and herbs TPC	-	-	-	-0,52±0,18	-0,47±0,25	-0,96±0,15
Siberian pine undergrowth and mosses TPC	-	-	-	0,64±0,16	0,69±0,25	0,85±0,27

Note: $R \pm m$ – correlation coefficient with error estimation.

Natural regeneration of Siberian pine is also inversely proportional to the TPP of herbaceous vegetation, but the correlation is weaker than that of pine regeneration (Table 6).

It is well known that deciduous tree species, especially birch, help increase soil fertility, and in moist conditions they also play the role of natural land reclamation agents. Another positive effect of deciduous species on reforestation of burnt areas is them suppressing the development of sod-forming grasses, which prevent regeneration of coniferous trees.

Our research has shown that there is a direct correlation between the total abundance of undergrowth of deciduous species (birch+aspen) and the amount of undergrowth of pine and Siberian pine: the correlation coefficients are $0,35 \pm 0,17$ ($t_{\phi} = 2,09$) and $0,51 \pm 0,15$ ($t_{\phi} = 3,30$) respectively. Thus, considering the reforestation process from all points of view, the opinion on absolute undesirability of a temporary change of forest-forming species to deciduous ones, does not seem entirely justified.

The main sources of woody plants' seeds in burnt areas are the forest edges located along the area's perimeter and some groves that cross the territory of burnt areas along natural landscape lowerings. To a lesser extent, individual surviving trees (which are usually practically absent) or groups of 5 or more specimens can sometimes act as potential seed sources.

The resistance of preserved seed trees (those located in tree groups, forest edges along the perimeter of the burnt area or groves partially crossing the area) to wind is of the utmost importance. In the middle taiga, the part of the forest edge of 5 m wide is subjected to the most severe destruction by wind. As we move deeper into the forest, the degree of destruction decreases and remains equal to 10–12% of the total volume of growing trees within the 30-meter edge zone. Low-growing sphagnum pine forests are the most wind-resistant; long-moss and sphagnum Siberian pine forests are moderately resistant, as well as birch and aspen forests. The highest degree of the destruction of edges was observed in the most productive green moss forest types (16–25%) [3]. Descending by wind resistance, tree species can be listed in the following order: pine, Siberian pine, birch, spruce, fir, aspen.

We have studied the success rate of natural regeneration of conifers depending on the distance from the seed trees. The results showed that the amount of pine undergrowth is determined by the distance from the seed trees according to the laws of the power function ($Y=aX^b$) (Fig. 4).

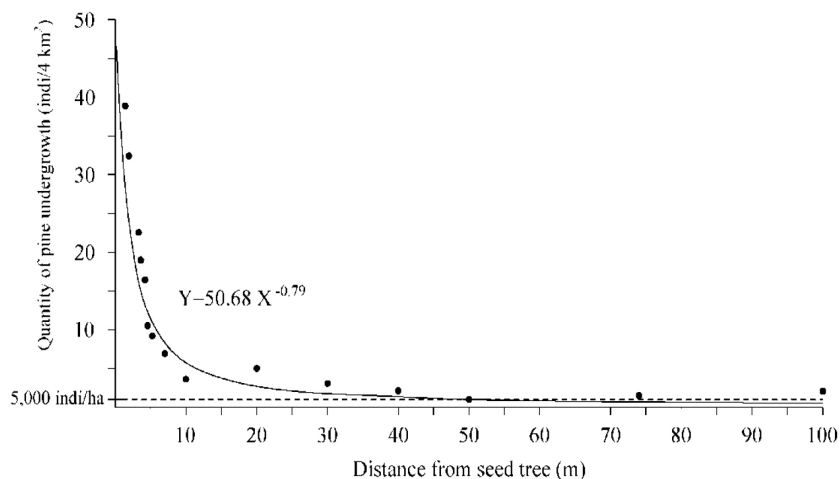


Fig. 4. The success rate of natural regeneration of pine in burnt green moss pine forests at different distances from individual seed trees and tree groups

In optimal growth conditions for pine regeneration (green-moss pine forests), at a distance of about 50 m from individual trees or tree groups, the amount of pine undergrowth stabilized at a level suitable for successful natural reforestation, and remained such at a distance of more than 100 m. In green-moss pine and Siberian pine forests, where forest edges or larger tree groups act as main seed sources, at a distance of about 100 m from the seed source the amount of undergrowth was more than twice the satisfactory level, and with further moving away it showed no clear tendency for decrease up to a 2-kilometer mark (Fig. 5).

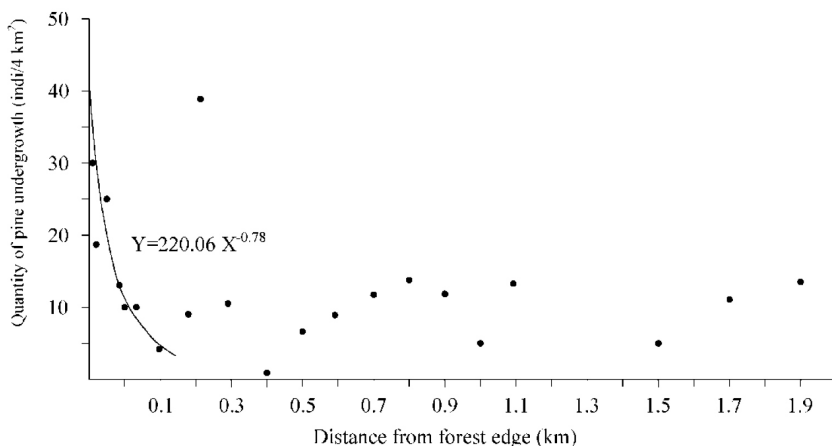


Fig. 5. The success rate of natural regeneration of pine in burnt green moss pine forests at different distances from the forest edges

Some quantitative differences in the dispersal of pine seeds from seed trees were noted depending on the position of the forest edge relative to the direction of the prevailing winds, but they do not change the qualitative picture. It is also important to mention the presence of young self-sown trees (0-5 cm high) in the center of the burnt areas, which may indicate that some of the pine seeds appeared there even 3-4 years after the fire, when heavily damaged trees should have already fallen out or dried out, and mostly non-damaged ones and viable – should have been included in the records.

All this allows us to assume that the distance from the seed trees does not play a determining role in the success rate of the natural regeneration of pine on large pine burnt areas, since its seeds spread in sufficient quantities (apparently over the crust that forms in spring) to a distance exceeding the actual size

of the burnt areas. The factors determining the amount of pine undergrowth are the conditions of seed germination and their further development.

This applies to an even greater extent to trees like birch and especially aspen, whose seeds are carried by the wind over much longer distances and are less demanding for germination conditions.

While conducting our research, we were also unable to identify a significant correlation between the amount of Siberian pine undergrowth in the burnt area and its distance from the seed trees. This is understandable, since the nutcracker, unlike rodents, carries the seeds of Siberian pine over distances of more than 6 km, preferring areas more distant and less forested areas that have smaller populations of other animals that can plunder its seed reserves [28]. Unlike pine seeds, the seeds of Siberian pine almost immediately get into favorable conditions for germination and further development of sprouts due to the help of animals.

Conclusion

We can conclude, that almost complete reforestation of burnt areas within 6-8 years after the fire is typical for the middle taiga subzone of Western Siberia. The general course of reforestation showed high rates of natural reforestation of both deciduous and coniferous forest-forming species: out of 105,290 hectares of surveyed areas that have been recorded as burnt back in 1988–89, 98,530 hectares can now be considered forested, with 27,950 hectares – as being covered by the main forest-forming species (pine). In most of the Siberian stone pine burnt areas, the undergrowth is dominated by fast-growing deciduous tree species, which leads to restoration of the original dark-coniferous communities through the preliminary deciduous forest stage. The sowing of the burnt areas by Siberian stone pine is carried out mainly by spotted nutcracker and Siberian chipmunk and does not depend on the distance from the seed trees but on the availability of conditions necessary for them to establish the seed caches.

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References

1. Arefyev, S. P. (2023). Dendrochronological analysis of the response of forest-forming tree species in the proposed Mystyg'egan wildlife sanctuary (Vakh River basin) to climate changes in the 20th–21st centuries. *Bulletin of Nizhne-*

- vartovsk University*, (6(63)), 18–34. <https://doi.org/10.36906/2311-4444/23-3>. EDN: <https://elibrary.ru/EOGYZT>
2. Arefyev, S. P., & Kazantseva, M. N. (2020). Fire frequency and natural regeneration of light-coniferous forests and woodlands in the Nadym District of the Yamalo-Nenets Autonomous Okrug. *Siberian Journal of Forest Science*, (1), 3–15. <https://doi.org/10.15372/SJFS20200101>. EDN: <https://elibrary.ru/ZQXFNN>
 3. Vakurov, A. D. (1975). *Forest fires in the North*. Moscow: Nauka. 100 p.
 4. Valendik, E. N., Matveev, P. M., & Sofronov, M. A. (1979). *Major forest fires*. Moscow: Nauka. 198 p.
 5. Ivanova, G. A., Konard, S. G., MacRae, D. D., Bezkorovaynaya, I. N., Bogorodskaya, A. V., Zhila, S. V., Ivanov, V. A., Ivanov, A. V., Kovaleva, N. M., Krasnoshchekova, E. N., Kukavskaya, E. A., Oreshkov, D. N., Perevoznikova, V. D., Samsonov, Yu. N., Sorokin, N. D., Tarasov, P. A., Tsvetkov, P. A., & Shishikin, A. S. (2014). *Impact of fires on ecosystem components of middle-taiga pine forests in Siberia*. Novosibirsk: Nauka, Siberian Branch. 232 p. ISBN: 978-5-02-019163-1. EDN: <https://elibrary.ru/LPPHNA>
 6. Vorobyov, V. N. (1982). *The nutcracker and its relationship with Siberian pine*. Novosibirsk: Nauka. 113 p.
 7. Gashev, S. N. (2000). *Mammals in the ecological monitoring system (case study of Tyumen Oblast)*. Tyumen: Tyumen State University Press. 220 p. ISBN: 5-88081-183-2. EDN: <https://elibrary.ru/QVSMXJ>
 8. Debkov, A. M., & Ilintsev, A. S. (2018). Structure and dynamics of forest regeneration on burned areas in the middle taiga of Western Siberia. *Forestry Bulletin*, 22(6), 31–39. <https://doi.org/10.18698/2542-1468-2018-6-31-39>. EDN: <https://elibrary.ru/YVDBDV>
 9. Dyubanova, N. V. (2013). *Morphoecological features of common juniper coenopopulations in the Pripyszhminsky borons of the pre-forest-steppe subzone of Western Siberia* (Candidate of Biological Sciences dissertation abstract). Yekaterinburg: Ural Branch of the Russian Academy of Sciences. 18 p. EDN: <https://elibrary.ru/SUUETN>
 10. Sannikova, N. S., Sannikov, S. N., Kochubey, A. A., & Petrova, I. V. (2019). Natural regeneration of pine on burned areas in the forest-steppe of Western Siberia. *Siberian Journal of Forest Science*, (5), 22–29. <https://doi.org/10.15372/SJFS20190503>. EDN: <https://elibrary.ru/GVSQYU>
 11. Evstigneev, O. I., Voevodin, P. V., Korotkov, V. N., & Murashev, I. A. (2013). Zoochory and seed dispersal distance in coniferous-broadleaf forests of Eastern Europe. *Advances in Modern Biology*, 133(4), 392–400. EDN: <https://elibrary.ru/QZMKZB>

12. Kazantseva, M. N. (2008). Ecological consequences of fires and oil pollution in taiga forests of the Middle Ob region. *Advances in Modern Biology*, 128(1), 108–112. EDN: <https://elibrary.ru/ICEESX>
13. Ivanova, G. A., Ivanov, V. A., Musokhranova, A. V., & Onuchin, A. A. (2023). Forest fires and their causes in Central Siberia. *Siberian Journal of Forest Science*, (6), 6–16. <https://doi.org/10.15372/SJFS20230602>. EDN: <https://elibrary.ru/WLJIIC>
14. Zhila, S. V., Ivanova, G. A., Ivanov, V. A., & Tsvetkov, P. A. (2019). Forest regeneration after fires of varying intensity in pine forests of Central Siberia. *Siberian Journal of Forest Science*, (6), 53–62. <https://doi.org/10.15372/SJFS20190606>. EDN: <https://elibrary.ru/ZQRDXW>
15. Matveeva, A. G. (2021). Dynamics of forest fires in the Far East. *Siberian Journal of Forest Science*, (6), 30–38. <https://doi.org/10.15372/SJFS20210603>. EDN: <https://elibrary.ru/HYXBFC>
16. *Guidelines for promoting natural regeneration of coniferous species in lowland forests of Tyumen Oblast*. (1999). Tyumen: Tyumen State University Press. 64 p.
17. Saltykov, A. N., Vatlina, T. V., & Belyaev, D. A. (2017). Seasonal dynamics of rodent abundance in coniferous-broadleaf forests of the “Smolenskoye Poozerye” National Park and assessment of their impact on conifer regeneration surges. *Belgorod State University Scientific Bulletin. Series: Natural Sciences*, (267(18)), 63–72. EDN: <https://elibrary.ru/ZHEVEX>
18. Sannikov, S. N. (1992). *Ecology and geography of natural regeneration of Scots pine*. Moscow: Nauka. 264 p. ISBN: 5-02-004130-0. EDN: <https://elibrary.ru/VTOSOX>
19. Seredovskikh, B. A., Yarosh, D. A., & Deryabina, V. V. (2023). Analysis of the forest fire situation in the Nizhnevartovsk District: status and trends. In *Proceedings of the 10th International Scientific and Practical Conference “Regional Aspects of Science and Education Development in Architecture, Construction, Land Management, and Cadastres at the Beginning of the 3rd Millennium”* (pp. 368–373). Komsomolsk-on-Amur: Komsomolsk-na-Amure State University. EDN: <https://elibrary.ru/TEVIYB>
20. Tumanik, N. V. (2024). Influence of the reclamation method on the formation of the pigment complex in Scots pine (*Pinus sylvestris* L.) on technogenic lands. *Siberian Journal of Life Sciences and Agriculture*, 16(3), 263–282. <https://doi.org/10.12731/2658-6649-2024-16-3-852>. EDN: <https://elibrary.ru/PHFEPK>
21. Chizhov, B. E. (1998). *Forest and oil of the Khanty-Mansi Autonomous Okrug*. Tyumen: Yu. Mandrik Publishing House. 144 p. ISBN: 5-93020-004-1. EDN: <https://elibrary.ru/WJQWPP>

22. Shvidenko, A. Z., & Shchepashchenko, D. G. (2013). Climate change and forest fires in Russia. *Forest Science*, (5), 50–61. EDN: <https://elibrary.ru/RDUBBH>
23. Shcherbov, B. L., Lazareva, E. V., & Zhurkova, I. S. (2015). *Forest fires and their consequences*. Novosibirsk: Academic Publishing House “Geo”. 153 p.
24. Schuldt, B., Buras, A., Arend, M., Vitasse, Y., Beierkuhnlein, C., Damm, A., Gharun, M., Grams, T. E. E., Hauck, M., & Hajek, P. (2020). A first assessment of the impact of the extreme 2018 summer drought on Central European forests. *Basic and Applied Ecology*, (45), 86–103. <https://doi.org/10.1016/j.baae.2020.04.003>. EDN: <https://elibrary.ru/OOWLQU>
25. Flannigan, M. D., Stocks, B. J., Turetsky, M. R., & Wotton, B. M. (2009). Impact of climate change on fire activity and fire management in the circumboreal forest. *Global Change Biology*, (15), 549–560. <https://doi.org/10.1111/j.1365-2486.2008.01660.x>. EDN: <https://elibrary.ru/MMRFCB>
26. Stewart, M. M. (1972). Relation of fire to habitat preference of small mammals on the Nyika Plateau. *Society of Malawi Journal*, 25(1), 33–42.
27. Talucci, A. C., Loranty, M. M., & Alexander, H. D. (2022). Siberian taiga and tundra fire regimes from 2001–2020. *Environmental Research Letters*, 17(2), 025001. <https://doi.org/10.1088/1748-9326/ac3f07>. EDN: <https://elibrary.ru/VWENXM>
28. Solonkin, A. V., Belyaev, A. I., Pugacheva, A. M., Hoi, N. D., Solomentseva, A. S., Egorov, S. A., Cuong, D. H., & Huong, T. T. T. (2024). The problem of reforestation of woody vegetation in mountain ranges of Kon Chu Rang Nature Reserve (Vietnam). *Siberian Journal of Life Sciences and Agriculture*, 16(3), 443–473. <https://doi.org/10.12731/2658-6649-2024-16-3-835>. EDN: <https://elibrary.ru/LCFZOR>
29. Kharuk, V. I., Ponomarev, E. I., Ivanova, G. A., Dvinskaya, M. L., Coogan, S. C. P., & Flannigan, M. D. (2021). Wildfires in the Siberian taiga. *Ambio*, (50), 1953–1974. <https://doi.org/10.1007/s13280-020-01490-x>. EDN: <https://elibrary.ru/RCPDIA>

Список литературы

1. Арефьев, С. П. (2023). Дендрохронологический анализ реакции лесобразующих видов деревьев проектируемого Мыстыгъеганского заказника (бассейн р. Вах) на изменения климата в XX–XXI столетиях. *Вестник Нижневарттовского университета*, (6(63)), 18–34. <https://doi.org/10.36906/2311-4444/23-3>. EDN: <https://elibrary.ru/EOGYZT>
2. Арефьев, С. П., & Казанцева, М. Н. (2020). Периодичность пожаров и естественное возобновление светловойных лесов и редколесий в Надымском

- районе Ямало-Ненецкого автономного округа. *Сибирский лесной журнал*, (1), 3–15. <https://doi.org/10.15372/SJFS20200101>. EDN: <https://elibrary.ru/ZQXFNN>
3. Вакуров, А. Д. (1975). *Лесные пожары на Севере*. Москва: Наука. 100 с.
 4. Валендик, Э. Н., Матвеев, П. М., & Софронов, М. А. (1979). *Крупные лесные пожары*. Москва: Наука. 198 с.
 5. Иванова, Г. А., Конард, С. Г., Макрае, Д. Д., Безкоровайная, И. Н., Богородская, А. В., Жила, С. В., Иванов, В. А., Иванов, А. В., Ковалева, Н. М., Краснощекова, Е. Н., Кукавская, Е. А., Орешков, Д. Н., Перевозникова, В. Д., Самсонов, Ю. Н., Сорокин, Н. Д., Тарасов, П. А., Цветков, П. А., & Шишкин, А. С. (2014). *Воздействие пожаров на компоненты экосистемы среднетаёжных сосняков Сибири*. Новосибирск: Наука. Сибирское отделение. 232 с. ISBN: 978-5-02-019163-1. EDN: <https://elibrary.ru/LPPHNA>
 6. Воробьёв, В. Н. (1982). *Кедровка и её взаимосвязи с кедром сибирским*. Новосибирск: Наука. 113 с.
 7. Гашев, С. Н. (2000). *Млекопитающие в системе экологического мониторинга (на примере Тюменской области)*. Тюмень: Издательство ТюмГУ. 220 с. ISBN: 5-88081-183-2. EDN: <https://elibrary.ru/QVSMXJ>
 8. Дебков, А. М., & Ильинцев, А. С. (2018). Структура и динамика возобновления лесов на горях средней тайги Западной Сибири. *Лесной вестник*, 22(6), 31–39. <https://doi.org/10.18698/2542-1468-2018-6-31-39>. EDN: <https://elibrary.ru/YVDBDV>
 9. Дюбанова, Н. В. (2013). *Морфоэкологические особенности ценопопуляций можжевельника обыкновенного в Припышминских борах подзоны предлесостепи Западной Сибири* (Автореферат диссертации кандидата биологических наук). Екатеринбург: УрО РАН. 18 с. EDN: <https://elibrary.ru/SUUNETN>
 10. Санникова, Н. С., Санников, С. Н., Кочубей, А. А., & Петрова, И. В. (2019). Естественное возобновление сосны на горях в лесостепи Западной Сибири. *Сибирский лесной журнал*, (5), 22–29. <https://doi.org/10.15372/SJFS20190503>. EDN: <https://elibrary.ru/GVSQYU>
 11. Евстигнеев, О. И., Воеводин, П. В., Коротков, В. Н., & Мурашев, И. А. (2013). Зоохория и дальность разноса семян в хвойно-широколиственных лесах Восточной Европы. *Успехи современной биологии*, 133(4), 392–400. EDN: <https://elibrary.ru/QZMKZB>
 12. Казанцева, М. Н. (2008). Экологические последствия пожаров и нефтяного загрязнения в таёжных лесах Среднего Приобья. *Успехи современной биологии*, 128(1), 108–112. EDN: <https://elibrary.ru/ICEESX>

13. Иванова, Г. А., Иванов, В. А., Мусохранова, А. В., & Онучин, А. А. (2023). Лесные пожары и причины их возникновения на территории Средней Сибири. *Сибирский лесной журнал*, (6), 6–16. <https://doi.org/10.15372/SJFS20230602>. EDN: <https://elibrary.ru/WLJIIC>
14. Жила, С. В., Иванова, Г. А., Иванов, В. А., & Цветков, П. А. (2019). Лесовозобновление после пожаров разной интенсивности в сосняках Средней Сибири. *Сибирский лесной журнал*, (6), 53–62. <https://doi.org/10.15372/SJFS20190606>. EDN: <https://elibrary.ru/ZQRDXW>
15. Матвеева, А. Г. (2021). Динамика лесных пожаров на Дальнем Востоке. *Сибирский лесной журнал*, (6), 30–38. <https://doi.org/10.15372/SJFS20210603>. EDN: <https://elibrary.ru/HYXBFC>
16. *Рекомендации по содействию естественному возобновлению хвойных пород в равнинных лесах Тюменской области.* (1999). Тюмень: Издательство ТюмГУ. 64 с.
17. Салтыков, А. Н., Ваглина, Т. В., & Беляев, Д. А. (2017). Сезонная динамика численности мышевидных грызунов в хвойно-широколиственных лесах НП «Смоленское Поозерье» и оценка их влияния на всплеск возобновления хвойных. *Научные ведомости БелГУ. Серия: Естественные науки*, (267(18)), 63–72. EDN: <https://elibrary.ru/ZHEVEX>
18. Санников, С. Н. (1992). *Экология и география естественного возобновления сосны обыкновенной.* Москва: Наука. 264 с. ISBN: 5-02-004130-0. EDN: <https://elibrary.ru/VTOSOX>
19. Середовских, Б. А., Ярош, Д. А., & Дерябина, В. В. (2023). Анализ лесопожарной обстановки на территории Нижневартовского района: состояние и тенденции. В *Материалы X Международной научно-практической конференции «Региональные аспекты развития науки и образования в области архитектуры, строительства, землеустройства и кадастров в начале III тысячелетия»* (с. 368–373). Комсомольск-на-Амуре: КнАГУ. EDN: <https://elibrary.ru/TEVIYB>
20. Туманик, Н. В. (2024). Влияние способа рекультивации на формирование пигментного комплекса у сосны обыкновенной на техногенных землях. *Siberian Journal of Life Sciences and Agriculture*, 16(3), 263–282. <https://doi.org/10.12731/2658-6649-2024-16-3-852>. EDN: <https://elibrary.ru/PHFERK>
21. Чижов, Б. Е. (1998). *Лес и нефть Ханты-Мансийского автономного округа.* Тюмень: Издательство Ю. Мандрика. 144 с. ISBN: 5-93020-004-1. EDN: <https://elibrary.ru/WJQWPP>
22. Швиденко, А. З., & Щепашенко, Д. Г. (2013). Климатические изменения и лесные пожары в России. *Лесоведение*, (5), 50–61. EDN: <https://elibrary.ru/RDUBBH>

23. Щербов, Б. Л., Лазарева, Е. В., & Журкова, И. С. (2015). *Лесные пожары и их последствия*. Новосибирск: Академическое издательство «Гео». 153 с.
24. Schultdt, B., Buras, A., Arend, M., Vitasse, Y., Beierkuhnlein, C., Damm, A., Gharun, M., Grams, T. E. E., Hauck, M., & Hajek, P. (2020). A first assessment of the impact of the extreme 2018 summer drought on Central European forests. *Basic and Applied Ecology*, (45), 86–103. <https://doi.org/10.1016/j.baae.2020.04.003>. EDN: <https://elibrary.ru/OOWLQU>
25. Flannigan, M. D., Stocks, B. J., Turetsky, M. R., & Wotton, B. M. (2009). Impact of climate change on fire activity and fire management in the circumboreal forest. *Global Change Biology*, (15), 549–560. <https://doi.org/10.1111/j.1365-2486.2008.01660.x>. EDN: <https://elibrary.ru/MMRFCB>
26. Stewart, M. M. (1972). Relation of fire to habitat preference of small mammals on the Nyika Plateau. *Society of Malawi Journal*, 25(1), 33–42.
27. Talucci, A. C., Loranty, M. M., & Alexander, H. D. (2022). Siberian taiga and tundra fire regimes from 2001–2020. *Environmental Research Letters*, 17(2), 025001. <https://doi.org/10.1088/1748-9326/ac3f07>. EDN: <https://elibrary.ru/VWENXM>
28. Solonkin, A. V., Belyaev, A. I., Pugacheva, A. M., Hoi, N. D., Solomentseva, A. S., Egorov, S. A., Cuong, D. H., & Huong, T. T. T. (2024). The Problem of Reforestation of Woody Vegetation in Mountain Ranges of Kon Chu Rang Nature Reserve (Vietnam). *Siberian Journal of Life Sciences and Agriculture*, 16(3), 443–473. <https://doi.org/10.12731/2658-6649-2024-16-3-835>. EDN: <https://elibrary.ru/LCFZOR>
29. Kharuk, V. I., Ponomarev, E. I., Ivanova, G. A., Dvinskaya, M. L., Coogan, S. C. P., & Flannigan, M. D. (2021). Wildfires in the Siberian taiga. *Ambio*, (50), 1953–1974. <https://doi.org/10.1007/s13280-020-01490-x>. EDN: <https://elibrary.ru/RCPDIA>

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