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RESEARCH ARTICLE

The State of the Spruce Stands of the Boreal and Boreal-Subboreal Forests of the Eastern European Plain in the Territory of the Udmurt Republic (Russia)

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This article presents materials evaluating the dynamics of spruce stands in the zone of coniferous-deciduous forests and the southern taiga zone of the European part of the Russian Federation in the territory of the Udmurt Republic. The analysis of the State Forest Register for the Udmurt Republic showed that the largest reduction in the area of spruce stands was observed in the southern part of the republic. The descriptions of the test areas established in various forestry zones revealed that the spruce stands were characterized by a low density of trees, whereby the absolute completeness of the studied stands varied from 2. 95 to 11. 1 m^2/ha. A high content of deadwood was noted, which in volume exceeded the stock of raw-growing forest. The analysis of forest litter on the trial plots showed that most of them were completely decomposed residues or litter, ranging from 44% to 77%; a prevalence of the upper undecomposed layer over the semi-decomposed middle layer was noted.

Key words: Coniferous species; Spruce stands; Dynamics; Timber stock; Forest litter

Introduction

Spruce stands form the evergreen dark coniferous forests of the Northern Hemisphere and contain significant timber reserves. A significant deterioration in the state of dark coniferous forests, which in some cases is accompanied by their drying, has manifested itself throughout the Northern Hemisphere. This process is very dynamic and covers the entire boreal zone from Europe to the North American continent, affecting all forest-forming species (Jose, 2019).

In the Russian Federation, the main areas of spruce stands are represented in the north of the Russian Plain, where they form the landscape of the European taiga (Utkina et al, 1995).

The causes of forest degradation and drying out are various. A number of authors associate forest damage directly with environmental pollution. For example, Hlasny and Sitkova (2010) cite air pollution and the disturbance of forest nutrition as the main reasons for the disappearance of spruce forests in the western part of the Carpathians (Hlasny& Sitkova, 2010). However, the role of natural stress factors should not be excluded. Most likely, the drying out of dark coniferous forests is the result of a combination of reasons. For example, Fedorov et al. (1998, 2000) associated the massive drying of spruce in the forests of Belarus with extreme droughts, with this effect increasing due to technogenic pollution, after which the weakened trees were by affected stem pests (Fedorov, 2005; Fedorov& Sarnatsky, 2001). Among the leading causes of drying, the following can be identified: the unevenness of precipitation, waterlogging, the spread of parasitic fungi, the dynamics of xylophages, and edaphic conditions (Lyubarsky, 1955; Chernenkova, 2013; Pukinskaya, 2014).

However, the extent of the degradation of boreal forests, affecting all forest-forming coniferous forests across continents, suggests the influence of global changes occurring in the biosphere, including in connection with human activities (Jose, 2019; Alyabyev, 2013; Caudullo et al, 2016).

The massive drying of spruce over a large area of the European part of the Russian Federation after abnormally high temperatures in 2010 aroused considerable interest among researchers, who focused on the issue of the resistance of spruce stands to adverse environmental conditions, anthropogenic stress, pests, and diseases (Korotkov, 2014; Maslov, 2015; Ivanchina, 2017). This problem is also relevant for Udmurtia, where the share of conifers is quite high.

A factor determining the state of the forest is also the forest litter. The features and properties of forest litter affect the process of soil formation, the formation of a living soil cover, the natural regeneration of the forest, and the change of species. The growth and productivity of a stand depend on the thickness of the forest litter. Furthermore, the state of the forest litter is an indicator of the recreational load, as with a change in the forest litter reserves and the nature of its distribution over the area, the recreational degradation of the forest landscape begins (Goguen& Arp, 2017).

The main indicators characterizing forest litter are stock and capacity. An increase in forest litter stocks occurs from south to north, which is associated with an increase in the degree of moisture (Likhanova, 2014). Forest litter stocks in coniferous forests are much larger than in deciduous forests, which is due to the greater decomposition rate of deciduous litter (Bogatyrev, 1998). The thickness of the forest litter allows us to judge the speed of the processes of the receipt and decomposition of litter (Solomatova, 2013). The dependence of the reserve and power of forest litter on anthropogenic impacts has been reflected in a number of publications (Tsiba, 2019; Burova, 2011).

Litter is an important source of easily mineralizable carbon, nitrogen, and phosphorus for microbial metabolism in forest ecosystems; however, decomposition depends on many biotic and abiotic factors, including the chemical composition of the litter and the type of plants, the soil properties, and the climate 9 Holmström, 2016; Li et al, 2016; Liu et al, 2016). . Bacteria and fungi are key agents in the decomposition of litter in forest ecosystems. Nevertheless, the specific roles of the interactions between different species of fungi in the process of litter decomposition are still unclear (Chen, 2018; Oli, 2018; Takahashi, 2015).

At present, the study of the state of forest litter in spruce stands in clearings and in areas prone to complex drying and damage by the typographus bark beetle is very relevant, since forest litter plays a highly significant role in forest biogeocenosis.

Three layers are distinguished in the forest litter profile, each of which is distinguished by the degree of preservation of the initial structure, the morphology, and the strength of the plant residues composing this profile: the upper layer is A0', the middle is A0" and the lower layer is A0'''. The mass accumulation and presence of all three layers in the forest litter profile depend on a number of factors: the physical and geographical conditions; the species composition and age of the plantings; the closeness of the canopy; and the water-thermal regime that develops under the forest canopy. The purpose of this study is to analyze the dynamics of the areas occupied by spruce stands, and to assess the state of coniferous stands on the territory of the Udmurt Republic (Russia).

Materials and Methods

Study area. The study was conducted in the eastern part of the East European Plain, in the basins of the Kama and Vyatka rivers, west of the Ural Mountains, between parallels 56°00' and 58°30' north latitude, meridians 51°15' and 54°30' east longitude (Figure 1). The area of the Udmurt Republic (UR) is 42. 06 thousand km^2. The territory of the UR is very elongated from north to south for about 320 km and from west to east for 200 km. The substantial length from north to south and the heterogeneity of the relief causes significant differences in temperature, humidity, wind regime, rainfall, and duration of sunshine between the northern and southern parts of the republic. In this regard, the territory of the UR is located within two landscape zones, namely the taiga (boreal) and subtaiga (boreal-subboreal). The conditional border between these zones passes along the line Vavozh - Nylga - Izhevsk - Votkinsk. Such a variety of climatic conditions made it possible to divide the forest management division into two zones: a taiga zone, which is a southern taiga region in the European part of the Russian Federation (northern part of the UR), and a zone of coniferous-deciduous forests, which is a region of coniferous-deciduous (mixed) forests in the European part of the Russian Federation (southern part of the UR) (On approval of the List, 2014).

A study of the dynamics of the areas occupied by spruce stands was carried out in the Udmurt Republic from 2009 to 2015, based on the analysis of fundamental materials (materials from the state forest register - Form 1. 8 (hereinafter - GLR)) provided by the Ministry of Natural Resources and Environmental Protection of the Udmurt Republic. A general description of the forest fund of Udmurtia is presented on the basis of the study of the Forest Plan (On approval of the Forest, 2019).

To assess the taxation parameters and the current state of spruce stands, 100 × 100 m sample plots were laid. The sample plots were selected based on the study of the forest inventory in each forestry as well as on the basis of existing materials for assessing the dynamics of the area of spruce stands in UR. Trial areas were laid in spruce stands, in places of their active drying out, and in spruce-red fir forests (Ex). To assess the state of the planting, an enumerative taxation method was used; within this method, all trees growing on the trial plot are taken into account (Ushakov, 1997). The condition of the trees was determined in accordance with the regulatory document - Appendix 1. Government Decisions . . . (On the Rules of sanitary safety, 2017).

The diameter of the trees was determined using a measuring fork, age was determined using measuring cores taken with a Haglof-350 mm drill, and height was determined using a Forestry Pro Nikon altimeter. The taxation parameters of the stand (average diameter, average height, average age, completeness, composition) were determined by recounting methods. During planting taxation, the distribution of trees using thickness steps was not carried out because the productivity of the plantings was determined according to the method of B. D. Zhilkin. This method is based on the distribution of trees into classes relative to the average diameter of the planting: Class I - 1. 46 and above, Class II - 1. 45 to 1. 16, Class III - 1. 15 to 0. 86, Class IV - 0. 85 to 0, 76, and Class V - 0. 75 and less (Grigoriev et al, 1989). In order to minimize the random error in calculating the average taxation parameters, the standard deviation (± σ) was used. The wood stock was determined by the formula proposed by Prof. N. P. Anuchin for shade-tolerant wood species (Ushakov, 1997).

$$M=10\times\sum G+0,\ 4\sum G(H-21)$$

Also, samples of forest litter from a total area of 1 m2 were taken from each sample area using the small sample method. The selected individual samples contained all three layers (A0', A0", A0''') of forest litter.

The mass of each sample was determined, after which further samples were taken from the samples to determine the humidity and content of the air-dried matter using the thermostat-weight method (GOST 28268-89 GOST 28268-89 Soils).

To study the component composition of the forest litter samples, the sieve analysis method was used, followed by a weighing and calculating of the percentage of each component of the total mass in terms of absolutely dry matter. The activity of cellulose decomposition of the forest litter in the studied spruce stands was determined using the Christensen laboratory method (Kruglov, 2018). Statistical analysis of the results was performed using the Microsoft Excel program Statistica 5. 5, using the descriptive statistics method.

Results

Udmurtia is a forest region with a forest area (as of January 1, 2018) encompassing 2, 065. 6 thousand ha. The average forest cover of the territory is 46. 2%; the distribution throughout the republic is uneven, varying from 6. 9% in the south to 72. 5% in the north.

The ratio of the areas comprising coniferous and soft-leaved species is almost the same, at 51% for coniferous and 49% for soft-leaved. According to the species composition, spruce and birch stands account for 790. 7 thousand ha and 669 thousand ha, respectively. Udmurtia is located at the junction of the areas of two species of spruce, namely spruce (*Piceaabies* (L.) Karst) and Siberian spruce (*PiceaobovataLedeb*.). These two species are found in natural ecosystems, as is their interspecific hybrid, Finnish spruce (*Piceafennica* (Regel) Kom.) (Mamaev, 1983). Dark coniferous stands are concentrated in the north of the republic and make up 74% (587 thousand ha), while in the south of Udmurtia they account for 26% (204 thousand ha).

Forest management in the UR is carried out by the Ministry of Natural Resources and Environmental Protection of the Udmurt Republic. Based on territorial management, all forests of the republic are divided into 25 forestries, of which 11 forestries are located in the coniferous-deciduous forest zone, and the remaining 14 forestries are in the southern taiga zone. Despite the

significant forest areas in Udmurtia, the last forest inventory was carried out in 1995-1997. However, partial forest management by tenants at rental sites is carried out, and updated information is reflected in the State Forest Register (GLR); in connection with this, we studied the dynamics of spruce stands based on the data from this document. However, the last field survey of the Udmurtia stands (Forest Inventory) was carried out from 1995 to 1997, with the exception of the Kiyasovsky forestry (Forest Inventory, 2016) and part of the Zavyalovsky forestry (Forest Inventory, 2006). It is in these forestries that the largest reduction in the area of spruce stands is noted. Thus, information on the state and distribution of spruce stands in Udmurtia is only relative.
The analysis of the information presented in the state forest register showed that the area of spruce stands from 2009 to 2015 decreased by 8% (65, 400 ha). A significant reduction in forests during the analyzed period occurred in the zone of coniferous-deciduous forests and amounted to 15% (29, 728 ha). In the southern taiga zone, there was also a decrease in the area of spruce stands by 6% (35, 959 ha).
In the south of the republic, in the zone of mixed forests, the most significant reduction in the area of spruce stands was recorded in the following forestries (%): Kiyasovskoye (48), Mozhginskoye (29), Vavozhskoye (16), Zavyalovskoye (13), and Alnashsky (12). In the north of Udmurtia in the southern taiga zone, the following reductions were noted: Yarskoye (23), Syumsinskoye (14), Uvinskoye (20), Igrinskoye (7. 8) and Yakshur-Bodinskoye (7. 9).
In forest districts where the largest decrease in the area of dark coniferous stands was recorded, an analysis of the age structure of the stands (by age groups) was carried out. In the area of coniferous-deciduous forests in the Alnashsky, Vavozhsky, Zavyalovsky, Kiyasovsky and Mozhginskyforestries, there was a decrease in area in all age groups, from young to overgrown. The most significant changes in the area of spruce stands over the entire age spectrum were observed in the Kiyasovsky (from 12. 7% to 73. 6%) and Mozhginsky (from 11. 6% to 32. 0%) forestries (Figure 1).

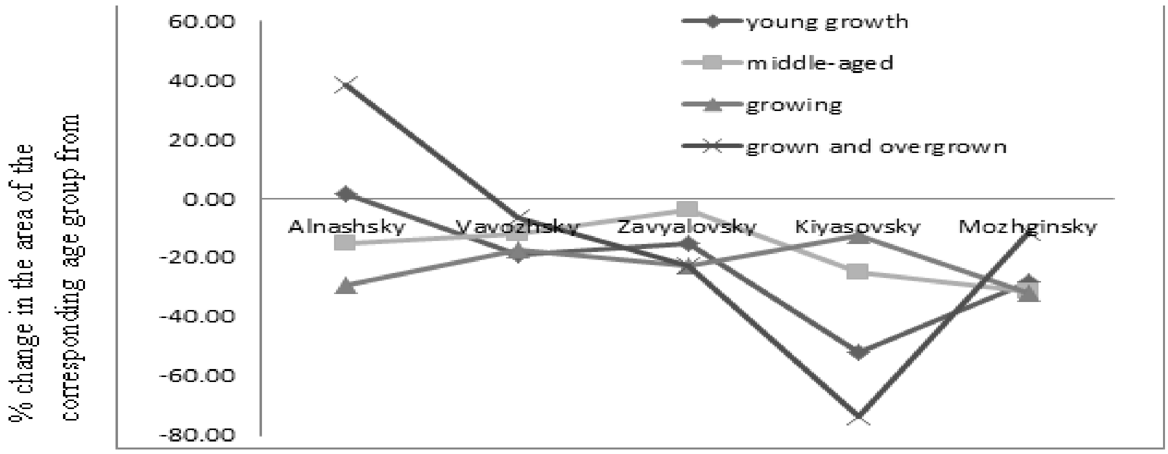

Figure 1. Changes in the area of spruce stands by age groups in the zone of the coniferous-deciduous forests of the Udmurt Republic

In the southern taiga zone, the largest reduction in area was observed in the group of young growths (from 11. 3% to 29. 0%), while the changes in the middle-aged and in the group of ripe and overripe stands were insignificant, with the exception of the Uvinsky and Yarskyforestries (Figure 2).

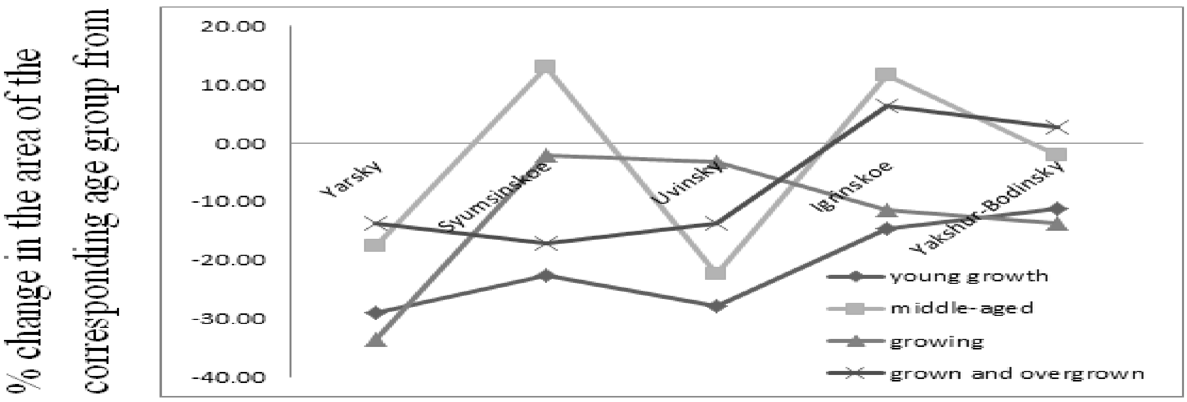

Figure 2. Changes in the area of spruce stands by age groups in the southern taiga zone of the Udmurt Republic.

Due to the fact that the information on the state and distribution of spruce stands in Udmurtia is relative, we further conducted field descriptions. Trial plots (TPs) were laid in forestries with a high proportion of spruce forests located in the two forest zones. In the zone of coniferous-deciduous (mixed) forests, TPs were established in the Zavyalovsky and Yaganforestries, and in the southern taiga zone, they were established in the Yakshur-Bodyinsky and Igrinskyforestries. The average taxation characteristics of the stands of the studied TP are presented in Table 1.
The soils in the TPs are typical for Udmurtia, namely sod-podzolic; in terms of particle size distribution, they are loams (Kovrigo, 2004). According to the productivity of stands in the Zavyalovsky, Yakshur-Bodinsky and Igrinskyforestries, they belonged to Class III. This class accounted for 31% to 57% of sampled trees. Stands in the Yaganskoye forestry are considered low-productivity stands. Meanwhile, 53% of trees belonged to Classes IV-V in the first TP, 74% Classes IV-V at the second TP, and there was a complete absence of Class I trees. The analysis of the distribution of the trees by diameter relative to the average revealed the

regularity of the distribution of the plants of the main canopy. Comparing the diameters of living and dead individuals of spruce revealed that most of the dead trees had a trunk diameter above average. The phenomenon of larger trees drying has also been noted by other researchers (Lyubarsky, 1955).

Table 1. Average taxation characteristics of the stands of the trial plots (Udmurt Republic, 2019).

№ PS	Forestry, district forestry (quarter, allotment)	Aaverage ± σ. (age, years)	Haverage. ± σ (planting height, m)	Daverage. 1, 3 ± σ (average trunk diameter, cm)	∑G, m2/ha M, m3	∑G, m2/ha* (sum of trunk cross-sectional areas)	M, m3** (stock of wood)	Composition
Coniferous-deciduous forest zone								
1	Zavilovskoe, Suburban (78, 3)	70 ± 7. 3	21 ± 2. 0	27. 9 ± 7. 1	10. 7 107. 0	14. 9	67. 2	9Е1П+Б
2	Zavyalovskoe, Suburban (158, 3)	67 ± 3. 8	23 ± 1. 9	26. 0 ± 5. 7	11. 1 119. 9	17. 9	87. 5	9Е1П
1	Yagan (115, 8)	60 ± 3. 7	18 ± 1. 5	25. 9 ± 12. 9	6. 0 52. 8	16. 6	93. 8	10Е+П
2	Yagan (214, 8)	65 ± 3. 7	22 ± 1. 1	21. 4 ± 4. 4	2. 95 30. 7	5. 9	31. 1	10Е
South taiga zone								
1	Yakshur-Bodyinsky, Selychinsky (81, 15)	77 ± 3. 56	18 ± 1. 33	22. 2 ± 6. 26	10. 1 109. 12	13. 4	29. 3	7Е1П1Б1Ос
2	Yakshur-Bodyinsky, Selychinsky (86, 37)	74 ± 5. 01	23 ± 1. 33	26. 8 ± 2. 90	17. 7 191. 2	26. 0	89. 9	9Е1Ос+П
1	Igrinskoe, Chutyrskoe (186, 14)	69 ± 2. 21	19 ± 2. 76	22. 9 ± 6. 58	19. 8 182. 16	22. 7	26. 0	8Е2П
2	Igrinskoe, Chutyrskoe	70 ± 2. 30	19 ± 3. 01	23. 9 ± 6. 20	26. 0 239. 2	27. 7	15. 73	9Е1П

Appendix: * - absolute completeness for dead trees
** - stock of dry wood in the trial plot

Forest plantings in the zone of coniferous-deciduous forests are characterized by a low density of trees of the main tier, with their fullness varying from 2. 95 to 11. 1 m^2/ha with a large number of dead trees (absolute fullness taking into account dead wood is 5. 9 to 17. 9 m^2/ha). Stands with a similar fullness are characterized as woodland.

According to the enumeration taxation, a fairly large supply of deadwood was noted in all the studied areas. Depending on the TP, the stock was between 31. 1 and 93. 8 m^3/ha, i. e. there was an increased risk of forest fires. In the TPs in the Yagan forestry, the stock of deadwood exceeded the stock of living tree timber, and in the Zavyalovsky forestry, the deadwood accounted for more than 50% of the stock of living tree wood.

At the planting sites located in the southern taiga zone, a low fullness was also noted; however, advancing to the north, the fullness of the stands increased. In these TPs, less dead trees and correspondingly less stock of dead wood were recorded.

The main cause of spruce death in the territory of the UR is the spread of the typographus bark beetle (Ipstypographus) (On approval of the Forest, 2019). This was confirmed by our research when laying the TPs and describing the vital state of the trees. On dead trees, we identified the characteristic traces of the typographus bark beetle.

Thinning of the main tree canopy at the TP in the zone of coniferous-deciduous forests, which is an environment-forming factor, led to a change in the plant community. The test areas under study had lost the main features of spruce forest ecosystems. In the living ground cover, forest nemoral herbs (European hoofed grass (*Asarumeuropaeum* L.) and wood sorrel (*Oxalis acetosella* L.)) have begun to be replaced by forbs (field sow thistle (*Sonchusarvensis* L.), cat grass (*Dactylisglomerulata* L.), blue grass (*Poapratensis* L.), hybrid clover (*Trifoliumhybrídum* L.), etc.), which in turn forms a dense turf that does not allow spruce seedlings to take root. Coniferous growth is absent (in the TPs in the Yagan forestry), or it is present (in the TPs of the Zavyalovsky forestry) but with insufficient trees (less than 500 pcs/ha), while poor quality (unreliable) growth such as common raspberries (*Rubusidaeus* L.), mountain ash (*Sorbusaucuparia* L.), forest honeysuckle (*Loniceraxylosteum* L.) and saggy birch are common among woody plants (*Betulapendula Roth*.), The latter begins to form the main tier.

It should be especially noted that during the study of the test areas, individual specimens of spruce in good condition were identified. Only some of them revealed holes in the trunk, but in general, the condition of such plants was good (according to external morphological characteristics). In places of damage to the trunk in such individuals, profuse gumming was noted. It is possible that the damage and death of some individuals and the good condition of others were associated with individual characteristics (the physiological and biochemical properties of wood). This was confirmed by our previous studies on the content of extractives in wood in individual representatives of the Spruce genus (*Piceapungens* / *Piceaobovata)* under various environmental growing conditions (Vedernikov, 2018).

Based on the example of two forestries located in the coniferous-deciduous forest zone (the Yagan forestry) and in the southern taiga zone (the Yakshur-Bodinskoye forestry), a comparative description of the state of forest litter was carried out (Tables 2 and 3). A statistical analysis of the moisture and the component composition of the samples within the TPs showed that in the Yagan forestry, TP1 was characterized by a higher moisture content of the litter compared to TP2 as well as a significantly higher weight fraction of A0' in the total fractional composition of the forest litter. In the Yakshur-Bodyinsky forestry, the litter in both sample plots had higher humidity than in the Yagan forestry. The higher litter moisture content was at TP 2. In trial area No. 1, which had a lower the litteriness of the litter, it was distinguished by a reliably higher mass index of the A0' fraction.

Table 2. Indicators of mass, humidity and dry matter content of the forest litter in the spruce forests of sorrel forests of the Yagansky and Yakshur-Bodinskyforestries of the Udmurt Republic.

Forestry	**№ Trial plot**	**Mass, g**	**Humidity, %**	**Dry content substance, %**
Yagan forestry	TP1	1222. 237	14. 4 ± 2. 4 8., 5…20. 3*	85. 64
	TP2	765. 624	8. 6 ± 0. 9 6. 5…10. 7	91. 40
Yakshur-Bodinsky forestry	TP1	1756. 038	31. 9 ± 7. 9 12. 3…51. 5	68. 12
	TP2	716. 818	38. 2 ± 2. 9 31. 0…45. 5	61. 76

* mean value ± standard deviation, confidence intervals for the mean value ($p < 0.05$).

Table 3. Component composition and cellulose-decomposing activity of forest litter in the spruce stands of the Yagansky and Yakshur-Bodinskyforestries of the Udmurt Republic.

District	**№ Trial plot**	**Cellulose-decomposing activity, %**	**The composition of the absolute dry matter, g**		
			A0'	**A0"**	**A0'"**
Yagan forestry	TP1	40. 05 ± 3. 02 35. 24…44. 86*	157. 7 ± 54. 7 70. 8…244. 8	116. 2 ± 67. 0 9. 5…222. 9	772. 8 ± 147. 9 405. 3. . 1140. 2
	TP2	82. 93 ± 3. 67 77. 10…88. 76	210. 4 ± 81. 3 81. 0…339. 7	184. 9 ± 67. 3 77. 9…291. 9	340. 8 ± 124. 4 31. 7…649. 9
Yakshur-Bodinsky forestry	TP1	60. 83 ± 8. 07 48. 00…73. 67	174. 7 ± 39. 4 111. 9…237. 5	75. 5 ± 10. 4 58. 9…91. 9	838. 4 ± 60. 9 686. 9…989. 9
	TP2	42. 49 ± 2. 05 39. 23…45. 75	126. 5 ± 18. 2 97. 5…155. 5	141. 5 ± 25. 1 101. 7…181. 4	195. 4 ± 44. 4 85. 1…305. 7

* mean value ± standard deviation, confidence intervals for the mean value ($p < 0.05$).

Thus, the results showed that in the Yakshur-Bodinsky forestry, the mass of forest litter is greater than in the forestry located in the south of the Yagan forestry, which is consistent with studies that attribute this to an increase in the degree of moisture (Vedernikov, 2018). This pattern is due to the fact that in the Yakshur-Bodinsky forestry, the average annual rainfall is higher (532 mm) than in the Yaganskoye forestry (511 mm).

We believe that such a difference in the indicators of the mass of forest litter also depends on the composition and completeness of the stands. The stands of the Yakshur-Bodinsky forestry are represented by mixed stands with the presence of deciduous species (7Е1П1Б1Ос and 9Е1Ос + П) and with high absolute densities (13. 4 and 26. 0 m^2/ha) for TP1 and TP2, respectively. The stands of the Yagan forestry are represented by pure spruce stands (10E + P and 10E) with an absolute fullness of 16. 6 and 5. 9 m^2/ha for TP1 and TP2, respectively.

In the study of the morphological (component) composition of the samples, we identified all three layers of forest litter: A0', A0" and A0'". It was found that most of the forest litter is completely decomposed residues or litter, ranging from 44% to 77% (A0'"). In the samples of forest litter in both forestries, the prevalence of the upper undecomposed layer (A0') over the semi-decomposed middle layer (A0") was noted.

The results of the study of the cellulose-decomposing activity of the forest litter are shown in Table 3. It is established that in stands with a higher density and higher moisture content of the forest litter, the activity of cellulose decomposition was significantly lower (by 42. 88% in the Yaganskiy and by 18. 34% in the Yakshur- Bodinsky forestry).

Discussion

The largest reduction in spruce stands is observed in coniferous-deciduous forests (15%) compared to spruce stands in southern taiga forests (6%). One of the indicators of forest reduction is the age structure of the stand. In coniferous-deciduous forests, a decrease in the stand was observed for all age groups: from young trees to overripe trees. In the South taiga zone - in the group of young growths. In addition to the age structure of the stand, the main indicators of deforestation (Michel & Seidling, 2015) are crown closure, damage and tree death. According to the studies of Thibodeau et al. (2000), in the coniferous-deciduous zone, low density of plantations and a high supply of dead wood leads to an increase in the supply of ammonium nitrogen and a decrease in its oxidation to nitrate forms, which is not a good nutrient substrate for spruce plantations (Aarnes et al., 1995). Clarification of the canopy, which is observed in the Yagan forestry (coniferous-deciduous zone) leads to an increase in insolation of the soil surface causing a change in the cellulose-decomposing ability of the soil in the direction of its increase (Table 3).

Soil factors significantly affect the growth of spruce stands (Lasota et. al., 2016). Spruce plantations, whose root system is located in the upper soil layers, are more susceptible to the influence of dry climatic periods, which subsequently leads to their drying out (Tužinský, 2002). Compared to the southern taiga zone, coniferous-deciduous forests have a low level of moisture in the forest litter (8. 6 ± 0. 9; 14. 4 ± 2. 4), which can subsequently lead to thinning of the forest stand in this zone. Since it is known that spruce is most sensitive to water stress, among coniferous species (Kharuk et al. 2015), this fact may explain a halving of the stand in the coniferous-deciduous zone (15%), compared with the southern taiga zone (6%).

Sustainable development of forest ecosystems, especially spruce stands in the context of global climate change (Tužinský et al., 2017), can only be achieved by improving the quality of forest litter, increasing the viability and restoration of the potential of forest ecosystems while protecting their initial state.

Conclusion

The reduction in the area of spruce stands in the Udmurt Republic from 2009 to 2015 amounted to 8%. The largest reduction occurred in the coniferous-deciduous forest zone and amounted to 15%; in the southern taiga zone, the decrease in area was 6%.
It should be noted that the data on the area and dynamics of the spruce stands are given on the basis of form 1. 8 of the State Forest Register, the information of which is reflected on the basis of updated data. However, the lack of modern field and distance surveys of the Udmurtia stands prevents the obtaining of reliable information about them.
Trial plots were laid in areas with the largest reduction in areas of spruce stands, in forestries with a high proportion of dark coniferous species, differing in the degree of reduction in areas of spruce stands, and in the places of their mass drying.
Studies have shown that spruce stands are classified as Classes III and IV in productivity. It is noted here that most of the dead trees were highly productive and belonged to Classes I to III. Plantings were characterized by a low density, with a significant number of dead trees, whereby the stock of wood reached 93. 8 m^3/ha.
The thinning of the main canopy has led to a change in the plant community, as a result of which succession processes have begun. In the TPs in a place of mass drying, spruce specimens were found to be in a good living condition, which may indicate the individual characteristics of the surviving plants. Their detailed study and subsequent mapping will allow the use of resistant individuals for reforestation. The forest litter in the studied coniferous stands included three morphological layers. Most of the forest litter completely comprises decomposed residues or litter, ranging from 44% to 77%. A prevalence of the upper undecomposed layer over the semi-decomposed middle layer was noted. In the Yagan forestry (the zone of coniferous-deciduous forests), which was characterized by clean spruce stands, in the test areas where the litter was characterized by higher humidity, the prevalence of an A0' horizon is noted. Similar features were also noted for the test area with a higher humidity of the forest litter in the Yakshur-Bolinsky forestry (south taiga zone), characterized by mixed stands with a high density, where high humidity of the forest litter reduced the cellulose-degrading activity.

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