Analysis of the state category of dark coniferous forests in the Republic of Bashkortostan

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Abstract. The article presents the results of an assessment of the state category of spruce (Picea obovata Ledeb.) stands on the territory of the Republic of Bashkortostan. The state category, phytopathogenic load and local damage by forest pests were determined. The state category was determined in accordance with the obtained practical score, focusing on the scale of the sanitary state of the stand. On the basis of the data obtained, an analysis of the weighted average estimates of the state category of dark coniferous forests with various shares of spruce was carried out. Based on the results of the statistical analysis, it was revealed that the forest pathological state of spruce stands did not depend on the share of spruce in the stand composition. Significant differences in the state category of spruce were found in contrasting forest types; in other growing conditions, no significant differences were observed. Timely forestry measures aimed to improve the state of forest stands can increase the average score of the state category by 0.5-0.7, which will allow them to be transferred to the category of stands with high biological resistance, and to conduct systematic and rational forestry.

1. Introduction

Dark coniferous forests are stands characterized by substantial shading due to the tree crowns being in closed conditions, and as a result, by poorly developed undergrowth. The ground cover is represented by ferns, juniper shrubs, honeysuckle, currant and stiff-leaved evergreen shrubs. Typical soils in such forests are podzolic and sod-podzolic.

In the Southern Urals, dark coniferous species are represented by Siberian spruce (Picea obovata Ledeb.) and Siberian fir (Abies sibirica Ledeb.). They grow in the central mid-mountainous part, in the region of mountain taiga dark coniferous forests, and in the low mountains of the western slope, in the region of broad-leaved-dark coniferous forests, where they act as edificators in primary dark coniferous stands.

Bashkortostan belongs to a temperate climatic zone with an Atlantic-continental climate. The climate is quite humid, winters are moderately severe, and summers are warm. The diverse relief, and, first of all, the presence of the Ural ridge passing in the meridional direction, cause significant differences in temperature and moisture in the territory of the republic. In general, forest pathological situation depends on weather conditions, soil and climatic factors [1, 2].

Dark coniferous forests occupy no more than 6% of the total forested area of the Republic of Bashkortostan. The main forest-forming species of dark coniferous stands are: Siberian spruce (Picea obovata Ledeb.) (occupies 4.5% of the total forested area) and Siberian fir (Abies sibirica Ledeb.)
(0.7% of the total forested area). Spruce stands are characterized by a low or medium basal area (from 0.4 to 0.7) [2, 3].

From the point of view of natural and economic zoning in the republic, six districts and two sub-districts can be distinguished: the Pre-Ural forest-steppe (left-bank forest-steppe region of flat deciduous forests and the right-bank region of flat mixed deciduous-coniferous forests), Ufimsky, Aisky, Pribelsky, Central mountain and Zauralsky [3]. Spruce and fir forests are concentrated in the Pre-Ural right-bank, Ufa, Aisk and in the northernmost high-mountainous part of the Central forestry region [3, 4]. The Ufa mountainous region of broad-leaved-dark coniferous forests covers the Ufa plateau, which is a low plateau with a gentle western and steep eastern slopes, and strongly indented by deep canyon-like, mostly waterless ravines. Soil-forming rocks of this region are: deluvium of clay deposits, eluvium, in places eluvium-deluvium of limestones and dolomites, and marls. Typical soils are: light gray medium podzolic, gray and dark gray, forest brown humus-carbonate. Woody vegetation is represented by spruce-fir forests of the II-III productivity class, with an admixture of oak, linden, and maple. Pre-Ural left-bank forest-steppe region of lowland broad-leaved forests covers the entire left bank of the river Belaya. The surface looks like a wavy-ridged plain cut by numerous ravines and river valleys. The parent rocks are deluvial brownish yellow clays, heavy and medium loams, sandstone eluviums, marl and gypsum. The soils of this region are divided into two types: forest (dark gray) and chernozems (podzolized, leached, carbonate and floodplain). Forest vegetation is represented by linden and oak stands, as well as by island-type pine forests on elevated forest elements. The most widespread are grass and ground elder types of forest growing conditions. Aisky district is located in the northwestern part of the Bashkir Urals. The relief of the northern part of the region is flat, undulating and ridged, and in the western part there are the foothills of the Urals. The northern part of the region is represented by spruce and fir forests with an admixture of broad-leaved species, and in the eastern part, by birch and aspen forests of the II-III productivity class.

The main soils of the region are meadow chernozems and mountain meadow soils. The central mountain forestry region occupies the mountainous part of the Republic.

Parent rocks are represented by eluvio-deluvial carbonate-free clays, eluvium of conglomerates of clayey shale sandstones. Soils are represented by four types: forest gray and dark gray, podzolic-gley, mountain podzolized and skeletal chernozems, as well as alpine mountain meadow.

Woody vegetation of the western part is represented by broad-leaved, and of the northern high-mountainous part, by spruce and fir low-productivity stands of the IV-V class of productivity, which under these conditions are gradually replaced by pine or pine and birch forests [3-5].

The forests of the Republic of Bashkortostan are exposed to various adverse factors that have a certain stressful effect on the most sensitive stands, thereby reducing their resistance to pests and pathogens, affecting the development and growth of the number of harmful organisms, and the formation of local outbreaks of the latter.

The main factor in the weakening and destruction of stands is the negative impact of weather conditions, soil and climatic factors; 52.6% of the total area of stands are disturbed and lose their resistance. The purpose of the work is to assess the weighted average state category of dark coniferous forests in Bashkiria.

2. Methods and Materials

2.1. Objects

The object of the study was natural spruce and fir stands growing on the territory of regional forestry units of the Republic of Bashkortostan. The study was carried out on the basis of a forest pathological survey carried out on 30 sample plots in six forest districts of the Pre-Ural right-bank, Central, Ufa, and Aisky forestry areas. The most common types of forest growing conditions in the studied areas were: Oxalidosa, Aegopodiosa, Aegopodiosa-Urticosa, Carico-Calamagrostidosa, Rupestrine.
2.2. Methods
The plots were selected according to forest inventory data. Forest stands with a predominance of spruce with an area of at least 3 hectares were chosen as sample plots. Sample plots were established in accordance with the procedure for conducting forest pathological examinations and the form of a forest pathological examination report. Simultaneously with the total counting of trees, for each specific tree, the state category was determined according to the Rules of Sanitary Safety in Forests and other rules, order [6-8]. The state category, phytopathogenic load and local damage by forest pests were determined. The state category was determined in accordance with the obtained practical score, using the scale of the stand sanitary state by B I Kovalev (table 1).

Table 1. Assessment of the sanitary state of stands according to the scale of B I Kovalev.

| #   | Weighted average category of sanitary condition | State of a stand  |
|-----|-----------------------------------------------|-------------------|
| 1   | up to 1.5                                      | Healthy           |
| 2   | 1.6 - 2.5                                      | Weakened          |
| 3   | 2.6-3.5                                        | Severely weakened |
| 4   | 3.6-4.5                                        | Declining         |
| 5   | Over 4.5                                       | Destroyed         |

In the new Rules of Sanitary Safety in Forests, the following state categories were additionally introduced: 5 (a) - fresh windblow, 5 (b) - fresh windfall, 6 (a) - old windblow, 6 (b) - old windfall and 7 - emergency trees [6].

3. Results and Discussion
The analysis of the inventory data on stands with a predominance of spruce produced the following statistical indicators (table 2). The average age of these stands was 76 years and the coefficient of variation of the age structure was ± 30%. The average stem diameter was 26 cm, with the coefficient of variation of ± 20%. The average growing stock was 183 m³, with the coefficient of variation of ± 29%. Based on the data obtained on the structure of stands with a predominance of spruce, it can be concluded that the overwhelming number of stands were middle-aged or mature. The discrepancy between the average growing stock per 1 ha and the value obtained as a result of statistical processing was 28% (the average growing stock on the territory of the Republic is 143 m³). All other indicators had a homogeneous distribution, since the value of the coefficient of variation does not exceed 33%, and the degree of data dispersion is significant in all cases, except for the diameter. As a result of the forest pathological examination and field data analysis, a number of reasons for the decrease in the biological resistance of stands were identified (table 2). On plots 1 and 16, we observed the impact of strong winds of previous years, resulting in an inclination of more than 10°, and bending or falling of trees. On plots 2, 3, 10, 11, 12, 13, 14, we identified outbreaks of a bark beetle (typographer). On plot 4, there was fir broom rust. On plots 5, 18, 19, 20, 22, 23, the impact of squally and hurricane winds of past years resulted in the destruction of tree trunks. On plots 6 and 7, we observed the consequences of canopy fire of the current year; and on plots 8 and 9, a stable ground fire of the current year of medium intensity. On plot 15, there was a change in the level of groundwater under the influence of soil and climatic factors, and on plot 17, necrosis-cancerous diseases of conifers (wound cancer and fir broom rust). On plots 21 and 24, we recorded the emergence of a large pine weevil which uses spruce as an additional source of food; and on plots 25-30, the presence of a fungal root rot (Heterobasidion annosum).

Based on the above data, the following conclusions can be drawn: the average state category of the dark coniferous stands ranges from 1.24 to 4.00. Although among the surveyed stands there were both healthy (average status category 1.0-1.5) and dying out (average category above 4.0), the bulk of the stands was characterized by impaired biological resistance. The average score for the status category of all stands under study was 2.02 (weakened stands that have not lost their biological stability); the percentage distribution of forest stands, depending on their state, was 13: 70: 10: 7, and the
quantitative distribution was 4: 21: 3: 2, from which it follows that the predominant number of forest stands belongs to weakened, but retaining biological resistance with an average condition score ranging from 1.6 to 2.5.

Table 2. Results of forest pathological examination and a brief description of stands on sample plots with different proportions of spruce (Picea obovata Ledeb.).

| # | Stand structure* | $A_{avg}$ | $H_{avg}$ | $D_{avg}$ | $P$ | Forest type | Growing stock per hectare m$^3$ | Average class of sanitary condition |
|---|------------------|----------|----------|----------|----|-------------|-------------------------------|-----------------------------------|
| 1 | 7S1F1L1B         | 80       | 26       | 28       | 0.7| Aegopodiosa | 230                           | 1.24                              |
| 2 | 6S4L             | 65       | 19       | 24       | 0.6| Aegopodiosa | 100                           | 2.38                              |
| 3 | 10S              | 50       | 21       | 26       | 0.6| Aegopodiosa | 110                           | 2.26                              |
| 4 | 4S2B2L1F         | 50       | 18       | 20       | 0.8| Aegopodiosa | 180                           | 1.32                              |
| 5 | 4B4S2F+A+L       | 50       | 20       | 20       | 0.5| Aegopodiosa | 110                           | 2.20                              |
| 6 | 7S3F             | 85       | 18       | 24       | 0.4| Aegopodiosa | 160                           | 4.00                              |
| 7 | 7S3F             | 70       | 23       | 26       | 0.6| Aegopodiosa | 130                           | 4.00                              |
| 8 | 7S2P1 L          | 100      | 26       | 44       | 0.5| Aegopodiosa | 240                           | 2.35                              |
| 9 | 6S1P3B           | 55       | 18       | 25       | 0.8| Aegopodiosa | 140                           | 2.59                              |
| 10| 4S3F2B1 L        | 95       | 20       | 28       | 0.5| Carico-Calama-grostidosa | 160 | 2.53                  |
| 11| 6S1F2S1F+ L      | 105      | 25       | 32       | 0.6| Carico-Calama-grostidosa | Raiprestrine | 190 | 1.89                  |
| 12| 7S2F1 L          | 105      | 23       | 28       | 0.6| Carico-Calama-grostidosa | 170 | 1.91                  |
| 13| 4S2F2S2F+ L      | 105      | 23       | 28       | 0.6| Oxalidosa | 180 | 2.05                  |
| 14| 5S3F2 L          | 48       | 15       | 20       | 0.8| Carico-Calama-grostidosa | 130 | 1.70                  |
| 15| 5S3F2P           | 97       | 23       | 26       | 0.7| Carico-Calama-grostidosa | Raiprestrine | 280 | 1.77                  |
| 16| 6S2P2B           | 97       | 23       | 32       | 0.6| Raiprestrine | 260 | 2.67                  |
| 17| 4S2F1P3B         | 105      | 23       | 28       | 0.6| Carico-Calama-grostidosa | 260 | 1.78                  |
| 18| 5S2F3L           | 75       | 22       | 28       | 0.5| Aegopodiosa | 170 | 1.70                  |
| 19| 5S2F3L           | 90       | 24       | 34       | 0.7| Aegopodiosa | 250 | 1.98                  |
| 20| 10S              | 45       | 13       | 16       | 0.9| Aegopodiosa | 130 | 1.81                  |
| 21| 4S2F2L1B1A       | 77       | 19       | 26       | 0.7| Aegopodiosa | 240 | 2.24                  |
| 22| 4S2F1B1P1A1L     | 107      | 23       | 36       | 0.5| Aegopodiosa | 220 | 2.27                  |
| 23| 10S+B            | 45       | 13       | 18       | 0.9| Aegopodiosa | 90  | 1.85                  |
| 24| 4S2F2L1B1A       | 77       | 19       | 26       | 0.7| Aegopodiosa | 240 | 2.33                  |
| 25| 8S2F             | 67       | 22       | 25       | 0.4| Oxalidosa | 140 | 1.92                  |
| 26| 10S+F            | 75       | 21       | 25       | 0.7| Aegopodiosa-Urticosa | 240 | 2.11                  |
| 27| 8S2F             | 70       | 22       | 25       | 0.6| Aegopodiosa-Urticosa | 220 | 1.76                  |
| 28| 6S3F1B           | 67       | 22       | 25       | 0.9| Oxalidosa | 170 | 1.33                  |
| 29| 6S2F1B1L         | 62       | 21       | 23       | 0.9| Oxalidosa | 170 | 1.31                  |
| 30| 9S1F             | 70       | 22       | 25       | 0.6| Aegopodiosa-Urticosa | 200 | 1.83                  |

* S - Spruce, F-fir, P-pine, B-birch, L-linden, A-aspen.

On the basis of the two-factor analysis of variance, significant differences in the state category depending on the share of spruce in the stand composition were not found. Presumably, this is due to implementation of a selective sanitary felling, as a result of which there was a large decrease in stand density and disappearance of differences between stands. However, when forest types were taken into account, significant differences in terms of the forest pathological state of spruce stands were found.
between Aegopodiosa and Carico-Calama-grostidosa types of forest growing conditions ($F_f = 3.7$; $F_t = 3.5$, at $p = 5\%$). Consequently, differences in the categories of forest pathological state are manifested only between contrasting forest types.

The main recommendations for increasing biological resistance of these stands are clear sanitary felling, land clearing, and dead tree harvesting, since they are the object of colonization by phytopathogenic organisms and forest pests. We also recommend creation of mineralized strips and fire breaks, and creation of forest plantations with the preservation of at least 30% of forest-forming deciduous species in the stand composition and the following care. If a change in the groundwater level is detected, it is necessary to create drainage systems, or artificial reservoirs, since an increase in the groundwater level negatively affects spruce plantations, leading to their death, because of the surface root system.

4. Conclusion
Summing up, it can be noted that, in general, dark coniferous forests of the Republic have an average score of the status category of 2.02, which characterizes them as weakened, but retaining biological stability.

The influence of the share of spruce in the composition of mixed stands does not have a significant effect on the forest pathological state.

The proposed set of measures can increase the average score of the state category by 0.5-0.7, which will allow the stands to be transferred to the high biological resistance category, and enable systematic and rational forestry.

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