Condition and Stability of Plantations in the Zonal Ecotone of the Forest and Steppe of the Southern Urals

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Abstract. In the conditions of the zonal ecotone of the forest and steppe of the Southern Cis-Urals, the current state of forest ecosystems is characterized, the radial growth of Scots pine is considered as an indicator of the sustainability of plantations. Forest phytocenoses of the Southern Cis-Urals have class 2 and 3 of biological resistance, unfavorable in sanitary terms, which leads to the appearance of permanent foci of mass reproduction of insect pests of leaves and needles. These pests are actually indicators of the sustainability of the forest ecosystem. The plantations are especially strongly weakened in the zone of medium, strong and maximum anthropogenic impact on the environment. Differences in the radial growth of Scots pine are observed in the zonal ecotone of the forest and steppe. The dynamics of the radial growth of Scots pine in the Orenburg forestry indicates a decrease in the indicator over the years, which is interconnected with the dry climate of the steppe zone and partly the technogenic influence of industrial enterprises in Orenburg. The dynamics of the radial growth of Scots pine crops in the national park “Buzuluksky bor”, on the contrary, increases over the years, which, in our opinion, is associated with more humid growing conditions in recent years. Comparing the average radial growth of Scots pine in the zonal ecotone of the forest and steppe, one can note higher rates in the forest zone of the national park “Buzuluksky bor” and lower rates in the steppe zone. The main method of collecting information on the state of forest cenoses was a field survey on temporary test areas, which were laid according to standard methods.

1. Introduction
Any forest plantations are susceptible to outbreaks of mass reproduction of harmful forest insects and the development of epiphytoties of various diseases. In some years, massive foci of pests and diseases can cover large areas and cause significant damage to forests. The main task of maintaining ecological safety in the region is to preserve the existing forest plantations, as well as to increase the area of artificial forests [1-4]. Due to climate change, in particular due to frequent droughts, the condition of hardwoods is deteriorating [4-9]. Scotch pine is considered to be one of the most resistant species due to such conditions [9-13]. In weakened and dying out stands, further deterioration of the sanitary condition of forest stands is predicted. The aim of our study was to assess the condition and biological...
stability of pine plantations. The objectives of the study included consideration of the dynamics of the radial growth of pine trees on the ecotone of the forest and steppe, the sanitary condition of plantings, the determination of the species state of particularly dangerous pests.

2. Statement of the problem
The very rugged relief, the sharply continental climate of the Southern Cis-Urals predispose to a variety of landscapes in the region. The zonal ecotone of the forest and steppe is distinguished by the fact that peculiar types of forest phytocenoses are formed with a highly differentiated structure. The zonal ecotone of the Southern Cis-Urals includes the border of flora and fauna of the forest and steppe zones, where a higher diversity in species composition is observed. On this territory, the analysis of the reasons for the decrease in the biological stability of forest plantations is relevant. The increased technogenic load on the territory of the Orenburg region is associated with numerous industrial enterprises of metallurgy, energy, gas and oil production and their processing. Natural and climatic factors, together with the impact of industrial enterprises, reduce the sustainability of tree plantations in the Orenburg region. The reasons for the decrease in resistance in the zonal ecotone of the forest and steppe remain especially poorly understood, which would make it possible to improve the system of ecological monitoring of the region's forests [14, 15].

3. Methodology
The studies were carried out in forest phytocenoses of the Southern Cis-Urals on the zonal ecotone of the forest and steppe, where their state and resistance, the species composition of insect pests of leaves and needles as indicators of a decrease in the stability of these ecosystems, and the radial growth of Scots pine were considered. The main method for collecting information on the state of forest cenoses was a field survey on temporary sample plots, which were laid according to standard methods. A detailed forest pathological survey of tree plantations was carried out on temporary sample plots. The radial growth of Scots pine trees was determined by the method of D.V. Silence [16]. The height, diameter, age of the trees were measured, the degree of crown eating and the category of the sanitary condition of plantings were determined according to the "Sanitary Rules in the Forests of the Russian Federation" for 6 classes. Also, the state of forests was determined by the biological stability of forest plantations [17]. The collection of field material was carried out in the period May-June, from temporary sample plots located in the divisional forestry of the Orenburg forestry - Komsomolsk, Pavlovsk and Shirokovskiy district forestry of the national park "Buzuluksky bor". From each sample plot, represented by 100 trees, 10 core samples were collected from the model trees. Temporary trial plots were laid according to OST 56-69-83 Forest Inventory Trial Areas. The bookmark method"(1983). The method of laying temporary sample plots was carried out in a rectangular or square shape, and included a sample of 100 trees each. For dendroecological studies, stands were selected, exclusively of artificial origin. Wood samples (cores) were obtained using an age drill at a height of 1.3 m perpendicular to the axis of the trunk, in the direction from north to south, drilled radial cores of wood with a diameter of 4 - 5 mm and a length of 10 - 15 cm. After extracting the cores, they were placed in paper containers that are labeled. In office conditions, the core samples were processed. Radial gain was measured with a Corimi Maxi core meter. Mathematical processing was carried out using standard methods. The material obtained as a result of the research was processed by standard statistical methods. A visual, or eye, assessment of the state of plantings was carried out, which was used to characterize their forest pathological state. In this case, the assessment of the state of plantings is carried out according to four main groups of parameters: general assessment of stability, or viability; resource assessment of pathological phenomena; assessment of the causes and factors of weakening or destruction of the forest; the appointment of the necessary forest protection measures. Their stability (biological resistance, viability) was also determined. To determine the stability of the stands of the forest and steppe ecotone, the degree of anthropogenic impact on forest phytocenoses was graded into five classes, depending on the presence of industrial enterprises and mineral extraction on the territory.
4. Results and Discussion

In our opinion, the current state and stability of forest phytocenoses in relation to abiotic and anthropogenic environmental factors is associated with the ecotone effect of the Southern Urals. The zonal forest and steppe ecotone is located on the territory of the Orenburg region on the eastern border of the Sharlyk, Alexandrovsky, Pervolotsky, and Ileksky districts. Tyulgansky district is assigned to zone I. On the territory of the region, according to natural and climatic characteristics, forest zoning, and features of woody vegetation, six zones are identified: I-Northern; II-Western; III-South-Western; IV-Central; V – Southern; VI – Eastern. The selected zones include representatives of the flora of forest and steppe areas. The forested area of zones I – III is 243,997 ha, including 39,732 ha of forest crops (16.28%). Weakened and dying plantings make up 3.88%. The forested area of zones IV – VI is 159516 ha, including 47141 ha of forest crops (29.55%). Weakened and dying plantings make up 11.12%.

We have noted the peculiarities of the climatic conditions of plant growth: in zones I – III, the average long-term vegetation period hydrothermal coefficient of Selyaninov is 0.93-0.96, in zones IV-VI 0.51 – 0.55. The reliability of the difference in the climate of the zones is more significant at the 0.1% level. The average temperature of January in zones I-III is -14.58°C, in zones IV-VI -15.92°C. The average temperature in July is 20.75 and 20.67°C, respectively. The total annual precipitation of zones I-III is 391.67 mm, and zones IV-VI is 308.33 mm. The total amount of precipitation in the warm period is 290 mm, in zones IV-VI-191.67 mm. The average depth of soil freezing in zones I – III is 100 cm, and in zones IV - VI it is 130 cm. The average height of the snow cover of zones I-III is no more than 36 cm, zones IV-VI-no more than 26 cm. The greatest weakening and death of tree stands was noted in the south and south-east of the region.

The degree of afforestation of the territory of the Orenburg region is 4.6%. Every year, sanitary and health measures are carried out on a large territory in the form of selective and continuous sanitary logging.

At the same time, the territory occupied by weakened, dying and dead plantings continues to increase. In 2015, the weakened and dying tree stands accounted for 28,663 ha, and the dead - 1149.6 ha.

In our opinion, the weakening and death of tree stands is also associated with anthropogenic impact. Therefore, we identified the strength of anthropogenic impact on forest phytocenoses, for which we classified the number of industrial enterprises in the districts of the Orenburg region, and also took into account the extraction of minerals. Thus, it was noted that the centers of mass reproduction of insect pests of leaves and needles are found in plantings growing on the territory of administrative districts, where the anthropogenic impact on the environment is assigned to classes III to V (medium, strong, maximum). The smaller area of the centers of mass reproduction of pests in areas with similar anthropogenic impact on plantings is associated with the periodic extermination of insects with chemical and biological preparations. It is noted that in the areas of the Orenburg region with medium, strong and maximum anthropogenic impact on the environment, the biological stability of forest phytocenoses is significantly reduced, so the trees are inhabited by various ecological groups of insect pests: leaves and needles and trunks, which is an indicator of the state of the plantings.

In the weakened and dying forest phytocenoses of the Southern Cis-Urals, in the zonal ecotone of the forest and steppe, insect pests of leaves and needles are ubiquitous, among which the gypsy moth (Lymantria dispar L.), the green oak leaf moth (Tortrix viridana L), the golden tail (Euproctis chrysoorrhoea L.), red-headed pine sawfly (Neodiprion sertifer Geoff.), star sawfly weaver (Acantholyda nemoralis Thoms.), in the south - red-headed sawfly weaver (Acantholyda erythrocephala L.). The primary centers of mass reproduction of this species can be associated with the peculiarities of the forest growing conditions of the damaged species. The frequency of formation of foci of mass reproduction of the gypsy moth and green oak leafworm in the territory of the zonal ecotone is from 5 to 11 years. Phenological features of pine needles pests are that they have a longer diapause in their life cycle, which is associated with periodic droughts. For example, Acantholyda nemoralis Thoms. diapause is 7 - 8 years,
On the territory of the Orenburg region, there are the southern borders of the habitats of many pests. Thus, the green oak leafworm is found on the territory of Russia in the range of the pedunculate oak. In the Orenburg region, the southeastern border of the range of this leaf-eating pest is located. The range of the gypsy moth is located in Europe. In the Russian Federation, this pest is recorded everywhere, because it is a polyphage - it damages more than 450 pitchforks of woody and shrub plants. This is a transzonal view. The area of the goldtail is located in Europe and Asia. In the Orenburg region, the eastern border of the insect's range passes. The red pine sawfly is found in Eurasia in the range of various species of pine trees. This is a transzonal view. The star sawfly weaver is also found in Eurasia. Transzonal view.

Figure 1. Distribution of areas of forest plantations with disturbed and lost resistance by the amount of drying

Figure 2. Distribution of forest areas by reasons broken and lost stability

Forest pathology monitoring as a sub-division of monitoring of forest lands in forest phytocenoses in the Orenburg region is carried out on an area of 413.1 thousand hectares. At the same time, new foci of pest reproduction and the spread of diseases are detected in a timely manner, and changes in the sanitary condition of plantings are noted. The reasons for the weakening and death of woody vegetation are also considered. The main causes include abiotic factors – forest fires, droughts, frosts, biotic factors-insect pests and pathogens, primarily rotten and sostudisto-necrotic, anthropogenic factors.

Scots pine is an ancient and amazing tree species with high adaptive abilities, it can both create clean plantings, and grow together with other coniferous or deciduous species, which helps this
species to occupy vast areas with different environmental conditions, so this breed is an interesting object for study and research.

In our time, it has become important for humanity to understand the research in the field of real changes in the Earth's biosphere, which are most associated with the anthropogenic factor. Due to changes in the environment, serious environmental and economic disasters can occur. This indicates the need for work that will study the mechanisms of adaptation and resilience of ecosystems to steadily changing environmental conditions. By studying the radial growth, some data can be obtained that are related to the dynamics of the forest and the establishment of a forecast of natural and climatic changes.

The radial growth of wood per year is associated with the biological properties of the breed, climatic factors, the conditions of the place of growth, the competitiveness of the tree in the forest, and "neither individual genetic features nor individual environmental factors, except for catastrophic events, determine the actual observed variability of the radial growth" [17].

The radial growth of scots pine can be considered the main quality in assessing the growth and development of the tree. It is related to the main taxation indicators. "With a significant variability of the territory in terms of natural and climatic conditions of growth, the width of the annual rings, in accordance with V. Shelford's law of tolerance, is determined only by limiting factors" [18,19].

Numerous changing parameters of climatic conditions are reflected in the value of the radial growth of the main forest-forming species. The radial increment changes under the influence of abiotic factors and biotic relationships. The radial growth of Scots pine is quite strongly associated with the characteristics of the ecotope. The radial growth of pine is associated with outbreaks of mass reproduction of pine sawflies with a strong overeating of the crown. We have identified the impact of solar activity, which leads to a decrease in the radial growth after two years. The dry vegetation period (low hydrothermal coefficient) of the current and next year, the hydrothermal coefficient of July after two years, and some influence of the hydrothermal coefficient of June after two years also have an impact. In our opinion, the relationship between the radial growth of trees and the climate is not always clear.

The minimum growth of scots pine in the Nezhinsky district forestry was recorded in 2018 – 0.68 mm. In general, since 2010, after the drought, the increase has been the lowest for the entire time of tree growth in this sample area. The maximum increase was recorded from 1970 to 1977. The average growth rate for 1 year is 1.8 mm. The temporary trial area in the Nezhinsky district forestry is located in the grass pine forest. Undergrowth – green ash. There is no undergrowth. The living ground cover includes the common carrot, the forest ground beetle, the common yarrow and the mountain bird.

The minimum growth of scots pine in the Komsomolsk district forestry was recorded in 2018 – 0.74 mm. The maximum increase was recorded from 1962 to 1972. The average increase for 1 year is 1.85 mm. The temporary trial area in the Komsomolsk district forestry is located in the grass pine forest. Undergrowth – green ash. There is no undergrowth. Living ground cover includes common thyme, plantain lanceolate, tipchak.

The minimum growth of scots pine in the Pavlovsky district forestry was recorded in 2018 – 0.78 mm. The maximum increase was recorded from 1970 to 1971. The average growth rate for 1 year is 1.92 mm. The temporary trial area in the Pavlovsky district forestry is located in the grass pine forest. Undergrowth – green ash and scots pine. There is no undergrowth. Living ground cover includes common hops, common snyt and sheep's fescue.

Due to numerous changes in natural factors, the question of studying the age structure of trees is becoming more popular, attention is paid to the study of the development of tree growth indicators for annual rings. Many factors and processes affect the response of cambium activity, including abiotic ones.

The dynamics of the radial growth of scots pine in the Orenburg forestry indicates a decrease in the indicator over the years, which is due to the dry climate of the steppe zone and partly to the technogenic influence of industrial enterprises in Orenburg.
The dynamics of radial growth of scots pine crops in the forest zone, on the contrary, increases over the years, which is associated, in our opinion, with wetter growing conditions in recent years. Comparing the average radial growth of scots pine in the zonal ecotone of forest and steppe, we can note higher indicators in the forest zone and lower ones in the steppe zone.

The average annual growth of Nezhinsky, Komsomolsky, Pavlovsky district forest districts is, respectively, 1.8 mm; 1.85 mm; 1.92 mm. The average growth in one year in five different types of forest of the Shirokovsky district forest district is 2.34 mm.

The overall dynamics of the radial growth of Scots pine in different types of forest in the forest zone differs significantly from that in the steppe zone. Possible reasons for this difference in the radial growth rates of Scots pine are: geographical location as more humid, sufficient availability of moisture during the growing season, the impact of abiotic and anthropogenic factors.

The radial growth of trees with a circular wood structure, especially some coniferous species, is one of the main indicators of optimal growth conditions in ecological studies of forest cenoses. When comparing the average radial growth of scots pine in the forest and steppe zones, it was noted that the increase is higher in the forest zone and significantly lower in the steppe zone. Possible reasons for the difference in the radial growth of pine can be noted such as the geographical location as more humid, sufficient moisture supply during the growing season, different effects of abiotic and anthropogenic factors, as well as different plant stability. The harsh climatic conditions of the Southern Urals affect the biological characteristics of leaf and needle pests, increasing outbreaks of their mass reproduction in the forests of the Southern Urals, which leads to a strong defoliation of the crown of plantings from year to year, a decrease in biological stability and the death of trees in a large area.

**5. Conclusion**

It was noted that in the zone of medium, strong and maximum anthropogenic impact on the environment, there is a decrease in the biological stability of plantings and the appearance of permanent foci of mass reproduction of pests of leaves and needles as indicators of this low resistance. The radial growth of trees with a circular wood structure, especially some coniferous species, is one of the main indicators of optimal growth conditions in ecological studies of forest cenoses. When comparing the average radial growth of scots pine in the forest and steppe zones, it was noted that the increase is higher in the forest zone and significantly lower in the steppe zone. Possible reasons for the difference in the radial growth of pine can be noted such as the geographical location as more humid, sufficient moisture supply during the growing season, different effects of abiotic and anthropogenic factors, as well as different plant stability. The harsh climatic conditions of the Southern Urals affect the biological characteristics of leaf and needle pests, increasing outbreaks of their mass reproduction in the forests of the Southern Urals, which leads to a strong defoliation of the crown of plantings from year to year, a decrease in biological stability and the death of trees in a large area.
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