Radial growth of artificial forest stands under the aerotechnogenic impact of the Orenburg gas chemical complex

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Abstract. With extremely low forest cover in the Orenburg region (4.6 %), where the environmental stress factor is particularly acute, forests have exceptional climate control, soil protection, and sanitary and hygiene. The priority area of practice and science is the preservation and growth of the forests of the region, which serves as a kind of framework in stabilizing the environmental situation in the region. The presented work shows the state of forest stands under conditions of anthropogenic impact. The culmination of the current radial growth has been established and the so-called “surge” of the current growth of tree stands has been detected with the accumulation of threshold levels of toxicants in a polluted environment, which subsequently leads to loss of stability and destruction of plantations.

1. Introduction

In the process of natural growth and development in the plantation, the diameter, cross-sectional area, height and species numbers are constantly changing, respectively, over time, the wood supply increases. Of greatest interest is the amount by which this taxation characteristic will change at a certain lifetime of the planting under the influence of technogenic emissions. The definition of this value should be based on the current growth, which is a measure of the impact for a certain period of time. It serves as an indicator of the duration, regularity, and also the intensity of the recreational load [1], and depends on the breed, age and location conditions and the complex of climatic factors [2, 3]. Current growth is a key indicator of forest productivity assessment; As an integral indicator, it is used for ground monitoring of forests, assessment of their condition and results of human activities.

The determination of the magnitude of the current radial growth of trees is based on the width of the annual layers [4, 5]. Of course, the data obtained on changes of this magnitude should be used in the practice of forestry in order to develop and design such economic activities that will increase the viability of plantations.

According to [6], in stands that grow closest to the source of emissions, there is a constant decrease in radial growth. The assimilation apparatus is disturbed and, as a consequence, a deviation from the norm in the photosynthetic activity of plants. Their growth rate slows down, the fruiting intensity decreases the ability to withstand negative environmental factors. Due to the effects of industrial emissions in trees, a decrease in radial growth was noted [7]. This issue has not been studied under conditions of atmospheric pollution of the gas-chemical complex.
2. Materials and methods
The aim of the research was to determine the radial growth in artificial forest cenoses of conifers (pine and larch), growing at different distances from the source of emissions (Fig. 1).

The studies were conducted in forest cultures on the territory of the Orenburg region in the zone of the Orenburg gas chemical complex.

![Figure 1. Radial current growth of Scots pine](image)

The main research method is the laying of permanent sample plots and temporary test plots according to the requirements and guidelines for laying test plots in forest crops with subsequent long-term or one-time observations on them to obtain versatile and reliable information on the state of forest communities and their dynamics. To study the experience of creating artificial plantations, forest management materials, books of forest cultures and other scientific and technical documentation were used.

The age of the crops at the time of the study was 37 years. The distance from the source of pollution was 5, 10 and 15 km. To compare the obtained parameters, the radial growth was studied in cultures of considerable distance from the source of emissions. In their composition, these were pure pine plantations (10P), at the time of the research, the age was 49 years old, pure larch crops (10L) age 44 years and mixed larch-ash (5L5A) age 38 years.

3. Results
The highest current growth in common pine crops, distant 5 km from the source, was noted at the age of 11 years, then there is a constant decrease from year to year and it reaches a minimum of 30 years. The culmination of growth in the stands of 10 and 15 km of the zone occurs at 16 years, and, starting from 30 years, the radial growth tends to increase. For the first time, the same pattern was noted by the Swiss scientist W. Beyschlag et al. This phenomenon shows the reaction of stands to the anthropogenic load, first there is a sharp decrease in radial growth, then its increase, and then with an increase in defoliation of crowns, a further decrease in growth follows.

Under the influence of extreme climatic factors, the culmination of growth in tree and shrub species can be observed in 3-8 years, then the current growth drops sharply [8]. It is also known that with an increase in the recreational load, the climax of growth is outstripped by an average of 5–10 years [9].

In pure pine plantations, more than 30 km away from the source, the highest growth is noted at 13 years of age and its gradual decrease in subsequent years.

The current radial growth of Siberian larch is shown in Fig. 2. According to the larch growth tables under the conditions of the Saratov region, the culmination of the average periodic radial growth is noted at 25 years old; in Bashkiria at 30 years old, i.e. in more favorable conditions, the highest increase is noted later. In artificial forest cenoses of Siberian larch, 15 km distant from the source, the maximum accumulation of radial growth occurs at 16 years, the graph has a wave-like shape, which
may indicate a reaction of trees to toxicants, and a sharp increase is observed from 22 years of age (Fig. 2). If we consider larch stands of various composition, then the maximum increase in net larch stands is noted at 14 years of age, and in mixed ones at the age of 13 years.

The wave-like dynamics of pollutant content in atmospheric air was reflected in the dynamics of the current growth. Pine and larch cultures, 15 km away from the gas chemical complex, responded to these changes – in the years of decreasing concentrations of pollutants, the current growth increased. Moreover, it should be noted that the reaction to these changes occurred in young forest cultures. With a slight decrease in emissions, the radial growth in larch crops of the 15 km zone increases slightly, while in pine it does not change its values.

Figure 2. Radial current growth of Siberian larch

With an increase in the level of air pollution, a decrease was noted. At the age of 30, the magnitude of the radial increase was practically independent of the dynamics of the content of pollutants in the air. A decrease in the growth of Siberian larch, and then an increase in it, is evidence of its greater gas resistance compared to ordinary pine. We believe that when threshold concentrations of pollutants are accumulated, plants react with an increase in radial growth, and then its decrease is noted, this is the so-called “surge” of the current growth, which in the future can lead to the death of forest cenoses.

As a result of studies of stands that are 15 km away from the source of emissions, it can be noted that here the accumulation of pollutants is higher than in the 5 and 10 km zone, which was reflected in a decrease not only in the current radial growth, but also in all taxation indicators.

Therefore, when comparing the values of the current growth with the indicators influencing it, it is necessary to take into account the delay factor, since the reaction of the stands does not occur immediately, but over time.

To study the dependence of the current radial growth on climatic conditions, the hydrothermal coefficient and the amount of precipitation for the active period of vegetation were chosen, because I. Kaliyev [1998] established that precipitation has a decisive influence on the growth of wood growth under conditions with sufficient heat.

So, the correlation coefficients in Scots pine between the current radial growth and hydrothermal coefficient were at a distance of 5 km – $r = -0.30$, 10 km – $r = -0.30$, 15 km – $r = 0.009$, more than 30 km – $r = -0.45$ (Fig. 3).

The presence of an average correlation ($r = 0.44$) between the growth and the amount of precipitation during the active growing season was found in pine forest cultures 15 km away from the source. In other cases, a correlation was not found, for example, in pine plantations, the distance from the source of which was 5 km, 10 km and more than 30 km, the correlation coefficient was $r = -0.60$, $r = -0.50$ and $r = -0.28$. 

![Current radial growth of Siberian larch](image-url)
In larch crops growing 15 km from the source, there is a weak correlation between the current radial growth and HTC \( r = 0.17 \), the analysis also revealed an average relationship between growth and the amount of precipitation for the active growing season \( r = 0.60 \) (fig. 4).

Growth rates were influenced by the conditions of previous years and the biological age of crops (fig. 5, 6).

**Figure 3.** Dependences of the current radial growth on the HTC (Scots pine).

**Figure 4.** Dependences of the current radial growth on the amount of precipitation for the active period of vegetation (ordinary pine).

**Figure 5.** Dependences of the current growth on the HTC (Siberian larch)
Figure 6. Dependences of the current growth on the amount of precipitation for the active period of vegetation (Siberian larch)

4. Conclusion
Summarizing the results of the studies, we can conclude that, due to the significant height of the OGCC pipes (180 m), as the distance from the source of pollution is in the range from 5 to 15 km, the average pine height decreases from 15 to 9.5 m and the gross content increases heavy elements from 2.7 to 3.0 mg / kg, followed by an increase in the first indicator as it moves 50-60 km from OGCC to 23.1 with a decrease in the second to 07 %. The ash content of forest litter in the emission zone (5–15 km) varies from 1.75 to 2.9 %, and at a distance of 50–60 km it decreases to 0.7 %. Siberian larch in the studied forest conditions of the Orenburg region is relatively stable and forms highly productive plantings. Artificial stands created on the territory of the region in different years grow and develop successfully, which allows us to consider Siberian larch as a promising species for afforestation in the Orenburg region under the influence of the gas processing industry. The results of scientific research significantly supplement the information on the growth of forest crops of Siberian larch in various soil and climatic conditions of the Orenburg region. The obtained data can be used in planning and conducting forestry operations in the Orenburg region.

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