Ecological potential of artificial stands of Scots pine in the Southern Urals

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Abstract. The created artificial stands of Scots pine perform an extensive complex of ecological functions, in particular, carbon deposition. The accumulation of phytomass in artificial forest coenoses has certain features in comparison with other stands of trees. A comparison of the data obtained with the indicators of natural stands under similar conditions shows a more active accumulation of biomass by artificial coenoses. At the age of 11, with the number of trunks of 5.5 thousand copies/ha, the wood stock is 65 m³/ha and phytomass (needles) - 23 t/ha. It is possible to estimate the phytomass of pine forest crops on the territory of the Orenburg region at 2.8 million tons, respectively, the reserve of deposited carbon is 1.4 million tons. With increasing age of trees, the value of phytomass and plantings of the studied breed increases. Forest crops growing in the conditions of the forest-steppe zone, in one year, give an increase of 9.2 t/ha, or 13.1 m³/ha. The volume of total phytomass of forest crops of scots pine in the conditions of the forest-steppe zone at the age of 5-15 years is 2449,689 tons, and the reserve is 3250,511 m³. In the forest fund of the Orenburg region (according to the forest fund accounting data as of 01.01.2021), scots pine occupies 37,6 thousand hectares (without Buzuluksky Bor National Park), which is 9.3% of the total forest area. These are mainly forest crops, 99% of which are young and medium-aged plantings. The biopotential of scots pine crops in this region is quite high, but the sanitary condition of these stands is extremely poor. In order to improve the sanitary condition of common pine crops in the conditions of both forest-steppe and dry-steppe zones, to increase the biological productivity and stability of pine plantations, there is a need for timely forest pathology examinations with subsequent appointment of sanitary and health measures.

1. Introduction.
Unbalanced use of natural resources naturally leads humanity to a global environmental catastrophe. The clearest signs of ecosystem distress are manifested in the zones of vegetation transformation, i.e., in ecotones, one of which is located in Orenburg region. This area, according to environmentalists, is one of the ten most polluted in the country. Industrial development of the territory, ploughing of land more than 60% (in some districts of the region – 90%), ill-considered use of water resources, destruction of tree and shrub vegetation in combination with possible remote consequences of the drying of the Aral Sea can be considered the cause of shallowing of the Ural River and small rivers of its basin.
Climatic features of the Southern Urals - severe winter (January minimum -42°C) and hot dry summer (July maximum +45°C) with a precipitation of 200-418 mm, create harsh conditions for the growth of woody and shrubby vegetation that provides a gentle amplitude of fluctuations in the territorial water table.

One of the most important functions of forest stands is the absorption of carbon dioxide and the release of oxygen into the planet's atmosphere. Forests are a huge "carbon reservoir" and play a positive role in the formation of the carbon balance.

Studies by a number of authors have shown that the ability of trees to accumulate and retain dust-like emissions, absorb carbon dioxide from the atmosphere, and release oxygen is influenced by the development of the assimilation apparatus of plantings, i.e., the projection of the crown and the mass of live needles.

The bio-productivity of forest crops in artificial plantings is practically not studied in comparison with natural ones. Forest crops, especially young ones, bind atmospheric carbon more intensively than natural plantings of a similar age.

2. Statement of the problem
The average forest cover of the region is 4.5%. Forests perform protective functions – anti-erosion (44%), especially valuable and forbidden strips that protect the spawning grounds of valuable commercial fish (18% each).

Protective afforestation in river basins is designed to prevent their shallowing, but the optimal forest cover should be at least 50% [1].

Plans to create water protection plantings have not been fully implemented, and the actual forest cover of these territories does not exceed 30%.

Black poplar, petiolate oak, scots pine and other species are recommended for creating water protection plantings.

The process of creating artificial plantings in dry-steppe and semi-desert conditions is extremely complex and often does not bring the desired results, but reforestation in the Orenburg region developed actively in the XX century and allowed increasing the planned forest cover of land by the beginning of the XXI century by 38.9% [2].

The created artificial stands of Scots pine perform an extensive complex of ecological functions, in particular, carbon deposition.

The productivity of artificial plantings in arid climates has not been sufficiently studied, and the relevance of this issue has increased many times in connection with the ratification of the Kyoto Protocol of Russia.

According to V.A. Usoltsev, the annual carbon deposition in the phytomass of plantings on the forested area of the Orenburg region increased by 21% in 24 years from 1983 to 2007, which is primarily due to the creation of forest crops [3].

The accumulation of phytomass in artificial forest coenoses has certain features in comparison with other stands of trees.

3. Materials and methods
The trial areas were laid in the forest-steppe (Buzuluksky district) and dry-steppe (Orenburg district) zones.

The stocks and distribution of phytomass in Scots pine crops were studied on the sample areas laid down according to OST 56-69-83.

All works on the laid-out areas were performed according to the original methods of V.A. Usoltsev [4].

A continuous enumeration of trees by species and thickness steps was carried out, the taxation indicators of the stand were calculated, and the selection of model trees was carried out, which were later cut down at the root neck for measuring morphometric indicators, separating the phytomass and weighing it.
Phytomass reserves were determined per 1 ha in relation to the cross-sectional areas of the model trees.

4. Results and Discussion

A comparison of the data obtained with the indicators of natural stands under similar conditions shows a more active accumulation of biomass by artificial coenoses.

Pine cultures of the Turgai island pine forests in the 10-year age (Ia class of bonitet) with the number of trunks of 7.8 thousand copies/ha accumulate wood of 30 m³/ha and phytomass (needles) of 20.7 t/ha, at the 20-year age, respectively, 104 m³/ha and 52.3 t/ha [5].

In the natural stands of these trees at 20 years of age, with the number of trunks of 28 thousand copies/ha, the stock is 66 m³/ha and phytomass (needles) is 39.1 t/ha.

A similar situation is observed in Orenburg region. Thus, according to Sokolov V.S. (1961), in the Buzuluk forest at the age of 10, with the number of trunks of 8 thousand copies/ha, the wood stock is 48.2 m³/ha and phytomass (needles) is 11.7 t/ha [6].

According to table 1, at the age of 11, with the number of trunks of 5.5 thousand copies/ha, the wood stock is 65 m³/ha and phytomass (needles) is 23 t/ha.

Based on the average stock of phytomass according to the data given in table 1, it is possible to estimate the phytomass of pine forest crops in the territory of the Orenburg region at 2.8 million tons, respectively, the stock of deposited carbon is 1.4 million tons.

Table 1. Phytomass of Scots pine crops in the forest-steppe and dry-steppe zones of the Southern Urals

| Phytomass in a completely dry state (t/ha) | Forest-steppe zone (Buzuluksky district) | Dry steppe zone (Orenburg district) |
|-------------------------------------------|----------------------------------------|-----------------------------------|
| Trunks in the bark                         | 0.46 0.76 0.91 3.31 25.9 90.8 87.0 153.1 |
| Trunk bark                                 | - - - - 5.34 7.96 -                  |
| Crown skeleton                             | 0.54 0.42 0.70 1.79 12.0 16.1 24.8 9.00 |
| Needles                                    | 1.62 1.66 2.87 4.42 23.0 10.3 9.40 6.92 |
| Total                                      | 2.62 2.84 4.48 9.52 60.9 117.2 121.2 169.1 |
| Age (years)                                | 4 5 6 7 11 33 34 44                  |
| Height (m)                                 | 1.0 1.1 2.8 2.55 5.8 12.8 14.3 23.0   |
| Diameter (cm)                              | 2.9 2.45 3.87 3.12 7.56 16.1 17.2 22.4 |
| Density (ex. / ha)                         | 5278 10116 5932 7348 5471 1433 1386 865 |
| Cross-sectional area (m² / ha)             | 3.48 4.78 6.98 4.96 24.6 29.3 32.2 34.0 |
| Bonitet class                              | IV IV III II Ia I I Ia                |
| Reserve (m³/ha)                            | 1.3 2.1 2.5 8.7 65 224 188 383        |

The sanitary condition of forest crops of scots pine in both forest-steppe and dry-steppe zones is unsatisfactory.

Thus, in the forest-steppe zone of the Southern Urals, a root sponge and a red pine sawfly are marked on a pine tree in view of more optimal abiotic living conditions than in the dry-steppe zone. Unsatisfactory sanitary condition of the forest – steppe zone stands at 11.6% of the land area occupied by forest stands, while in the dry-steppe zone 18.5%.

Similarly, the number of dead plantings is distributed in the forest-steppe zone – 0.6%, in the dry-steppe zone 16.15%.
Considering the reasons for the weakening, it can be noted that in the forest-steppe zone, the main ones are unfavorable weather conditions and soil and climatic factors-75.72%, diseases of plantings-15.54%, forest fires-8.32%, insect damage – 0.42%.

In the dry-steppe zone, the most adverse impact on plantings is caused by unfavorable weather conditions and soil and climatic factors-59.81%, forest fires-37.27%, plant diseases-2.9%, and some other factors-0.03% (figure 1-4).

The dynamics of the radial growth of scots pine in the dry-steppe zone shows that there is a decrease in growth in recent years, which is due to the more arid climate of the dry-steppe zone and partly the technogenic influence of industrial enterprises.

The dynamics of radial growth of scots pine crops in the forest-steppe 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 – steppe zone-2.34±0.12 mm and lower- in the dry – steppe zone-1.86±0.03 mm.

The average height of trees of ordinary pine of artificial origin exceeds this indicator of trees of natural origin by 20%, a similar relationship can be noted with respect to the average diameter of trees of forest crops by 25%. The length of the beetle-free part of the trunk of scots pine in the forest-steppe zone cultures is 3.5±0.07 m, which is 31% more than in the dry-steppe zone plantings, which indicates the presence of higher competition among trees, as well as their faster growth in these plantings and better growing conditions.

This is also evidenced by the difference in the length of the dead part of the branches - in the forest-steppe zone it is 16.9±0.01 m, which is 16% more than in the stands of the dry-steppe zone. The length of the living (assimilative) part of the crown is 3.5±0.03 m in the forest-steppe zone, and 17% less in the dry-steppe zone.

Biological productivity of artificial pine stands shows that with an increase in taxation indicators, there is an increase in the dry phytomass of trees, which is expressed by a high coefficient of determination, which varies from 0.949 to 0.991.

There are also minor differences in the determination of the total phytomass, calculated using the diameters at the height of the breast and at the root neck. The values of the total phytomass of the model trees calculated using the regression equation and the experimental data obtained from the sample areas differ slightly, within 4%.
The data of phytomass stocks of model trees from the sample areas allow us to calculate the reserves of the ground part of phytomass per 1 ha of forest in young plants of 4-11 years of age. Knowing the productivity of stands per 1 ha of forest, it is fashionable to determine the productivity of all stands of scots pine of a certain age and growing conditions.

With an increase in the age of trees, the value of phytomass and plantings of the studied species increases. Forest crops growing in the conditions of the forest-steppe zone, in one year, give an increase of 9.2 t/ha, or 13.1 m³/ha. The volume of total phytomass of forest crops of scots pine in the conditions of the forest-steppe zone at the age of 5-15 years is 2449,689 tons, and the reserve is 3250,511 m³.

Comparative analysis of phytomass stocks in young forest-steppe zone plants growing in wet conditions have aboveground phytomass compared to pine crops growing in the dry-steppe zone. The conducted quantitative assessment of the main environmental functions of pine young trees of the forest-steppe zone showed that the functions performed by plantings according to the weighted average annual absorption of carbon dioxide per 1 ha of plantings is 4.6 t/ha. With age, there is an increase in phytomass and, as a result, the volume of carbon dioxide absorbed by the plantings from the atmosphere increases.

5. Conclusion

Thus, the creation of artificial plantings is a promising direction in solving global problems caused by climate warming.

Increasing the area of artificial plantings is an extremely urgent task for such ecologically disturbed region, as Orenburg region.

In general, the total phytomass reserves of plantings in the territory of the Southern Urals amount to 40.5 million tons [7].

In the forest fund of Orenburg region (according to the forest fund accounting data as of 01.01.2021), scots pine occupies 37.6 thousand hectares (without Buzuluksky Bor National Park), which is 9.3% of the total forest area. These are mainly forest crops, 99% of which are young and medium-aged plantings.

Thus, the biopotential of scots pine crops in this region is quite high, but the sanitary condition of these stands is extremely unfavorable. In order to improve the sanitary condition of common pine crops in the conditions of both forest-steppe and dry-steppe zones, to increase the biological productivity and stability of pine plantations, there is a need for timely forest pathology surveys with subsequent appointment of sanitary and health measures.

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