Influence of protective forest planting on the resistance of agroecoses on the boundaries with agromeliorations

Olesya Azarova, Aleksandr Tereshkin, Anna Kalmykova, Dmitriy Mashtakov and Galina Zaigralova

Saratov State Agrarian University named after N.I. Vavilov, Saratov, Russia

E-mail: lmsus1920@mail.ru

Abstract. The article is devoted to the study of a unique object of protective steppe afforestation - the Guselsky forest reclamation experimental site, which is a system of protective forest plantings with a total area of 24.5 hectares. Protective plantings have good vitality and support the original dense structure. Analysis of the biometric materials of the sample plots shows that the most stable tree species on the southern chernozems and quite suitable for protective afforestation turned out to be pedunculate oak and white acacia. Under these conditions, they can be used as the main ones, since they have good preservation and valuation indicators. In protective forest plantings, the process of soil leaching is underway, which improves the water-physical, and, consequently, the forest-growing properties of the southern chernozems. Currently, these plantings have both protective and recreational roles due to partial development for low-rise buildings.

1. Introduction

Academician N.I. Vavilov attached great importance to field-protective forest belts in the system of measures to protect crops from unfavorable natural conditions. In 1928, in his article, he wrote: “That year, in the North Caucasus, we could see a most curious picture of the extraordinary effectiveness of forest protection zones. You could see in our beautiful state farm “Khutorok” in the North Caucasus, what role was played by the protective zones, which literally saved the winter wheat crop from death” [1].

A lot of valuable objects of steppe protective forestry have been created in the Saratov region. One of such objects is the Guselsky forest reclamation experimental site, which is a system of protective forest plantations with a total area of 24.5 hectares and protects 190 hectares of agricultural crops. The site is located on the southern chernozems of the steppe zone, 7 km from the center of Saratov on the slope to the river Volga. It is a part of the structure of the Saratov agglomeration and adjoins in the development zone.

The site was founded in 1925-1929 with the participation of the staff of the Department of Forest Melioration under the direct supervision of the Honorary Academician of VASKHNIL, Professor N.I. Sus. It was created as an experimental one, to conduct continuous monitoring studies of the state of a wide range of tree and shrub species in the harsh forest conditions of the South-East, to establish optimal mixing patterns for plantings and observe individual elements of the microclimate under the protection of the system, snow distribution, soil moisture and agricultural productivity cultures, as well as the systemic ameliorating role of protective forest plantings in the conditions of a dismembered
relief. Protective forest plantings were laid out of a linear and massive type, of a dense and openwork structure with a width of 20 - 50 m. The distance in the row spacing was 1; 1.5; 2 m.

The first observations of the growth and condition of the belts, as well as their influence on the microclimate and harvest were carried out by N.S. Sokolova (1937), and in the prewar years by F.I. Serebryakov. Later, the state and growth of the belts were studied by graduate students: E.G. Yashin (1952) and S.V. Petrichenko (1967) under the guidance of Associate Professor of the Department of Forest Management I.A. Fedotov, Yu.I. Zubkov (1972) under the guidance of Associate Professor A.V. Kanofiev, I.M. Duganov (1982) under the guidance of Associate Professor A.I. Razarenov [2-3].

The last study was conducted by the authors in 2018. About 90 years have passed since the establishment of the Guselsky forest reclamation experimental site. The situation on the territory has changed. The site, which was previously used in agriculture, is currently mostly used for low-rise cottage buildings. However, most of the plantings have survived.

2. Materials and methods
Test plots within the city were laid according to generally accepted methods. Data processing was carried out using the Life program [4]. The recreational and aesthetic assessment was carried out using an improved method. The maximum number of points is 103 [5].

The purpose of our research was to determine the state of tree and shrub species, assess their viability, aesthetic appeal, influence on soil fertility, prospects for the further use of forest plantations in the greening system of low-rise buildings.

Considering the fact that one of the main species in the protective steppe afforestation is the common oak (Quercus robur L.), a great attention was paid to the study of its growth. In 1982 I.M. Duganov laid 7 test plots out of 12. One trial plot with silver birch (Betula pendula Roth) has been laid to study its growth. They were also laid two plots with black locust (Robinia pseudoacacia L.), one plot with green ash (Fraxinus lanceolata Borkh), and one plot with ash-leaved maple (Acer negundo L.).

3. Results and Discussion
According to the research data of 1982, it follows that the forest belts, having a dense structure, since they contained up to 40-60% of shrubs in their composition, accumulated powerful snow deposits annually. Thawed waters deeply soaked the soil under the plantations. For this reason, a different type of water regime was formed under them - periodic leaching, characteristic of podzolized and leached chernozems of the forest-steppe [6]. For the southern chernozems of the steppe, the non-leaching type is characteristic.

Changes in the humidification regime due to the accumulation of additional snow masses and the filtration of melt water directly in the plantations led to the formation of humus inflows into horizon B, which are absent in the steppe. This simultaneously leads to leaching of carbonates, from 40–45 to 63–68 cm, as the depth of boiling increased from HCl. The high penetration of the roots of the horizons A, B and BC leads to their looser composition in comparison with open spaces. The distance from the lower boundary of the humus horizon A to the upper boundary of the occurrence of carbonates increases to 18–23 cm. On the southern chernozems of the steppe, this distance is practically absent or does not exceed 5–8 cm.

Thus, based on the analysis of the above characteristics, it can be concluded that there is a process of soil leaching under protective forest plantations of high density. This process should be considered as positive, improving the water-physical, and, consequently, the forest-growing properties of the southern chernozems, excluding their degradation.

During the estimate survey in 2018, it was found out that some of the plantings in which the permanent test plots were located were damaged during construction, so they were re-planted by the authors. Plantation data and vitality indicators according to E.S. Pavlovsky [7] are given in tables 1 and 2.
Table 1. Biometric indicators of oak mixed with black locust on different soils.

| Number of plot | Soil                                           | Species of wood          | Conservation of forest plantation, % | H, m | d, cm | Sustainability class |
|----------------|-----------------------------------------------|--------------------------|-------------------------------------|------|-------|---------------------|
|                | Estimate survey in 1982                       |                          |                                     |      |       |                     |
| 1.             | Leached, thin, middle loamy chernozem         | Common oak               | 25                                  | 11.6 | 15.3  | 3                   |
|                |                                               | Black locust             | 36.4                                | 10.8 | 13.8  |                     |
| 2.             | Leached, medium-sized, sandy loam chernozem   | Common oak               | 25                                  | 12.0 | 17.2  | 2                   |
|                |                                               | Black locust             | 32                                  | 10.3 | 14.1  |                     |
| 3.             | Southern, thin, weakly crushed, heavy loamy   | Common oak               | 20                                  | 9.0  | 15.0  | 3                   |
|                | chernozem, with small solonetzes              | Black locust             | 22.5                                | 10.0 | 4.5   |                     |
|                | Estimate survey in 2018                       |                          |                                     |      |       |                     |
| 1.             | Leached, thin, middle loamy chernozem         | Common oak               | 20                                  | 11.8 | 25.6  | 2                   |
|                |                                               | Black locust             | 28.2                                | 11.6 | 16.9  |                     |
| 2.             | Leached, medium-sized, sandy loam chernozem   | Common oak               | 22                                  | 13.9 | 32.5  | 2                   |
|                |                                               | Black locust             | 37.5                                | 12.9 | 17.9  |                     |

The state of common oak mixed with black locust on various soil differences was determined on three samples in 1982. Until 2018, one sample has survived. Sample No. 2 had to be repeated. The results of estimate survey in 1982 and 2018 confirm that common oak has the best biometric indicators in the conditions of leached sandy loam chernozems, and the worst in saline soils.

Common oak grows better on sandy loam soils than on loamy soils. Indicators of common oak on trial plot No. 3 indicate a rather high biological resistance of it on saline soils. At the same time, black locust under these conditions practically did not worsen its growth in comparison with non-saline soils, confirming its high salt tolerance. Within the limits of the samples, we did not note the dry top of the oak, for 30 years its height increased by 0.2–1.9 m, the diameter by 9.3–14.7 cm. The increase in the share of safety of black locust is explained by its replenishment in the rows with shoots and self-sowing [8].

The data obtained in the study in 1982 of various mixing schemes with other species showed that the best combination of all studied is the common oak and green ash, where the height of the oak was 12.4 m, the diameter was 21.0 cm; the preservation rate was the highest (30.7%) (table 2).

Common oak mixed with common elm (Ulmus laevis Pall) is characterized by good biometric indicators. However, the rapid growth of the elm at a young age, its dense and wide crown led to a biophysical form of mutual influences (shading), which negatively affected the safety of the oak (17.4%). Approximately the same regularity in the development of oak was in mixing it with another elm species, stocky elm (Ulmus pumila L.): safety - 19.6%, height - 12.0 m, diameter - 19.1 cm).

The lowest biometric indicators of common oak and its preservation were observed in combination with ash-leaved maple (Acer negundo L.) and black locust, which are distinguished by rapid growth at a young age, have a wide spreading crown and have a huge potential competitive ability.

2018 data show that, in general, all plantings have good vitality indicators and support the original dense structure. The process of formation of the second layer of black locust, green ash, field maple (Acer campestre L.) and Tatar maple (Acer tataricum L.) is active. Arboreal caragana (Caragana arborescens Lam.) and Tatar honeysuckle (Lonicera tatarica L.) are well preserved in the edge rows.

The analysis of the estimation materials of the sample plots shows that the most stable tree species on the southern chernozems and quite suitable for protective afforestation turned out to be common oak and black locust, which under these conditions can be used as the main ones, since they have good preservation and biometric indicators. Weeping birch, as the main species, has low durability without reforestation felling. The use of green ash and ash-leaved maple as accompanying ones is
justified only in anti-erosion plantations from the side of the ravine edges. At present, overgrown stands of complex species and age composition with a trunk density of up to 18,000 pcs/ha have formed in such plantings. This provokes a high mortality and low indicators of the sanitary and vital state of the breeds.

Table 2. Biometric indicators of oak mixed with other wood species.

| Number of plot | Soil                                          | Wood species              | Conservation of forest plantation, % | H, m   | d, cm | Sustainability class |
|----------------|----------------------------------------------|---------------------------|-------------------------------------|--------|-------|---------------------|
| 1              | Leached, thin, middle loamy chernozem        | Common oak               | 25                                  | 11.6   | 15.3  | 2-3                 |
| 2              |                                              | Black locust             | 36.4                                | 10.8   | 13.8  |                     |
| 3              |                                              | Siberian elm             | 19.6                                | 12.0   | 19.1  | 2-3                 |
| 4              |                                              | Common oak               | 17.4                                | 13.9   | 20.8  | 2                   |
| 5              |                                              | Common elm               | 22.1                                | 13.8   | 20.0  |                     |
| 6              | Light loamy, ferruginous, light eroded chernozem | Ash-leaved maple   | 28.3                                | 10.2   | 18.0  | 3                   |
| 7              | Leached, middle loamy chernozem              | Common oak               | 30.7                                | 12.4   | 21.0  | 2                   |
|                |                                              | Green ash                | 30.6                                | 11.2   | 18.5  |                     |

Estimate survey in 1982

Tatar maple can be used as an accompanying species, especially in the inner rows, which in an adult state does not strongly compact the lower tier of the belt, provide high wind permeability and efficiency of the belts.

In recent decades, the increase in the area of Saratov is due to the lands that previously performed agricultural and forestry purposes. That is why a significant area of forest plantations of the Guselsky forest reclamation experimental site appeared on the territory of the city. A dense network of linear plantations, as before, improves the microclimate of the area, protects against noise, dust, and the development of erosion processes. Currently, these plantings are fully protective, aesthetic and recreational, as they are located in the residential area.

To assess the attractiveness of protective forest plantings, we compared them with linear plantations of general use. The average score for common plantings is 56 points (boulevards on Rakhova and Astrakhanskaya streets, 50 let Oktyabrya prospect). The Cosmonauts Embankment is characterized by the highest comparison score - 61. The integral assessment of protective forest plantings is 44-46 points. The large difference between the maximum score and obtained results is explained by the use of several species in the mixing scheme, the lack of contrast in the trunks and their colorfulness in all test plots. Forest belts are of the same age.

To assess the attractiveness of protective forest plantings, we compared them with linear plantations of general use. The average score for common plantings is 56 points (boulevards on Rakhova and Astrakhanskaya streets, 50 let Oktyabrya prospect). The Cosmonauts Embankment is characterized by the highest comparison score - 61. The integral assessment of protective forest plantings is 44-46 points. The large difference between the maximum score and obtained results is explained by the use of several species in the mixing scheme, the lack of contrast in the trunks and their colorfulness in all test plots. Forest belts are of the same age.

On the test plots, there is mortality in the form of fallen trees and dry branches. There is a household waste in recreation areas. Most of the protective forest plantings are in a thickened state, since thinning is not carried out in these stands. The lack of measures to care for plantings reduces the state of life due to the presence of dry branches, which also leads to a decrease in the passability and visibility of these areas. The ground cover consists of weeds: dandelion, chicory, plantain, meadow
clover, shepherd's purse, etc. The bulk of the belts is thickened with black locust young growth [8-9]. The comparative evaluation results are shown in table 3.

| Place of plot, planting    | Species composition       | Aesthetic valuation |
|----------------------------|---------------------------|---------------------|
| Guselka (line planting)    | Common oak                | 46                  |
|                            | Black locust              |                     |
| Guselka (line planting)    | Common oak                | 46                  |
|                            | Green ash                 |                     |
| Guselka (line planting)    | Common oak                | 46                  |
|                            | Ash-leaved maple          |                     |
| Guselka (forest)           | Common pine               | 44                  |
| Cosmonauts Embankment (line planting) | Siberian elm         | 61                  |
| Boulevard on Rakhova street| Lombardy poplar           | 57                  |
|                            | Siberian elm              |                     |
|                            | Horse chestnut            |                     |
| Boulevard on Astrakhanskaya street | Lombardy poplar     | 57                  |
|                            | Siberian elm              |                     |
|                            | Lombardy poplar           |                     |
| Boulevard on 1st Dachnaya street | Siberian elm    | 56                  |
|                            | Green ash                 |                     |
|                            | Lombardy poplar           |                     |
| Boulevard on 2nd Dachnaya street | Siberian elm    | 56                  |
|                            | Green ash                 |                     |
|                            | Horse chestnut            |                     |

At present, the protective forest plantings are inferior in aesthetic characteristics to the plantings of common use. However, residents use them for short-term and long-term rest, as evidenced by the numerous bonfire sites and equipped places for pastime found on the test plots. The current state of forest belts is not a limiting factor when visiting them. Citizens seeking solitude prefer uncomfortable forest belts to city parks and squares. Plantings of common use are exposed to excessive recreational loads, which negatively affects not only plantations, lawns, but also the emotional state of a person who is resting [10-13].

4. Conclusion
The significant width of deciduous plantations allows them to be transformed, if necessary, into avenue or boulevard. This goal can be achieved by partially cutting down the inner or edge rows. It is possible to quickly implement the necessary changes to increase the attractiveness of forest belts by planting flowering shrubs, stable ornamental species instead of dead crops, and re-forming felling.

An increase in species diversity due to shrubs such as Cossack juniper (Juniperus Sabina L.), common barberry (Berberis vulgaris L.), crown mock-orange (Philodelphus coronaries L.), Japanese spirea (Spiraea japonica L.) will increase their decorative qualities and create uneven-aged and more sustainable plantings. Preservation of common oak and white acacia in the composition of transformed plantings will further improve the water-physical, and, therefore, forest-growing properties of southern chernozems.

References
[1] Forest and field 1991 (Saratov) 185
[2] Zatsepin A V, Tsyplokov V V and Zhurikhin D S 1998 Saratov forests: 200 years of the Russian forest department (Saratov) 382
[3] Razarenov A I 1983 Forestry and protective afforestation (Saratov) 184
[4] OST 56-69-83 Test forest management areas, method of laying 1984 (Moscow) 23
[5] Azarova O V and Tereshkin A V 2006 *Systemic studies of natural and technogenic complexes of the Lower Volga region* (Saratov) 84
[6] Barsukov P A 2000 *Criteria for evaluating technological methods for restoring the ecological functions of soils* (Moscow) 93
[7] Matthies G Ya, Pavlovsky E S and Kalashnikov A F 1984 *Agroforestry Handbook* (Moscow) 93
[8] Tereshkin A V and Azarova O V 2006 *Problems of biology, ecology, chemistry and teaching methods* 9 93-99
[9] Azarova O V, Tereshkin A V and Upolovnikov D A 2007 *Bulletin of the Saratov State Agrarian University named after N.I. Vavilov* 1 84
[10] Pavlovsky E S 1988 *Ecological and social problems of agroforestry* (Moscow) 283
[11] Eroshina N L and Kalmykova A L 2013 *Bulletin of landscape architecture* 32 54-61
[12] Kalmykova A L, Tereshkin A V, Zaigralova G N, Eskov D V and Kornienko M Yu 2019 *Amazonia Investig* 8 93
[13] Proezdov P N, Mashtakov D A and Barinov Yu V 2018 Productivity of the forest band system on chernozem of the southern steppe of the Volga region. *MATEC Web Conf.* 212 07011