Experience of afforestation of steep slopes by sowing and planting PMCR by the example of the Republic of Tatarstan

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Abstract. The article presents the results of afforestation of steep slopes by the example of the Republic of Tatarstan. The total area of forests of the Republic of Tatarstan is 1 million 268 thousand ha, including the area of forest fund lands of 1 million 232 thousand ha, which is 18.7 % of the region's territory. The use of planting material with a closed root system in the creation of protective forest plantations (gully, field protection) guarantees a rooting rate higher than the average norm. The forest cover of the Republic of Tatarstan will increase and is expected to be 17.6 percent at the end of 2029. The research was conducted on a slope in the hydrographic network of the Shumbutka River, where intensive soil flushing occurs. The study area contains 23.10 hectares of protective forest plantations. All surveyed stands have relatively high values in the categories "healthy" (81.0%), "weakened" (18.0%) and "severely weakened" (1.0%). There are no trees in the categories of "dried out", "fresh drywood" and "old drywood", which reduce the overall stand weakening values. According to the results of the conducted research, we revealed that afforestation of steep slopes with the Saba sword tool allows planting in hard-to-reach places (steepness of more than 12%). It is impossible to use machinery there; the use of planting material with a closed root system gives positive results, which is mainly reflected in a high survival rate of tree species. In the second year of the research, the closed root system provides higher biometric indices of planted crops. Positive results were obtained in the sowing of oak cherry with the sword tool "Saba". Ground germination was 67.0%. Preservation by the end of the growing season of 2023 was 85.0%. According to the proposed technology, oak trees in biogroups grow better than acorns do when sown alone. The growth intensity of tree species mainly depends on the agro-technique of protective forest plantations, soil and climatic conditions, slope exposure, availability of water in the soil, the degree of infestation by various diseases and pests.

1 Introduction

Rational use of land and improvement of soil fertility are an actual direction in most regions of the Russian Federation. Every year, the need to protect soils from erosion increases, which should include agrotechnical, hydraulic and forest ameliorative measures. An important role belongs to protective forest plantations, which reduce the impact of unfavourable factors on the development of agricultural crops [2–5]. Forest plantations provide long-term protection of soils from erosion and contribute to further improvement of the structure and water resistance of soil aggregates [7, 8]. They form a framework of erosion protection in forest-agrarian landscapes, and the efficiency of the entire hydroforest-reclamation complex depends on their location on the terrain. About 1 thousand hectares of agricultural lands are annually taken out of turnover due to the growth of ravines in the republic. Afforestation, and especially field protection afforestation, in different zones of the Russian Federation clearly demonstrates the positive role of this process, both for the protection of the natural environment and for the protection of agricultural crops from various negative impacts [2, 3, 9].

Due to the ongoing climatic changes associated with the trend of global warming and increasing the frequency of recurrence of dangerous agrometeorological phenomena (droughts, forest fires, dust storms, dry winds, etc.), the urgent problem is the protection of agricultural production from the effects of adverse environmental factors. Large-scale droughts, which lead to the greatest losses of agricultural products, occur every 3–4 years in Russia, while localised droughts are repeated annually. Domestic and international science has proven that the most important place in the system of measures to protect crops from droughts and dry winds and soils from water and wind erosion, to increase crop yields and land fertility belongs to forest reclamation of agro-landscapes. It has been established that of all types of forest plantations, the greatest influence on the climate is exerted by field-protective forest belts [1–4]. Under current climate change conditions, carbon storage in FFAs is of particular interest [16]. Poplar (Populus) is

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a promising species in carbon sequestration in northern and continental climates [15].

2 Objects and methods of research

The object of research is territorially located in the Predkamya zone of the Republic of Tatarstan (Rybno-Slobodsky municipal district).

The reconnaissance survey was carried out by visual assessment of the condition of the plantation. The presence and nature of insect damage, signs of disease development, fruiting bodies of fungi, mechanical damage, etc. were noted. When carrying out the work we were guided by the rules of sanitary safety in forests, approved by the Decree of the Government of the Russian Federation of 20 May 2017, No. 607. They were also approved by the Order of the Ministry of Natural Resources of Russia of 16.09.2016, No. 480 "On approval of the order of forest pathological surveys and the form of the act of forest pathological survey" [10, 11, 12].

The efficiency of establishing protective plantations with a closed root system was assessed by the rooting rate of planting material. In the course of the research, we carried out inventory of forest crops, which consists of determining the presence of forest crops, their area and condition by field survey. The timing of the inventory depends on the forest zone and is carried out from 1 September to 15 October [6]. During the inventory, only viable plants with preserved healthy apical shoots in coniferous crops and in deciduous tree species with the possibility to continue growth from dormant buds are taken into account.

3 Analysis and discussion of the results

The total area of forests in the Republic of Tatarstan is 1 million 268 thousand ha, including 1 million 232 thousand ha of forestlands, which is 18.7 % of the region's territory.

The forest cover of the territory is 17.5%; the average age of plantations is 54 years. The total percentage of forest cover varies in different municipal districts of the republic and depends on physiographic, climatic, soil conditions, natural phenomena and human economic activity. The forest cover of Rybno-Slobodsky District is 25.0 per cent.

The use of planting material with a closed root system in the creation of protective forest plantations (gully, field protection) guarantees a rooting rate above the average norm. The forest cover of RT will increase and is expected to be 17.6 percent by the end of 2029.

To protect arable land and agricultural crops from unfavourable factors, soil-protective forest plantations are created. Strips are created in areas with weak manifestation of water erosion on flat watersheds and gentle slopes that are steep up to 1.5-2°. In the Republic, 108.5 ha of field protection plantations have been established in Verkhneuslonsky, Leninogorsky, Novosheshminsky, Sarmanovsky, Spassky and Cheremshansky districts.

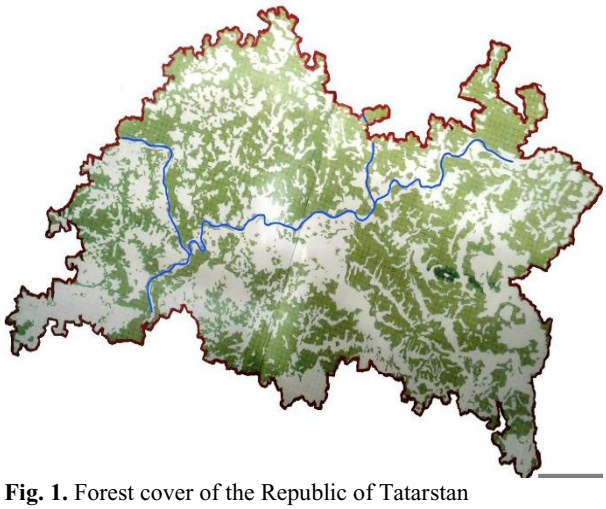


Fig. 1. Forest cover of the Republic of Tatarstan

An unnamed gully was selected for the study, which is located in the hydrographic network of the Shumbutka River and is a left tributary in its middle reaches. The Shumbutka River then joins the Shumbut River at a distance of 10,600 metres. An unnamed brook flows through the gully; the watercourse belongs to the Kama Basin District. Along this ravine, there are settlements Alan-Polyan and Ureevo-Chelny of Rybno-Slobodsky municipal district of the Republic of Tatarstan. There is also the federal motorway M-7 "Volga" Moscow-Vladimir-Nizhny Novgorod-Kazan-Ufa, which passes through the ravine.

The ravine starts its development at 158 metres (Baltic altitude system). The lowest point is at 92 metres, where the stream flows into the Shumbutka River near the village of Ureevo-Chelny; the average gradient is 6.73 ‰.

In some sections, the maximum lateral slope reaches 200%, where the vegetation layer is washed away.

According to the surveys carried out here, forest ameliorative plantations were previously established in the drive-separation zone (field protection zones) and in the saddle part. To prevent the development of erosion, it is advisable to establish erosion control plantations on the slopes of the gully (steepness of more than 12%) in the part of the Shumbutka River hydrographic zone. The soil on the slope is heavily washed away and is characterised by low fertility.

Protective forest plantations grow on the study area of 23.10 hectares. The plantations are of natural and artificial origin with the predominant species being the common pine. This species is a tree of the first size, which is fast-growing; it grows in a variety of conditions: in sands, medium-light-loving. It is not drought tolerant on heavy soils, but it grows on drier light soils; it is not salt tolerant; its crown density is average [13].

Table 1 shows that all surveyed stands have relatively high values in the category "healthy" (81.0%), "weakened" (18.0%) and "severely weakened" (1.0%). There are no trees in the categories of "dried out", "fresh drywood" and "old drywood", which reduce the overall stand weakening values.

Table 1. Results of tree condition assessment based on enumeration data

Types of woody plants	Life form of plants (der., bush.	Number of woody plants by condition (%)					
		Good	Satisfactory		Unsatisfactory		
		1	2	3	4	5	6
Site No. 1 – 10C							
Common pine	wood	79.0	21.0	-	-	-	-
Site No. 2 – 10C+B							
Common pine	wood	82.0	18.0	-	-	-	-
Hanging birch	wood	100.0	-	-	-	-	-
Site No. 3 – 10C							
Common pine	wood	85.0	15.0	-	-	-	-
Site No. 4 – 5C5B							
Common pine	wood	91.0	3.0	6.0	-	-	-
Hanging birch	wood	93.0	7.0	-	-	-	-
Plot No. 5							
Common spruce	wood	85.0	15.0	-	-	-	-
Banksa pine	wood	38.0	62.0	-	-	-	-

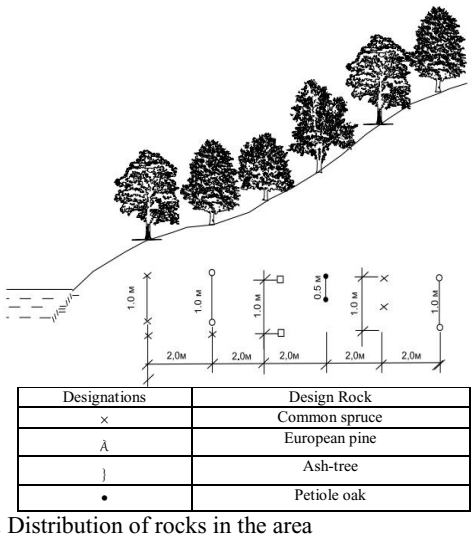
According to Rodin R.A., reclamation works start from the lower part of the slope. The upper and middle parts of gully slopes can be left for natural afforestation at the expense of the near-gully strip [14].

For comparison, seedlings of European spruce and common pine were planted with OCS and WQS (Fig. 2, Fig. 3).

Fig. 2. Planting seedlings with a closed root system

Fig. 3. Planting seedlings with an open root system

The spacing of planting places of 1.0x2.0 m for common pine and common spruce is shown in Figure 4.



Designations	Design Rock
×	Common spruce
Â	European pine
}	Ash-tree
•	Petiole oak

Fig. 4. Distribution of rocks in the area

For the conditions of Rybno-Slobodsky district of RT, the optimal variant is the following scheme: C – E – Yas – D – C–E. A composition of plantations is 3E3C2D2Yas. An initial density is 5000 pcs/ha.

Planting was carried out manually with the help of the Saba sword tool, without preliminary soil cultivation. The inventors of the model were specialists of the State Budgetary Institution "Sabina Forestry Training and Experimental Sabina Forestry". They are actively engaged in the introduction of experimental design, scientific and production achievements in the sphere of forestry of the republic. The Saba sword has already been used for several years in forest plantations in the Sabinsky lesnichestvo and was recommended by the Ministry for use in other lesnichestvos of the republic. The Saba sword is the most necessary hand tool for

planting seedlings and saplings of forest crops and laying FFAs. It is lightweight, easy to use, and even a teenager can handle it.

Seeds of common ash and oak acorns were sown between rows of pine and spruce. The Saba sword tool was also used for sowing acorns. Five to six acorns were sown per well. The distance between holes was 0.5 m (Fig. 5).

Fig. 5. Sowing acorns of petiole oak trees

During the research, the condition of established protective forest plantations was assessed in terms of conservation and biometric indicators of tree species (Table 2).

Table 2. Biometric indices of tree species at the research site

Breed	Average diameter, mm	Average height, cm	Growth per year, cm
2022			
Common pine OCS	2.4±0.4	16.1±1.4	4.1±1.3
Common pine ZKS	2.3±0.4	16.2±1.6	4.2±1.7
European spruce OCS	2.19±0.18	13.32±1.10	1.35±1.02
European spruce ZKS	2.25±0.20	13.83±1.23	1.83±1.23
2023			
Common pine OCS	4.15±0.5	26.25±2.8	12.42±0.93
Common pine ZKS	4.35±0.5	27.1±3.16	14.16±1.16
European spruce OCS	3.67±0.56	13.27±1.89	3.25±0.63
European spruce ZKS	3.82±0.27	118.43±1.58	5.71±0.76

According to the obtained data, seedlings of common pine grown by different methods in natural conditions in the first year of transplanting do not differ in biometric indices: an average diameter and height are practically at the same level. The growth for one year was 4.2 cm. A similar picture is observed for European spruce. European spruce differs in height depending on the location of the groundwater table. In the upper part of the slope, European spruce lags behind in growth compared to the lower part of the slope, where the water table is much higher. On average, the height of spruce in the upper part of the slope did not exceed 1.8 cm.

The average size of the root system was also measured. Therefore, according to our data, the root system development is more intensive in the seedlings grown with SCS compared to that of the seedlings grown with ZKS. The root system of plants grown with SCS in the first years does not go beyond the substrate. The advantages of ZKS can be seen in biometric indicators and a high survival rate.

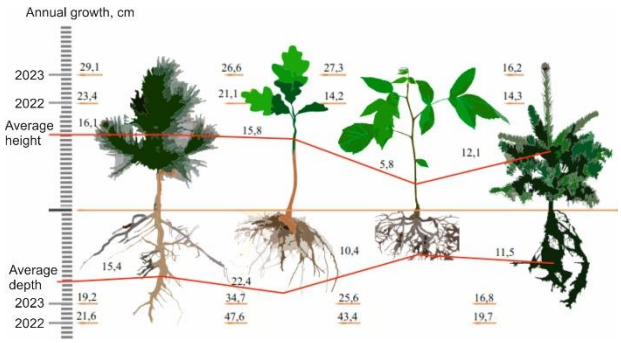


Fig. 6. Biometric indicators

Analysis of the rooting of the cultures in 2022 showed that the seedlings of common pine were generally healthy with both CWD and WQS. The crop survival rate ranged from 84.0% to 91.0%.

The weakening of tree species is related to pine infestation with common shutter from 3.0 to 5.0%. The degree of pine needles infestation by common shutter up to 25% is weak. Trampling and eating woody species by cattle in the lower part of the slope from 6-11% was also observed at the site.

In 2023, development of the Schutte pine disease did not increase, ranging up to 3.0% on average. Preservation of pine trees was 75.0 and 81% with OCS and ZKS, respectively.

The rooting rate of European spruce in 2022 in the variants with ZKS and OKS differed. In the variant with an open root system, it was lower by 14% compared to ZKS. In 22.0 % of seedlings, the needles yellowed. According to literature data, the main cause of spruce death is the lack of water and nutrients, which is reflected in the premature yellowing and falling of needles. Yellowed needles in the variant with ZKS are much less (6.0%). The condition of European spruce by the end of the vegetation period was satisfactory. However, spruce preservation decreased to 54.0% in the variants with OXS and to 75.0% in the variants with ZKS.

At the end of the growing season, we counted the average number of seedlings (Fig. 7) and measured biometric indices (Table 3, Fig. 8). According to our counts, the average number of oaks in one hole was 4. Ground germination averaged up to 67.0% of the sown acorns.

Fig. 7. Oak cherry in one well

The mean diameter for annual seedlings was 1.7 mm, and the mean height was 7.6 cm, which is normal for this breed.

Table 3. Biometric indices of tree species at the research site

Breed	Average diameter, mm	Average height, cm
Indicators 2022		
Petioled oak	1.7±0.4	7.56±0.82
Common ash	1.2±0.1	5.8±0.67
Indicators 2023		
Petioled oak	3.18±0.21	18.68±1.94
Common ash	2.44 ±0.17	9.83±0.41

Fig. 8. Measurement of oak biometrics

At the end of the growing season of 2023, the preservation of oak cherry in the holes was also counted. Therefore, the preservation of oak cherry was in the range from 85.0 to 90.0%. In our opinion, the decrease of oak preservation in wells is due to intraspecific competition.

One-year growth of petiole oak was 19.0 cm, with an average diameter of 3.0 mm.

Literature analysis shows that plantations grown from seeds are more stable and durable. They grow better than those grown from seedlings and saplings do. The common ash was also introduced into culture by sowing. It is a tree of the first size, rather fast-growing, demanding of soil, more shade-tolerant when young. Biometric parameters of common ash are given in Table 3. Ash trees on the plot had no signs of weakening. Ground germination of seeds was 57.0%. The average height of ash trees by the end of the 2023 growing season was 10.0 cm, and the average diameter was 2.5 mm. Preservation of ash trees by 2023 significantly decreased (55.0%).

Fig. 9. Common ash on the site

4 Conclusions

In the course of the research work, the following conclusions were reached.

Creation of protective forest plantations on steep slopes helps to reduce soil erosion and increase fertility. The proposed technology of afforestation of steep slopes with the Saba sword tool allows planting in hard-to-reach places (with steepness of more than 12%), where it is impossible to use machinery. The use of the planting material with a closed root system gives positive results, which is mainly reflected in a high rooting rate of tree species. In the second year of the research, the closed root system provides higher biometric indices of planted crops. Positive results were obtained when sowing oak cherry using the Saba sword tool. Ground germination

was 67.0%. Preservation by the end of the growing season of 2023 was 85.0%. According to the proposed technology, oak in biogroups grows better than that in the single sowing of acorns. The growth intensity of tree species mainly depends on the agro-technique of protective forest plantations, soil and climatic conditions, slope exposure, availability of water in the soil, and the degree of infestation by various diseases and pests. Infestation of Schutte's pine was detected in the surveyed area in insignificant quantities. In this case, no additional forest management measures are required. In order to prevent cattle from eating the planted and sown tree species, it is advisable to introduce yellow acacia as a part of thorny shrubs.

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