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ANALYSIS OF THE EFFICIENCY OF FOREST RESTORATION IN THE TERRITORY OF ALTAI

SUMMARY

In this paper, the trend of changes in the surface of forests created by natural succession, artificial establishment and combined in the area of Altai (Russian Federation) was investigated. The method of time series analysis for the period 2019-2023 was used. The obtained dispersion measures show that the linear trend model is representative. A trend of increasing the area under forest by an average of 368.5 hectares per year was determined as a result of afforestation and natural progressive succession of vegetation. The area of actually established forests in the analyzed period was larger than planned each year (7237 ha/year), and individual growth rates show an increase in new forest areas. The success of afforestation with white pine seedlings expressed by area in all years of the analyzed period was above 50%. However, in these areas, the success of afforestation with white pine seedlings shows a negative trend, i.e. a decrease of 58.2 ha/year.

Keywords: *Forest restoration, afforestation, Altai, Pinus sylvestris.*

INTRODUCTION

The area of forests in the world is decreasing, which affects the reduction of the effects and functions of forests (FAO 2020), and therefore forest restoration is a priority for most countries and forestry development strategies. The main task today is to ensure a balance between biological productivity and the use of forest resources. This balance is enshrined in the concept of sustainable development of forest ecosystems and is a fundamental principle of global forest policy (UNDP, 2016; Baumgartner, 2019). Numerous challenges in forest management such as fires, conversion of forest land into industrial land, deforestation, climate change, diseases and pests lead to a reduction in forest area. Although the risks and

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uncertainties in forest management are increasingly pronounced, the strategic goals of forestry development envisage an increase in the area under forests. The European Union's Forestry Development Strategy envisages the planting of 3 billion seedlings by 2030 (EC, 2013). Comparing this strategy with pan-European criteria and indicators for sustainable forest management, it was noted that the New European Forest Strategy includes boundaries (thresholds and ranges) for sustainable management (Lier et al., 2022), within which the establishment of new forests or increasing forest cover is of great importance.

International definitions (FAO, 2020) in terms of increasing forest cover refer to the expansion of forests on areas that previously had some other purpose. The establishment of new forests is usually done in a natural, artificial and combined way. The establishment of forests naturally on areas where there was no forest before implies a natural progressive succession of vegetation. Artificial establishment of forests (afforestation by planting seedlings) is carried out mainly on areas where previously, in the foreseeable future, there was no forest, and the goal is to preserve the economic, ecological and social functions of forests. Objects favorable for afforestation are most often clearings, forest clearings, areas damaged by fires and other areas that are not covered with forest vegetation but are suitable for afforestation. There are areas of forest land on which it is necessary to carry out a combined natural and artificial establishment of forests, most often as a result of very heterogeneous habitat conditions or efforts to establish mixed stands in the same habitat. Combined afforestation is carried out by planting and sowing in forest areas where natural afforestation of forest plantations of valuable species is not fully ensured forests trees (Chzhan and Puzanova, 2012). One of the directions for increasing the productivity of forests is artificial afforestation on lands that are not covered with forest vegetation (Zalesov and Lugansky, 2002; Khairetdinov 2011). The latter is explained by the fact that artificial plantations created with standard planting material with timely and high-quality agrotechnological and sylvicultural care are superior in productivity to natural plantations of the same age (Yusupov et al. 1999; Zalesov et al. 2015). Artificial afforestation is particularly relevant in areas that experience intense recreational activities (Dancheva et al. 2014) and other anthropogenic influences (Uzhgin et al. 2012), as well as in areas with difficult soil and climatic conditions (Danilik et al. 2001; Freiberg et al. 2012).

Artificial afforestation in the Altai region is associated with a number of difficulties. Especially, due to the rare fruiting of high-quality seeds of the main tree species for growing planting material. In addition, tight deadlines for sylvicultural work often lead to their failure, since planting seedlings with an open root system in dry warm weather in conditions of the steppe climate sharply reduces the survival rate of seedlings. In order to minimize these shortcomings in the Altai Territory, in 2009 it was decided to establish a Forest Seed Selection Center as part of a Russian project to improve the quality of forest restoration. The Altai Territory was chosen as the only area beyond the Urals where such a center was built. The purpose of the creation of this Center was to organize the processing and storage of up to 2,000 kg of seeds and the cultivation of 7 million seedlings of

white pine with a closed root system with forest seeds of improved genetic characteristics. This provided not only an increase in the quality of planting material, but also created the possibility of a sharp increase in the period of formation of forest crops with a significantly lower risk to their survival. Otherwise, the need for intensive development of nursery production and afforestation developed in the sixties of the last century, in the period of intensification of forest protection and afforestation of virgin and pasture lands. Also, the large forest fires that engulfed forests in the Altai region in the 1990s, as well as the need to restore lost forests, gave impetus to the development of a base of forest nurseries. In the Altai Region, up to 40 million seedlings of various tree species are grown annually in 30 nurseries, eight of which nurseries are classified as "High Culture Forest Nurseries".

Since 2019, the regional project "Forest Conservation" has been launched in the Altai Territory within the framework of the national project "Ecology". The main tasks are to ensure a balance between biological forest production and use, an annual increase of 7,200 hectares of forest area, including afforestation of 3,500 hectares, equipping forest holdings with specialized firefighting equipment and forming a stock of seeds for afforestation (Dobrynin and Mishchenko, 2021).

MATERIAL AND METHODS

The Altai Territory occupies the southern part of Western Siberia (Fig. 1) and includes four natural zones: the steppe, the forest-steppe, the low mountain taiga of Salaira and the foothills of the Altai taiga. The land of the Forest Fund of the Russian Federation, located on the territory of the Altai Territory, occupies 4,433,300 hectares, which is 98.4 percent of the forests in the region and 26.4 percent of all land in the region. There are 31 forestry areas in the Altay territory. The climate of the Altai region according to the Köppen-Geiger system is classified as a Warm-summer humid continental climate (Dfb) where there is no significant difference in the amount of precipitation between the seasons (He et al. 2021). The average annual temperature is 0,5-2,1^{o}C, and the average annual rainfall is 250-350 mm. It can be magnified up to 700 mm. The dominant land is mountain brown forest soils lighter granulometric composition. In addition to these lands, there are also sub-sill soils on which afforestation was carried out. A comparison of soils belonging to the same type occurring in the northwestern, central and southeastern regions of the Altai Mountains in terms of the ratio of carbon in humic acids to carbon in fulvic acids (Cha/Cfa) as one of the integral indices of humus composition, showed that there are no significant differences between these soils (Dergacheva et al).

Data collection was carried out on the basis of available records on the number of seedlings, area, tree species and survival rate in the period from 2019 to 2023 (Forest Seed Selection Center, 2024). The survival rate of seedlings was determined (Pilipko, 2013):

$$A_{p(\%)} = \frac{A + \frac{1}{2}A_d}{A_S} \quad (1)$$

$A_{p(\%)}$ - Survival rate
A - Area with live plants (ha)
A_d - Area with dubious plants (ha)
A_s - Total area of planting or seeding places (ha)

Figure 1. The location of the Altai territory (red color) on the map of Russia

For the purpose of statistical data processing, time series analysis was applied using linear trend (2), trend standard deviation (3) and coefficient of variation (4) (Velicer et al. 2003; Hadživuković, 1991).

$$\hat{y}t = a + bx \quad (2)$$

$$\sigma_{\hat{y}} = \sqrt{\frac{\sum_{t=1}^{N} y^2 - a\sum_{t=1}^{N} y_t - b\sum_{t=1}^{N} x_t y_t}{N}} \quad (3)$$

$$V\hat{y} = \frac{\sigma_{\hat{y}}}{\bar{y}} 100 \quad (4)$$

The analysis includes the following features:
- Ps – the area actually restored planting of seedlings and natural regeneration,
- R – artificially restored area (afforestation),
- Rk – combined renewal,
- Pps – The area is successfully afforested with white pine seedlings.

RESULTS AND DISCUSIONS

The total forested area in the Altai region in the last 10 years amounted to 120,000 hectares. In the period from 2013 to 2017, the area of forests that was

naturally regenerated amounted to 33,100 ha, while the share of artificial afforestation was 26,900 ha. The largest area within the artificial establishment of forests was treated with agrotechnical measures (9,800 ha) as well as planting seedlings on the area of 2,010 ha (Table 1). Sowing of seeds in regional forest nurseries was carried out on a total area of 18.8 ha.

Table 1. Silvicultural treatments in the artificial establishment of forests of the Altai Region (2013-2017) (Source: Department of Forests of the Altai Region, 2018)

Silviculture treatmens	Area (ha)	(%)
Planting seedlings	2.010	13,4
Combined afforestation	910	6,1
Promoting natural regeneration	490	3,3
Agrotechnical measures	9.800	65,3
Land preparation	1.800	12,0

According to the forest management plans of the Altai Region in the period 2019 to 2023, an equal area for forest restoration by natural, artificial and combined methods is planned, which annually amounts to 7,237 ha.

The area of forests actually established in the analyzed period was larger than planned each year (Table 2). Individual growth rates determined on the basis of the chain index show an increase in new forest area (Ps) and area created by combined regeneration (Rk), except for the period between 2019 and 2020.

Table 2. Planned and actual afforestation in the Altai Region (2019-2023)

Year	Pp (ha)	Ps (ha)	S_P	R (ha)	S_R	Rk (ha)	S_{Rk}	$R_{\%}$
2019	7237	7981		3720		362,0		46,6
2020	7237	7734	-3,1	3782	1,7	258,9	-28,5	48,9
2021	7237	7994	3,4	4003	5,8	321,0	24,0	50,1
2022	7237	8129	1,7	3511	-12,3	332,8	3,7	43,2
2023	7237	9626	18,4	3715	5,8	344,8	3,6	38,6

Pp – Planned area for the establishment of new forests; Sp, S_R, S_{Rk} – rates of change in the characteristics analysed; $R_{\%}$ - Participation in artificial restoration

The analysis of trends shows that the realized (actual) increase in forest cover is conditioned by the planting of seedlings and natural regeneration (progressive succession of vegetation) on average by about 368.5 ha per year (Table 3). A slight increase is also shown by combined regeneration (3.95 ha), which is the result of the lack of areas that could be renovated in this way (Fig. 2).

In the Altai region, due to the specific conditions of habitats and the way of management on relatively large areas, mainly natural regeneration is applied by progressive succession of vegetation, and artificial afforestation by planting seedlings is used in conditions of difficult natural regeneration or failure of restoration. The artificial method of reforestation is not very applicable due

to the low survival rate of plantings of forest crops and their death (Puzanova, 2019). The problems of artificial intelligence are indicative on the basis of the negative value of the individual rate in the middle of the analyzed period (-12.3).

Table 3. Measures of the Representativeness of the Linear Trend of Analyzed Parameters

Parameters (ha)	$\hat{y}t = a + bx$						
	Ȳ (ha)	a	b	r^2	σ (ha)	$V\hat{y}$ (%)	e (ha)
Ps	8292,8	7198,3	368,5	0,58	434,8	5,2	408,6
R	3746,2	3830,5	-28,1	0,06	152,5	4,0	115,8
Rk	323,9	312,0	3,95	0,02	34,8	10,7	25,6
Pps	2139,2	2313,2	-58,2	0,46	88,65	4,1	82,12

Ȳ - Average value of the analysed characteristic; r^2 – The coefficient of determination.; σ – The standard deviation.; $V\hat{y}$ – Coefficient of Variation; e – residuals (average);

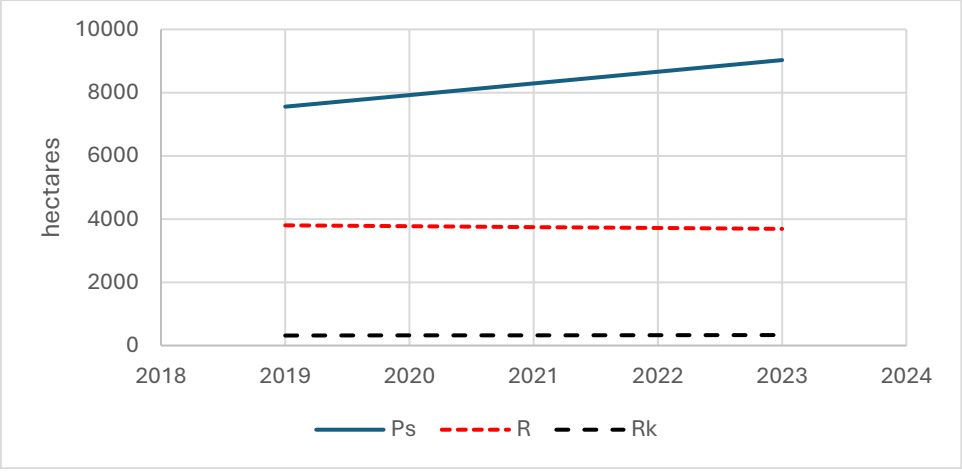

Figure 2. Trend of analyzed characteristics in the period 2019-2023

The main species for afforestation in the Altai region is white pine (*Pinus sylvestris* L), followed by Siberian spruce (*Picea obovata* Ledeb.). When establishing new forests artificially, individual selection instead of mass selection is very important. Thus, studies of 46 different provenances of *Pinus brutia* Ten. in Turkey showed a better current increment of the two basic taxation elements (tree diameter and height) in individual selection within the same provenance (Ozben and Bilir, 2022). Such principles of selection are also used when establishing plantations in the Altai region at the Seed Selection Center. The total area covered by forests in the Altai Territory is 3.825 million hectares. The average forest cover along the edge is 32.8%. Forests cover the territory of the region unevenly, in spots. These are mostly even-aged stands formed as a result of habitat conditions

that are suitable for the bioecological characteristics of white pine. Due to favorable natural conditions and a very wide range of this species, artificial regeneration is an advantage in the establishment of new forests. It is characteristic that in the same time periods of the analyzed period, the absolute change in the areas that were successfully afforested with white pine based on the coefficient of linear trend direction shows a decreasing flow by about 58.2 ha on an annual basis (Fig. 3).

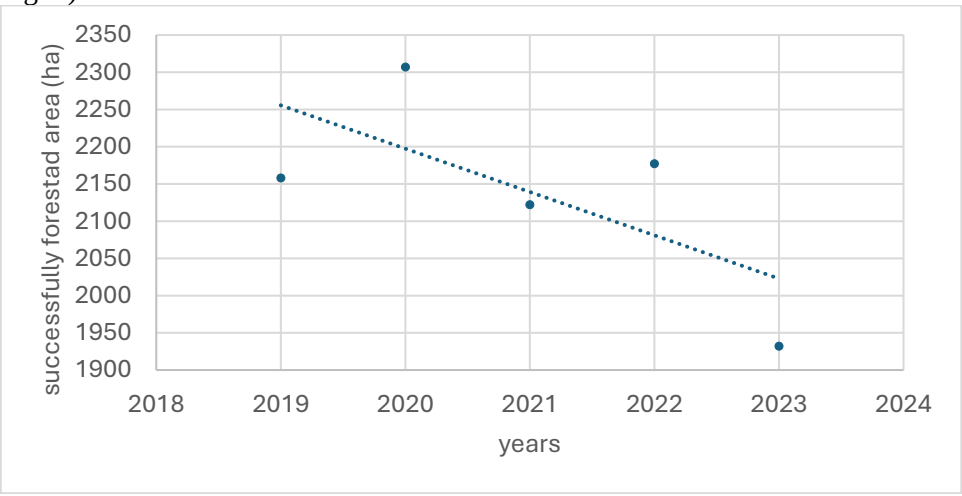

Figure 3. The trend of changing successfully afforested areas with white pine seedlings

The standard deviation of the trend of successfully afforested areas with white pine seedlings is 88.6 ha, and the coefficient of variation is 4.1%. The obtained dispersion measures show that the linear trend model is representative. In relation to the plan, the actual establishment of forests with white pine seedlings every year in the period 2019-2023 is planned to afforest the same area (3,720.69 ha). A successfully afforested area with a percentage of surviving seedlings of more than 50% was noted every year, and the most successful was 2022 with a seedling survival rate on an area of 2,177 ha (62%). By the way, white pine is a very useful species for establishing new forests in degraded habitats. For this reason, it is also used for afforestation of ore waste dumps for the purpose of land reclamation (Vacek et al. 2021). The productivity of white pine expressed by volume increase in habitats after mining is lower by 9 to 32% compared to the original natural native habitats in the Hradec Králové region in the Czech Republic. Such results can be expected in the Altai region, especially on poor soils that lack water. However, new research is also needed in terms of the quality of newly established stands and monitoring of their growth and development due to the trend of constant changes in risk factors caused by climate warming.

CONCLUSION

Throughout the analyzed period from 2019 to 2023, the afforestation plan in the Altai region was regularly exceeded. Thus, based on the above data, the main

way of successful forest restoration in the Siberian region is to promote natural regeneration, since this method makes it possible in such natural and climatic conditions to increase the reproductive potential of coniferous forests, as well as to reduce the period of silviculture, reduce labor and costs compared to artificial afforestation. The artificial method of afforestation is not very applicable due to the low survival rate of forest seedlings, especially white pine, and their death, due to the problem of limited financial and technical capabilities of forestry enterprises, low technological level of production and lack of flexible adaptation to local conditions. That is why artificial afforestation is used here when natural regeneration is difficult for conifers. Combined afforestation is used where natural and artificial methods of forest restoration need to be combined in a single forest area. The trend of increasing the area under forest in the Altai region is in line with the promoted global Sustainable Development Goals (SDGs) and the efforts of forestry to contribute to the fight against key environmental endangering factors.

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REFERENCES

Baumgartner, R. (2019). Sustainable Development Goals and the Forest Sector-a Complex Relationship Forests. Forests 10(152):1–10

Chzhan, S.A., Puzanova, O.A. (2012). Forestry. Reforestation on Cuttings: Textbook. allowance. – Bratsk: Brest State University Publishing House, p. 144 (*In Russian with english abstract*)

Dancheva, A.V., Zalesov, S.V., Mukanov, B.M. (2014). Influence of recreational loads on the state and stability of pine plantations of the Kazakh hills Yekaterinburg: Ural. State Forestry Technician. University,195 p. (*In Russian*)

Danilik, V.N., Isaeva, R.P., Terekhov, G.G., Freiberg, I.A., Zalesov, S.V., Lugansky, V.N., Lugansky, N.A. (2001). Recommendations for Reforestation and Forest Breeding in the Urals. Yekaterinburg: Ural. State Forestry Technician. acad.,117 p. (*In Russian*)

Dergacheva, M.I., Kovaleva, E.I., Ryabova, N.N. (2007). Humus of soils of the Altai Mountains. Eurasian Soil Sc. 40, 1264–1269.

Dobrynin, D.A., Mishchenko, V.V. (2013). Actual Issues of the Functioning of the Economy of the Altai Territory,13, pp 25-37 (*In Russian*)

EC (2021) A New EU Forest Strategy: for forests and the forest-based sector. In: Commission E (ed) COM (2021) 659 final, Brussels, pp 17

FAO (2020) Global Forest Resources Assessment 2020. Rome. P.184. ISBN: 978-92-5-132974-0

Freiberg, I.A., Zalesov, S.V., Tolkach, O.V. (2012). Experience of creating artificial plantations in the forest-steppe of the Trans-Urals]. – Yekaterinburg: Ural. State Forestry Technician. University,121 p.

Hadživuković, S. (1991). Statistical methods with application in agricultural and biological research. Faculty of Agriculture, Institute of Agricultural Economics and Rural Sociology, p. 584 (*In serbian*)

He, H., Luo, G., Cai, P., Hamdi, R., Termonia, P., De Maeyer, P., Kurban, A., Li, J. (2021). Assessment of climate change in Central Asia from 1980 to 2100 using the Köppen geiger climate classification. Atmosphere, 12(1), 123

Yusupov, I.A., Lugansky, N.A., Zalesov, S.V. (1999). The state of artificial pines of young trees under conditions of aero-industrial emissions. Yekaterinburg: Urals. State Forestry Technician. acad., 1999. - 185 p. (*In Russian*)

Khairetdinov, A.F. (2011). Introduction to forestry. State Forestry Technician University, Yekaterinburg: Ural, 202 p. (*In Russian*)

Lier, M., Köhl, M., Korhonen, K.T., Linser, S., Prins, K., Talarczyk, A. (2022). The New EU Forest Strategy for 2030: A New Understanding of Sustainable Forest Management? Forests 2022, 13, 245.

Ozbey, A.A., Bilir, N. (2022). Variation in growth among provenances of *Pinus brutia* in a 32-year-old experiment from southern Turkey. Agriculture and Forestry, 68 (2): 83-91.

Pilipko, E.N. (2013). Methodology of Forest Ecosystem Research: Methodological Manual. VGMHA Research Center, p. 32

Puzanova, O.A. (2019). Fundamentals of reforestation measures in the Siberian region. Proceedings of Bratsk State University.Series: Natural and Engineering Sciences, No1, 2019, pp.157-162.

Uzhgin, Yu.V., Zalesov, S.V., Kryuk, V.I. (2012). Formation of Artificial Plantations in the Area of the East Ural Radioactive Trace. Bulletin of the Bashkir State Agrary University, 3 (23), pp 79-83. (*In Russian*)

UNDP (2016). UNDP Support to the implementation of the 2030 agenda for sustainable development. United Nations Development Programme, p 26

Vacek Z., Linda R., Cukor J., Vacek S., Šimůnek V., Gallo J., Vančura K. (2021): Scots pine (*Pinus sylvestris* L.), the suitable pioneer species for afforestation of reclamation sites? Forest Ecology and Management, 485: 118951

Velicer, W.F., Fava, J. L. (2003). Time Series Analysis. In J. Schinka and W. F. Velicer (Eds.), Research Methods in Psychology (581-606). Volume 2, Handbook of Psychology (I. B. Weiner, Editor-in-Chief.). New York: John Wiley & Sons

Zalesov, S.V., Opletaev, A.S., Zalesova, E.S., Bunkova, N.P. (2015). Productivity of Artificial Plantations in the North Forest-Steppe Forest Plant District of the Sverdlovsk Region. Bulletin of the Altai State Agrarian University, 11, pp. 65-70. (*In Russian*)

Zalesov, S.V., Lugansky, N.A. (2002). Improving the Productivity of Pine Forests of the Urals. State Forestry Technician University, Yekaterinburg: Ural. 331 p. (*In Russian)*