DOI: 10.15838/esc.2019.1.61.6
UDC 630:330.4, LBC 65.34+65.053
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Issues Related to the Motivation of Tenants of Forest Plots to Use Effective Methods of Reforestation in Russia*

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* The study was supported by the Russian Foundation for Basic Research (research project No. 17-06-00514 A).
For citation: Gulin K.A., Dianov S.V., Antonov M.B. Issues related to the motivation of tenants of forest plots to use effective methods of reforestation in Russia. *Economic and Social Changes: Facts, Trends, Forecast*, 2019, vol. 12, no. 1, pp. 108-123. DOI: 10.15838/esc.2019.1.61.6

Abstract. The forest sector is a key sector in the Russian economy. The existing demand for forest products on the part of domestic and foreign consumers contributes to a steady increase in the volume of logging. At the same time the restoration of forest resources is becoming increasingly important. Detailed elaboration of this issue is a critical factor in maintaining the trend of enhancing the economic performance of the forest complex in the long term, on the one hand, and in ensuring environmental safety, on the other hand. In Russia the task of reforestation is mainly delegated to the tenants of forest plots. Today the problem of strengthening their interest in ensuring the quality of the works they perform is of great importance. The main goal of the study, the findings of which are presented in our paper, is to determine the mechanisms of formation of tenant behavior models that affect decision-making on the implementation of reforestation. We use methods such as system approach, analysis and synthesis, generalization and comparison, classification and systematization. Research findings of our study consist in the substantiation of the increase in the share of artificial reforestation as a factor that ensures the growth of forest use efficiency, as well as the mechanisms of formation of tenants' behavior in the planning and implementation of reforestation. We choose the forest complex of the Vologda Oblast as the main object for our study. Certain features of the current legislation are identified as the main problem of its potential development. In formulating our findings we use comparison with the models of the process of reforestation existing in Finland, where higher indicators of the qualitative composition of forests have been achieved. A distinctive feature of our study is its focus on the possibility of further application of its findings in the development of agent-based models. We carry out practical implementation of such models. With their help, it is possible to search for the most optimal solutions to determine the ways of shifting to a more effective model of reforestation.

Key words: forest complex, reforestation, agent-based modeling.

1. Introduction

The forest complex plays an important role in the Russian economy. The total stock of wood in Russia amounts to 82.1 billion cubic meters, and the share of valuable species comprises 77%. The volume of estimated cutting area is 635 million cubic meters, and the annual wood increment – 994 million cubic meters[1]. The country's forest resources make it possible to fully meet domestic needs for timber and wood products, as well as export these goods.

However, the significance of forests cannot be measured solely from an economic perspective. Being one of the most valuable renewable natural resources, they play an environment-forming and environment-protecting role. Forests growing on the Russian territory account for more than 1/4 of the world's wood biomass. In this regard, the optimal combination of forest management and conservation is an extremely important objective.

The problems of forest conservation and use are becoming more diverse and complex. Forest management standards are changing as they have to meet increased international, social, environmental and economic requirements. There are risks of deforestation from fires, pests and other adverse factors exacerbated by climate change, forests are losing their biodiversity.

[1] *Strategy of forest development in Russia up to 2020.* Approved by the Oder of Ministry of Industry and Trade and Ministry of Agriculture of Russia no. 248/482, dated 31.10.2008.

2. Reforestation in Russia

One of the key issues hindering the development of the forest complex in Russia is low wood removal per unit area of operational forests. Insufficient forest management prevents the use of forest soil fertility and maximizes wood increment, which in turn limits the possibility of increasing the harvesting volume in already operating forests, and in efficient reforestation does not ensure the reproduction rate of economically valuable forests on the most productive forest lands.

Over the past 20 years the annual reforestation volume has decreased by almost 2 times and has stabilized at the level of 800–900 thousand hectares (*Tab. 1*), while the share of artificial reforestation in recent years has not exceeded 21–23%.

The Vologda Oblast is among Russian regions whose economy largely depends on the forest complex. Among Russia's entities, it ranks second in production of industrial wood and chipboard; third – in production of plywood; fourth – in production of lumber[2].

The total forest area in the Vologda Oblast comprises 11,657.5 thousand ha including forest lands – 11,473.4 thousand ha. According to the State Forest Register, the total forest areas of the region's forest resources in January, 1st 2017 amounted to 1614.93 million m^3, including coniferous – 817.03 million m^3 (50.6%). The share of spruce stands comprised 26.6%, pine – 23.9%, birch – 36.6%, aspen – 11.3%, other species – 1.6%. The total wood stock in mature and over-mature forests is estimated at 1,074.6 million m^3.

For a long period, extensive forest exploitation aimed at removing coniferous wood stocks was carried out; no required attention was paid to the reforestation process. This was typical not only for the Vologda Oblast but also for all Russian regions. As a result, the share hardwood significantly increased, the sanitary and forest pathology state of forests deteriorated. Thus, according to the records of the Timber Fund in 1927, soft-wood occupied about 10% of the entire territory of the Vologda Oblast covered with forest. Today, this figure has reached almost 50%. To solve this problem, considerable attention has been paid to the efficiency of afforestation in recent times.

Despite the fact that researchers interpret the concept "effective reproduction of forest resources" is various ways, they have come to a consolidated opinion that there is a need to improve reforestation efficiency. N.A. Moiseev [1] interprets efficient reforestation as a complex of measures aimed at dynamically

Table 1. Performance of felling and reforestation in Russia, 2000–2016

Indicator	2000	2004	2006	2008	2010	2011	2012	2013	2014	2015	2016
Clear felling, thousand ha	622	658	671	742	781	904	873	969	928	939	996
Reforestation, thousand ha	914	734	821	829	813	857	840	870	864	803	843
including artificial, thousand ha	263	230	195	191	171	197	183	187	187	182	179
Coverage of reforested clear felling, %	147	112	122	102	88	84	83	81	80	75	74
Share of artificial reforestation, %	29	31	24	23	21	23	22	21	22	23	21
Compiled from: *Russia in Figures. 2017: statistical digest*. Rosstat. Moscow, 2017. 511 p.											

[2] *Development of the forest complex of the Vologda Oblast for 2014–2020: state program*. Approved by the Vologda Oblast Government no. 1110, dated 28.10.2013.

Table 2. Performance of reforestation volume in the Vologda Oblast in 2000–2017

Indicator	2000	2010	2011	2013	2014	2015	2016	2017
Reforestation, total, thousand ha	22.4	32.3	44.2	43.6	44.8	49	52	72.6
Including: artificial (planting)	7	4.5	6.4	6.2	6.4	6.7	7.2	7.8
promoting natural reforestation	15.4	27.8	37.8	37.4	38.4	42.3	44.7	64.3
Share of artificial reforestation, %	31	14	14	14	14	14	14	11
Compiled from: *Vologda Oblast in Figures: statistical digest*. Vologdastat, Vologda, 2018. 150 p.								

balancing the growing needs in the long run using events held in advance. According to P.V. Vasilyev [2], "the main condition and sign of expanded in advance reproduction is continuous increase in effective and potential stock of qualitative wood on the exploitation areas". N.I. Kozhukhov [3] refers to expanded forest reproduction as a process of continuous growth in productive capacity of communities.

Increased attention to issues of forest restoration from both scientific community and state administration bodies has begun to paid off. The total volume of reforestation activities in the Vologda Oblast during 2000–2017 increased more than 3 times (*Tab. 2*). At the same time, the volume of artificial reforestation remained at the level of 7–8 thousand ha, which is only 10.7% – almost two times lower than the average Russian indicators.

3. Reforestation practice: experience of Russia and Finland

It would be possible to assume that such a proportion of artificial and natural reforestation methods is a consequence of climatic conditions of the North of Russia and characteristics of the growing forest species. But, for comparison, in neighboring Finland, with similar natural conditions, the share of artificial (seeding, planting) reforestation reaches 80%. This is surprising, especially given that forest management practices in both countries use almost the same reforestation methods: natural (including measures to promote natural reforestation) and artificial such as seeding and planting of seedlings with bare and root-balled root system. Moreover, unlike Finland, Russia uses a combined reforestation method, which is a combination of natural and artificial methods. Although in Finnish forestry this method is not highlighted, they also try to supplement forest areas with self-seeding, which increases the density and enrich the composition of artificial plantations [4].

In both countries, reforestation is regulated by the state. But it should be noted that the Reforestation Rules, approved by the order of the Ministry of Natural Resources of the Russian Federation no. 375, dated 29.06.2016, according to which all reforestation activities in our country are carried out, describe the entire procedure of activities in more detail compared to the regulations in Finland. These Rules represent a detailed instruction on the choice of reforestation method depending on the state of the forest area, soil type, and presence of undergrowth. At the same time, when elaborating the Rules, it was almost impossible to take into account all natural and climatic features of each forest area, and the changing economic and social conditions due to the large size of the Russian territory.

Finnish legislation in the sphere of reforestation (forest and nature protection legislation, the law on planting stock trade, orders of the Ministry of Agriculture and Forestry) establishes minimum requirements for reforestation and use of planting material

(seedlings and seeds). Immediate methods of creating forest crops, selecting methods and means of reforestation are regulated by internal guidelines of forest using enterprises, with the level of requirements often exceeding minimum requirements of the country's legislation. Moreover, reforestation requirements are laid down in the forest certification program of Finland.

Yet, despite the similarity of approaches to forest management in both countries, there are fundamental differences in the ratio of reforestation methods used. In Finland, for example, the share of natural reforestation (including its promotion) is around 20%, and 80% of reforestation activities is associated with the creation of new forest crops. At the same time, as *Table 1* shows, the ratio of these types of reforestation in the Russian Federation is exactly the opposite. And in the regions of its North-West, where climatic conditions are most close to those in Finland, the share of artificial reforestation in the total amount of the works is even lower: for example, for the Vologda Oblast (see Tab. 2), the ratio is 11% of planted forests vs. 89% of natural forests. On the one hand, this situation has developed largely under the influence of economic factors and organizational and technological capabilities of Russian forest users. But, on the other hand, we cannot but point out the fundamental difference in the very approach to reforestation. Thus, in Russia, artificial reforestation is used only if the use of combined and natural reforestation cannot ensure the creation of valuable forest species on the land plot.

A distinctive feature of the Finnish approach to the choice of the method of reforestation is the final profitability, and the main task is to grow a new forest stand on a forest plot in a reasonable time; the forest stand should consist of the wood species that are the most valuable from an economic point of view and the most stable in terms of the possibility of growth in the existing soil and climatic conditions. At the same time, if we assess the economic costs of the entire cycle of forest management from reforestation and up to the main felling, then we find out that natural reforestation, taking into account all the necessary work to preserve the undergrowth, felling care and clarification, is not always less expensive in comparison with artificial reforestation. Especially when it is necessary to repeat the works due to the failure of natural reforestation. According to the experience of Southern Finland, planting or sowing compared to natural renewal helps reduce the time in which forest species reach maturity up to five years, which is needed for basic logging for pines and up to 15 years for spruce. In addition, the delay in reforestation only for five years reduces the economic productivity of forests by a quarter [5].

Table 3. Comparison of the effectiveness of reforestation methods, %

Forest species	Reforestation method	Results	
		Good	Satisfactory
Spruce	Planting	61	27
	Seeding	38	31
	Promoting natural reforestation	19	20
Pine	Planting	55	25
	Seeding	45	27
	Promoting natural reforestation	34	22

Own compilation with the use of the source: Saksa T., Kankaanhuhta V. *Metsänuudistamisen laatu ja keskeisimmät kehittämiskohteet Etelä-Suomessa*. Metsäntutkimuslaitos, Suonenjoen yksikkö. 90 s.

The high efficiency of reforestation methods such as planting and seeding was confirmed by the results of the inventory of reforestation objects (2000–2006) in Southern and Middle Finland *(Tab. 3)* [6].

In Finland, three quarters of forest plots are privately owned. In this regard, the Finnish forest use standards are not so thoroughly regulated in comparison with the Russian ones. The long history of private forest ownership in Finland contributes to a high level of interest in efficient management on the part of owners, which ultimately leads to a higher level of income. And it is the potential rather than the momentary income that is decisive in the organization of reforestation. Moreover, the costs are taken into account throughout the whole period of cultivation of forest crops, and in practice the low-cost method of reforestation is often not the most profitable one.

When comparing the cheapest method of creating forest stands – natural restoration – with a more expensive, artificial one, we can say that the first method is much less reliable. The final result here largely depends on such parameters as the quality of seed trees and the yield of seeds during the period of regrowth of the felling site. At the same time, it is difficult to achieve the desired composition of tree species and ensure high rates of their growth at the initial stage of development. In addition, there are significant financial costs and time costs of agronomic care so as to avoid the possibility of suppression of self-seeding with grass, and provide additional reseeding in case of insufficient density of the undergrowth [7].

In this regard, Finnish forest owners see reforestation not as an additional burden to the harvesting process, but as part of a continuous forest management process. Thus, the current situation concerning income and expenses affects the decision to carry out logging and, as a consequence, to ensure reforestation measures [8]:

$$NVP = \sum_{i=1}^{t} \frac{T_i}{(1+r)^i} - \sum_{n=1}^{t} \frac{K_n}{(1+r)^n},$$

where NVP is the net value present of the income;

T_i – income from cutting;

K_n – the cost of forestry;

t – felling cycle, years;

i – income, year;

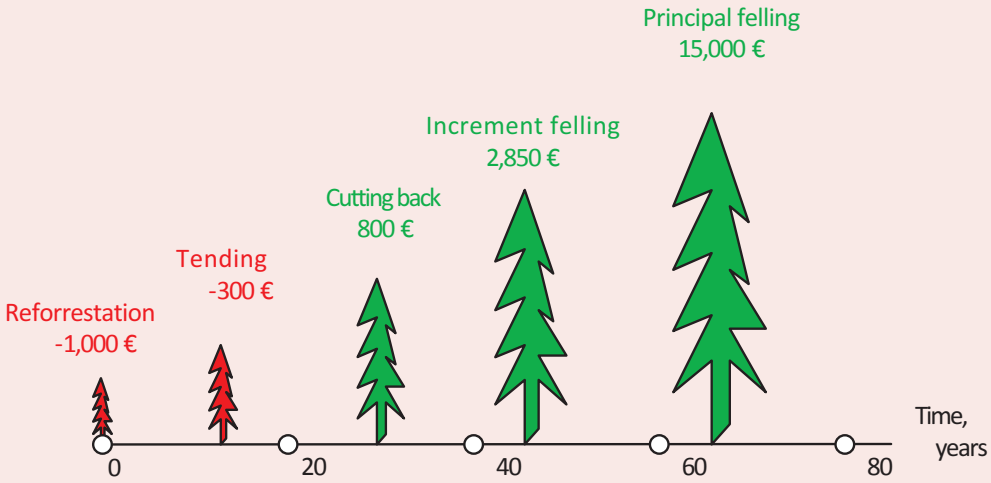
n – expenses, year;

r – interest rate.

Table 4. An example of calculating the present value of the income of the forest management project at the plot of shamrock and bilberry spruce forest in southern Finland

Year	Incomes/ expenses	NVP (r=0.03)	Calculation formula	Notes
0	-1000	-1000	$=1000/(1+0,03)^0$	First year: 2000 spruce seedlings / ha, cost: 1000 EUR/ha
13	-300	-204	$=300/(1+0,03)^{13}$	After 13 years: care for young seedlings, cost: 300 EUR/ha
30	+800	+330	$=800/(1+0,03)^{30}$	After 30 and 45 years: profit from two commercial improvement cutting
45	+2850	+754	$=2850/(1+0,03)^{45}$	
65	+15000	+2196	$=15000/(1+0,03)^{65}$	After 65 years: profit from the main felling
Current estimate of incomes	3280		=330+754+2196	
Current estimate of expenses	1204		=1000+204	
Current net value of incomes (r = 0,03)	2076		=3280-1204	The forest owner chose a 3 percent rate to estimate the expected yield. The value of NVP>0 indicates the benefit of investing in the forest plot.
Compiled with the use of the source: Nyugren M. *Reforestation in Finland.* Joensuu: Natural Resources Institute Finland, 2005.				

Figure 1. Stages of forest management activities for the forest management project at the plot of shamrock and bilberry spruce forest in southern Finland



Compiled with the use of the source: Nyugren M. *Reforestation in Finland.* Joensuu: Natural Resources Institute Finland, 2005. 22 p.

Table 4 shows an example of calculating the present value for a forest management project on a site of shamrock and bilberry spruce forest in southern Finland. The project involves five stages: planting of seedlings, care for the young growth in 13 years, improvement cutting in 30 and 45 years and the main felling in 65 years *(Fig. 1)*.

The solution that leads to the highest real net worth would be the optimal solution. Thus, investing in reforestation is beneficial provided that the NVP at the selected interest rate remains positive.

4. Factors affecting the choice of reforestation method by Russian forest users

It would seem that orientation toward long-term profit is quite an objective criterion when choosing an effective method of forest management, and in particular when choosing a method of reforestation. And if the experience of Finland proves the advantages of artificial reforestation over natural reforestation, then we can assume that in the North-West of Russia, and in particular in the Vologda Oblast, this method of reforestation should prevail. But in this case, the current legislation of the Russian Federation is beginning to play a key role.

In accordance with the Forest Code of the Russian Federation, the transfer of forest areas to forest users for timber harvesting is carried out on the basis of lease agreements of the forest area concluded following the auctions. Arranging and conducting the works on reforestation on such sites shall be provided by their tenants and performed in strict accordance with the rules of reforestation approved by Order No. 375 of the Ministry of Natural Resources of Russia dated June 29, 2016.

The term of the lease agreement can be from 10 to 49 years. But the practice of recent years shows that all lease agreements are concluded for the maximum period – this is due to the fact that longer lease terms will contribute to increasing the responsibility of forest users with regard to timber harvesting, reforestation, and forest care activities. But is this really the case?

Table 5. Ages of forest felling for the Vologda Oblast

RF constituent entity	Forest-forming species	Quality class	Ages of forest felling, years	
			Protective forests	Commercial and reserved forests
Vologda Oblast	Pine, larch, spruce	III and higher	101 – 120	81 – 100
		IV and lower	121 – 140	101 – 120
	Birch, black alder	All quality classes	71 – 80	61 – 70
	Aspen, gray alder	All quality classes	51 – 60	41 – 50
	Willow	All quality classes	51 – 60	41 – 50
Compiled with the use of the source: "On establishing the age of felling": Order No. 105 of the Federal Forestry Agency dated April 9, 2015.				

The social, environmental and even economic justification of these terms of lease of forest areas have already aroused great doubts at the stage of discussion of the draft Forest Code of the Russian Federation [9, 10].

It takes several decades to restore forests using any method. Thus, according to Order No. 105 "On establishing the age of felling" dated April 9, 2015 of the Federal Forestry Agency, felling ages for the Vologda Oblast are established depending on forest forming breed and quality class from 81 to 140 years for coniferous breeds and from 41 to 80 years for deciduous breeds *(Tab. 5)*. At the same time, according to the Forest Plan of the Vologda Oblast, pine, spruce, birch and aspen belong to the target forest tree species. That is, if the term of the lease agreement is limited to 49 years in accordance with the current legislation, the tenant may be interested in ensuring effective reforestation only in the first 10 years of the lease agreement and only in forest areas with the least valuable forest species, such as aspen, alder, and willow tree.

This problem can be partially solved with the help of a provision contained in the Forest Code of the Russian Federation, according to which the former tenant who has properly executed the lease agreement of the forest plot has the preferential right to conclude a lease agreement for this forest plot for a new term. That is, it is assumed that a conscientious tenant who performs all the necessary requirements for the development of the forest plot actually becomes its owner (tenant at will) and therefore should be interested in carrying out effective measures for reforestation and forest care in order to obtain greater profits in subsequent periods for his/her descendants. But the very possibility and conditions of using the pre-emptive right to conclude a lease agreement cause a lot of economic and legal issues.

There is a question regarding the procedure for determining the size of the rent at the conclusion of a new lease agreement. It would seem that a conscientious tenant who has properly fulfilled all the conditions under the previous contract can count on a certain economic incentive in the form of a reduction factor in the calculation of the rent. But today the size of the rent at implementation of the preferential right to conclude the lease agreement of the forest plot with the former tenant is defined on the basis of Resolution No. 53 of the Government of the Russian Federation "On establishing the procedure for determining the size of the rent under the lease agreement of the forest plot concluded according to Item 2 of Part 4 of Article 74 of the Forest Code of the Russian Federation" dated February 1, 2016.

Table 6. Results of auctions on the lease of forest plots in the Vologda Oblast in 2015–2017

No.	Initial price, rub.	Land plot area, ha	Initial price of 1 ha, rub.	Price offered by the winner, rub.	Increasing factor
2015					
1.	5 106 620.79	26 365.00	193.69	5 106 620.79	1.00
2.	282 089.90	1 898.00	148.62	1 001 419.40	3.55
3.	337 221.95	7 743.60	43.55	505 832.95	1.50
4.	317 911.30	11 708.00	27.15	604 031.56	1.90
5.	424 663.22	9 808.00	43.30	913 025.90	2.15
6.	264 304.30	5 026.00	52.59	370 026.06	1.40
7.	420 697.74	2 754.00	152.76	2 482 116.96	5.90
8.	747 269.76	1 930.00	387.19	971 450.70	1.30
9.	2 574 004.55	7 371.00	349.21	8 108 114.44	3.15
10.	988 306.51	5 570.00	177.43	1 284 789.49	1.30
11.	231 755.52	1 747.00	132.66	3 012 822.72	13.00
12.	1 013 088.00	8 741.00	115.90	12 106 401.60	11.95
13.	481 223.65	4 647.00	103.56	6 231 845.67	12.95
14.	174 287.45	2 464.00	70.73	174 287.45	1.00
15.	5 500 089.08	14 906.00	368.98	5 500 089.08	1.00
16.	6 292 355.33	24 526.00	256.56	6 292 355.33	1.00
17.	471 081.79	1 332.60	353.51	1 507 461.75	3.20
18.	1 050 603.30	1 497.60	701.52	1 418 314.49	1.35
19.	534 471.59	3 648.00	146.51	1 309 455.41	2.45
20.	302 471.53	5 573.00	54.27	5 625 971.69	18.60
2016					
21.	2 373.12	226.00	10.50	2 373.12	1.00
22.	1 025 184.00	4 669.00	219.57	1 076 443.20	1.05
23.	1 244 496.52	6 529.00	190.61	1 306 721.35	1.05
24.	1 275 884.00	9 734.60	131.07	1 275 884.00	1.00
25.	111 154.87	44 577.00	2.49	122 270.35	1.10
26.	78 608.46	4 618.00	17.02	78 608.46	1.00
27.	173 731.20	5 543.00	31.34	173 731.20	1.00
28.	1 368 716.22	6 949.00	196.97	1 368 719.22	1.00
2017					
29.	284 880.18	3 839.00	74.21	2 578 165.79	9.05
30.	1 752 829.44	8 439.00	207.71	1 752 829.44	1.00
31.	1 171 015.93	3 400.00	344.42	2 751 887.53	2.35
32.	314 844.77	4 514.00	69.75	314 844.77	1.00
33.	8 712 948.98	62 753.00	138.85	26 138 846.98	3.00
34.	376 304.49	2 382.00	157.98	1 016 021.97	2.70
35.	707 969.28	5 366.00	131.94	1 309 743.10	1.85
36.	362 789.88	3 809.00	95.25	1 179 066.93	3.25
37.	1 779 217.00	14 955.00	118.97	5 693 494.40	3.20
38.	1 162 691.57	11 970.00	97.13	4 127 555.15	3.55
39.	2 259 912.96	4 314.00	523.86	5 197 799.86	2.30
40.	1 313 040.00	2 190.00	599.56	2 954 340.00	2.25
41.	7 964.24	92.00	86.57	7 964.24	1.00
42.	4 961 805.20	25 797.00	192.34	5 209 895.46	1.05

Source: own elaboration on the basis of the data from the official website of the Russian Federation that contains information about auction (https://torgi.gov.ru).

According to this method, the amount of rent under the lease agreement is determined by the formula:

$$R = R_{MIN} \times F_I,$$

where: R_{MIN} – the minimum size of the rent under the lease agreement defined according to Parts 2 and 3 of Article 73 of the Forest Code of the Russian Federation (rubles);

F_I – the increase factor calculated according to the formula:

$$F_I = \frac{R_{auction}}{R_{initial}},$$

where: $R_{auction}$ – the size of the rent formed according to the results of the auction on the sale of the right to conclude the executed lease agreement (rubles);

$R_{initial}$ – the initial price of the subject of the auction (the initial amount of rent) (rubles).

In 2015–2017, we analyzed the auctions on the lease of forest plots in the Vologda Oblast and found out that the increase factor for various auctions ranges from 1.0 to 18.6 *(Tab. 6)*. The very value of the increase factor can hardly be called objective, even at present. It does not depend directly either on the area of the plot or on the initial price, but rather is a kind of derivative of the ability of bidders to negotiate, because the auctions are held in an open form, and their participants tend to know each other well. Accordingly, it is useless to talk about objectivity with regard to the increase factor after 49 years.

Table 7. The rate of payment per unit of timber volume of forest stands of the Arkhangelsk-Vologda district

Wood species	Stumpage price rate	Transportation distance	Rate of payment for 1 solid cubic meter			
			Industrial wood without bark			Fuel wood (with bark)
			large	medium	small	
Pine	1	Under 10	126.72	90.54	45.36	2.88
	2	10.1–25	115.2	82.44	41.4	2.88
	3	25.1–40	97.92	69.84	35.1	2.52
	4	40.1–60	75.06	53.28	27.36	2.52
	5	60.1–80	57.24	41.4	20.7	1.44
	6	80.1–100	46.26	33.3	16.56	1.44
	7	100.1 and more	34.74	24.84	12.6	1.08
Spruce	1	Under 10	114.12	81.72	41.4	2.88
	2	10.1–25	103.5	73.8	37.26	2.88
	3	25.1–40	87.84	63.54	30.96	2.52
	4	40.1–60	67.32	48.78	23.58	1.44
	5	60.1–80	51.66	37.26	19.26	1.44
	6	80.1–100	41.4	29.52	15.12	1.08
	7	100.1 and more	30.96	22.14	11.52	1.08
Birch	1	Under 10	63.54	45.36	23.22	3.78
	2	10.1–25	57.24	41.4	20.7	3.78
	3	25.1–40	49.14	35.1	16.92	2.88
	4	40.1–60	37.62	27.36	12.96	2.52
	5	60.1–80	28.8	20.7	10.8	2.16
	6	80.1–100	23.22	16.56	8.1	1.44
	7	100.1 and more	16.92	12.6	6.66	1.08
Aspen	1	Under 10	12.6	9.18	5.22	0.36
	2	10.1–25	11.52	8.1	4.14	0.36
	3	25.1–40	9.9	7.38	2.88	0.36
	4	40.1–60	7.38	5.58	2.52	0.36
	5	60.1–80	5.58	4.14	2.52	0.14
	6	80.1–100	5.22	2.88	1.44	0.14
	7	100.1 and more	2.88	2.52	1.44	0.11

Compiled with the use of the source: Resolution No. 310 of the Government of the Russian Federation "On the rates of payment for a unit of forest resources and on the rates of payment for a unit of forest plot area in federal ownership" dated May 22, 2007.

We should also note that rent is calculated with the use of such an indicator as the minimum size of the rent under the lease agreement; it is determined in accordance with Parts 2 and 3 of Article 73 of the Forest Code of the Russian Federation and calculated on the basis of Resolution No. 310 of the Government of the Russian Federation "On the rates of payment for a unit of forest resources and on the rates of payment for a unit of forest plot area in federal ownership" dated May 22, 2007. The rate of payment per unit of timber volume of forest stands of the Arkhangelsk-Vologda district is given in *Table 7*.

The amount of the minimum rent is directly influenced by such factors as the composition of the forest species of the plot, their quality, the total amount of wood on the plot and the degree of development of forest infrastructure. That is, in the case of high-quality reforestation, forest care and the development of forest infrastructure both at the expense of the tenant and with the help of other sources (for example, the development of the federal and regional road network, the implementation of projects to create forest clusters), rental rates can significantly increase, which, on the one hand will reflect the potential increase in the cost of reserves in the forest plot, and on the other hand will lead to an increase in the costs for the tenant.

In addition to economic issues regarding the implementation of the preferential right to conclude lease agreements, there exist quite a few legal issues [11].

First, as practice shows, Russian forest legislation has been continuously changing in recent years; thus it does not protect tenants from any possible changes. Such a situation is likely to cause the need to conclude a new contract, or it can simply lead to the termination of the existing one.

Second, of the tenants perform their obligations properly under the forest lease agreement, it still does not guarantee the possibility of their concluding a new contract on the same terms, even if they have a preferential right. The lessor, in accordance with the current legislation, may refuse to conclude a new contract with the tenant. In this case, the refusal will be considered legitimate when concluding a contract with a new tenant within one year from the date of expiration of the previous contract.

Thus, the existing procedure of providing forest plots for lease for timber harvesting contains virtually no economic incentive for forest users to organize measures for enhanced reforestation.

Of course, we can assume that for tenants who have entered into lease agreements with the increasing factor close to one, the preferential right to conclude new lease agreements can be considered as an incentive for such work. But in view of all other factors, its impact is very small.

Along with the above attempt to encourage tenants to ensure quality reforestation by providing preferential right to conclude a lease agreement for a new term, Russian legislation provides for a number of punitive measures applied to the tenants who are negligent in the performance of their duties.

Such measures could include fines and an early termination of the lease agreement. But we can hardly recognize these measures as effective.

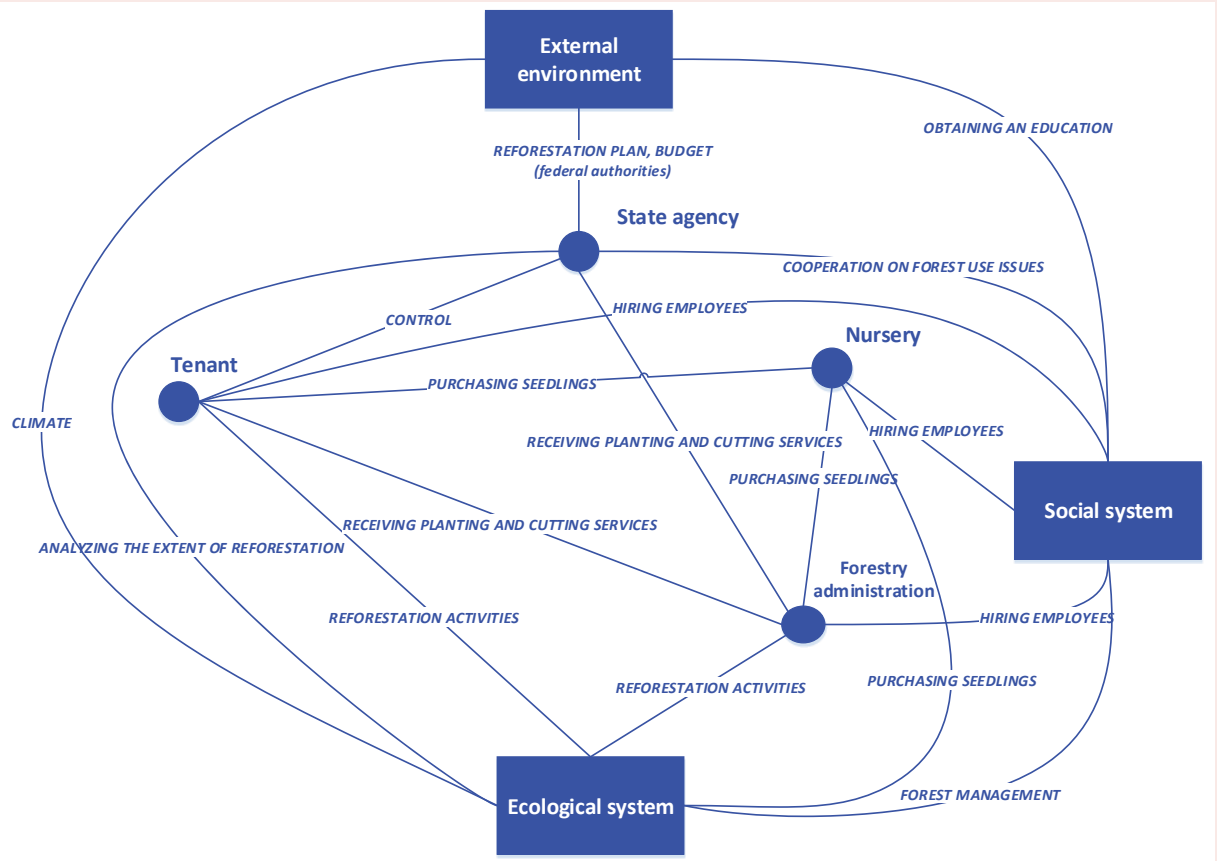
Thus, according to Article 8.27 of the Code of the Russian Federation on Administrative Offenses, the violation of rules of reforestation, afforestation, forest care and forest seed growing is punished by the warning or the imposition of an administrative penalty. For citizens, the amount of the fine is from 200 to

500 rubles; for officials – from 500 to 1,000 rubles; for legal entities – from 5,000 to 10,000 rubles. As you can see, the amount of fines is not comparable with the cost of renting a forest plot, or with the profit, or even with the minimum necessary costs for the formal implementation of reforestation measures.

A slightly more pronounced effect, particularly for the loggers who intend to use the plot for a long period of time and who do not focus on immediate profit, is provided by the possibility of early termination of the lease agreement. Given the shortage of available forest plots with the desired characteristics related primarily to transport accessibility, the cases of termination of lease agreements due to the failure to implement reforestation measures are extremely rare. Tenants try to comply with the requirements of forest legislation. At the same time, there is also a reverse side to the termination of the lease agreement of the forest plot, concluded by the results of the auction: in accordance with the Forest Code of the Russian Federation, such agreement is terminated only in court. In general, taking into account the likely judicial appeals, this procedure may be delayed for several years. During this period, the forest plot can be significantly damaged.

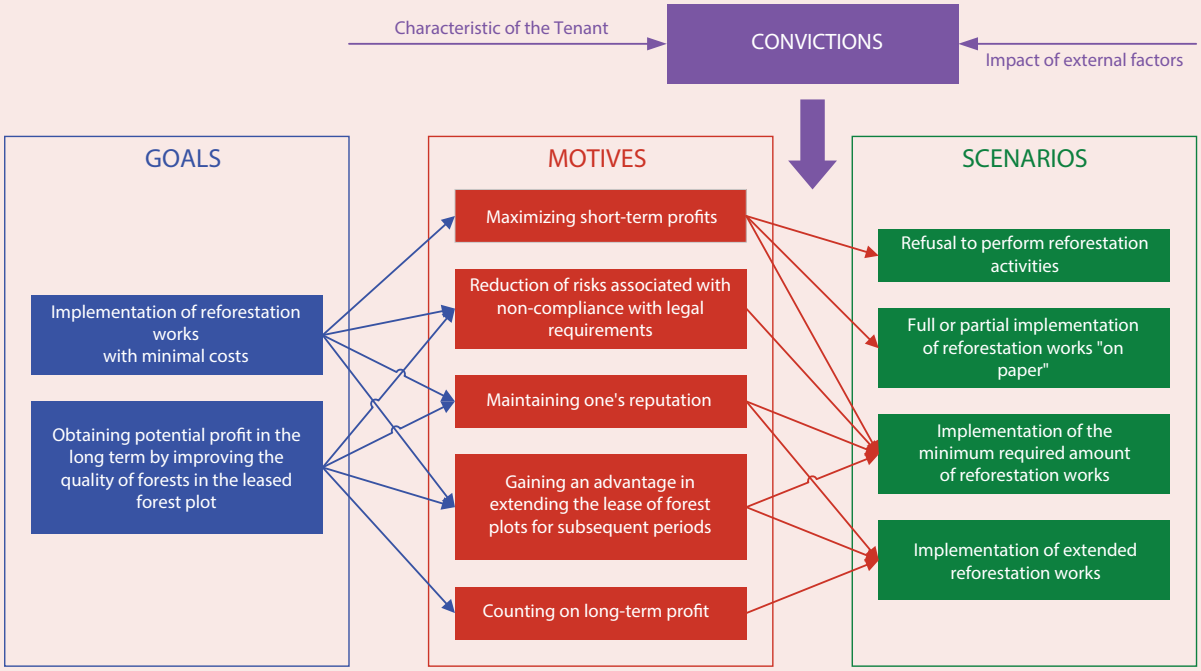
In general, it is necessary to recognize that the current forest legislation provides for the

Figure 2. General functional diagram of reforestation model



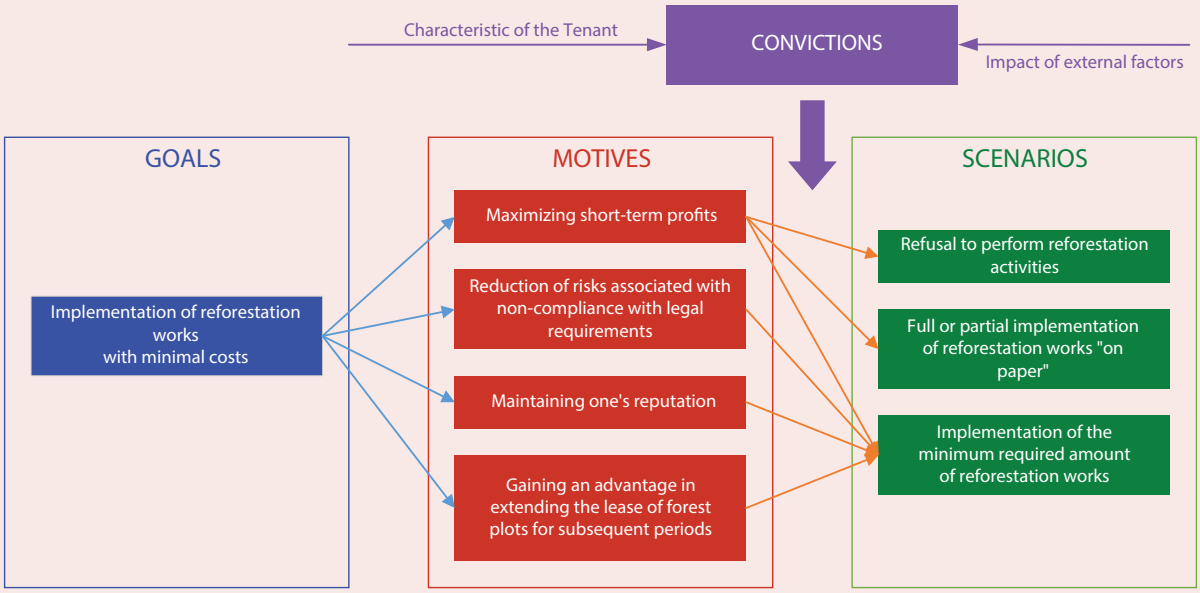
Source: Gulin K.A., Dianov S.V., Antonov M.B. An agent-based approach to implementing the model of forest restoration. *Problemy razvitiya territorii*, 2018, no. 1 (93), pp. 83-97.

Figure 3. Algorithm for selecting a scenario of behavior for the Tenant agent



Source: Gulin K.A., Dianov S.V., Antonov M.B. An agent-based approach to implementing the model of forest restoration. *Problemy razvitiya territorii,* 2018, no. 1 (93), pp. 83-97.

Figure 4. The algorithm for selecting the scenario of behavior for the Tenant agent in accordance with current legislation



Source: own compilation.

implementation of the minimum necessary requirements for reforestation, but in no way stimulates forest users to organize high-quality enhanced reforestation.

5. Possibilities of applying agent-based models in choosing and implementing new approaches to reforestation

In the modern Russian practice of forest management, the way of natural reforestation with the adoption of all possible measures to increase the volume of measures promoting it is actually recognized as the main one. This state of affairs cannot fully ensure a qualitative result, and today it is necessary to move to an intensive model of forest management [12]. At the same time there is a need to create simulation models that can provide the process of management decision-making in the selection and implementation of new approaches to reforestation.

Due to the high complexity of the real system of the forest complex, as well as the duration of the processes occurring in the forestry, the choice of adequate tools to solve the problem of modeling is of particular relevance. We think that agent-based modeling is the most promising tool to be used in this field. Its distinctive feature is the use of software entities – agents that have their own behavior and are able to interact. This makes it possible to simulate a system that most closely corresponds to reality [13]. Recently, agent-based modeling is increasingly used in simulation modeling of various processes in the forestry [14–24].

In the work "An agent-based approach to implementing the model of forest restoration" [25] we propose a paradigm for constructing a reforestation model as a sub-model of the regional forest complex using agent-based modeling. Within its framework, a functional scheme of the reforestation model was developed *(Fig. 2)*.

The key agents in this scheme are Tenant agent and State Department agent. Within the framework of the model, the Tenant is a legal entity or individual entrepreneur who has a lease agreement for a forest area for the purposes of timber harvesting. The Tenant performs the function of reforestation in accordance with the existing requirements. For its implementation, it cooperates with the State Department.

Each agent has its own behavior model, the elements of which are the goals of functioning, beliefs, motives, and scenarios. The goals set the parameters for the values of the characteristics of the agent that it seeks to achieve. Scenarios contain the possible algorithms of actions for the agent to achieve the goals *(Fig. 3)*. Motives and beliefs help choose a scenario for the agent's behavior in relation to specific conditions. Motives determine the priority, and beliefs – the possibility of the scenario.

From the reforestation perspective, the Tenant can pursue two objectives:

– executing the required reforestation works with minimal costs;

– obtaining potential profits in the long term by improving the quality of forests in the leased forest plot.

Certain motives correspond to these goals, and, depending on their own beliefs and the influence of external factors, the Tenants choose a particular scenario.

It would seem that the task of modeling the behavior of the Tenant is quite easy. It is necessary to create such external impacts that would help the Tenants make long-term profits their main goal. But, as it was shown above, within the framework of the current legislation it is not so simple to do.

Therefore, we can say that the main and only goal of the Tenant in the performance of

reforestation is to minimize costs, and the algorithm for selecting the scenario is greatly simplified *(Fig. 4)*.

6. Conclusion

Thus, having compared the approaches to reforestation in the North-West of Russia, in particular in the Vologda Oblast, and in Finland, we can note that, despite the fact that all loggers pursue a common goal – obtaining profit, the main task for Russian entrepreneurs in the implementation of forestry activities is to minimize costs in any acceptable way, while Finnish forest owners primarily set the task of increasing potential profits in the long term.

And the main task in the modeling of reforestation processes in the framework of agent-based models is to determine the conditions under which it is possible to achieve targets for enhanced forest reproduction.

The main contribution of our work to the development of theoretical and applied science is the fact that it determines the mechanisms for the formation of the behavior of forest plot tenants in the planning and implementation of reforestation; these mechanisms can be used to find optimal solutions and determine the ways for transition to more effective models of reforestation.

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Received December 26, 2018.