MODELING AND FORECAST OF SOCIO-ECONOMIC PROCESSES

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Models of Forest Management Institutional Environment Formation at the Regional Level of the Russian Federation*

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Abstract. The experience of effective forest management in the most developed forest countries proves the important role of the institutional environment in this process. Taking into account the territorial specifics is a necessary condition for its formation. In the Russian Federation, there has been a long-standing controversy about the ineffectiveness of the institutional environment existing in forest management. First of all, this applies to the institution of forest plots lease defined in the Forest code. As a rule, the discussions are based on the general indicators of forest development reducing the objectivity of individual elements evaluation. In this regard, one of the most important tasks at the moment is creating a methodology and tools allowing to obtain the estimates related to the development of individual elements of the forest management institutional environment, in particular, the elements of the forest lease system. The main purpose of the research is to develop the general approaches in order to analyze the dynamics of the environment elements formation associated with the lease of forest plots in the region of the Russian Federation and obtain the appropriate models on this basis. To achieve this goal, the system of forest lease in the Vologda region was studied and the models for the development of its main elements were formed. The methods of system approach, analysis and synthesis, generalization and comparison, classification and systematization, mathematical statistics were used. The scientific novelty of the research involves developing approaches to creating the models describing the dynamics of the forest lease system elements development in the Russian Federation using linear approximation of time series of their parameters. The theoretical significance lies in the development of a methodology for studying the dynamics of the institutional environment formation associated with the system of forest lease in the region of the Russian Federation. In practical terms, the research findings will allow to determine the main trends in the development of the forest lease system at a higher quality level for further comprehensive analysis, as well as to make short- and medium-term forecasts.

Key words: forest complex, institutional environment, modeling, forest plots lease.

1. Introduction

More than 20% of the world's forests are located on the territory of the Russian Federation, which is much more than in the leading timber-producing countries of the world: the USA, Canada, China, Sweden, and Finland. At the same time, the Russian Federation's share in the global timber market is only about 3%. The industry's contribution to the country's GDP is estimated at just over 1%[1]. This is partly caused by the fact that most of the Russian forests are not suitable for intensive sustainable forest management due to low productivity [1]. The main reasons for this situation also include high dependence on foreign economic conditions; high degree of equipment physical deterioration; low level of wood raw materials processing causing lower productivity and high waste volume; lagging in the development of advanced technological orders; insufficient provision with highly qualified personnel; gaps in the legal framework; high level of illegal wood trafficking; depletion of the resource base in the most accessible areas; underdeveloped forest infrastructure; imperfect and permanently changing institutional environment; rather low investment attractiveness of the industry in general [2]. Many authors have come to the conclusion that the main problems of the forest sector are related to the inconsistency of the

[1] Prospects of the forest complex in the modern economy: innovative development. *ProDerevo*. Available at: https://proderevo.net/analytics/main-analytics/perspektivy-lesnogo-kompleksa-v-sovremennoj-ekonomike-innovatsionnoe-razvitie.html (accessed: 19.12.2019).

institutional environment with the peculiarities of market regulation in Russia [3; 4; 5].

The basis of forest management in the conditions of state ownership of the forest Fund is the distribution of rights and responsibilities between the state and private timber business [6; 7]. The state's withdrawal from performing its production functions of forest management is associated with the development of long-term use on the basis of concession agreements and lease agreements. The formation of a rational forest policy aimed at improving the efficiency of the Russian forest sector involves the creation of appropriate institutional forms. The choice of the most optimal configuration of the institutional environment is complicated by the territories' diversity in the Russian Federation, as well as by the transition to an intensive model of forest management. Currently, there is a broad discussion on the necessity to make changes to the Forest code. There are constant changes in legislation in the field of forest management relations. This indicates an unsettled system of institutional relations. In the context of the tasks to be solved, it is extremely important to assess the effectiveness of the existing institutions, determine their compliance with modern realities and develop the main directions for changing the institutional environment, taking into account the current world practice and its thoughtful adaptation to the Russian conditions [3; 8]. All this ultimately requires creating adequate models that allow such work to be carried out effectively and comprehensively. The quality of models primarily depends on the adequacy of the micro-level process display. However, to date there is no formal description of them that could be used for creating simulation models. In the Russian Federation, this situation is fully typical of the forest lease system which is formed mainly at the regional level. In this regard, we set a new research task to study and develop adequate models for the development of the institutional environment elements associated with the forest plots lease at the regional level of the Russian Federation.

The main objectives of the study are to assess the prospects for the development of the existing forest management institutional environment in the Russian Federation and to develop the approaches to analyze the dynamics of the environment elements formation including the forest plots lease in the region of the Russian Federation to obtain the appropriate models on this basis.

2. International experience of forest management

The formation of the forest complex institutional environment at the state level is a multi-faceted task requiring to take into account the characteristics of forest resources and their formation conditions, the existing administrative structure, the adopted state strategy of forest industry development, the social structure, the mentality of the population and other factors. The main criterion is to find the optimal balance between the development of economic functions and the preservation of ecological and social functions of forests.

Federal state structure requires the redistribution of areas of responsibility between the center and the territories. There are various options, but the following two approaches are generally pointed out: the distribution of state forest land by type of ownership (Federal forests under the jurisdiction of the Federal center, regional forests under the jurisdiction of regional state authorities); the distribution of functions of state management of forests and the forest sector vertically and horizontally, that is, with the participation of Federal, regional and municipal authorities. The countries that have implemented the first approach are the United States and Canada [9-13], among those who followed the second approach are

India and Brazil [14; 15; 16]. The experience of large countries such as the United States and Canada shows that decentralizing forest management becomes a proper strategy if there is an appropriate legal and institutional framework at the national level. Problems of forestry development are best solved at the local level. Changes aimed at decentralization should be combined with the establishment of strong guidelines at the regional level (for example, within the framework of regional forest development programs), the creation of an effective monitoring and control system to prevent uncontrolled use of forests for short-term political interests.

Institutional methods include specification of property rights, creation of a market for rights of use and competition, taxation, credit, certification, audit, insurance, easements, formation of public opinion and responsible environmental behavior.

Property relations form the foundation of the entire economic system of society and determine its functioning effectiveness, thereby creating an institutional basis for socio-economic and economic processes [17]. In most countries, various types of ownership of forest land are legally established. As a rule, this is state, private and communal (public) ownership of forests and forest lands. Regardless of the type of ownership, forest legislation is mandatory for all owners, and the state reserves the right to control the condition, use, protection of forests and reforestation. State forestry management with the predominance of a particular type of property has its own specifics [18]. Each country is searching for a "golden mean" in this issue, i.e. the ratio of types of property based on the existing social, economic and natural characteristics. Private ownership prevails in the United States, Finland, Sweden, and Germany [19; 20; 21], state property is in Canada [22; 23], Poland [24]. By changing ownership regimes, it is possible to influence people's behavior, since alternative regimes generate different incentive structures. However, you shouldn't choose one of the property regimes as a standard of reference. When making decisions on the development of private ownership of forests, it is necessary to study in more detail the features of the institutional environment in the country and try to conduct a multi-method interdisciplinary analysis of possible consequences.

Some scientists (see, for example, [25]) have tested the hypothesis that gradual forests privatization can help solve many problems of the industry in the country and move to the stage of its intensive development by creating economic incentives for sustainable forest management. The obtained conclusions indicate that there are no statistical grounds for rejecting the hypothesis of a positive impact of private ownership of forest land on the specific stocks of forest stands, but the revealed relationship is rather weak, indicating the need to study in more detail the features of the institutional environment of a particular country when making decisions on the development of forests private ownership.

The former socialist states, such as Romania, the Baltic States, the Czech Republic, and Slovakia, have gained some experience in transitioning from state to private ownership of forests [26; 27]. It shows that successful institutional reforms reveal some common elements [28]:

1) National forest policies and strategies should be the basis for institutional change, and not the reverse.

2) Direct relationships (administrative, financial) between the structures responsible for the implementation of state functions and management of state forests are eliminated in

order to avoid potential conflicts of interest; to ensure the independence, transparency and neutrality of the state forest management body.

3) Markets can be the best driving force for sustainable forest management, but they can lead to resource depletion without the necessary protective mechanisms.

4) Sustainable forest management provides the necessary framework for policy options analysis. Decisions on policy options should be preceded by a quantitative and qualitative assessment of their impact.

5) Stakeholder Participation and transparency are essential for evaluating policy options and implementing institutional changes.

It is obvious that other countries' experience cannot be applied in its pure form, it should be rethought taking into account the specifics of Russia's socio-economic conditions. Forest legislation should be reviewed in such a way as to create a clear institutional framework for business entities and ensure the achievement of long-term strategic goals related to sustainable forest management, taking into account their own experience.

3. The problems of forest management institutional system formation in the Russian Federation

The current model of forestry in the Russian Federation was established in the Forest code of 2006. Its content contains two main ideas: the vertical redistribution of power and the involvement of private businesses in forest management. This was to ensure, respectively, the effectiveness of management (the situation is better seen locally) and utilization (the presence of an economically interested owner). Thus, a number of state powers in the field of forest relations were transferred to the state authorities of the Federal subjects, and a long-term lease of forest plots became the main form of forest management.

It should be noted that in this case, the mechanism was launched almost "blindly". In fact, it was a kind of "trigger" for the implementation of ideas that had a rational basis, but were not fully developed. As a result, problems that had to be urgently addressed arose, since they were already encountered in real processes. They used to be "somehow resolved" in the current regime, and in the long term they were brought to the appropriate level of decision-making. Eventually, the rules of the game were adjusted. Sometimes it is not enough to make only one adjustment. All this continues to this day, naturally, causing a negative attitude on the part of the professional community. Moreover, some statements are rather harsh, for example: "This code violated the continuity with all the previous stage in the history of forest science and practice development" [8].

The following problems are highlighted among the main ones [8; 29]: the problem of forest ownership, in particular, the right to own forest resources has not been developed; there is no clear division of management rights between the subjects of forest relations (the Russian Federation, regions and forest users); there is no transparent procedure for granting rights to use forest plots; the existing institutional environment does not create conditions for public participation in the process of forest management; lobbying the interests of large capital contributes to the removal of medium and small forest businesses from the arena of forest relations, which entails adverse social consequences; the economic mechanism of lease relations is not perfect.

Paradoxically, the most discussed ideas are those that formed the basis of the Forest code. Various researchers express diametrically opposite points of view on the issue of centralization/decentralization of forest management, and the introduction of the

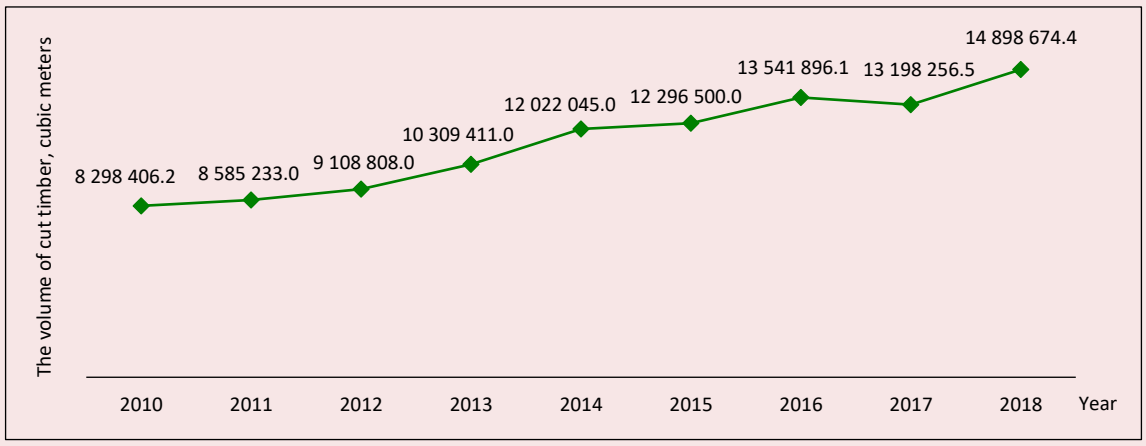
institution of private ownership of forests. Professor N.A. Moiseev insists that "it is important to return forest management from the regional level to the Federal one" [8]. At the same time, one of the possible scenarios described in the "Forecast of the Russian forest sector development until 2030" involves the transfer of part of the forest Fund's land to the ownership of the Russian Federation's constituent entities.

The issue of transferring forests to private ownership is even more controversial. Today, Russia is the only state among the top 10 countries-world loggers, where there is no private ownership of forest land [25]. However, most researchers agree that the country is being prepared for its appearance. Moreover, some of them believe that the existing system of long-term lease is already becoming a kind of private property [18]. This is partly confirmed by the "Forecast of the Russian forest sector development until 2030". The document indicates the implementation of the provision of article 9 of the Constitution of the Russian Federation determining the privatization of forest lands and the emergence of private forests as a possible scenario for the development of the forest relations system. It is claimed that the soil has already been prepared for this purpose by the current Forest code, in which a forest plot is declared as a plot of land. This practically means that forest relations are included in the system of land relations, where private ownership of land has already been recognized for a long time; leased forest plots are subject to state cadastral registration with boundary marking; leased forest plots are subject to state registration of rights and transactions. However, many researchers are inclined to believe that it is still premature to introduce the institution of private ownership of forests, as, first, it is negatively treated by the population as they see a potential infringement of their rights in free forests visiting and meeting their needs for forest goods; secondly, it is necessary to take into account the risk of inefficient and sometimes destructive activities of the owner in relation to the forest, which can lead to serious consequences [25]. Sergey Anoprienko, Deputy Minister of natural resources and ecology of the Russian Federation, head of the Federal forestry Agency, said at the forum "LPC 360°: from all points of view": "In modern realities, private ownership of forests does not seem to be appropriate"[2]. His following statement caused the general consensus: "We can return to this issue only after careful consideration of all possible threats, taking into account the opinions of environmentalists, the expert community, the country's leadership, and when there is a common understanding of how effectively this will solve the existing problems of the forest industry".

The most reasonable opinion, from our point of view, is expressed by G.B. Kozyreva: "The main thing is not who is the owner of forest resources, but how his rights are specified" [29]. It is necessary to understand how thoroughly the existing system of forest ownership in Russia has been studied. According to the developers of the current Forest code, the institutional environment for long-term lease of forest plots in a socially oriented market economy and state ownership of the forest Fund should have ensured a balance of interests of the state, business and society in the framework of sustainable forest management. In this regard, it is necessary to understand the patterns and relationships that underlie the development of the forest lease system. This is what will make it possible to model its dynamics and determine its prospects.

[2] *LesPromInform magazine*. Available at: https://lesprom-inform.ru/news.html?id=11802 (accessed: 19.12.2019).

Figure 1. Dynamics of timber cutting on the territory of the Vologda Oblast by tenants who signed a lease agreement for logging purposes, for the period of 2010–2018, cubic meters



Source: compiled by the authors on the basis of information from the website of the Department of forestry of the Vologda Oblast (https://dlk.gov35.ru); Vologda Oblast open data portal (http://data.gov35.ru/).

The current system of assessment of the lease institute operates only with general parameters (volume of logging, area of reforestation, etc.). They characterize the effectiveness of the system at a certain point in time, but cannot give an answer about the reasons for its behavior. However, it is the indicators that characterize the parameters of the development of individual elements of the system over time that can be used, first, to search for various dependencies, and second, to form the models. Our analysis has proved that there are currently no works dedicated to this topic. In this regard, the authors studied the dynamics of development of leasing forest land system on the territory of the Vologda Oblast, which occupies one of leading places among regions of Russia on the availability of forest resources. The total area of its forests is 11.473 million hectares (79% of the region's territory). Timber reserves exceed 1.6 billion cubic meters. The annual allowable cut is 29.729 million cubic meters, including 10.6 million cubic meters of coniferous forests. 18.251 million cubic meters of wood were leased to forest users. 1021 forest lease agreements have been signed. The dynamics of wood harvesting by tenants who have signed a lease agreement for logging purposes is shown in (*Fig. 1*).

4. Analysis of the dynamics of forest plots lease system formation in the Vologda Oblast

Two main elements of the system were analyzed: forest plots leased (lease agreements) and tenants. We studied how the parameters of these elements are formed, and considered the dynamics of their development over time. Besides, attention is drawn to the possibility of their use in creating agent-oriented models for the development of the regional forest complex. The authors focused on publicly available sources of information, containing mainly the data from the Department of forestry and the Vologda Oblast open data portal[3].

Vologda Oblast is a fairly large region in the North-West of the European part of the Russian Federation. On the territory of the region's municipal districts, there are 26 forestries operating. The parameters of each of them

[3] *Vologda Oblast open data portal*. Available at: http://data.gov35.ru/

Table 1. The total land area of the forest Fund of the Vologda Oblast forestries and the average volume of cut timber per hectare on their territories in 2018

District forestry	Total land area of the forest Fund, ha	Average volume of cut timber per hectare, cubic meters/ha
Babaevskoye	835 548	1.233915945
Babushkinskoye	691 366	1.387130261
Belozerskoye	452 463	1.543447752
Vashkinskoye	247 167	1.172021346
Velikoustyugskoye	637 788	1.755426568
Verkhovazhskoye	366 212	1.937440062
Vozhegodskoye	501 442	0.968301419
Vologodskoye	225 126	0.507822286
Vytegorskoye	1 218 900	1.345413898
Gryazovetskoye	381 770	1.545564083
Kaduyskoye	257 466	0.807928037
Kirillovskoye	350 838	0.45501599
Kichmengsko-Gorodetskoye	606 129	1.366542436
Mezhdurechenskoye	304 815	1.148946082
Nikol'skoye	644 844	1.67413514
Nyuksenskoye	461 344	1.303179406
Sokol'skoye	294 988	1.285174312
Syamzhenskoye	327 564	1.565391801
Tarnogskoye	437 666	1.277743759
Totemskoye	736 192	1.517003716
Ust-Kubinskoye	168 402	0.997612855
Ustyuzhenskoye	273 058	0.313541445
Kharovskoye	281 715	1.670390288
Chagodoshchenskoye	200 834	0.705249111
Cherepovetskoye	427 033	1.236391567
Sheksninskoye	141 835	0.514844714
Compiled on the basis of: the information on the website of the Department of forestry of the Vologda Oblast (https://dlk.gov35.ru); the information from the Vologda Oblast open data portal (http://data.gov35.ru/); forest technical regulations of Vologda Oblast forestries.		

have their own specifics, which must be taken into account. It is quite difficult to evaluate the characteristics of manifold objects and then ensure their formation and support in the model, so the authors suggest an approach according to which the forestries are divided into clusters. It is based on the principle of placing them in the space "Land area of the forest Fund – Average volume of timber cut per hectare". The parameter values for each forestry are shown in *table 1.*

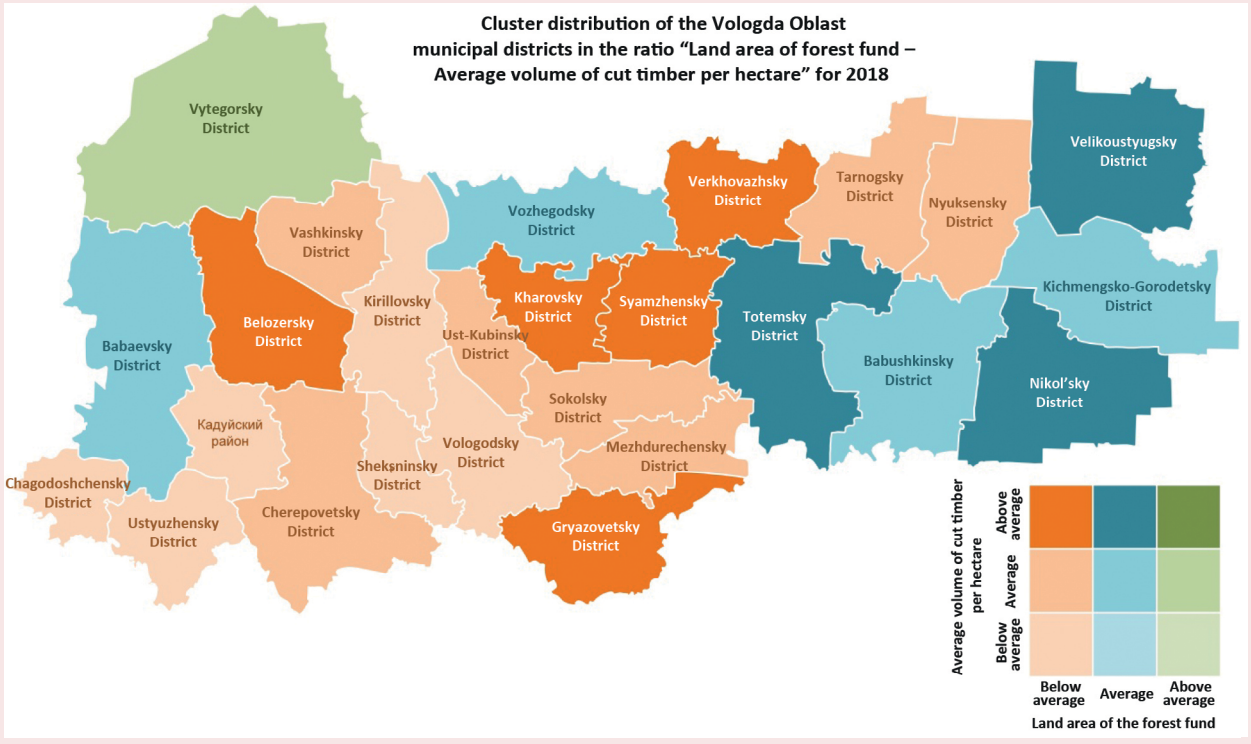
Space dimensions were selected on the basis of the fact that these indicators in their entirety can characterize the formation of forest plots for rent and tenants. The space was divided into nine clusters by dividing it equally vertically and horizontally by the parameters of the forest land area and the average volume of cut timber per hectare (below average, average and above average). The total area boundaries of the clusters are determined based on the minimum and maximum values of these indicators. As a result, all forestries were located in six clusters (*Fig. 2*).

The geographic representation of the forestries distribution in the space "Land area of forest Fund – Average volume of cut timber per hectare" on the map of the Vologda Oblast is of interest (*Fig. 3*). Its more detailed interpretation can be presented in a separate

Figure 2. Graphic display of the Vologda Oblast forestries in the space
"Land area of forest Fund – Average volume of cut timber per hectare"

Source: compiled by the authors.

Figure 3. Geographic display of the forestries distribution in the space
"Land area of forest Fund – Average volume of cut timber per hectare"



Source: compiled by the authors.

work related to the overlay of locations of various infrastructure facilities, enterprises on the map, the consideration of individual characteristics of territories, such as population density, and other elements. In this study, we only believe that representatives of the same cluster have similar characteristics in the dynamics of the forest lease system development.

The following notations are used when identifying the clusters: NP – below the average indicator of forest Fund land area; SP – the average indicator of forest Fund land area; VP – above the average indicator of forest Fund land area; NO – below the average indicator of the average volume of cut timber per hectare; SO – the average indicator of the average volume of cut timber per hectare; VO – above the average indicator of the average volume of cut timber per hectare. Thus, the notation "VP:SO" means that the territory belongs to the cluster "Above the average indicator of forest Fund land area – The average indicator of the average volume of cut timber per hectare". One representative forestry from each of the four clusters was selected for further analysis: Vologodskoye (NP:NO cluster), Mezhdurechenskoye (NP:SO cluster), Kharovskoye (NP:VO cluster) and Nikolskoye (SP:VO cluster). Due to the small number of participants in the remaining two clusters, it was decided to select one forestry that is closest to their common border, the Babaevskoye forestry (clusters SP:SO and VP:SO).

The general purpose of the lease agreements dynamics analysis was to determine the trends in the development of the amount and area of the leased land plots, as well as the lease duration. This will allow further modeling of the processes of changing their overall structure, since in reality they are mostly random in nature.

In accordance with the existing legislation, it is possible to lease forest plots for various purposes. The current distribution of lease agreements by type of use in the Vologda Oblast is shown in *figure 4*.

Figure 4. Distribution of lease agreements by the types of use in the Vologda Oblast

Type of lease	Number of plots	Land area of plots, ha
Harvesting of food forest resources and collecting medicinal plants	1	44577
Activities in the hunting sector	17	163056
Farming	10	17.9434
Research and educational activities	3	343.2
Recreational activities	72	135.9251
Growing of planting material of forest plants (saplings, seedlings)	3	16.5816
Performing works on the geological study of subsurface resources, development of mineral deposits	74	631.8932
Construction and operation of reservoirs and other artificial water bodies, as well as hydraulic structures, seaports, sea terminals, river ports, berths	63	245.2401
Construction, reconstruction, and operation of linear facilities	360	7101.9976
Religious activities	1	0.11
Performing survey work	4	0.6427
Timber cut	504	6870027.14

Source: compiled by the authors on the basis of the information from the website of the Department of forestry of the Vologda Oblast (https://dlk.gov35.ru); the information from the Vologda Oblast open data portal (http://data.gov35.ru/).

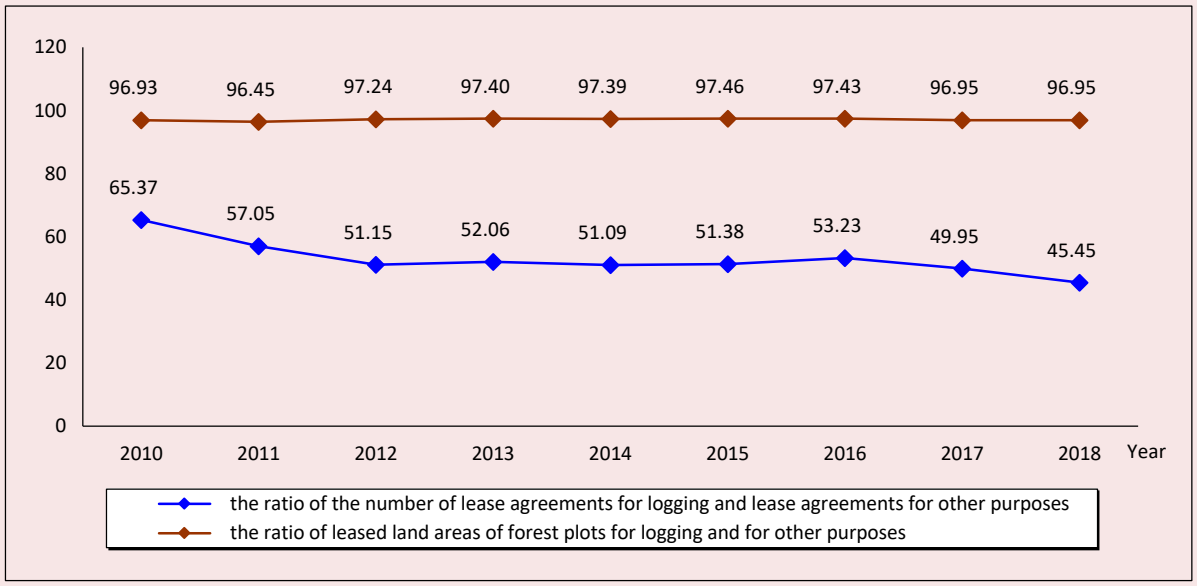
If quantitatively the lease agreements for logging and other purposes are approximately the same, then the largest share of the leased land area is accounted for by logging. The dynamics of time series of the ratio of the quantity of lease agreements for logging purposes and lease agreements for other purposes, as well as the land areas indicated in them (*Fig. 5*) shows that over the nine years (from 2010 to 2018), the ratio of areas remains almost unchanged making up about 97% in favor of lease agreements for logging purposes. At the same time, in terms of quantity, a trend of increasing the share of contracts for other purposes is obvious.

Based on the presented graphical representation of the dependency, we can talk about its linear nature. Using the linear approximation tools of Microsoft Excel software, the following function of trend change in the ratio of the number of lease agreements for logging and lease agreements for other purposes was obtained: $y = -0.0162x + 0.6109$, with the approximation confidence value $R^2 = 0.6427$. Obviously, this functional relationship has time constraints, but it can be used for short- and medium-term forecasts. In addition, when developing an intensional model [30], you can change its parameters when new data about the current development of the modeled system is received.

Similar dependencies exist in the time series of the quantity of lease agreements for logging and other purposes, as well as the areas of leased forest plots indicated in them. The corresponding diagrams and functional dependencies are shown in *table 2*.

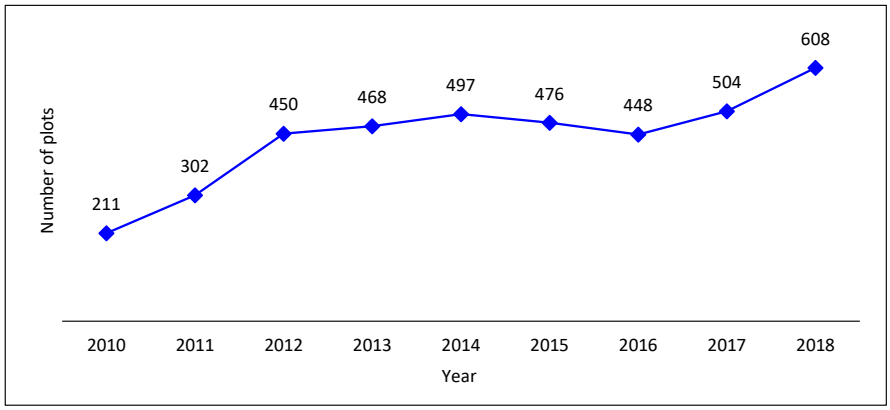
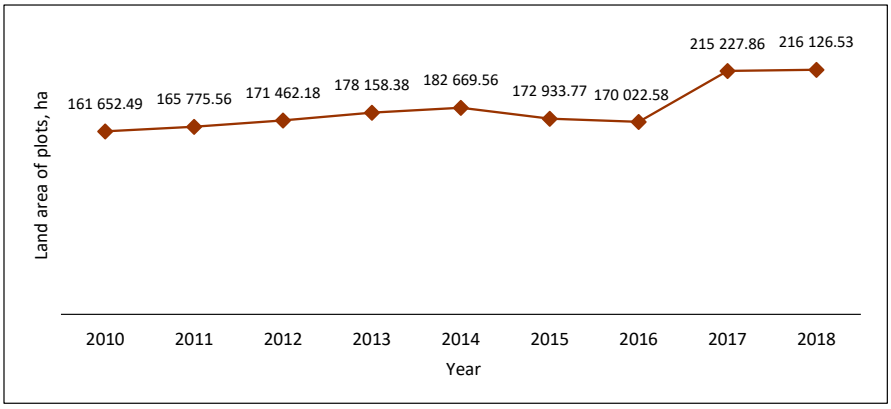
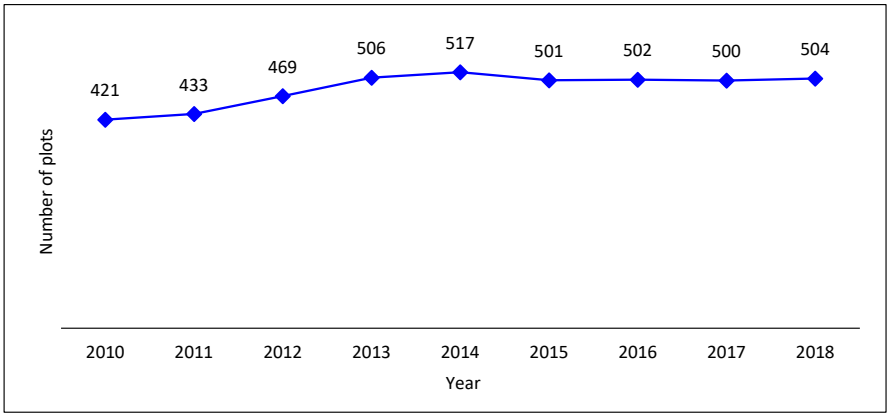
When making forecasts within the clusters using the obtained equations, the initial values of the parameters of territories included in the cluster should be taken into account. Thus, the calculation of the projected figure on a certain territory should have the following order: first, one computes the value of the equation on the projected indicator for the cluster to which

Figure 5. Dynamics of the ratio of the quantity of lease agreements for logging purposes and lease agreements for other purposes, as well as the land areas indicated in them, for the period 2010–2018



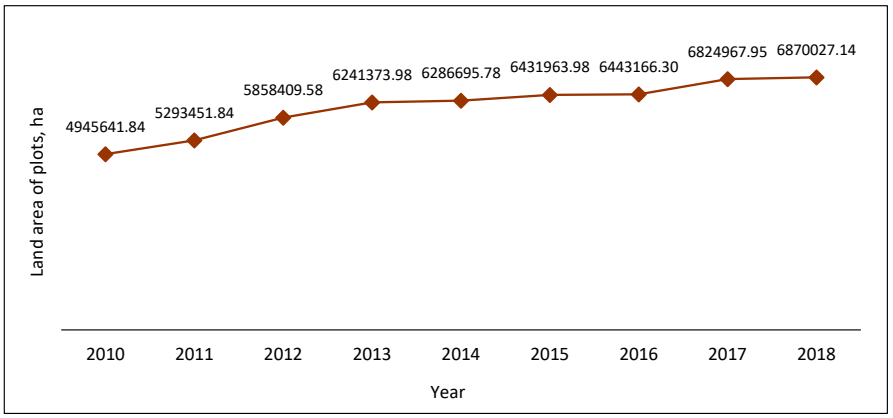
Source: compiled by the authors on the basis of the information from the website of the Department of forestry of the Vologda region (https://dlk.gov35.ru); the information from the Vologda region open data portal (http://data.gov35.ru/).

Table 2. Diagrams and functional dependencies in time series of the quantity of lease agreements for logging and other purposes, as well as the areas of leased forest plots indicated in them

Time series diagram	Dependency equation received by linear approximation / R-squared value
Change in the number of plots under lease agreements for purposes other than logging (in the region)	
	$y = 36.633x + 257.28$ $R^2 = 0.7367$
Change in the area of land plots under lease agreements for purposes other than logging, ha (in the region)	
	$y = 5969.2x + 151713$ $R^2 = 0.6486$
Change in the number of plots under lease agreements for logging purposes (in the region)	
	$y = 9.9x + 434.17$ $R^2 = 0.6103$

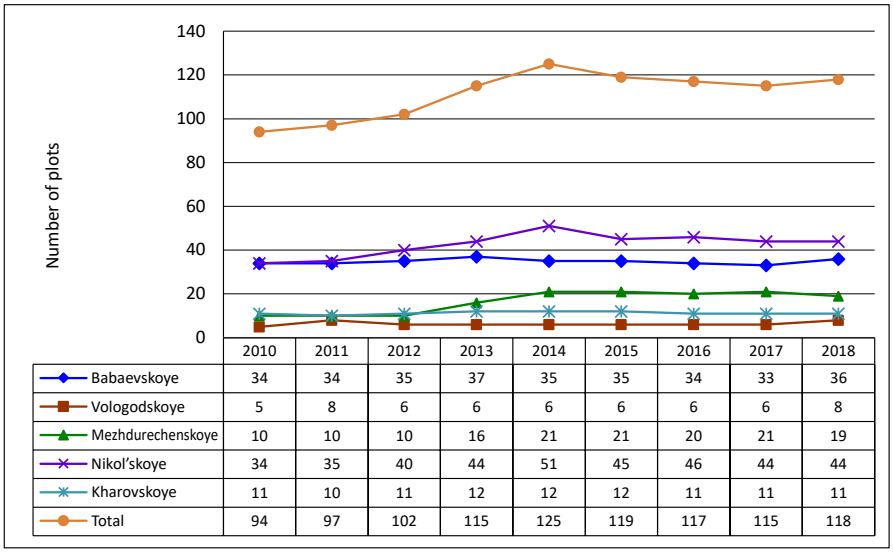
End of Table 2

Change in land area of plots under lease agreements for logging purposes, ha (in the region)



$y = 227537x + 5E + 06$
$R^2 = 0.9048$

Changes in the number of plots under lease agreements for logging purposes (by cluster)



	2010	2011	2012	2013	2014	2015	2016	2017	2018
Babaevskoye	34	34	35	37	35	35	34	33	36
Vologodskoye	5	8	6	6	6	6	6	6	8
Mezhdurechenskoye	10	10	10	16	21	21	20	21	19
Nikol'skoye	34	35	40	44	51	45	46	44	44
Kharovskoye	11	10	11	12	12	12	11	11	11
Total	94	97	102	115	125	119	117	115	118

SP:SO and VP:SO (Babaevskoye)
$y = 0.0167x + 34.694$
$R^2 = 0.0014$

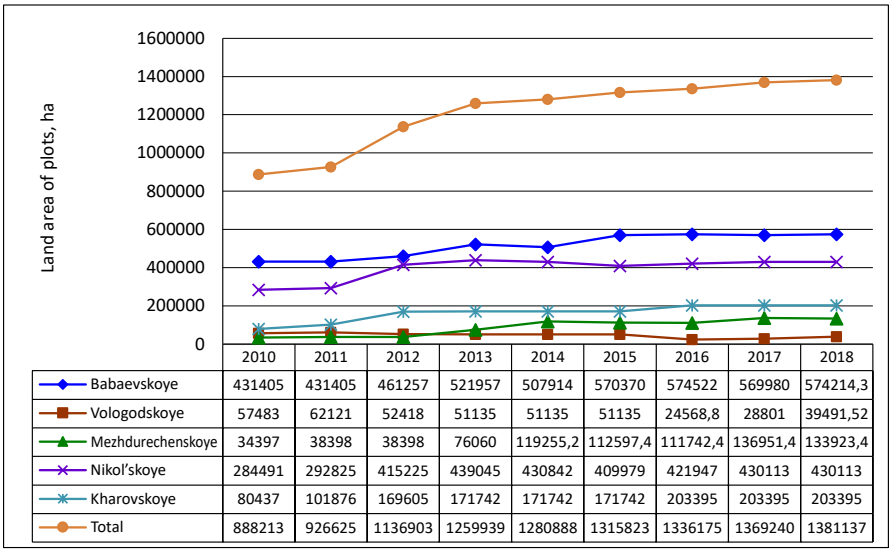
NP:NO (Vologodskoye)
$y = 0.1x + 5.8333$
$R^2 = 0.075$

NP:SO (Mezhdurechenskoye)
$y = 1.5667x + 8.6111$
$R^2 = 0.7141$

SP:VO (Nikolskoye)
$y = 1.3333x + 35.889$
$R^2 = 0.4593$

NP:VO (Kharovskoye)
$y = 0.05x + 10.972$
$R^2 = 0.0422$

Change in land area of plots under lease agreements for logging purposes, ha (by cluster)



	2010	2011	2012	2013	2014	2015	2016	2017	2018
Babaevskoye	431405	431405	461257	521957	507914	570370	574522	569980	574214,3
Vologodskoye	57483	62121	52418	51135	51135	51135	24568,8	28801	39491,52
Mezhdurechenskoye	34397	38398	38398	76060	119255,2	112597,4	111742,4	136951,4	133923,4
Nikol'skoye	284491	292825	415225	439045	430842	409979	421947	430113	430113
Kharovskoye	80437	101876	169605	171742	171742	171742	203395	203395	203395
Total	888213	926625	1136903	1259939	1280888	1315823	1336175	1369240	1381137

SP:SO and VP:SO (Babaevskoye)
$y = 21032x + 410733$
$R^2 = 0.8819$

NP:NO (Vologodskoye)
$y = -3793.7x + 65445$
$R^2 = 0.6605$

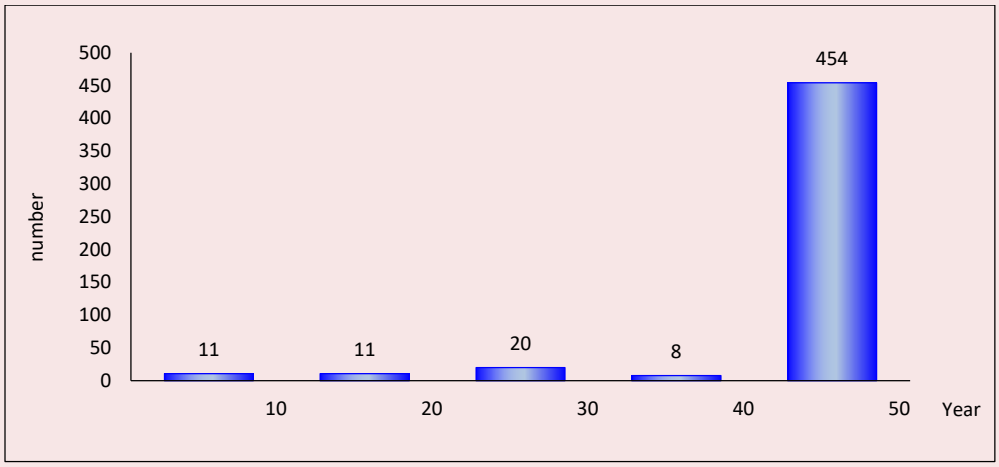
NP:SO (Mezhdurechenskoye)
$y = 14617x + 15998$
$R^2 = 0.8794$

SP:VO (Nikolskoye)
$y = 16312x + 313393$
$R^2 = 0.5375$

NP:VO (Kharovskoye)
$y = 14399x + 92150$
$R^2 = 0.7919$

Compiled on the basis of: the information on the website of the Department of forestry of the Vologda Oblast (https://dlk.gov35.ru); the information from the Vologda Oblast open data portal (http://data.gov35.ru/).

Figure 6. Histogram of the distribution of forest plots lease duration in the Vologda Oblast



Source: compiled by the authors on the basis of the information from the website of the Department of forestry of the Vologda Oblast (https://dlk.gov35.ru); the information from the Vologda Oblast open data portal (http://data.gov35.ru/).

the territory is related to, and then the difference between the initial values of the projected figure of territory selected as basis for the cluster and the projected indicator of the territory for which the predictions are made, is subtracted from it.

Histogram of lease duration distribution is presented in *figure 6*.

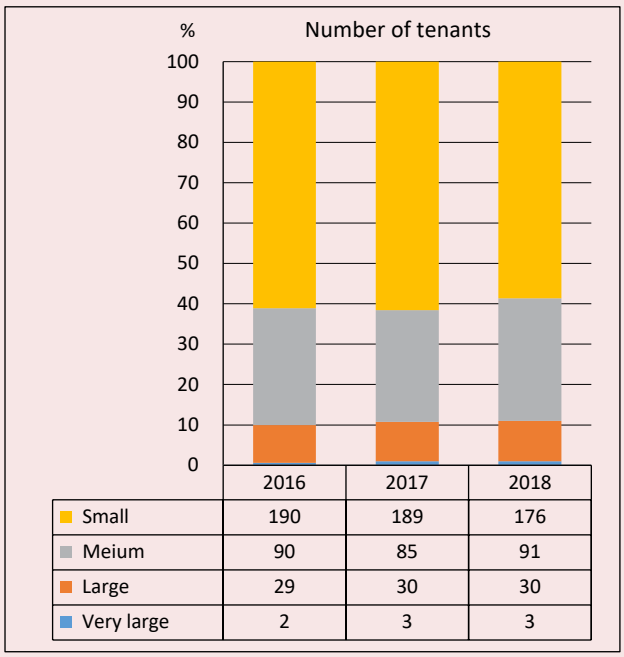
A significant preponderance of lease agreements with a duration of more than forty years is presented. In this case, it is difficult to choose the distribution law, so for modeling purposes, it is advisable to use a discrete probability distribution when forming the lease duration under the contract. At the same time, the presented histogram is used to determine the intervals and probability values, taking into account that the current legislation limits the range of possible lease terms for a forest plot to 10-49 years.

The general purpose of the analysis of the composition of forest plots tenants was to determine the dynamics of changes in their quantitative composition, taking into account production capabilities. Tenants with different capabilities differ in their behavior patterns, so during the analysis the tenants were divided into four groups depending on the annual volume of timber cut4: very large (more than 500 thousand cubic meters); large (from 100 to 500 thousand cubic meters); medium (from 20 to 100 thousand cubic meters); small (less than 20 thousand cubic meters). It can be assumed that the behavior of each tenant in certain situations will be similar to the behavior of any other tenant belonging to this group. The ratio of the number of tenants and the number of leased plots by groups in dynamics (2016–2018) is shown in *figure 7*. It is revealing that with the almost constant number of very large and large tenants, the number of leased plots increases due to a decrease in the share of the number of leased plots by small tenants.

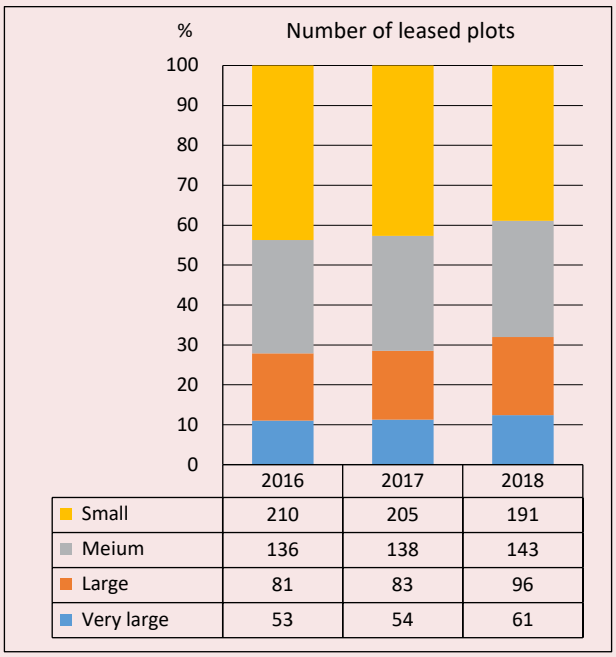
The time series of the number of tenants of forest plots in the Vologda Oblast by groups for the period of 2011–2018 are shown in *Fig. 8*.

[4] Logging in Russia: state and target vision. *ProDerevo*. Available at: https://proderevo.net/industries/wooden-logging/lesozagotovka-v-rossii-sostoyanie-i-tselevoe-videnie.html (accessed: 19.12.2019).

Figure 7. The ratio of the number of tenants and the number of leased plots by groups for the period of 2016–2018



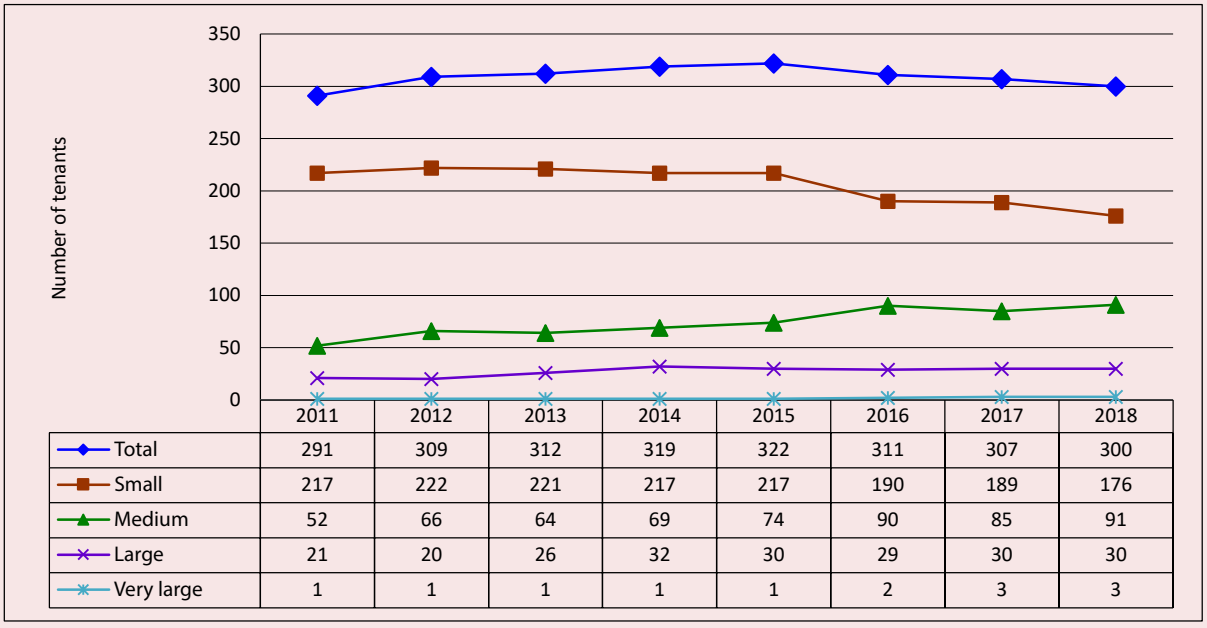
	2016	2017	2018
Small	190	189	176
Meium	90	85	91
Large	29	30	30
Very large	2	3	3



	2016	2017	2018
Small	210	205	191
Meium	136	138	143
Large	81	83	96
Very large	53	54	61

Source: compiled by the authors on the basis of the information from the website of the Department of forestry of the Vologda Oblast (https://dlk.gov35.ru); the information from the Vologda Oblast open data portal (http://data.gov35.ru/).

Fig. 8. Time series of the number of tenants of forest plots in the Vologda Oblast by groups for the period of 2011–2018



	2011	2012	2013	2014	2015	2016	2017	2018
Total	291	309	312	319	322	311	307	300
Small	217	222	221	217	217	190	189	176
Medium	52	66	64	69	74	90	85	91
Large	21	20	26	32	30	29	30	30
Very large	1	1	1	1	1	2	3	3

Source: compiled by the authors on the basis of the information from the website of the Department of forestry of the Vologda Oblast (https://dlk.gov35.ru); the information from the Vologda Oblast open data portal (http://data.gov35.ru/).

Table 3. Trend functions of changes in the time series reflecting the number of tenants of forest plots in the Vologda Oblast

Tenants	Dependency equation obtained by linear approximation / the value of reliability approximation
Very large	$y = 0.3214x + 0.1786$ $R^2 = 0.7386$
Large	$y = 1.4286x + 20.821$ $R^2 = 0.6058$
Average	$y = 5.369x + 49.714$ $R^2 = 0.9043$
Small	$y = -6.4881x + 235.32$ $R^2 = 0.7724$
All	$y = 0.631x + 306.04$ $R^2 = 0.0242$
Compiled on the basis of the information from the website of the Department of forestry of the Vologda Oblast (https://dlk.gov35.ru); the information from the Vologda Oblast open data portal (http://data.gov35.ru/).	

Using the linear approximation tools of Microsoft Excel software, we obtained trend functions for each group with respect to changes in the time series of the number of tenants (*Table 3*).

5. Conclusion

The dynamics of the development of a system including the lease of forest plots depends on many different factors. Determining their full list and the nature of their impact on the system is a complex task that has no solution to date. Approaches reflected in the paper allow to quantify the trends of key elements of the system of rent, as well as to forecast the values of their parameters in future periods and to determine the degree of system response to external interferences (including control). They are based on the models obtained by linear approximation of trends in the development of parameters of the corresponding elements.

The approaches are tested by the authors on the example of the system of lease of forest plots in the Vologda Oblast. On the basis of the available historical data, we have obtained the dependencies using which in the short term it is possible to predict changes in the number and area of leased land, the number of tenants, and the lease term. Thus, in accordance with the Forest plan of the Vologda Oblast, approved by the order of the Governor of the Vologda Oblast dated November 30, 2018, no. 4807-R, for the period of 2018–2027, in Babaevskoye forestry, it is planned to provide three plots with a total area of 6302 hectares for logging purposes. According to forecasts obtained by means of the models developed by the authors, in 2027, compared to 2017, the number of leased plots will increase twice, and their area will increase by 219329 hectares. In the course of further research, the authors plan to make a more detailed interpretation of the obtained models on the example of the forest complex of the Vologda Oblast.

This work contributes to the development of theoretical approaches to the methodology for studying the dynamics of the institutional environment formation associated with the lease of forest plots in the region of the Russian Federation and applied aspects of its modeling. Practical significance of the research consists in providing an opportunity to determine the main trends in the development of elements of the forest lease system, making forecasts of their development, and using the results in the construction of various models of the forest complex.

To date, the authors of the paper have developed a number of agent-oriented models of the regional forest complex, including a model of reforestation [31]. It contains three types of agents: a forest plot, a tenant, and a government Agency. The general structure of forest plots and tenants is considered in statics, i.e. only agents corresponding to the situation at the beginning of the simulation are created and function in the model. Using the developed approaches, it becomes possible to more adequately describe the processes taking place due to the formation of dynamics of changes in the model elements. This can fully apply to other models of the regional forest complex, since the elements considered are basic in this subject area. The authors analyzed the development of the forest lease system in the Vologda Oblast and obtained the models for the formation of its main elements.

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