Mathematical methods for the evaluation of lands of forest fund

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Annotation. The article provides an overview of various methods for assessing the forest fund infrastructure during cadastral valuation, including a couple of possible methods of mathematical modeling, with the help of which it is possible to assess the impact of the forest fund infrastructure on the cadastral value, as well as the advantages and disadvantages of these methods.

1. Introduction
State cadastral registration of land in the Russian Federation is mandatory and is the basis for updating the tax base. More than two-thirds of the territory of the Russian Federation is occupied by forest lands; the Leningrad Region is no exception (figure 1). In accordance with the current legislation, the sale and purchase of forest lands is prohibited, but they can be leased, therefore, the rational management of the forest fund plays a key role in the economy of the Russian Federation. Nowadays underdeveloped: rational use, land management of the forest fund, their cadastral valuation.

Cadastral valuation of land resources is one of the indicators of rational and effective land management is their cadastral valuation. The purpose of the cadastral valuation of forest lands is to determine their value for tax purposes, to determine the amount of rent for the use of forest lands and to establish a tax on forest use. For these purposes, forest land is differentiated by productivity.

Cadastral valuation is carried out by budgetary institutions, this is due to changes in legislation from 2017. However, the methods, approaches and methods for conducting a cadastral valuation of forest lands do not differ from other valuation measures for real estate [1]. Nowadays, the methodology of cadastral valuation of forest land is imperfect and has several disadvantages. Carrying out a cadastral valuation of forest land is associated with the transfer of land for rent (figure 2), to establish rental rates, in some cases to assess the pricing policy of rental rights to forest land, which directly include arrays.
The cost of forest land depends on many factors, one of them is the degree of development of forest infrastructure, which is not taken into account in the state cadastral valuation of forest lands. Forest infrastructure involves the construction of roads, warehouses, fire reservoirs, bridges, hydraulic structures and other facilities. The degree of development of forest infrastructure is very low in the regions of Russia, but such an infrastructural structure is necessary to ensure the rational use, protection, protection, and reproduction of forest lands. Therefore, the problem of improving the methodology of cadastral valuation of forest lands is relevant.

At present, appraisers need to take into account the infrastructure of the forest fund as part of forest plots, as well as assess the impact of this infrastructure on the cadastral value of land. The latter is one of the main tasks that have not been resolved at this stage in the development of land relations. The new method of cadastral valuation of forest lands will allow to differentiate the lands of the forest fund by cadastral value. As part of a previous study, a classification of the infrastructure of the forest fund was developed [2].

2. Methods and Materials
The primary task of the study is to analyze the existing methodology for determining the cadastral value of land. The cadastral value of a land plot is a monetary value calculated that is determined according to the approved methodology and reflects the value of the land plot with its existing use in accordance with the law [3]. In relation to lands of other categories, methods have been developed according to which, when cadastral valuation, restrictions and burdens are taken into account.

Currently, the cadastral value (COP) in accordance with the Methodological Instructions on the State Cadastral Assessment [4] is calculated by (1):

\[ C = C_f \cdot S, \]

where, \( C_f \) - the specific indicator of the cadastral value, rubles / m\(^2\); \( S \) - land area, m\(^2\).

Moreover, \( C_f \) for lands of various categories and types of permitted use depends on a large number of different factors. For example, for \( C_f \) for the lands of settlements it depends on such factors as physical characteristics (type of permitted use, area, etc.); location characteristics (municipal district, settlement, etc.); environmental characteristics (proximity to recreation areas, water bodies, public transport stops, etc.); characteristics of the territory of the settlement (social infrastructure, communal infrastructure, environment, urban information, socio-economic indicators [3].

Indicator \( C_f \) lands of the forest fund depends on the location of the land in relation to forestry, logging, fire-fighting, economic roads [5]. The presence of a network of well-arranged roads in the forest provides the most complete use of forest wealth, increases the overall culture and efficiency of forestry
production. In addition, proximity to points of sale and processing of products also affects the cadastral value of such sections of the forest fund. In addition to these data, figure 2 presents an extended classification of infrastructure objects, which can also affect the total value of the cadastral value [6].

Earlier, we proposed another formula for assessing the infrastructure of the forest fund during cadastral valuation, which takes into account this classification. The cadastral value of land is determined by the following (2):

\[ C = C_f \cdot S \cdot k_{IF} \]  

(2)

where, \( C \) - cadastral value of the land; \( C_f \) - a specific indicator of the cadastral value of the forestry in which the land is located; \( S \) - land area; \( k_{IF} \) - the correction factor for the development of infrastructure of the forest fund lands.

Thus, the specific cadastral value of the cadastral value (\( C_f \)) of forest lands will reflect their quality, taking into account the degree of infrastructure development.

Figure 2. Types of forest land infrastructure.

Unfortunately, the determination of the cadastral value by formula 1 is not possible to do this. Thus, encumbrances are not taken into account when calculating the cadastral value, although their necessity was justified earlier. The authors proposed a different formula for determining the \( (C_f) \) taking into account all indicators, from the area of encumbrance to its appearance [3]. The cadastral value of the land, taking into account restrictions (encumbrances), is calculated according to (3):

\[ C = C_f \cdot P_N + \sum_{i=1}^{n}(C_f \cdot P_o \cdot P_{ij}^{P} \cdot k_j) \]  

(3)

where, \( P_N \) - land area without restrictions (encumbrances); \( P_o \) - the area of the \( i \)th land plot with restrictions (encumbrances); \( k_j \) -is the coefficient of reducing the cost of the site as a result of the \( j \)th restriction.

The coefficients of reducing the value of the land due to the availability of restricted regime zones for the lands of settlements have been developed on the basis of the State University for Land Management [6, 7]. However, detailed calculations are not presented in the publication.
In [8], it is proposed to carry out a cadastral assessment of garden, vegetable garden and summer
cottage plots in an urban area, taking into account the factor sign “the availability of ZOUIT zones with
special conditions for the use of territories”, which is justified by qualimetric and expert analyzes. A
study of the market reaction to the presence of ZOUIT on the studied land plots is carried out by the
method of qualimetric modeling. This method may be applicable for forest areas, however, some of the
data is quantitative, indicated in the classification. Such data were quantified to assess the effects of data
on cadastral value. Qualimetry appeared due to the development of methods designed to measure quality
or, more precisely, to express the qualitative certainty of an object in quantitative characteristics, under
the influence of practical requirements.

The use of qualimetric modeling has several advantages over similar methods of quantitative
assessment:
- a graphical representation of the dependence of value on the "quality" of the object;
- the possibility of harmonizing weighting factors of pricing factors in accordance with market
analysis;
- the relationship of the numerically expressed "quality" of the object and its value;
- implementation of the method does not require a large number of analogous objects, which allows
you to objectively establish the value of the object in an underdeveloped market.

It is proposed to assess the impact of the availability of forest fund infrastructure on the cadastral
value by the method of qualimetric modeling. For this, a number of qualitative indicators must be
converted into quantitative ones. In accordance with the developed classification and methodology, the
coding of factors affecting the value of forest fund plots will look like in table 1.

Table 1. Coding of factors affecting the value of land.

| Factor level | Availability of infrastructure | Engineering Communication | Transport infrastructure | Remoteness from points of sale |
|--------------|-------------------------------|---------------------------|--------------------------|--------------------------------|
| 1            | +                             | electricity, gas pipeline, water supply | asphalt road | less than 10 km |
| 2            | -                             | -                         | Dirt road | 10-30 km |
| 3            | -                             | -                         | -                      | 30 km |
| 4            | -                             | -                         | -                      | more than 50 km |

In our opinion, the coefficient of development of the forest fund infrastructure is a spatial value that
requires a different approach to assessment; according to this methodology, the assessment of
infrastructure is subjective. On the one hand, the transport infrastructure of the region’s forest territories
is part of the general regional transport infrastructure within the classification attribute “territorial
affiliation”, on the other hand, the transport infrastructure of the region’s forest territories has a number
of significant specific features and is characterized by other technical, operational and economic
properties in accordance with proposed definition. [1]. It is proposed to assess the impact of the forest
fund infrastructure on cadastral value using spatial analysis methods in order to avoid the conversion of
qualitative data into quantitative ones. To determine the infrastructure development coefficient, it is
necessary to use the software products to calculate the density of infrastructure objects in the territory
being evaluated, use the obtained values as parameter values, and then determine the total infrastructure
provision ratio based on these densities.

The application of the theory of fuzzy sets is another option for assessing the impact of infrastructure
on cadastral value. This theory has already been used to solve many practical and theoretical problems
[9]. For example, such a theory was used to assess the development conditions of deposits in the Arctic
seas using the example of the Southeastern part of the Barents Sea. The selected factors have a different
nature, they are heterogeneous and have different dimensions. We used criteria weights that showed the
importance of a parameter for the overall analysis. The researcher can vary the weight of the parameters
depending on the specific problem, which makes the approach more flexible, unifies the methodology
and expands the possibilities of its application [10]. The approach proposed in this work can be used to
model the $C_f$ of the forest fund lands and create a visual picture of the location of the forest fund infrastructure in a given territory.

Mapping transport accessibility based on road network data is one of the classic GIS tasks. The most common way to model transport accessibility is to build isochron - lines of equal time spent on overcoming space relative to given points [11]. The construction of isochrones can be carried out using the QGIS software product. In this program, data preparation and cartographic presentation of the results are carried out, and in GRASS the simulation itself performs modeling. All the work can be done entirely in GRASS, but, according to the author, the general manipulation of geodata and the presentation of cartographic materials are more successfully and conveniently implemented in QGIS. Using these software products, it is supposed to calculate isochrones and build heat maps of the density of forest infrastructure facilities. The “Heatmap Creation” module uses a nuclear estimation of the distribution density to create a raster density map (heatmap) from the initial point vector layer. Density is calculated by the number of points in a certain area, the more the number of points gives a higher density value. Heat maps make it easy to identify clusters of points and identify “hot” areas.

3. Results and Discussion

The theory of fuzzy sets is one of the most effective mathematical theories aimed at processing uncertain information and integrating well-known approaches and methods in many respects. The theory of fuzzy sets allows you to process heterogeneous information that is characteristic of real-world problems and overcomes the disadvantages associated with accounting for the uncertainty that are inherent in risk accounting methods in the discount rate and methods based on probability theory. Nowadays, the theory of fuzzy sets is widely applicable in various fields of science. The main problem is the uncertainty in assessing the infrastructure of the forest fund, the inaccuracy of information, as well as the lack of completeness of data when performing the analysis. Such work will be relevant only for the North-West region, including for the Leningrad region as part of a study to assess the impact of the forest fund infrastructure on cadastral value. The level of development of forest infrastructure is not so high in other regions of the Russian Federation, which limits the application of this technique throughout the country. It is not possible to determine the cadastral value taking into account the infrastructure of the forest fund according to formulas (1) and (3), or these formulas require improvement. It is possible to record the infrastructure of the forest fund most fully using formula 2. However, it is necessary to take into account the infrastructure development coefficient not only for calculating the total cadastral value of a particular plot, but also in determining the specific cadastral value of the forestry as a whole.

4. Conclusions

The liquidity of the land depends on many factors, such as: the economic situation in the area, seasonal fluctuations, the infrastructure of the area, transport accessibility (both by personal and public transport, the quality of access roads), the actual use of neighboring land plots, the physical characteristics of the property (area, cultivation level), and from one of the main characteristics - utilities (water, electricity, gas). It is necessary to conduct a qualitative analysis of the infrastructure for the objective cadastral value of the forest fund plots in the assessment territory. Infrastructure assessment methods proposed in this article can give a full analysis of objects and show the nature of their impact on cadastral value.

References

[1] Kovyazin V and Romanchikov A 2018 The problem of cadastral valuation of forest land, taking into account forest fund infrastructure [in Russian – Problema kadastrovoj ocenki lesnyh zemel’ s uchetom infrastruktury lesnogo fonda] (Saint - Petersburg: Journal of Mining Institute vol 229) pp 98-104

[2] Kitcenko A, Kovyazin V and Romanchikov A 2019 Modern conditions and prospects of the development for the infrastructure to improve the economy of the nature management Scientific and Practical Studies of Raw Material Issues 2019 1st edition pp 205-211

[3] Chernetskaya Yu V 2012 Improving the methodology for calculating cadastral value land subject
to encumbrances and land restrictions for the purposes taxation [in Russian – Sovershenstvovanie metodiki rascheta kadastrovoj stoimosti zemel'nogo uchastka s uchetom obremenений i ogrаничений на землю для целей налогообложения] (Saint - Petersburg: Journal of Mining Institute) 196 pp 105-109

[4] Order of the Ministry of Economic Development of Russia vol 226 dated 05.12.2017 "On approval of guidelines on the state cadastral valuation" (as amended on 08.09.2018)

[5] Kuvaldin B I 1976 Forestry roads (arrangement and maintenance) (Moscow: Forest industry)

[6] Kovyazin V, Romanchikov А and Kitcenko A 2019 Classification of lands infrastructure forest Found Jop Conference Series: Earth and Environmental Science 316 012022. DOI: 10.1088 / 1755-1315 / 316/1/012022

[7] Varlamov A A and Galchenko S A 2000 Land Cadastre Training and Practical Guide. Moscow

[8] Senkovskaya K E 2018 Cadastral valuation of garden, garden and country lands, taking into account zones with special conditions for the use of territories [in Russian – Kadastrovaya ocenka sadovyh, ogorodnyh i dachnyh zemel' s uchetom zon s osobymi usloviyami ispol'zovaniya territorij] PhD thesis St. Petersburg p 194

[9] Chernov V G 2010 Fundamentals of the theory of fuzzy sets Textbook. allowance Vladimir State un-t (Vladimir: Publishing house Vladimir state University) p 96

[10] Pivovarov K N and Zolotukhin A B 2018 The use of the multicriteria approach and fuzzy mathematics methods for assessing the conditions for the development of deposits in the Arctic seas on the example of the southeastern part of the Barents Sea Arctic [in Russian – Kadastrovaya ocenka sadovyh, ogorodnyh i dachnyh zemel' s uchetom zon s osobymi usloviyami ispol'zovaniya territorij] (Moscow: Ecology and Economics) vol 3 (31) pp 100-111 DOI: 10.25283 / 2223-4594-2018-3-100-111

[11] Demidova P and Gorelikov V 2013 Impact of Common Real Property Land Site Value Unit to Market Value of Non-commercial Horticulture Land in Leningrad Region [in Russian – Vliyanie doli stoimosti zemel'nogo uchastka edinogo ob'ekta nedvizhimosti na rynochnuju stoimost' zemli sadovodcheskikh nekommercheskikh ob'edinenij Leningradskoj oblasti] (Saint - Petersburg: Journal of Mining Institute ) 204 pp 198-202