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Modeling the Cadastral Value of Land Plots of Gardening and Horticultural Non-Profit Partnerships Taking into Account the Influence of Local Factors of the Territory

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Abstract: Concerning the dependence of land taxation on the cadastral or market value of lands in developed and developing countries, the role of land resources in the system of socio-economic development is quite high. World studies show the presence of methodological problems related, among other things, to the composition of price-forming factors of mass assessment. In relation to garden and vegetable garden lands, the issue of taking into account factors related to the immediate environment and soil quality is especially relevant, which is associated with the social justice of land taxation. The current paper aims to determine the influence of factors of the immediate environment and soil fertility on the cadastral value of the lands under consideration by determining which methodological apparatus has been built. Modeling of the specific indicator of cadastral value (SICV) of land plots is performed on the example of five gardening and vegetable gardening partnerships of the Belgorod district, where 79% of the territory is occupied by agricultural lands, which are quite diverse in soil composition, relief, and other studied factors. A linear model of dependence between local factors and the UPCS is proved. The reliability of the model is confirmed by testing for homoscedasticity, autocorrelation, and statistical significance of factors. The results of determining the cadastral value demonstrated an average change of 10%.

Keywords: cadastral valuation; land tax; modeling; soil quality; relief; moisture supply; well; remoteness

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1. Introduction

Natural resources, in the context of the implementation of the concept of sustainable development, determine the system of their modern use on a global scale [1]. The demand for land in the context of human society development is determined by its use in all sectors and spheres of activity, but the main thing is that it is a spatial accumulator of various types of resources and a place for the formation of a favorable human habitat [2,3]. The volumes of land resource consumption are determined not only by their natural properties (fertility, relief, hydrographic, and other conditions) but also by human needs, while socio-economic needs do not arise in isolation but depend on the technical capabilities of society. Economically justified minimization of environmental damage is interconnected with the degree of development of methods for assessing natural resources, the main ones of which are land [4]. When assessing land resources, the issue of determining their cadastral value is especially relevant. This is due to the fact that the cadastral value, which is the result of the state cadastral valuation (GKO) carried out by state budgetary institutions (GBUs), is the taxable base for calculating land tax [5]. This study examines land plots in horticultural non-profit partnerships and horticultural non-profit partnerships (GNPPs and ANPPs,

respectively), which include non-profit associations of citizens for gardening, vegetable gardening, and joint farming. Over the past three years, the number of registered garden plots in the Russian Federation has increased by 30%, and the Union of Gardeners in Russia, based on the assessment results, classifies 60 million citizens into this category [6]. However, according to the agricultural censuses for 2006 [7] and 2016 [8], the area of agricultural land plots in GNPPs and ANPPs in the constituent entities of the Russian Federation was decreasing. At the same time, in many developing countries of the world, the independent cultivation of agricultural products is becoming a necessary source of food, and the agricultural sector provides jobs and income to the population [9]. All this confirms the development of the GNPPs' sphere and, accordingly, this sector of the land market.

In recent years, scientists have also paid attention to the methodological issues of cadastral land valuation. In his works, S.V. Gribovsky suggested improving the system of quality assessment and the methodological apparatus of cadastral valuation of real estate objects [10]. A.V. Sevostyanova, although considering the valuation of lands of populated areas, emphasized the accounting of land rent from fertility [11] since within the boundaries of populated areas, there are agricultural land plots of varying quality. Problems of agricultural land valuation were also studied by A.E. Sagaidak and A.A. Sagaidak. They proposed the solution for Russia in the development of a land market based on auction trade, which will ensure an equilibrium price based on the interaction of supply and demand [12]. Researchers from different countries have suggested using different models and methods for mass valuation. The advisability of using a hedonic model in valuation in Malaysia for making more investment decisions was substantiated by A. Yusof and S. Ismail [13]. Comparing the methods of constructing classical regression models and spatial statistics models, the authors Kim B. and Kim. T. [14], based on the available factual data on transactions, came to the conclusion that geostatistical methods that take into account the presence of spatial patterns in price formation are best suited for valuing land plots and houses located on them in Korea. Considering the complex nature of real estate pricing, as well as the objective difficulties of constructing high-quality valuation models using the classical regression method, a number of researchers proposed using the neural network method to improve the objectivity and accuracy of valuation results. The advantage of using this method in valuation practice is described by Mccluskey W., Davis P., Haran M., Mccord M., and McCilhatton D. [15]. The results of comparing the methods of regression analysis and neural networks in the implementation of mass valuation of various types of real estate are featured in works by Abidoye R. B., Chan Albert P. C., Ghorbani S., and Afgheh S. M. [16,17].

P.M. Sapozhnikov determined the indicators of cadastral value of soils in agroclimatic subzones of agricultural landscapes [18]. S.A. Galchenko, R.V. Zhdanova S.I., and others identified the factors of cadastral value that affect the sustainability and efficiency of land use and, accordingly, land taxation [19]. I.G. Raguzin and T.I. Baltyzhakova paid attention to the issues of accounting for landfills, industrial facilities, and other unattractive objects when calculating the cadastral value. They introduced this factor into the model for assessing the cadastral value of a segment of land plots intended for gardening, vegetable gardening, and low-rise development in St. Petersburg, which improved the quality indicators of the model without taking them into account [20]. The first of the above authors, together with O.Yu. Lepikhina, examined the issues of applying machine learning methods to calculate the cadastral value, which have been successfully implemented in different countries [21], as well as issues of taking into account the availability of social infrastructure for the assessed areas as price-forming factors, using spatial characteristics [22]. N.A. Alekseeva proposed a method of correlation–regression analysis of the cadastral value of land plots, which allows adjusting the prices of the objects of analysis, showing deviations in the cost of land plots, as well as explaining the reasons for underestimation or overestimation of the cadastral value. This subsequently allows for the adjustment of socio-economic policy, optimizing the accrual of land tax to local budgets [23]. A. Bangayan-Manera is of

the opinion that it is necessary to take into account urban planning, environmental factors, and factors associated with the use of land in the cadastral valuation of lands of populated areas [24], and I.S. Dyachkova believes that it is necessary to take into account historical and cultural assessment factors [25]. A. Agosto, using the example of land plots intended for residential construction, identified 11 cost factors, including economic, legal, and quality of life factors [26]. These proposals were expanded by A.L. Zhelyaskov and D.E. Seturidze, having also included social and demographic indicators for agricultural lands [27]. Together, V.N. Berdnikova, A.V. Osennyaya, and B.A. Khakhuk, having examined the socio-economic factors for the territory of Krasnodar Krai, identified the most significant ones, including the level of development of small and medium-sized businesses and the number of people permanently residing in the territory [28]. The team of authors consisting of V.F. Kovyazina, A.A. Kitsenko, and Seyed Omid Reza Shobairi proposed taking into account the degree of infrastructure development as a cost factor for the cadastral value of forest lands [29]. Zhuravlev E.G. and Konovalova E.V. noted the factor "availability of a water body" as significant in relation to lands under individual residential development [30]. From an environmental perspective, T. Fauk and P. Schneider discussed the impact of green spaces on land value, proposing the creation of a unified valuation matrix to determine a standard base value for land [31]. H.R.M. Nisansala and P.C. Kaluthanthri examined a range of factors influencing value to modernize the land valuation process, including access to transportation infrastructure, distance to schools, commercial establishments, hospitals, and urban centers, population, terrain slope, and land-use conditions [32].

Moving away from the controversy of scientists studying the issues of the significance and consideration of various factors influencing the cadastral value of lands of different categories and types of permitted use, it is worth paying attention to alternative author's studies, which deal with factors capable of reducing the cadastral value. For example, E.L. Kuleshova talks about taking into account unfavorable environmental factors, among which she singles out soil pollution [33]. V.S. Gorbunova and others consider radiation, noise, and electromagnetic pollution, including air, soil, and groundwater pollution, among other factors [34]. E.N. Bykowa notes the influence of negative infrastructural externalities on the cadastral value of lands encumbered by security zones caused by the presence of linear objects within the boundaries of such lands [35]. Along with her, a number of authors, including A.A. Varlamova [36], V.Yu. Sutyagina [37], K.E. Senkovskaya [38], and Yu. V. Chernetskaya [39], developed methods that provide for the accounting of encumbrances, including those associated with the presence of security zones within the boundaries of land plots, by introducing correction factors into the cadastral value model.

At the same time, there are currently methodological and practical problems in the field of cadastral valuation of agricultural land and garden land. For example, E. Wójciak and A. Cienciała, in relation to agricultural land in Poland, noted a high degree of correlation between the obtained valuation results and market prices using the index method technology and also highlighted the problem of determining the spread and dimension of correction factors, including the impossibility of fully reflecting the existing development potential of agricultural land [40].

Many authors pay attention to the analysis and influence of various cost factors on the value of the lands under consideration. Thus, based on factor analysis in relation to garden and vegetable garden lands, S.E. Badmaeva and I.S. Andryushchenko identified such hidden price factors as the availability of transport infrastructure facilities, the distance to public transport stops, and the prestige of the area where the facility is located [41]. For agricultural lands, the authors L. Meissner and O. Musshoff noted the influence of soil quality on their value [42]; a similar relationship was proven by J. Choumert for agricultural lands in Argentina [43]. Positive–negative dynamics of changes in the value of land in the province of Huambo, Angola, from such factors as location, market dynamics, the presence of water on the site, proximity to tourist destinations, and physical conditions of agricultural fields, were noted by E. Lote and F.O. Tavares [44]. J. Szturc and V. Hybler, using the Czech Republic as an example, noted the influence of soil quality as a factor

in land valuation on their value, indicating a tendency for land value to increase with the highest soil quality, using the results of soil appraisal [45]. V. J. Burton and others emphasized the necessary consideration of soils and their biodiversity when valuing land in order to increase the objectivity of the results [46]. S. A. Mamantova and O. P. Kolpakova, when performing a cadastral valuation of lands of gardening and vegetable gardening associations, came to the conclusion that it is necessary to take into account individual characteristics of land plots, including the qualitative condition of the soil, and to replace the generalized factor "Landscape and ecological attractiveness" with a combination of several factors [47].

The presented analysis of Russian and foreign studies by the authors in the field of cadastral valuation of agricultural GNPP and ANPP lands allows us to conclude that there are various kinds of problems in the methodological support of the cadastral valuation process, as well as practical issues. For this reason, many authors are making attempts to solve them by proposing methodological developments to improve the current regulations for determining the cadastral value, including proposals for various cost factors that, in their opinion, affect the cadastral value of the lands in question. However, despite the current trend of modernizing the cadastral valuation process, such issues as taking into account local factors when assessing GNPP and ANPP lands, the consideration of which is not provided for by the Methodological Guidelines (Order of Rosreestr dated 04.08.2021 No. P/0336), remain unresolved [48].

2. Materials and Methods

The objective of this study is to determine the influence of immediate environmental factors and soil fertility on the cadastral value of GNPP and ANPP land plots. In this regard, the work substantiates the composition and necessity of taking into account the specified local factors when determining the cadastral value of GNPP and ANPP land plots. Proposals are put forward aimed at changing the calculation scheme for determining the cadastral value, determining the cadastral value of land plots in the segment "Gardening and vegetable gardening, low-rise residential development" using the Belgorod district of the Belgorod region as an example. Analysis of changes in the cadastral value is obtained by the State Budgetary Institution, along with the results of the study.

The objective of the study is to change the model of the SICV composition of cost factors to take into account the factors of the immediate environment and soil fertility in the Belgorod district of the Belgorod region. The scientific novelty of the study lies in obtaining a model for calculating the cadastral value, taking into account the influence of local factors and modifying the methodology for cadastral valuation of GNPP and ANPP lands, which is regulated by methodological guidelines on state cadastral valuation (Order of Rosreestr No. P/0336 dated 8 April 2021), which do not provide for taking into account such factors [48].

The scientific research was conducted based on an integrated approach to solving the set tasks. The review of Russian and foreign scientific studies by the authors was conducted using methods of the theoretical level, including generalization, comparison, induction, deduction, and the hypothesis method. The Avito platform and the data of the report on the results of the cadastral assessment of the State Budgetary Institution of the Belgorod Region were used to collect initial market data. The resulting part of the study was obtained using the functionality and software add-ons of GIS Axioma 6.0, especially in terms of creating GIS projects that visualize the sample and analyze the initial market data. The use of MS Excel add-ons allowed us to conduct correlation and regression analyses and obtain a model of the land SICV.

The territory under study was the Belgorod District of the Belgorod Region of the Russian Federation, where the last state cadastral valuation (GKO) was carried out in 2022, including land plots of the GNPP and ANPP. Among the cost factors of the cadastral value of the land plots of the considered segment, the cadastral appraisers during the GKO took into account the following factors: the distance to the administrative center of the

settlement and the nearest public transport stop, the distance from the settlement to the city of Belgorod and from the settlement to the center of the municipal district, the presence of a central sewerage system and central water supply in the settlement, the population of the municipal district/urban district, and average monthly wages in municipalities, urban districts, and the center of the urban/rural settlement [49].

Modern practice of cadastral valuation of land plots often does not reflect the full picture of their market pricing due to the mass nature of its implementation and failure to take into account many significant factors that could affect the amount of cadastral value [50]. This circumstance often leads to an overestimation of land tax, in connection with which, within the framework of this study, it is proposed to take into account the factors of the immediate environment and soil fertility (local factors) in order to study their influence on cadastral value of lands in the segment under consideration. It is worth noting that local factors can be identified and analyzed specifically in the territory of the assessed land plots or their immediate surroundings; for example, in the territory of GNPP, ANPP, or individual housing construction (IHC), where the market value of land plots in the said partnerships can be formed due to the specifics of the implementation of business, economic, and managerial activities, expressed by a set of price factors influencing their market value. The following local factors are proposed in the work: distance to the railway station in km; soil quality of GNPP, ANPP, and individual housing construction in quality points; relief inside GNPP, ANPP, and individual housing construction, slope in %; the presence of a borehole (well); the distance from solid waste storage sites in m. Along with the above, factors taken into account during the GKO of 2022 will also be considered, including the distance to the nearest populated area, the distance to a reservoir, the distance to the forest, the type of access road surface, and the presence of a capital construction project on the land parcel.

The composition of the factors of the immediate environment and soil fertility is justified from the point of view of pricing on the open land market, as well as the demand and preferences of a potential buyer for the relevant land plots.

Below is a brief justification for each of the factors under consideration.

(1) “Distance to the railway station”.

As the distance of GNPP and ANPP land plots from passenger railway stations increases, the demand for them decreases, which is reflected in the market price. This is due to the need for transport links in the absence of personal vehicles.

(2) “Soil quality within the partnership”.

The quality of soils for the considered intended purpose of land plots (Federal Law (FL) No. 217-FZ dated 29 July, 2017) the cultivation of basic agricultural crops [51], which in turn provides the population (owners of GNPP and ANPP land plots) with personal food products, constituting an important cost factor of the cadastral value. This is due, among other things, to the need to withdraw part of the differential land rent of the first type through land taxation. Demand in the land market also reacts to the quality of the soil, which is associated with the possible economic consequences of its decline due to negative degradation processes such as erosion, swamping, flooding, etc.

To study the influence of this factor, GNPP and ANPP located in territories with different types of soils are used in the following work (see Figure 4). Figure 1 shows the location of GNPP "Domostroitel" in the Belgorod region.

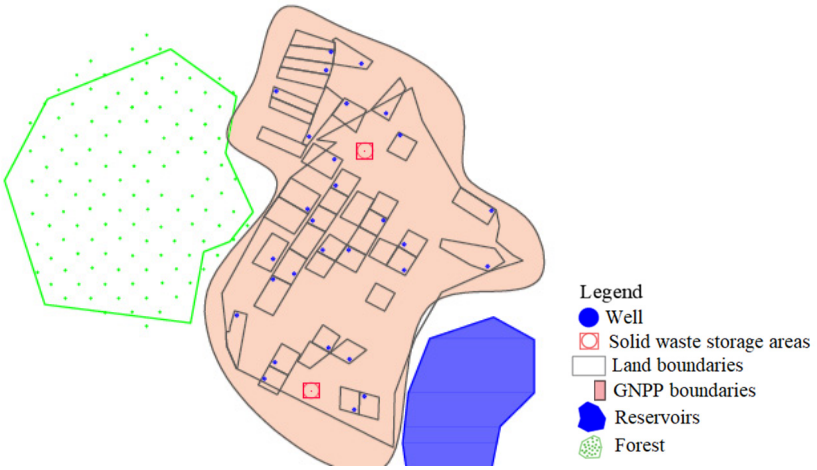


Figure 1. Location of GNPP "Domostroitel" within the boundaries of the Belgorod region [52].

(3) "Relief inside the partnership". The layout of the territory, including the placement of capital construction projects (residential buildings, non-residential buildings), as well as engineering infrastructure facilities (pedestrian paths, local sewerage, gas networks, boreholes, wells, etc.), depends on the terrain of the territory of GNPP and ANPP land plots. This, in turn, can differentiate the future costs of the land owner, reducing them with favorable terrain and increasing them with unfavorable terrain (flooded lowlands, sharp difference in heights on one site), which will accordingly affect pricing on the land market. Figure 2 shows the terrain within the boundaries of the territory of GNPP "Domostroitel" [53].

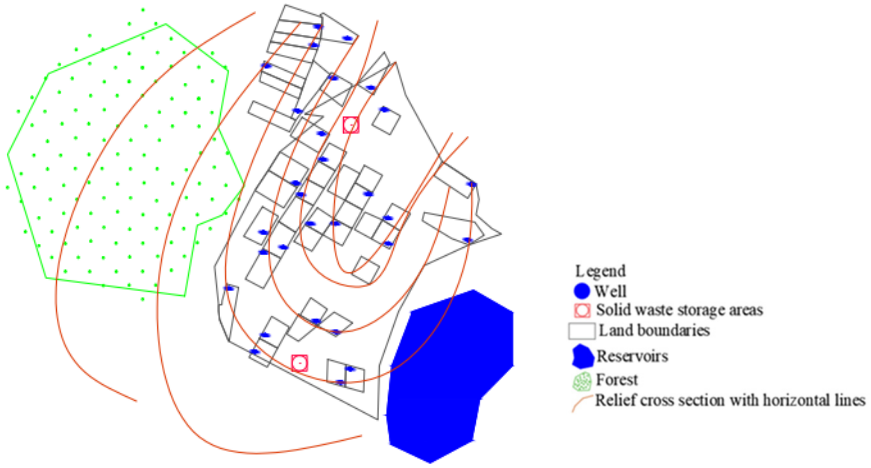


Figure 2. Relief within the boundaries of GNPP "Domostroitel", Belgorod region [53].

(4) "Availability of a well (water well)". Water supply affects both the provision of economic (irrigation of agricultural crops) and domestic needs (drinking, sewage) [54]. The presence of water supply sources on a land plot changes the demand and prices on the land market towards an increase.

(5) "Remoteness from solid waste storage areas".

For the territory of GNPPs, ANPPs, or cottage villages, there are always places for waste and garbage storage. If the site is located further from solid waste storage sites, it will be more attractive to potential buyers [55], which is due to the absence of possible negative consequences in the form of air, soil, water, green space, and other components of natural environment pollution. At the same time, environmental issues are particularly relevant at present, where many Russian researchers are engaged in issues of assessing the current

state of natural components, such as soils and green space, offering various solutions of both theoretical and practical significance [56–58].

Based on the preliminary substantiation of the composition of factors of the immediate environment and soil fertility, a hypothesis was put forward about the need to take them into account when determining the cadastral value of land plots of GNPPs, ANPPs, and individual housing construction.

Figure 3 shows the algorithm of the methodology that takes into account the specified local factors in the system of cadastral valuation of land plots of GNPPs, ANPPs, and individual housing construction.

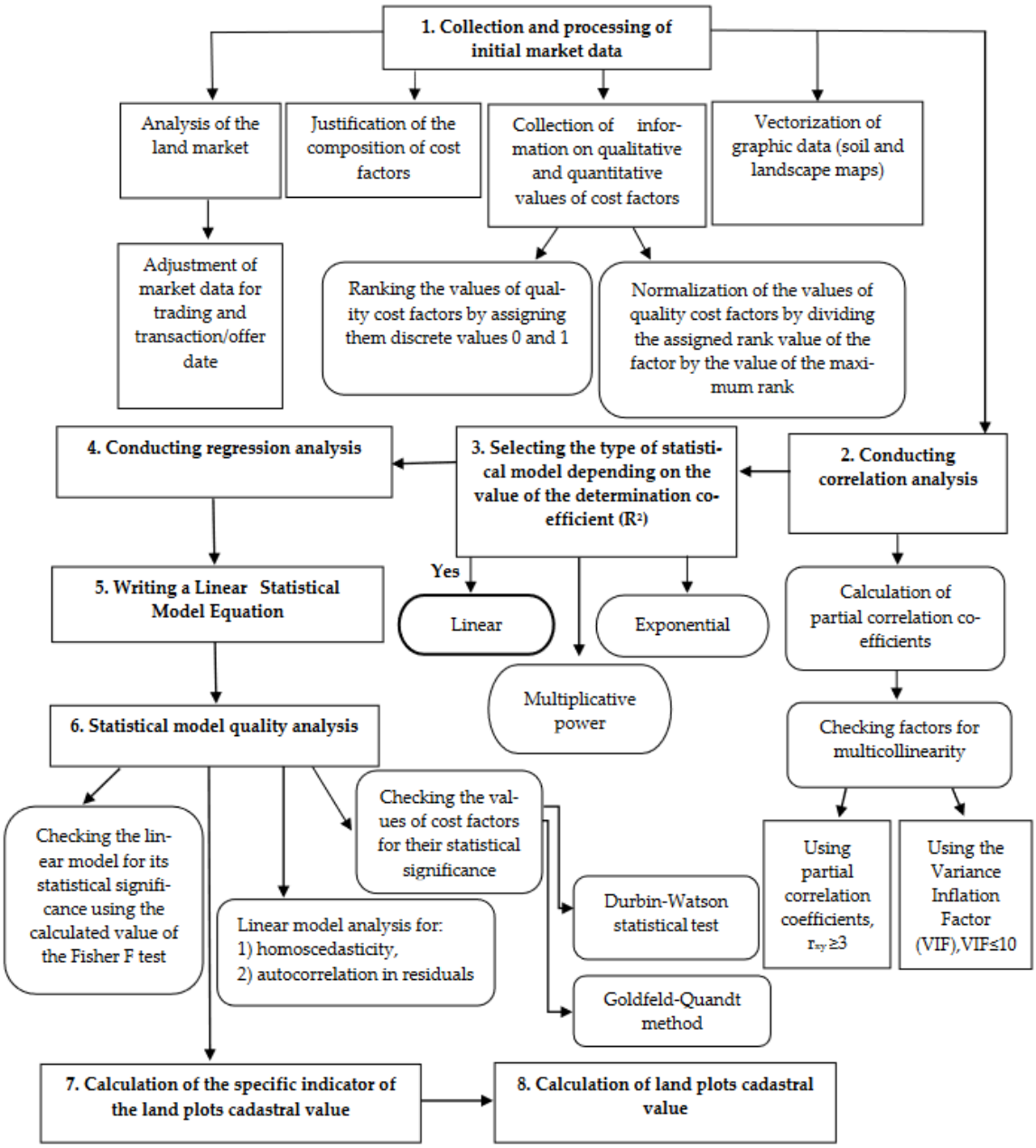


Figure 3. Algorithm for calculating the cadastral value of land plots for GNPPs, ANPPs, and individual housing construction.

The study was conducted in several stages. In the process of collecting initial market information on transactions and offers, a sample of 350 land plots of the type of permitted

use under consideration was prepared, located within the boundaries of 5 GNPPs of the Belgorod District of the Belgorod Region.

During the second stage of the study, a GIS project was prepared based on satellite images and an in-kind survey of the territory to determine, using MapInfo functions, the values of location factors determined by accessibility in m or km. Landscape and soil maps were used to determine the types of soils within the boundaries of the assessed territories and the features of the relief structure. The value of the cost factor "Soil quality inside GNPP, ANPP, IHC" was assigned based on the materials of NPO GeoGIS LLC. According to these data, leached chernozems, dark gray forest chernozems, typical chernozems, and gray forest chernozems with site quality scores of 60, 58, 62, and 55, respectively, occur in the territories of GNPPs, ANPPs, and IHCs [59]. The results determining the soil quality scores of soil types within the boundaries of the study areas were obtained by superimposing a vectorized soil map of the region and a GIS project with the boundaries of land plots and GNPPs, ANPPs, and IHCs (see Figure 4).

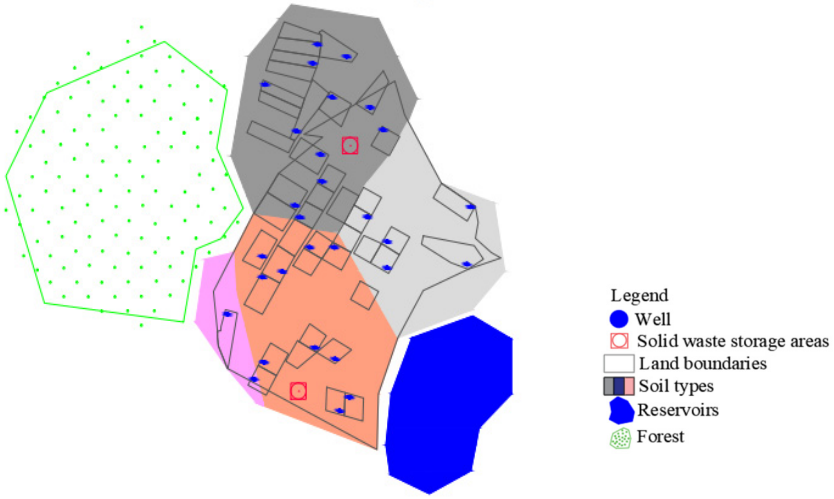


Figure 4. Overlay of GNPP "Domostroitel" on the soil map of the Belgorod region.

In the third stage, initial market data were analyzed using MS Excel add-ins. It should be noted that the analyzed local factors were divided into quantitative and qualitative factors, where the values of the latter were specified discretely, using dummy variables with values from 0 to 1, based on the absence or presence of a feature, respectively. The factor values were ranked by dividing them into ranges of factor values and assigning ranks (ordinal numbers) to them. Ranking was carried out in relation to factors such as "Relief inside GNPP, ANPP, and IHC", "Availability of a well (water well)", and "Type of public road surface" by assigning their discrete values (0 or 1) and normalizing the values of the indicators by dividing the rank value of the factor by the value of the maximum rank. Taking into account the existing differentiation in the initial market data, it was necessary to make several types of adjustments for the trade and date (transactions, offers). However, the adjustment of the date of the transaction/offer was calculated quarterly due to the small dynamics of offers during the exposure period.

During the fourth stage, the significance coefficients were calculated, and the factors were tested for multicollinearity using two methods: partial correlation coefficients and variance inflation coefficients. Partial correlation coefficients are determined by the following formula:

$$r_{xy(z)} \frac{r_{xy} - r_{xz} \cdot r_{yz}}{\sqrt{(1 - r_{xz}^2) \cdot \left(1 - r_{yz}^2\right)}}, \quad (1)$$

where r_{xy}, r_{xz}, and r_{yz} are the partial correlation coefficients of the studied variables.

The variance inflation factor (VIF) is calculated using the following formula:

$$\mathrm{VIF} = 1/(1 - \mathrm{R}_i{}^2), \tag{2}$$

where $\mathrm{R}_i{}^2$ is the coefficient of determination of the *i*-regressor.

It is generally accepted that if the value of a factor is (VIF > 10), then such a factor is excluded since its presence can lead to multicollinearity.

At the same time, the presence of multicollinearity between factors indicates the use of factor characteristics that are constituent elements of each other. In the case of revealing the presence of multicollinearity between factors, one or more dependent variables can be excluded by means of a simple method. However, in practice, the exclusion of a factor may not always depend on the value of the correlation coefficient obtained as a result of correlation analysis, but, for example, due to the peculiarities of market pricing and the logical justification of existing information [60].

The next stage was a regression analysis using the MS Excel add-in "Data Analysis—Regression". Based on initial market data, three regression models were constructed (multiplicative (power), linear, and exponential), among which the value of the determination coefficient (R^2) was the highest for the linear model, in connection with which it was preferred for further modeling of the cadastral value of land plots:

$$y = f(x_1, x_2, \ldots x_p), \tag{3}$$

where (x_i) are independent variables of land plot characteristics, and (y) is a dependent variable (market value of land plots).

It should be noted that each cost factor was introduced into the model sequentially [61], where during the next stage of factor introduction, the quality of the model was checked, taking into account the values of such indicators as t-statistics (t > 3) and F significance ($\alpha = 0.05$), provided that the specified reliability of the model was not exceeded.

At the same time, it was necessary to check the regression model for compliance with the normal distribution law, provided that the values of statistical significance should not be greater than ($p < 0.05$) for each cost factor included in the model. After that, the resulting model of future cadastral values was analyzed for homoscedasticity using the Goldfeld–Quandt method and autocorrelation in the residuals was checked. When using the Goldfeld–Quandt method, it was necessary to perform the following steps:

(1) Ordering observations by one of the factors;

(2) Exclusion of the population (C) of central observations subject to the following condition:

$$\frac{n - m}{2} > p, \tag{4}$$

where p is the number of parameters being estimated, (C) is the set of central observations, and n is the number of factors;

(3) Dividing the remaining observations into two equal sets and constructing paired linear regression models;

(4) Determining the residual sums of squares for each of the groups (S_1, S_2) and determining their ratio for testing the direct and inverse dependence of the dispersion of the residuals on the square of the factor:

$$F_{\mathrm{obs}} = \frac{S_1}{S_2}, \tag{5}$$

where S_1 and S_2 are observation groups.

It is important to specify the condition of the null hypothesis of homoscedasticity, which is satisfied if the ratio F_{obs} (5) satisfies F_{crit} degrees of freedom for each residual sum of squares [62]:

$$\frac{n - \mathrm{C} - 2p}{2} > p. \tag{6}$$

As was said earlier, 350 observations were carried out in the study, among which 150 central observations were excluded, and 2 groups of 100 observations were considered. For each of the groups of observations, linear regression models were built, and preference was given to those undergoing the stage during which regression analysis and regression coefficients were determined (see Table 1). After that, the values of the SICV of land plots of the considered segment were determined, and their cadastral value was calculated using a sample of plots of GNPP "Domostroitel" in the Belgorod region.

3. Results

In accordance with the methodology for determining the cadastral value of land plots of the segment under consideration, taking into account local factors, 350 similar objects were taken, which corresponded to the conditions of representativeness of the sample.

Based on the presented sample of similar objects, the values of the significance coefficients were calculated using the MS Excel add-in "Data Analysis—Correlation", and a check of factors for multicollinearity was performed, the results of which are presented in Table 1.

Table 1. Checking factors for multicollinearity.

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
Y	1										
X_1	0.995	1									
X_2	0.086	0.090	1								
X_3	−0.022	−0.023	0.117	1							
X_4	0.039	0.032	0.044	0.049	1						
X_5	0.291	0.290	−0.026	−0.100	−0.014	1					
X_6	−0.211	−0.209	0.075	0.104	0.041	−0.806	1				
X_7	−0.058	−0.058	0.009	−0.008	−0.008	−0.183	0.096	1			
X_8	−0.146	−0.139	0.010	0.048	−0.089	−0.523	0.499	0.209	1		
X_9	−0.234	−0.243	−0.072	0.020	0.096	−0.626	0.483	0.054	0.284	1	
X_{10}	−0.419	−0.409	0.039	0.092	0.021	−0.816	0.785	0.109	0.484	0.478	−1

X_1—distance to the nearest settlement; X_2—distance to the reservoir; X_3—distance to the forest; X_4—type of driveway surface; X_5—distance to a railway station; X_6—soil quality inside GNPPs, ANPPs, and individual housing construction; X_7—relief inside GNPPs, ANPPs, and individual housing construction, slope; X_8—availability of a capital construction project on the land plot; X_9—availability of a well; X_{10}—distance from solid waste storage areas.

Checking the factors for multicollinearity showed a strong correlation between the factors: the values of (X_5), (X_6), and (X_{10}) were above 0.75. The identified relationship may indicate an erroneous distribution of factor values since the identified factors are not related to each other from the point of view of market pricing and a logical explanation of the current market situation on the assessment date [63].

Since the previous test showed multicollinearity between factors that is not related to logic and research, a test was conducted to determine the variance inflation factor (VIF). The results of the test are presented in Table 2.

Table 2. Results of VIF calculation for factors.

Factor Name	VIF Value
Distance to the nearest settlement (X_1)	9.067
Distance to the reservoir (X_2)	1.112
Distance to the forest (X_3)	1.325
Type of driveway surface (X_4)	1.069
Soil quality inside GNPP, ANPP, individual housing construction (X_6)	1.034
Relief inside GNPP, ANPP, individual housing construction, slope (X_7)	1.169
Availability of a well (X_9)	1.125
Distance from solid waste storage areas (X_{10})	1.217

Since, according to Table 3, the value of the VIF coefficient for all factors under consideration is less than 10, the factors included in the model are not multicollinear.

Table 3. Results of regression analysis.

Regression Statistics				
Plural R	0.99			
R-squared	**0.99**			
Normalized R-squared	0.99			
Standard error	1.34			
Observations	350			
	Coefficients	**Standard error**	**t-statistics**	***p*-meaning**
***Y*-intersection**	44.863	2.540	17.663	0.000
Distance to the nearest settlement (X_1)	4.327	0.025	174.252	0.000
Distance to the reservoir (X_2)	0.115	0.033	0.443	0.027
Distance to the forest (X_3)	0.011	0.027	0.403	0.018
Type of driveway surface (X_4)	0.247	0.191	1.292	0.019
Soil quality inside GNPPs, ANPPs, and individual housing construction (X_6)	0.079	0.047	1.665	0.030
Relief inside GNPPs, ANPPs, and individual housing construction, slope (X_7)	0.033	0.156	0.215	0.023
Availability of a well (X_9)	0.441	0.179	2.461	0.014
Distance from solid waste storage areas (X_{10})	−4.491	1.208	−3.718	0.000

The next stage was a regression analysis, where the factors with the highest value of the pair correlation coefficient (0.995) were included first. Then, by alternately including each of the presented factors in the model, their final set was selected. In this case, the criteria for selecting factors in the final model were the values of the determination coefficient (R^2), the average approximation error, the Student's t-criterion, and the calculated value of the Fisher F-criterion, which are responsible for the quality of the cadastral value model. However, it is worth noting that if the value of the determination coefficient decreased when including the next factor in the model, it was subject to exclusion in order to avoid deterioration in the quality of the constructed model. As a result of the regression analysis, only eight factors out of ten turned out to be significant, which is due to the change in the value of the coefficient of determination (R^2) within the range from 0.73 to 0.99, which reflected the high significance of the model and its adequacy from the point of view of the features of market pricing. Thus, the following factors were included in the final regression model: X_1, X_2, X_3, X_4, X_6, X_7, X_9, and X_{10} (see Table 3).

In accordance with the data presented in Table 3, a linear statistical regression model equation was constructed:

$$Y = 4.327 \cdot X_1 + 0.115 \cdot X_2 + 0.011 \cdot X_3 + 0.247 \cdot X_4 + 0.079 \cdot X_6 + 0.033 \cdot X_7 + 0.441 \cdot X_9 - 4.491 \cdot X_{10} + 44.863, \quad (7)$$

where Y is SICV, X_1 is the distance to the nearest settlement, X_2 is the distance to the reservoir, X_3 is the distance to the forest, X_4 is the type of driveway surface, X_6 is the soil quality inside GNPPs, ANPPs, and individual housing construction, X_7 is the relief inside GNPPs, ANPPs, and individual housing construction, including slope, X_9 is the availability of a well, and X_{10} is the distance from solid waste storage areas.

Substituting the values of cost factors into the model when determining the SICV should be performed in a standardized form.

After constructing the model, it was necessary to check it for statistical significance, the results of which are provided in Table 4.

According to the data in Table 4, the value of "Significance F" did not exceed the reliability of the model ($\alpha = 0.05$). Then, the values of cost factors and market prices of similar objects were checked for compliance with the normal distribution law, the results of which are presented in Table 5.

Table 4. Results of statistical significance of the model.

	df	SS	MS	F	Significance F
Regression	8	70,402.63	8800.329	4918.044	0.000
Remainder	341	610.18	1.789		
Total	349	71,012.82			

Table 5. Results of statistical significance of factors.

	p-Value
Y-intersection	0.00000000
Distance to the nearest settlement (X_1)	0.00000000
Distance to the reservoir (X_2)	0.02725312
Distance to the forest (X_3)	0.01821540
Type of driveway surface (X_4)	0.01932121
Soil quality inside GNPPs, ANPPs, and individual housing construction (X_6)	0.03024612
Relief inside GNPPs, ANPPs, and individual housing construction, slope (X_7)	0.02314561
Availability of a well (X_9)	0.01424323
Distance from solid waste storage areas (X_{10})	0.00000010

The test of the regression model for homoscedasticity confirmed the hypothesis of homoscedasticity since $F_{obs} < F_{crit}$ (see Table 6). Such a test of the model indicates its reliability and the high level of the data obtained. To test the model for autocorrelation in the residuals, the Durbin–Watson statistical criterion was used since the regression model equation contains a free term. The test results are presented in Table 6.

Table 6. Results of residual sums of squares, Fobs, and Durbin–Watson tests.

Indicators	Value
I-group (S_1)	1068.850
II- group (S_2)	3522.230
F_{obs}	2.623
F_{crit}	2.768
D_{obs}	1.523
D_1	1.100
D_2	2.100

Next, the values of the SICV were calculated by substituting each of the factors selected at the stage of regression analysis into the equation of the linear regression model (see Table 7).

Table 7. Results of determining the SICV of land plots.

No	CN	*X*1	*X*2	*X*3	*X*4	*X*7	*X*9	*X*10	*X*6	S_{lp}	$Y_{(mar)}$	SICV $_{2022}$	SICV $_{new}$	SICV $_{new}$ —SICV $_{2022}$
1	31:15:0111011:22	6.575	1.087	3.392	0	0	0	0.08	58	759	76.568	63.59	76.740	−13.15
2	31:15:0111011:23	10.301	9.022	5.048	0	1	1	0.3	60	987	94.280	63.59	94.169	−30.58
3	31:15:0111011:24	2.930	4.708	1.844	1	0	0	0.3	58	522	60.701	63.59	62.851	0.739
4	31:15:0111011:26	0.905	1.903	3.344	0	1	0	0.3	60	400	51.845	63.59	56.944	6.65
5	31:15:0111011:27	2.066	1.364	1.016	0	0	0	0.3	60	467	56.765	63.59	57.343	6.25
6	31:15:0111011:28	5.090	4.219	2.732	1	0	0	0.3	60	605	69.803	63.59	71.047	−7.46
7	31:15:0111011:29	0.743	8.136	0.752	0	0	0	0.3	60	386	57.995	63.59	54.129	9.46
8	31:15:0111011:3	1.121	3.606	2.408	1	0	0	0,3	60	600	66.482	63.59	57.664	−5.93
9	31:15:0111011:30	5.630	4.689	2.972	0	0	0	0.3	58	671	72.263	63.59	70.461	−6.87
10	31:15:0111011:31	7.358	1.573	5.576	1	0	0	0,1	58	800	80.258	63.59	82.619	−19.03
...														

In order to visualize the results obtained for determining the cadastral value of land plots, an estimated zoning of the studied territory of GNPP "Domostroitel" was performed based on the SICV value. The range of SICV values varies from RUB 53 to 103/sq.m. The

results of the assessment zoning confirmed the hypothesis regarding the influence of factors of proximity and soil fertility on the market value of land plots since land plots located within the boundaries of soils with a high bonitet score have high SICV values compared to land plots located within the boundaries of the least fertile soils. Similarly, land plots located far from solid waste storage sites have higher SICV values compared to land plots located within walking distance of solid waste landfills (see Figure 5).

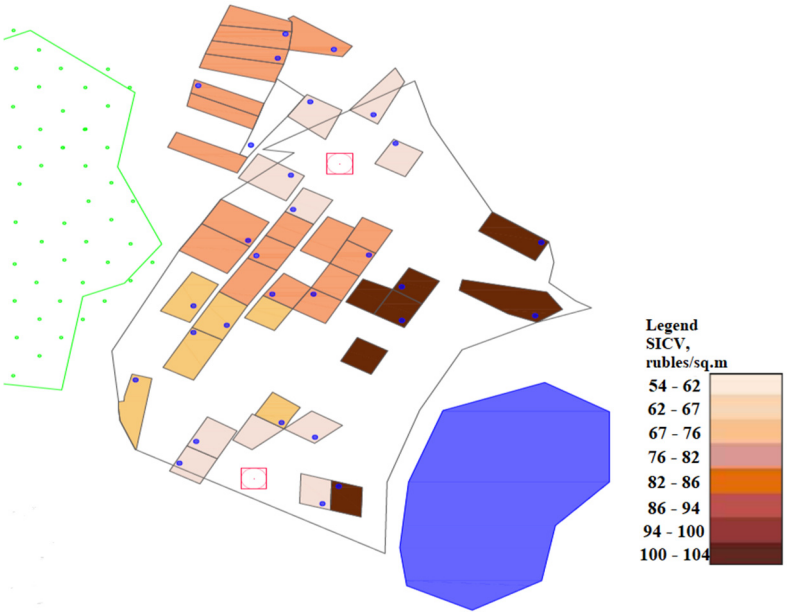


Figure 5. Zoning of the territory of GNPP "Domostroitel" according to SICV, taking into account the influence of local factors.

Taking into account the data presented in Table 8, the cadastral value of land plots was determined as the product of the SICV and the area of the land plot (see Table 8).

Table 8. Results of determining the cadastral value of land plots.

No	CN	S_{lp}	$SICV_{2022}$	CV_{2022}	$SICV_{new}$	CV_{new}
1	31:15:0111011:22	759	63.59	48,264.81	76.740	58,245.66
2	31:15:0111011:23	987	63.59	62,763.33	94.169	92,944.80
3	31:15:0111011:24	522	63.59	33,193.98	62.851	32,808.22
4	31:15:0111011:26	400	63.59	25,463	56.944	22,777.60
5	31:15:0111011:27	467	63.59	29,696.53	57.343	26,779.18
6	31:15:0111011:28	605	63.59	38,471.95	71.047	42,983.44
7	31:15:0111011:29	386	63.59	24,545.74	54.129	20,893.79
8	31:15:0111011:3	600	63.59	38,154	57.664	34,598.40
9	31:15:0111011:30	671	63.59	42,668.89	70.461	47,279.33
10	31:15:0111011:31	800	63.59	50,872	82.619	66,095.20
...						

The proposed composition of local factors and the algorithm of the cadastral valuation methodology, taking them into account, made it possible to obtain cadastral value values in the amount of the market value of land plots in the segment under consideration.

4. Discussion

As a result of regression analysis, a model of the cadastral value of land plots was obtained. The results of the analysis of the statistical significance of the model (Table 5) indicate the high reliability of the results, the absence of randomness, and the presence of a pattern (Significance F < 0.05). All factors included in the model have a statistically

significant relationship with cost since (p-value < 0.05). Analysis of the regression model for homoscedasticity and autocorrelation in the residuals showed the reliability of the data obtained. In the model, the value of the coefficient X10 turned out to be negative (−4.491), which fully explains the dependence of the cost of land plots with increasing distance from solid waste storage sites. Analyzing the model, it is worth noting that such local factors as the quality of soils inside the GNPP, the topography inside the GNPP, and the type of access road surface turned out to be statistically significant, along with the factors of territorial accessibility and engineering support of the territory.

The obtained model of cadastral value was tested on land plots of GNPPs, ANPPs, and IHCs in the Belgorod district of the Belgorod region. The implementation of the obtained model reflected the difference in the cadastral value from the market value of the land plots under consideration. The range of the difference varied from 7.8% to 16.7% for all analyzed GNPPs. At the same time, the difference between the market value and the cadastral value determined within the framework of the next round of the GKO of 2022 amounted to 35%, which indicates the effectiveness and reliability of the methodology proposed in this study.

When comparing the results of determining the cadastral value within the framework of the study and the cadastral value determined based on the results of the GKO of 2022, a change in the determination coefficient (R^2) of the regression model from 0.73 to 0.99 was noted. The results of determining the cadastral value showed its change by an average of 10%.

5. Conclusions

Based on the above material, we can present the following conclusions.

Firstly, being one of the types of raw materials, land resources represent the basis for the future development of the country, which requires effective public administration [64]. In the environment of a state's market economy, such resources are one of the types of economic assets and, at the same time, a strategic resource on which the food security of the entire country depends [65], ensuring the functioning of the revenue side of local budgets. In this regard, the market and cadastral valuation of land resources should reflect the accuracy, reliability, and effectiveness of existing regulations for its implementation, which is due to the need to obtain objective results, for example, the cadastral value of such resources, the value of which, in accordance with the established trend of market pricing, should be in the range of market value.

Secondly, the composition of local cost factors is substantiated both from the point of view of demand and preferences of potential buyers and from the point of view of the pricing system on the open land market. The specified factors of the immediate environment and soil fertility according to the results of modeling the SICV of land plots of GNPPs, ANPPs, and IHCs turned out to be significant and influenced market pricing and, therefore, should be taken into account when determining the cadastral value as the taxable base for land tax.

Thirdly, the obtained model has limitations in its application only for the assessment of land plots of GNPP of the Belgorod region, which is associated with the locality of land markets in certain territories of municipalities. The composition of price-forming factors of cadastral value in other markets may change, but the technology of their accounting is applicable in the conditions of an active land market.

Fourthly, among the justified cost factors included in the calculation model of the SICV, the study included such local factors that are grouped into factors of the immediate environment, described by the distance to a water body, forest, or settlement, and factors characterizing the pavement of the access road, availability of a well (water well), and factors characterizing the quality of soils, which include the type of soil and relief inside GNPPs, ANPPs, and IHCs. The factor of distance from the places of storage of solid waste was ambiguous in this classification since it is also a factor of the immediate environment, which is reflected in the potential attractiveness of land plots for buyers. It is also a factor of soil fertility, which is due to the possibility of negative environmental consequences.

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