Integrated modeling for assessing the rational use of agricultural land

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Abstract. The article discusses the possibility of using integrated modeling to determine the rational use of agricultural land. Models for agricultural land, agricultural production buildings and settlements were developed. The principles of social and economic assessment of the use of territories by the level of their capitalization were described. The models reflect the state of territories and their individual components when making decisions on investment to ensure sustainable development of the territory. Scientific and technological progress and innovations are changing the ratio in the resource provision of the constituent territories, creating an imbalance in the resources of its elements, which develops the system. Violation of the “reference” distribution of resources of the model’s layers causes instability, excessive or insufficient resources determining the control subject of the area. The materials make it possible to supplement the theoretical provisions on land management, including the introduction of an indicator of socio-economic development of the territory; capitalization ratios of the individual components of the territory, reflecting the essence of the territory as a land resource with improvements, taking into account the share of each participant in the reconstruction of the territory, which integrates the harmonious state of the territory as a spatial-territorial system.

1. Introduction

For developed countries, including Russia, land ownership and land relations have always been determining factors in their socio-economic development. Land reforms has become the basis for new social relations in market conditions. In the early 1990s, land reforms became the basis for denationalization of land ownership and reorganization of territories through land redistribution between various businesses. Elimination of the public land ownership monopoly, land privatization aimed at creating a multi-structure economy and transferring land to efficient business entities required the reconstruction of territories. However, the lack of fundamental regulatory documents defining the main provisions on land management, the law on land management and a clear public land policy led to the fact that during this period only current tasks of land redistribution were solved. At the same time, the volume of on-farm land management works aimed at improving economic efficiency and rational use of land decreased, and issues of land redistribution were resolved without determining ways of its effective and rational use.

Over this period, the structure of land ownership, primarily agricultural land ownership, changed. The area of agricultural land decreased due to intensive, non-rational development of agricultural territories. According to the 2006 All-Russian Agricultural Census, the disposal of agricultural land was...
41.5 million ha [1, p. 12]. The area of agricultural land increased by 2.5 million hectares due to shrubs and light forests [2]. The organization of agricultural enterprises and agricultural technologies changed significantly. Investors understood that without land management, economic methods for assessing the rational use of land, it was impossible to organize the efficient use of territories.

This situation contributed to the development of land management projects. As a result of these works, shortcomings in the land management due to poor redistribution of land resources between business entities were identified.

First of all, the basic functions of land management were lost. Negative consequences are still an obstacle to the economic development. As a result of the current policy, stability of land management and principles of territorial organization were violated [3].

To change this situation, it is necessary to improve the land legislation on land management, regardless of their category, using unified land management methods [2, 4].

On November 8, 2018, Prime Minister D.A. Medvedev signed the “Plan of Measures to Improve the Legal Regulation of Land Relations”, which provides for the replacement of the concept “land category” with the concept of “territorial zoning” with subsequent determination of the type of permitted use. This plan is aimed at using land management methods throughout the country, regardless of the category of land. However, the draft law “On Land Management” leaves the zone for the use of land management methods only for agricultural land and excludes the concepts “rational use” and “economic assessment of land management”, which is contrary to the national spatial development strategy until 2025 and the sustainable development of territories. The general principles of spatial development of the Russian Federation ensure integrity of the territories; socio-economic development of territories; an integrated approach to the socio-economic development of each type of territories; rational nature management.

Land management of territories is the basis of socio-economic relations; therefore, it performs one of the most important functions - the reflection of integral living conditions of people through the level of development of the spatial and territorial system where land is a system-forming basis. To determine sustainability and the development level for the spatial system, it is necessary to use a quantitative socio-economic indicator of land management and development of the territory, which belongs to the scientific category - an integrated economic and social system.

2. Literature review

The organization of municipal territories has determined the basis for modern formation of territories of rural settlements through inter-farm and intra-farm land management. The main goal of land management of agricultural (agricultural) lands is organization of its rational use and protection. This goal is achieved by such arrangement of the territory, which contributes to the economic efficiency of agricultural activities of economic entities. Therefore, when assessing and conducting land management works on the construction of agricultural land, the most important condition is to take into account the diversity of natural conditions, agroecology, intensity of agricultural production, anthropogenic characteristics taking into account the economic conditions created by the government.

The usefulness of agricultural lands was determined by soil fertility and expenditures of the agricultural producer for growing, processing and delivering agricultural products to the consumer. Identification of the value of agricultural land for rural business entities is the basis of economic assessment of these lands.

Existing methods for assessing agricultural land are used to determine the value of agricultural land. There is no single method of assessment. The methods depend on the availability of information on soil fertility and assessment purposes. The existing methods involve the calculation of profit from agricultural activities capitalized according to the capitalization coefficient or the calculation of the cost of land by comparative weighting coefficients for land fertility. The empirical coefficient of the land share in agricultural income, the rent value established by the administration and the land capitalization coefficient obtained by the expert method are used, which makes estimates subjective. Land relations are regulated by regulatory coefficients. The main purpose of assessments is to determine the tax base. Therefore, the capitalization ratio is established by the fiscal authorities, the rental income is taken as a
value of income. This approach to the assessment of agricultural land allows the comparative assessment of various farms, but does not determine the value of land and does not identify the object and subject of management to improve the rational use of land.

When conducting land management works, economic calculation is carried out to determine the ratio of areas of agricultural land to lands used for placing buildings. These works are based on the optimal farm structure in accordance with agricultural activities and the technical level of agricultural production [5]. However, these methods lack cost characteristics of land plots, but the undoubted advantage is a comprehensive approach to the economic analysis of agricultural production, which allows successful land formation.

The economic analysis of effectiveness of land management was proposed by A.V. Chayanov. This method is based on the change in the level of land capitalization, which is the most progressive vision for assessing the effectiveness of agricultural land. Unfortunately, the level of capitalization of territories is considered as capitalization of land rent using the same capitalization rate established before and after land surveying i.e. the method is reduced to determining the increment of land value due to changes in rents and external economic conditions. This method does not exclude the subjectivity of assessment and does not reveal the influence of components of the territory on the level of its capitalization.

The use of existing land valuation methods oriented to market information creates results that are far from reliable and contradict the principles of social and economic usefulness of agricultural territories. A quantitative indicator reflecting sustainability of territorial development has not yet been determined. Therefore, these problems are being studied by the scientific community.

3. Results

This article discusses the possibility of using integrated modeling to determine the rational use of agricultural land.

The complex modeling assumes the presence of components in a holistic system whose functionality is opposite in terms of resource consumption and production [6]. The harmonious state of the complex system is determined by the equilibrium ratio of multidirectional resources of the components subordinate to the same goal. In addition, complex modeling includes an active element - a person who changes the structural balance of the system due to scientific and technological progress. The fundamental principles of integrated modeling correspond to the features of an integrated spatial - territorial system.

A comprehensive model was developed for built-up areas taking into account the evolution of urban development [7]. In [8], the model of a complex object of conversion (COTR) was formed, the properties of the facility model were identified.

The scope of this model was expanded, and [9] showed the functionality of this model and the significance of the “territory” layer in ensuring structural homogeneity of the model. The infographic COTR model is shown in Figure 1.

| Consumer products                  |
|-----------------------------------|
| Territory Products                |
| Equipment of buildings, structures of the territory |
| Technological platform of the territory |
| Buildings and facilities of the territory |
| Engineering and transport networks and communication system of buildings, structures of the territory |
| Territory (geographical location, natural resources, climate, human resources, etc.) |

**Figure 1.** The COTR model.
The model contains a recurrent dependence of its layers in mutual directions (from bottom to top, from abstract to concrete, and from top to bottom, from specific needs of inhabitants to peculiarities of territories). The criterion of rational integrated development of territories is determined through the level of its capitalization. Using these models, the method was developed for calculating the capitalization coefficient for a land plot [8]. Moreover, these works showed that changes in each layer determine the level of capitalization, which acts as an indicator of feasibility of the investment project.

To develop objective methods for assessing the value of agricultural land by the estimated value of the capitalization coefficient, a complex land management model (CLMM) based on the COTR model was developed. In contrast to the COTR model which considers the territory with an already formed land plot (layer 7 of this model is considered as a single component (geographical location, natural resources, climate, human resources, etc.)), in the land management model this layer is divided into the component "land" and system elements - "land management" in accordance with the need for their implementation [10]. Depending on the functional purpose of the territories, the content of this model changes, preserving the structure and functional significance of each system layer. As a result, the triple CLMM model was developed. The triplicity is due to its structure. The land management model of the territory is presented in the unity of three worlds. The first inert world is land and the gene component of development of the world as a whole; the second world is a person who transforms the world by creating material artificial objects, which influence his spiritual development; the third artificial (material) world is created by human labor to meet human needs. The components of the model are system layers.

The generalized complex triple model of the territory, including the organizer of territorial reorganization, the land management model and the model of a system of executors of the project of reorganization of the territory (SET) is presented in Figure 2.

| SET                | CLMM                      |
|--------------------|---------------------------|
| Investor 8         | Consumer products (CP)    |
| Investor 7         | Territory Products (TP)   |
| Investor 6         | Object functionality (OF) |
| Investor 5         | Territory objects (TO)    |
| Investor 4         | Technological platform of the territory (TPT) |
| Investor 3         | Engineering and transport networks (ETN) |
| Investor 2         | Territory use form (TUF)  |
| Investor 1         | Territory organization form (TOF) |

Figure 2. Integrated triple territory model.

The arrangement of the territory is carried out by the organizer, who designs the interaction of various structural layers of this model and activities of the project executors [8]. In this model, there is a recurrence dependence of each system layer (from top to bottom), and a dependence of executors from bottom to top.
For agricultural land, this model is transformed into a territory model for agricultural land and a model for agricultural production buildings and settlements. In these models, the system layers of the model are replaced by layers inherent in lands of a certain category. The transformation of the models is presented in Figures 3, 4 and 5.

| Generalized system layers | System layers of agricultural land |
|---------------------------|-----------------------------------|
| Consumer products (CP)    | Consumer products (CP)            |
| Territory Products (TP)   | Seed material (SM)                |
| Object functionality (OF) | Accompanying works (AW)           |
| Territory objects (TO)    | Type of crop (TOC)                |
| Technological platform of the territory (TPT) | Mechanized works and fertilizers (MWF) |
| Engineering and transport networks (ETN) | Engineering and transport networks (ETN) |
| Territory use form (TUF)  | On-farm land management (OFLM)    |
| Territory organization form (TOF) | Inter-farm land management (IFLM) |

**Figure 3.** Transformation of the model for agricultural land.

| Generalized system layers | System layers of agricultural industrial buildings |
|---------------------------|--------------------------------------------------|
| Consumer products (CP)    | Consumer products (CP)                          |
| Territory Products (TP)   | Consumer property (CPr)                         |
| Object functionality (OF) | Internal equipment of the building (IEB)         |
| Territory objects (TO)    | Manufacture building (MB)                        |
| Technological platform of the territory (TPT) | Industrial building design (IBD) |
| Engineering and transport networks (ETN) | Engineering and transport networks (ETN) |
| Territory use form (TUF)  | On-farm land management (OFLM)                   |
| Territory organization form (TOF) | Inter-farm land management (IFLM) |

**Figure 4.** Transformation of the model for agricultural production facilities

The mathematical model for calculating results of the recurrent interference of the layers and determining socio-economic parameters of the results of the investigated investment process was described in [7]. This model includes the method of economic analysis, which involves the use of economic parameters characterizing the spatial - territorial system:

- market value of the object (VO);
- net operating income from each element of the land management model (NOI);
- distribution of shares of the value of the land plot, land management works and improvements (L, LP, B);
- object capitalization ratio (RO);
- capitalization ratio for a land plot (RL);
- capitalization ratio for land management (RLP);
• capitalization ratio for investments in agricultural production or buildings (RB);
• entrepreneur’s profit margin (PE);
• CBR key rate (RRF)

| Generalized system layers | System layers of agricultural settlements |
|---------------------------|------------------------------------------|
| Consumer products (CP)    | Consumer products (CP)                   |
| Territory Products (TP)   | Consumer property (CPr)                  |
| Object functionality (OF) | Internal equipment of the building (IEB)  |
| Territory objects (TO)    | Residential building (RB)                |
| Technological platform of the territory (TPT) | Residential building project (RBD) |
| Engineering and transport networks (ETN) | Engineering and transport networks (ETN) |
| Territory use form (TUF)  | Zoning and development project (ZDP)      |
| Territory organization form (TOF) | Planning project (PP)                  |

**Figure 5.** Transformation of the model for an agricultural settlement.

The investment-innovative analysis is carried out by solving a system of six equations, three of which describe the valuation of a land plot using residual methods. The following valuation methods were used: the intended use method, the residual method and the distribution method.

Three other equations describe the relationship of economic parameters, which are the basis for calculation. The relationship between the shares of elements of the territory and the capitalization ratios is described by the investment group technique and determined by the equation \( RO = RL \times L + RLP \times LP + RB \times B \). The market value of an object determines the relationship between net operating income and capitalization ratio using the direct capitalization valuation method equation. The entrepreneur’s profit reflects the level of risks when developing the territory and is calculated by the equation in the form of the sum of capitalization ratios of individual elements and the key rate of the Central Bank of the Russian Federation.

This system of six equations is solved by the iterative method by varying market indicators within the limits determined by structuring market information on price classification, until the residual value of the estimated land is equal using three valuation methods.

The system of six equations can be solved with respect to any of the specified parameters, depending on the task and reliable data on the land market, the market of agricultural works and agricultural products.

The approach allows us to reduce the uncertainty of calculations due to the interconnection of the equations, the use of a structured information database. However, it includes the uncertainty in the weight coefficients of the elements; therefore, it solves management issue only by determining the value of the land share using the expert analysis.

To eliminate this drawback and determine an indicator for the development of the spatial and territorial system, a methodological approach to the calculation of decomposition of the market property value into the weight values of each layer of the land management model was described in [8].

Having the weight of each layer of the model, the method of economic analysis is used to calculate the capitalization coefficient of the land and all layers of the models, subject to a harmonious state of the system (“reference” state). Changes in the deviation of the object from the “reference” value provides information on the development or degradation of the system. Since this calculation is based on all the elements that make up the spatial - territorial system, the values of capitalization coefficients reflect capabilities and needs of all participants in reorganizing the territory.
This fact allows us to introduce a concept “the level of capitalization of the territory”, which has all the attributes of a scientific category (an objective calculated value that determines the reaction of land to the results of human activities and reflects socio-economic relations in society with the targeted use of land for developing of the spatial system).

4. Conclusion
The models reflect the state of the territory and its individual components when making decisions on investment to ensure sustainable development of the territory. Scientific and technological progress and innovations are changing the resource ratio of the constituent territories, creating an imbalance in the resources, which leads to the development of the system. Violation of the “reference” distribution of resources of the model layers leads to the instability, excessive or insufficient resources in a particular layer, thereby determining the control subject of the area. In the broken layer, a result that is not consistent with the mode of functioning of the layers is created. The way out is to select investors to compensate for the imbalance, to restore the rhythm of production and consumption of products of a particular territory.

The land management models for agricultural lands and the method of social and economic analysis of the relationship between the participants make it possible to supplement the theoretical provisions of land management, including the introduction of an indicator of socio-economic development of the territory, into the theory and practice of land management; capitalization ratios of individual components of the territory. By determining the share of each participant in the reorganization of the territory, one can integrate the harmonious state of the territory as an integrated spatial system. Effective methods of land assessment were identified. They are part of the organizational and economic mechanism for regulating land relations between business entities and land plots based on the environmental and socio-economic effectiveness of land management, allowing land redistribution by competitive organizational and technological solutions.

References
[1] 2014 Statistical materials of the development of agricultural production in Russia (Moscow: Russian Agricultural Academy) p 4
[2] Volkov S N, Komov N V and Khlystun V N 2015 How to achieve effective land management in Russia? International Agricultural Journal 3 3-7
[3] Volkov S N 2011 The history of land management in Russia: the millennium experience (Moscow: State University of Land Use Planning)
[4] Volkov S N and Khlystun V N 2014 Land policy: how to make it effective? International Agricultural Journal 1-2 3-6
[5] Tatarinov K A 2018 Workshop on the Economics of Land Management (Irkutsk: BSU Publishing House) Available at: lib-catalog@bgu.ru.
[6] Mokhov A I 2015 Modeling of research in the natural sciences based on complex engineering Vestnik of the Academy of Natural Sciences 1 25-30
[7] Sevostyanov A V and Antipov O A 2014 Economic regulators in the land use management of a large city in the process of urban development Land management, cadastre and land monitoring [in Russian – Zemleustrojstvo, kadastr i monitoring zemel’] 9 76–81
[8] Svetlakov V I and Mokhov A I 2019 The level of capitalization of the territory is an indicator of socio-economic development for the choice of investor Proc. of the XVIII Int. Sci. Conf. "Modernization Of Russia: Priorities, Problems, Solutions: Trends and Prospects for Development” (Institute of Scientific Information on Social Sciences of the Russian Academy of Sciences, Moscow) pp 893-896
[9] Svetlakov V I, Komov N V, Konokotin N G and Sevostyanov A V 2019 Models for calculating indicators of rational use of land in the development of the Arctic zones Moscow Economic Journal 11 Available at: https://qje.su/nauki-o-zemle/moskovskij-ekonomicheskij-zhurnal-11-2019-49/
[10] Konokotin N G 1998 *Economic fundamentals and methods of the anti-erosion organization of the territory: Theory, methodology, practice*, abstract of the doctoral dissertation (Moscow)