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Original paper

A model for assessing the regional land-use territorial development

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Abstract: It is proved that the regional land-use territorial development is influenced by many factors, so the study of the assessment of territorial development is an urgent task. As a result of generalization of theoretical and methodological provisions, the definition of regional land-use territorial development is given, which is characterized as a system category that defines permanent transformational changes and considers spatial, urban, environmental and investment factors and improves land-use efficiency. It is established that the existing methodological approaches to the assessment of territorial development of land-use do not have a comprehensive approach and consider only certain factors. For a comprehensive and comprehensive assessment of the level of territorial development of land-use, a model is proposed, which is based on the definition of an integrated indicator. The formation of the model includes the following main stages: geofactor analysis, formation of a multilevel system of indicators, assessment and establishment of the level of impact of the indicator, determination of integrated indicators for each factor, formation of a general integrated indicator of land-use, interpretation of results. The technological feasibility of the model is determined by the formation of a set of spatial, urban, investment and environmental factors, the construction of a multilevel diagnostic system of indicators, their evaluation based on modern methods and the development of mathematical models. To obtain actual spatial and cadastral data to assess the territorial development of land-use, it is advisable to use forms of administrative cadastral reporting and space images.

Keywords: territorial development, land-use, geofactor analyze, integrated assessment, multi-level diagnostic system

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1. Introduction

In modern conditions of Ukraine, the systematization of theoretical and methodological approaches and building of a model for assessing the regional land-use territorial development becomes especially important due to the accumulation of a significant number of scientific developments and regulatory support for the development of regions, the use of their land and creation of united territorial communities (Mamonov et al., 2020). The regional land-use territorial development is influenced by a large number of factors such as: spatial; urban planning; investment; ecological; geographical and other.

In the existing scientific works the theoretical positions concerning an estimation of a level of territorial development of regions taking into account separate factors are defined and substantiated. The author (Palekha, 2009) considers geographical factor. In this case the value of territory is observed on the base of differential rent theory as economic-geographical category. The infrastructural and geographical constituents are picked out within the differential urban rent. The paper (Blandinier, 2001) examines the impact of landscaping and maintenance of territories by enterprises, institutions, organizations, requirements for landscaping on the territorial development of regions. The importance of using geospatial data and cadastral information in the assessment and planning of regional land-use territorial development is proved in the papers (Williamson et al., 2010; Martyn, 2011; Shipulin, 2014). A methodical approach to assessing the efficiency of land-use of agricultural lands has been developed by the authors (Stupen et al., 2011; Riasnianska, 2016). The main indicators of land-use efficiency are those that characterize the degree of land-use, the level of land-use, sown areas of agricultural land, crop yields and their gross harvest, production per capita. It is indicated that the main directions of improving the efficiency of land-use are the implementation of a system of measures to increase soil fertility, inter-farm integration of land-uses, improving the system of improving the efficiency of state land management, development of territorial organization projects (Tretyak and Babmindra, 2003). In this context, it should be noted that theoretical and methodological approaches are characterized by disunity and the absence of a single system.

Thus, the formation of the principles of a comprehensive model for assessing the regional land-use territorial development, considering many of factors (spatial, urban, environmental and investme) is an urgent task. The article aims to form the principles of constructing a model for assessing the territorial development of land-use in the regions. According to the aim, the following tasks were solved:

- determination of the territorial development of land-use in the regions;
- characteristics of the directions for assessing the territorial development of land-use in the regions;
- building of a model for assessing the territorial development of land-use in the regions.

2. Materials and methods

As a result of the generalization of theoretical and methodical provisions, the regional land-use territorial development is defined. Such a territorial development is characterized as a systemic category that determines the constant transformational changes and

considers spatial, urban, environmental and investment factors and leads to the formation of a qualitatively new state, ensuring increased efficiency of land-use. To assess the level of territorial development of land-use in the regions, an evaluation model is proposed, the formation of which includes the following stages:

1. Conducting geofactor analysis for (Wen and Mamonov, 2021):
   – the implementation of a complex of spatial, investment, urban planning, and ecological factors affecting territorial development of the region's land-use, based on current scientific and methodological advances and normative-legal maintenance;
   – the development of a multi-level indicator system;
   – the use of expert assessments to identify factors that have the greatest impact on regional land-use territorial development.
2. Considering the values of estimation coefficients for the formation of a multi-level system of indicators by applying the quasi metric models of the proposed factors transition to the corresponding spatial, investment, urban planning, and environmental factors.
3. Application of analytical and expert assessment methods to assess the third-level system of spatial, investment, urban planning, and environmental indicators.
4. Building mathematical models based on the method of estimating the geometric mean to determine second-level spatial, investment, urban planning, and environmental indicators.
5. Construction of a mathematical model for determining integrated spatial, urban, investment, and environmental indicators of regional land-use territorial development.
6. The application of the method of hierarchies analysis to determine weights that define the relevance of spatial, investment, urban planning, and environmental factors in the framework of territorial development.
7. Determination of integrated spatial, investment, urban planning, and environmental factor of regional land-use territorial development.
8. Evaluation of the integrated land-use indicator.
9. Development and substantiation of the scale for regional land-use territorial development.
10. Interpretation of the results obtained.

To assess the territorial development of the use of land in the regions, it is important to have complete and reliable information on the distribution of land in a settlement by land and landowners (land-users). One of the sources of such information is the forms of administrative cadastral reporting No 11-zem and 15-zem (Order of the Ministry of regional development, construction and housing and communal economy of Ukraine "On approval of forms of administrative reporting on the quantitative accounting of lands (forms No 11-zem, 12-zem, 15-zem, 16-zem) and Instructions for completing them", 2015), but there is no connection with cartographic materials. Therefore, to obtain spatial data on the qualitative composition of the city's lands, it is recommended to use orthorectification colour satellite images of high spatial resolution as topographic and geodetic materials (Pilicheva, 2009; 2016). On the satellite image, for each line of the administrative cadastral reporting form No. 15-zem, the corresponding territories are

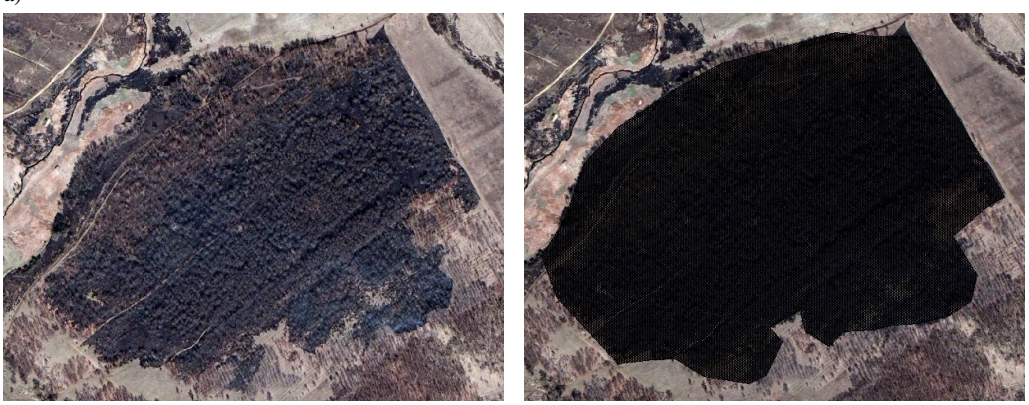
highlighted, and their areas are calculated. The allocation of territories became possible as a result of visual interpretation of the space image by colour and texture.

The following errors occurred during the formation of territories:

– geometric error – due to errors in the satellite image, which is about 1 m;
– an error in the visual interpretation of a satellite image, which is divided into an error in determining the border of the territory and an error in determining the category of land.

The error in the visual interpretation of a satellite image is significant and many times greater than the geometric one, so the geometric error can be neglected in the future. Examples of the formation and assignment of the allocated territory to a specific category of land are presented in Figure 1, where the left shows a space image, and on the right – the boundaries of the formed territory. Figure 1a shows an example of the formation of a territory without a clear border and Figure 1b – with a clear border. Accordingly, in the first case, the decryption error exceeds the geometric error several times.

a)



b)

Fig. 1. Examples of the formation of territories with a clear and without a clear border: a) territories of forests and other wooded areas, b) territories under residential one- and two-story buildings

When forming the territories, three groups were identified according to the complexity of assignment to the corresponding category of land:

– Group 1 – unambiguous assignment;
– Group 2 – conditional assignment (includes several categories or ambiguous assignment to the corresponding category);
– Group 3 – impossible assignment.

It was impossible to allocate the territories of the 3rd group, which is due to the need to have additional information about the location of the respective lands. Therefore, only groups 1 and 2 are highlighted on the cartographic material. The distribution of the formed territories within the settlement is presented in Figure 2. The formed territories are located unevenly, i.e. fragmentation is present. An attempt to identify areas of different categories was performed on the example of 3 settlements. The results are given in Table 1.

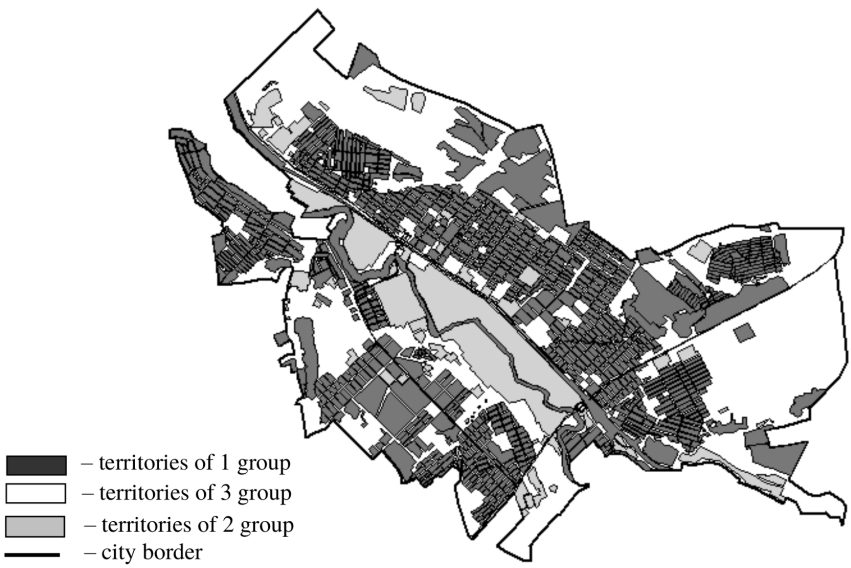


Fig. 2. Distribution of the formed territories within the settlement

According to Table 1, we can conclude that from a satellite image, it is possible to distinguish from 50% to 65% of the total area of a settlement without additional information about the lands. Based on the study, the principles of building a model for assessing the regional land-use territorial development are determined, as follows (Wen and Mamonov, 2021):

– the scientific validity principle is characterized by determining the territorial development level, based on scientific and methodological developments, regulatory and legal support;
– the complexity principle refers to a set of indicators that combine spatial, investment, urban planning, and environmental factors and is determined by a series of interconnected actions aimed at determining the level of territorial development of land-use in the regions;

Table 1. The procedure for the foresight methodology implementation in the direction of sustainable management of recreational land use

Land category by the form 6-zem	Settlement A		Settlement B		Settlement C	
	Area		Area		Area	
	hectare	%	hectare	%	hectare	%
Group 1						
Railway transport	85.22	1.29	218.10	11.37	20.10	0.39
Forests and other wooded areas	249.47	3.78	115.27	6.00	101.23	1.99
Agricultural land	438.49	6.65	99.48	5.18	587.52	11.52
Under residential buildings with one- and two-floors	870.99	13.20	465.33	24.25	963.36	18.89
Under residential buildings with three or more floors	311.91	4.73	121.89	6.35	161.79	3.17
Cemeteries	29.38	0.45	6.06	0.32	21.09	0.41
Total (Group 1)	1985.46	30.10	1026.13	53.47	1855.09	36.37
Group 2						
Lands for water supply and wastewater treatment + inland waters	124.86	1.89	5.31	0.28	19.35	0.38
Lands of industry + lands of commercial and other use + lands for production and distribution of electricity	688.21	10.43	108.64	5.66	238.62	4.68
Land under roads + land of streets, embankments, squares	620.67	9.41	187.15	9.75	387.53	7.60
Total (Group 2)	1433.74	21.73	301.10	15.69	645.59	12.66
Total (Group 1 + 2)	3419.20	51.83	1327.23	69.16	2500.68	49.03

– the systematization principle is determined by a multilevel spatial, investment, urban planning and environmental indicator system, providing an assessment basis for regional land-use territorial development;
– the integrity principle is characterized by the establishment of a single system for evaluating the level of regional land-use territorial development, which provides an integrated indicator for informed decision-making;
– the goal-orientation principle is determined by the focus on achieving goals aimed at – ensuring the territorial development, considering a range of spatial, investment, urban planning, and environmental factors;
– the structuredness principle – characterized by a clear structure of indicators determined at different levels;
– the development principle is determined by the development of measures to ensure the land-use territorial development based on its established level;
– the adequacy principle is characterized by the definition of appropriate levels of territorial development that reflects the directions and characteristics of spatial, investment, urban planning, and environmental security impacts as well as changes.

3. Results

The results of geofactor analysis are used to build a model for assessing the territorial development of land-use in the regions. To carry out geofactor analysis in the system of assessment of territorial development of land-use in the regions, it is proposed to build a multi-level system that includes spatial, urban, investment and environmental factors. The definition of factors is based on the generalization of theoretical and methodological approaches, the existing regulatory and legal support and domestic and international experience in ensuring land relations and the results of expert analysis. In this context, it should be noted that experts are selected to use the method of expert analysis. The selection of input factors (F_i) used to build the system is based on the generalization and systematization of theoretical and methodological approaches, regulatory and legal support, international and domestic experience. As a result, the following input factors are identified: F_1 – spatial, F_2 – urban planning, F_3 – investment, F_4 – ecological, F_5 – political, F_6 – social, F_7 – demographic, F_8 – intelligent, F_9 – informational, F_{10} – economic, F_{11} – regional, F_{12} – local.

As a result of the expert analysis, it was determined that the largest average values were for the factors: F_1 – spatial, F_2 – urban planning, F_3 – investment, F_4 – ecological. An appropriate scale has been constructed to make a decision on the selection of factors (Table 2).

Table 2. The scale of values of expert assessments used to select factors of territorial development of land-use, rel. unit (developed by the author)

Value	Characteristic
0	the factor does not affect the territorial development of land-use of the regions – is not included in the evaluation system
0.01–4	the factor does not have a significant impact on the regional land-use territorial development – is not included in the evaluation system
4.01–7	the factor significantly affects the territorial development of land-use of the regions – is included in the evaluation system
7.01–9.99	the factor is essential for the formation and implementation of territorial development of land-use – is included in the evaluation system
10	the factor is determined by the absolute impact on the formation and implementation of territorial development of land-use – is included in the evaluation system

Thus, to build a system for assessing the territorial development of land-use and determine the level of impact, the following factors are used: F_1 – spatial, F_2 – urban planning, F_3 – investment, F_4 – ecological.

To assess the reliability of the results of expert assessments on the selection of factors for the regional land-use territorial development, the coefficient of concordance was determined, which is 0.64. This indicates a moderate level of coherence of expert opinions, allows to apply the results of the selection of factors in the context of building a system for assessing the territorial development of land-use in the regions.

In this work, considering the complexity and a significant number of factors that form the directions of territorial development of the use of land in the regions, it is proposed to build a multi-level assessment system. The results of determining the number of levels of factors (R_i) in the system, obtained using the method of expert assessments, are presented in Table 2. It should be noted that R_i consists of:

- R_1 – 2 levels (system, integrated);
- R_2 – 3 levels (local, system, integrated);
- R_3 – 4 levels (detailed, local, system, integrated);
- R_4 – 5 levels (primary, detailed, local, system, integrated).

Determination of the number of factor levels in the system for assessing the regional land-use territorial development and their selection is carried out according to the ranges of values presented in Table 2. Thus, according to the results of the study, three levels are accepted – local, systemic, integrated. To harmonize the opinions of experts, the coefficient of concordance was determined equal to 0.77, which indicates their high level.

At the local level (level 3) factors (primary) are formed and determined, which are formed based on regulatory and legal support, existing theoretical and methodological approaches, domestic and foreign experience. At the system level, (level 2) factors are formed and determined, which generalize a set of local factors for building a system of territorial development of land-use in the regions. At the integral level (level 1), integral spatial, urban planning, investment and environmental factors are formed and determined. It should be pointed out that a multi-level system of factors has been built (Fig. 1), which is determined by the hierarchy, and the grouping of factors, which is carried out at each level according to spatial, urban planning, investment and environmental characteristics and features.

The relationship between the factors is established at each level separately based on their influence on the system factor, and then its influence on the integral factor. The relationship between integrated spatial, urban, investment and environmental factors is determined by applying appropriate criteria, such as weights. Characterizing the presented system of factors, we build a mathematical model that determines the formation and interaction of factors at level 1:

$$F_1,\ F_2,\ F_3,\ F_4 \subset F \tag{1}$$

where F – generalizing factor of territorial development of land-use in the regions.

Let's define a subset of spatial factors of the level 2 $(f^i_{jy}) \subset F_1$, $i = 2$, $j = 1$, $y = \overline{\overline{1.5}}$. The model superscript i determines the level of the system of factors, the lower j is the ordinal number of the subset of factors and y is the ordinal number of the factor in their subset. Thus, the integral spatial factor (F_1) consists of systemic factors: territorial (f^2_{11}), functional (f^2_{12}), social (f^2_{13}), political (f^2_{14}), the level of cartographic and geodetic support of land-use in regions (f^2_{15}). The subset of urban planning factors is determined as follows: $(f^i_{jy}) \subset F_2$, $i = 2$, $j = 2$, $y = \overline{\overline{1.12}}$. Urban planning factors (F_2) are formed from factors: zonal (f^2_{21}), functional-planning (f^2_{22}), structural planning (f^2_{23}), planning and

restrictive (f^2_{24}), engineering training and equipment of territories (f^2_{25}), transport support (f^2_{26}), historical and architectural (f^2_{27}), functioning of the construction industry in the regions (f^2_{28}), the level of development of territories (f^2_{29}), building density (f^2_{210}), the level of application of spatial information in urban planning (f^2_{211}), the level of formation of cadastral information in the field of land-use in the regions for urban planning (f^2_{212}).

A subset of investment factors is determined as follows: $(f^i_{jy}) \subset F_3$, $i = 2$, $j = 3$, $y = \overline{\overline{1.12}}$. Investment factors ($F_3$) are determined by the following factors: evaluative (f^2_{31}), the level of use of funds, property and property rights (f^2_{32}), intellectual (f^2_{33}), stakeholder (f^2_{34}), innovative (f^2_{35}), territorial development of regions (f^2_{36}), attracting foreign investment in the field of land relations in the region (f^2_{37}), public-private partnership (f^2_{38}), the level of investment activities in the field of land-use in the region by domestic investors (f^2_{39}), the level of formation of special economic zones to ensure investment in the use of land in the regions (f^2_{310}), the level of providing a special regime of innovation activities of technology parks in the field of land-use of the regions (f^2_{311}), implementation of investment projects in the field of land-use of the regions on the principle of "single window" (f^2_{312}).

A subset of environmental factors is determined as follows: $(f^i_{jy}) \subset F_4$, $i = 2$, $j = 4$, $y = \overline{\overline{1.15}}$. Environmental factors (F4) consist of factors: environmental development (f^2_{41}), the level of waste management (f^2_{42}); the level of rationing and accounting of waste management (f^2_{43}), functional factors to reduce or prevent waste generation (f^2_{44}), the level of notification of the threat or occurrence of emergencies (f^2_{45}), the level of information on the occurrence and prevention of emergencies (f^2_{46}), the level of the shelter of the population in protective structures of civil protection (f^2_{47}), the level of implementation of evacuation measures (f^2_{48}); the level of engineering protection of territories (f^2_{49}), the level of radiation and chemical protection of the population and territories (f^2_{410}), the level of medical protection, ensuring sanitary and epidemic well-being of the population (f^2_{411}), the level of biological protection of the population, animals and plants (f^2_{412}), the level of psychological protection of the population (f^2_{413}), the level of technological security (f^2_{414}), the level of fire safety (f^2_{415}). As a result of the analysis of the multi-level factor system, it was determined that it consists of three levels that form a hierarchy of factors. The presented system allows determining the level of factor influence for the implementation of integrated assessment.

4. Conclusions

The theoretical and methodological content of the category "regional land-use territorial development" should be considered through the prism of systemic spatial, investment, urban planning, and environmental factors, the interaction of which leads to a qualitatively new state of land relations, considering social, institutional, managerial features, and the level of stakeholder relationships operating in the field of regional land-use (Wen and Mamonov, 2021). This statement allows us to determine that the regional land-use territorial development is characterized by areas of its assessment, a set of information

and geoinformation tools, and this requires the creation of a theoretical and methodological system (platform) to improve land-use efficiency.

The model used to determine and assess the territorial development of the regional lands is justified. This allows developing a methodological approach to the integrated assessment of regional land-use territorial development as a basis for the theoretical and methodological platform based on the information and analytical support, a multi-level diagnostic system of spatial, urban, investment and environmental factors, methodological and analytical procedures modelling of territorial development. The technological feasibility of the model is determined by the formation of a set of spatial, urban, investment and environmental factors, the construction of a multi-level diagnostic system of indicators, their evaluation based on modern methods and the development of mathematical models. The model is based on innovative valuation technology through the use of modern tools and interconnected stages, which allowed to determine the integrated indicator, to carry out modelling to ensure the territorial development of land-use in the regions. The principles of constructing a model for assessing the land-use territorial development in regions are proposed. This makes it possible to ensure the implementation of the corresponding model. In the assessment model of land-use territorial development in regions, it is offered to apply the geofactor analysis which allows constructing the multi-level system of factors, to carry out their selection and to create a quantitative basis for an assessment of territorial development.

Author contributions

Conceptualization: K.M.; Methodology development: I.S.; Writing – original draft: M.P. and V.K.; Writing – review and editing: E.S.

Data availability statement

The raw/processed data required to reproduce these findings cannot be shared at this time as the data also forms part of an ongoing study.

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