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AUTOMATION OF NORMATIVE MONEY VALUE OF LANDS OF SETTLEMENTS WITH THE USE OF GEOINFORMATION TECHNOLOGIES

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Abstract. In this paper, the constituent elements of geoinformation support for the normative monetary valuation of the lands of settlements has been considered. A set of geospatial data necessary for land value of settlements at each of its stages has been formed. A method of economic and planning zoning based on the theory of fuzzy sets is proposed, namely the method of arranging objects according to a set of features, which allows applying real values of evaluation indicators and calculating their integral values. The algorithm of automated zoning with the use of GIS tools has been considered. Based on the proposed set of geospatial data, an ArcGIS tool was created using the Model Builder application, which allows you to determine the normative money value of a separate land plot and generate a report.

Keywords: normative money value, lands of settlements, GIS, economic and planning zones.

Introduction

Normative money value of the lands of settlements in accordance with the Law of Ukraine "On Land Valuation" allows determining the amount of land tax, state duty when granting, mining, and inheriting land plots in accordance with the law, rent for communal and state-owned land plots, allows calculating losses forestry and agricultural production. Such assessment of land allows authorities to manage the development of the territory through indicators of economic stimulation of rational use and protection of land. In addition, the assessment of land ownership is a mandatory component of all investment processes and collateral transactions, the data of the normative assessment can serve as a certain criterion that does not allow to vary the indicators of the expert assessment (Pro otsinku…, 2004).

Taking into account the fact that carrying out a normative money value of the lands of settlements requires taking into account the influence of a number of regional, zonal and local factors of the location of land plots on the territory of the settlement, which have a spatial relationship with the object of land assessment, according to its content, it can be attributed to the tasks of spatial analysis.

Taking into account the importance of the normative money value of the lands of settlements, the use of geospatial data in its implementation, the task of using geoinformation technologies to automate the instruments of normative money value of the lands of settlements at various stages arises.

1. Analysis of research

Many scientists were and are engaged in the improvement of the procedure of money value of land with the use of geo-information technologies. Among them are Voytek-hovich, Palekha, Lyashchenko, Gubar, Martyn, Kryvobok-ov, Shipulin, Shterndok and other.

In particular, the scientific and practical aspects of the creation of geospatial data and the application of geo-information mapping in the normative money value of the lands of settlements are considered in the work of Patychenko (2013).

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The definition of geoinformation support for the integral assessment of the spatial factors of the land of the metropolis, which is characterized as a system of interacting elements that function on the basis of the use of geoinformation systems tools, was proposed in the study of Shipulin (Shypulin & Shterndok, 2017).

By its content, the money valuy of land is classified as a task of geo-informational (spatial) analysis, since its implementation requires taking into account the influence of multiple factors of the regional, local and zonal location of land plots on the territory of the settlement, which have a spatial relationship with the object of valuation, according to the works of Palekha, Shipulina and Sterndoka (Shypulin et al., 2015).

In addition to the development of general approaches and concepts regarding the use of geo-information technology in conducting regulatory money valuy, scientists are solving tasks related to the automation and formalization of individual stages of land valuation. In particular, Kryvobokov, based on the theory of fuzzy sets, proposed ways to formalize the evaluation zoning of urban lands and used GIS models for this (Kryvobokov, 2005).

In the work of Kravchenko, Liashchenko, Horkovchuk developed and implemented technological schemes and geospatial models for taking into account the influence of local factors on the normative money valuy of land plots of settlements based on the calculation in GIS of the fractions of the area occupied by the zones of certain factors on the land plot. To solve this problem, it is proposed to use a grid model and the method of sequential overlay analysis (Liashchenko et al., 2014).

The above analysis indicates the need to use geoinformation technologies both for the development of thematic digital maps and at the stages of taking into account regional, zonal and local factors. In our opinion, not enough attention is paid to the development of technological schemes and GIS tools for the normative money value of individual land plots and the formation of relevant extracts.

2. Research methods

The procedure for carrying out a normative money value of the lands of settlements is established by the Procedure (Pro zatverdzhennia…, 2016). and the Methodology (Pro Metodyku…, 1995). Having considered the indicated sources, we consider it expedient to use the ArcGIS software complex for automating calculations and forming elements of technical documentation for land assessment of the settlement.

Taking into account zonal factors in the normative money value of the lands of settlements is carried out by establishing the values of the Км2 coefficients for territories homogeneous in terms of price-forming factors. The value of the km^2 coefficient is calculated as the product of factor estimates taking into account the weight characteristics of each of the factors (Dekhtiarenko et al., 2007; Kryvobokov, 2005; Pro zatverdzhennia…, 2016).

In order to formalize economic and planning zoning, it is advisable to apply the method of mathematical modeling under conditions of uncertainty, which is based on the theory of fuzzy sets (Siavavko & Rybytska, 2000). When determining the values of indicators of estimated zonal factors, the problem arises that all indicators are measured in different systems of units. It is precisely the theory of fuzzy sets that will allow us to bring these values to one system of units, namely weight. Let us consider in more detail the mathematical basis of the method of arranging objects according to a set of features.

The essence of modeling is as follows. Suppose that we have n factors A1, … , An and ω = (ω1, …, ωn) is a vector of relative weights of these factors, while the following requirement is fulfilled:

$$\sum_{i=1}^{n} \omega_3 = 1. \qquad (1)$$

Suppose that the results of a pairwise comparison of factors by weights are described by the ratio of their weights. In this case, the results of this pairwise comparison can be presented in the form of a square matrix of order n:

$$
\begin{array}{c|cccc}
A_n & I & II & \dots & k \\
\hline
I & \dfrac{\omega_I}{\omega_I} & \dfrac{\omega_I}{\omega_{II}} & \dots & \dfrac{\omega_I}{\omega_k} \\
II & \dfrac{\omega_{II}}{\omega_I} & \dfrac{\omega_{II}}{\omega_{II}} & \dots & \dfrac{\omega_{II}}{\omega_k}. \\
\dots & \dots & \dots & \dots & \dots \\
k & \dfrac{\omega_k}{\omega_I} & \dfrac{\omega_k}{\omega_{II}} & \dots & \dfrac{\omega_k}{\omega_k}.
\end{array}
\qquad (2)
$$

In order to find the vector ω by the matrix of relative weights *A*, the following equation must be solved:

$$(A - nI) \times \omega = 0, \qquad (3)$$

where ω – the vector of relative weights of the factors under consideration, *I* – unit matrix.

To find the vector of weights ω by matrix *A*, it is sufficient to solve Equation (3). Since the rank of the matrix *A* is equal to 1, then n is the only eigenvalue of this matrix. And, therefore, Equation (3) has a nonzero solution. But the elements of matrix A are not the exact values of factor weight ratios, but their estimates are proposed by experts. Therefore, instead of Equation (3), it is necessary to consider a more general equation, which has the following form:

$$(A - \lambda_{\max} I) \times \omega = 0, \qquad (4)$$

where $\lambda_{\max}$ – the maximum eigenvalue of the matrix $A (\lambda_{\max} \geq n)$.

The significant difference of $\lambda_{\max}$ from n indicates some internal inconsistency in the expert's assessments of the values of the elements of matrix *A* and the need for their review and clarification. If the value of $\lambda_{\max}$ is sufficiently

close to n, then the normalized vector ω – the solution of Equation (4) – can be considered an acceptable estimate of the relative weights of the considered factors, established on the basis of matrix A (Siavavko & Rybytska, 2000).

The application of the method of arranging objects according to a set of features in economic and planning zoning requires the establishment of a set of zonal factors and indicators. The importance of each of the indicators is established by the method of pairwise comparison. The essence of this method is that a matrix of preference coefficients is formed during a pairwise comparison of criteria. If the first criterion is more important than the second, the coefficient is 1.5, if they are equally important – 1.0, and if less important – 0.5. In case of pairwise comparison, the coefficient of superiority k_{ij} of the criterion in the row relative to the criterion in the column is indicated.

The weight of each of the criteria λ_3 is calculated according to the following formula:

$$\lambda_3 = \frac{P_i}{\sum P_i}. \tag{5}$$

The value of P_i is defined as the sum of the products of each element of the strip by the elements of the column vector $\sum k_i$.

With the help of GIS tools, the values of the indicators for each assessment area are determined. According to Equations (1)–(5), the values of the evaluation indicators are converted into weights, and after multiplying them by the weights of the zonal factors, the weight coefficients of the value of the evaluation districts are obtained.

The calculation of the complex index of the value of the territory (Ii) is carried out by the weighting coefficients of the value of the territory for each evaluation district using the given formula:

$$Ii = Vp / V, \tag{6}$$

where V – the average value of weighted coefficients of value in the settlement; Vp – the weighting factor of the value of the assessment district.

We carry out the unification of assessment districts into economic and planning zones. We calculate the values of zonal coefficients km^2 for each separate economic

and planning zone. They are defined as a weighted average value from the indices of the assessment districts included in this zone.

It is expedient to combine assessment districts into economic and planning zones using thematic mapping tools, namely, the method of classifying the quantitative values of "natural boundaries". According to this method of "natural boundaries", class boundaries are created in such a way as to best group similar values and maximize the differences between classes, which is convenient for combining assessment districts into economic and planning zones (ArcGIS tutorials, n.d.).

3. The results of the research

Approbation of the proposed approach was carried out on the example of the lands of the village of Klevan, Rivne region (Ukraine). The following thematic layers were formed for the implementation of the normative money value: the boundary of the settlement, assessment districts, economic planning zones, land plots, zones of influence of local factors.

The first created layer The border of the village has the following attributes: Name; The area before calculation, m^2; Costs, hrn/m^2; Np; Nk; Tsnm. This list of attributes made it possible to calculate the basic land value of Klevan settlement (Pro zatverdzhennia…, 2016; Pro Metodyku…, 1995) using the Field Calculator (Figure 1).

As a result of the analysis of the characteristics of the territory of the town of Klevan, in accordance with the Order (Pro zatverdzhennia…, 2016), a list of factors that significantly affect the value of the land of this settlement was established for the evaluation districts: accessibility to the city center U1; accessibility to concentrated places of employment U2; accessibility to places of rest U3; accessibility to passenger transport U4; level of air cleanliness and noise level of the territory U5; heat supply level U6; water supply level U7; sewage level U8; gas supply level U9; flooding with groundwater U10; supply by stores U11; provision by household service facilities U12; provision by cultural and sports facilities U13; provision by health care facilities U14; provision by schools U15; provision by kindergartens U16; location in the sanitary protection zone U17; soil quality U18.
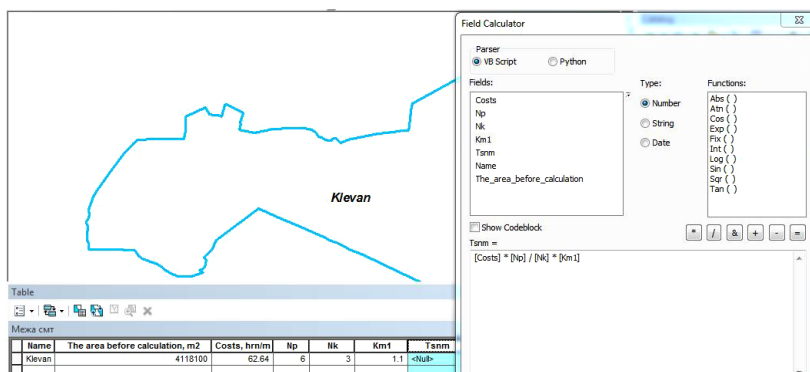

Figure 1. The boundary layer of the settlement with attributive characteristics and calculation
of the base value for the settlement of Klevan using the field calculator

The peculiarity of applying the method of arranging objects according to a set of features is that the indicators of factors can be determined in different units, but in the end they are reduced to one system of weights, which makes it possible to evaluate economic and planning zones comprehensively. Therefore, we will determine in which units and with which GIS means we will obtain the values of indicators for each factor.

Accessibility to the community center of the village, accessibility to concentrated places of employment, accessibility to places of recreation, distance to transport stops were determined directly in the geoinformation system in kilometers. To formalize indicators, the inverse distance was used, since the shorter the distance from the source of this factor to the evaluation area, the greater the value of land in this area.

Level of air cleanliness and noise. This factor was evaluated on a 3-point scale, where "3" points were assigned in the case of the cleanest air and the least noise pollution of the territory, "1" – in the case of the worst conditions (for example, location near industrial zones, major highways, railways, etc.).

The level of engineering support and improvement of the territory. This factor was also evaluated on a 3-point scale, "3" is the presence of engineering communications, "2" – engineering communications are located in the nearby area, "1" – the absence of communications nearby).

Groundwater inundation factors and soil quality are estimated according to the value of the depth of groundwater in meters and the average weighted arable credit score of each for each district.

Provision by stores. When evaluating this factor, the formalized indicator is the number of stores in the evaluation area.

Provision by cultural and sports institutions, schools. Kindergartens, nurseries, health care institutions. These factors were evaluated on a 2-point scale, "2" – presence, "1" – absence of an institution in the district.

Placement in a sanitary protection zone. The factor was evaluated on a 3-point scale, "3" – the district does not cross the sanitary protection zones, "2" – the district partially crosses the sanitary protection zones, "1" – the district is completely within the boundaries of the sanitary protection zones.

As a result of the measurements made by means of GIS, a table was obtained containing the values of indicators of zonal factors in the section of the assessment districts. Applying the formulas of this method (1–5), we will calculate the weight values for all evaluation indicators in the range from 0 to 1. At the same time, the weight of each factor was calculated by the method of pairwise comparison.

After carrying out calculations for all factors, we will get a matrix of columns with the value of the weighting coefficients of the indices of the value of the territory, which in their essence are integral coefficients of the value of each of the evaluation districts, defined in weights, the sum of which is equal to one.

Further, according to Equation (6), the weighting coefficients of the territory value indices are translated into the values of the value indices of the assessed districts. The results of the calculations are given in Table 1.

Table 1. Indices of the value of the territory of the second town of Klevan

Assessed districts	Weighting coefficients of the value	Area of the assessed district, ha	I_i
1	0.019	3.4200	0.7981
2	0.020	8.2200	0.8393
3	0.020	10.5700	0.8451
4	0.020	11.6200	0.8608
5	0.019	5.7100	0.8190
6	0.025	17.3300	1.0693
7	0.027	15.5200	1.1418
8	0.020	7.8100	0.8292
9	0.021	18.4700	0.8907
10	0.026	16.5200	1.1201
11	0.021	16.4000	0.8926
13	0.027	12.4900	1.1421
14	0.020	8.1000	0.8646
15	0.020	7.8600	0.8648
16	0.021	8.4800	0.8742
19	0.023	6.5100	0.9668
21	0.023	14.7500	0.9781
22	0.024	13.5000	1.0221
23	0.022	13.3400	0.9267
24	0.023	19.3600	0.9569
25	0.022	1.6000	0.9565
26	0.029	28.9300	1.2139
27	0.025	11.7800	1.0585
28	0.022	38.0100	0.9212
29	0.022	2.0800	0.9410
31	0.026	15.2800	1.1242
32	0.026	19.1500	1.0895
33	0.022	4.9100	0.9236
34	0.023	5.2700	0.9847
35	0.023	23.7000	0.9751
38	0.025	6.5000	1.0632
39	0.027	13.3000	1.1644
40	0.028	16.1300	1.2051
41	0.027	21.5500	1.1333
42	0.024	13.9300	1.0142
43	0.021	19.6500	0.9031
44	0.021	23.8000	0.9071
45	0.023	10.8700	0.9838
46	0.021	35.3100	0.8933
47	0.029	10.3700	1.2321
48	0.021	13.5100	0.8967
49	0.030	5.2900	1.2891
50	0.022	3.2400	0.9437
Weighted average coefficient	**0.0235**	**580.14**	

The value of the complex indexes of the value of the territory Ii serves as the main criterion for unifying the evaluation districts into economic and planning zones. In addition, the formation of assessment zones is influenced by the contiguity of districts and mainly the same type of functional use.

To solve this problem, it is advisable to use GIS thematic mapping tools. Evaluation districts as a layer in ArcMAP have the following attributes: number, area, value of evaluation indicators (distance to the city center, credit score, ...). The unification of districts was performed in ArcMAP using the "natural boundaries" classification method (Figure 2). By consistently selecting the number of classes, we choose the best zoning option. The criteria for the effectiveness of zoning are the optimal number of zones, their equal size and location around the center of the settlement. The result of the best zoning option for the territory of Klevan is shown in Figure 3. Zonal coefficients were calculated as the area-weighted average of the values of the combined assessment districts.

On the basis of the obtained results, a layer of economic and planning zones was formed by combining the assessment districts (Figure 4).

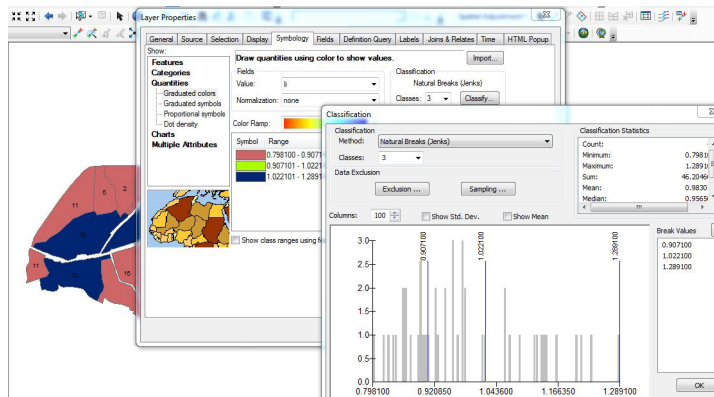To calculate the normative money value of a separate

Figure 2. Unification of assessment districts into economic and planning zones

The complex indexes of the value
- 0.798100–0.907100
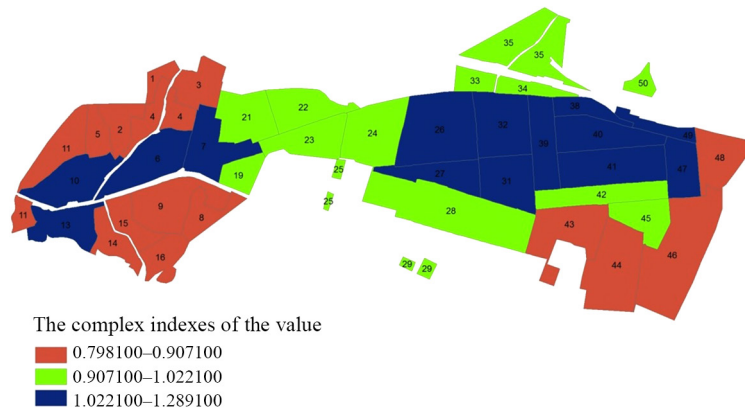- 0.907101–1.022100
- 1.022100–1.289100

Figure 3. The result of uniting the evaluation districts into zones according to the value indices
of the territory of the town Klevan based on the method of arranging objects according to a set of features
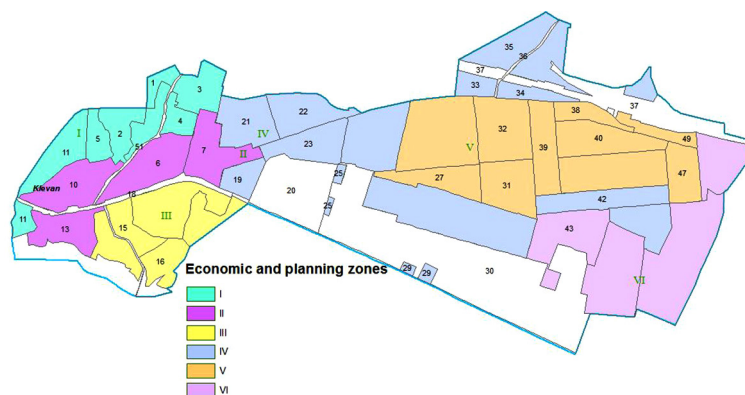

Economic and planning zones
- I
- II
- III
- IV
- V
- VI

Figure 4. Economic and planning zones of the town of Klevan

land plot according to the methodology (Pro Metodyku…, 1995), it is necessary to take into account the zonal coefficients, so let's supplement the attribute table of the Economic and planning zone layer with Km2 values (Figure 5).

Their attributive data is necessary for the assessment of a separate land plot. First of all, it is the area of the evaluated site, its purpose, according to which the coefficient of functional use is established. For example, according to the Order (Pro zatverdzhennia…, 2016), a land plot with the purpose of 02.01 for the construction and maintenance of a residential building, farm buildings and structures has Kf = 1. A cadastral number field was also created for searching and identifying land plots. This layer with all attribute data can be obtained from the Public Cadastral Map of Ukraine (Figure 6).

In order to take into account the influence of local factors on the evaluation of the land plot, a corresponding layer has been created. Based on the range established in Order (Pro zatverdzhennia…, 2016), the values of the corresponding coefficients are entered into its attribute table.

In the future, the total cumulative coefficient of Km3 is determined by multiplying all local coefficients that appear on this land plot; depending on the area occupied by the spread of one or another factor within a separate plot of land. The value of its coefficient may vary slightly (within the established range, while the product cannot exceed 1.5 or be less than 0.5) (Pro zatverdzhennia…, 2016; Shypulin et al., 2015).

For example, a sanitary protection zone around cemeteries was built using GIS. As is known, in accordance with the State Sanitary Rules for Planning and Development of Settlements, the size of the sanitary and protective zone of cemeteries is 300 m (Pro zatverdzhennia…, 1996). According to the Order (Pro zatverdzhennia…, 2016), we will enter the value of the local coefficient for the sanitary protection zone, in this case we will take the average value of $km^3 = 0.88$ (Figure 7). In a similar way, zones of influence of other local factors were created on the territory of Klevan town.

To develop an automated tool for the normative money value of a separate land plot, we will use Model Builder, which is a visual programming language in ArcGIS and allows you to form geoprocessing workflows and create new tools based on a combination of existing ones (ArcGIS tutorials, n.d.).

When calculating the normative money value of a separate plot using GIS, a number of problems must be solved, first of all, find the plot that needs to be valued. This can be done by cadastral number by applying the ArcGIS Select tool in the layer by attribute. This tool allows you to
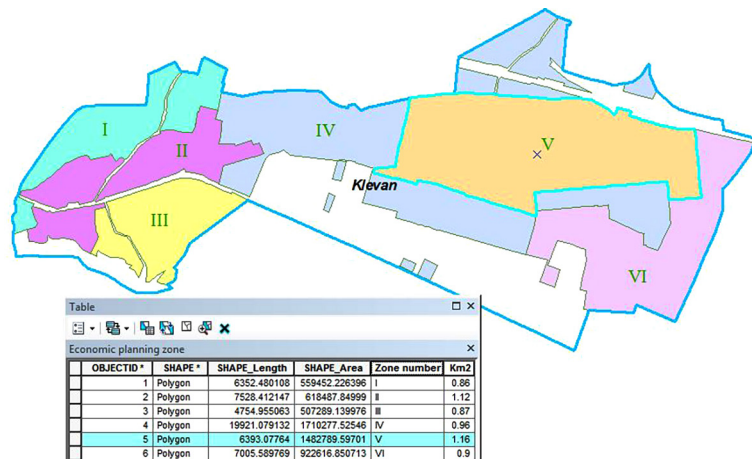

Figure 5. Economic planning zone layer with attribute table

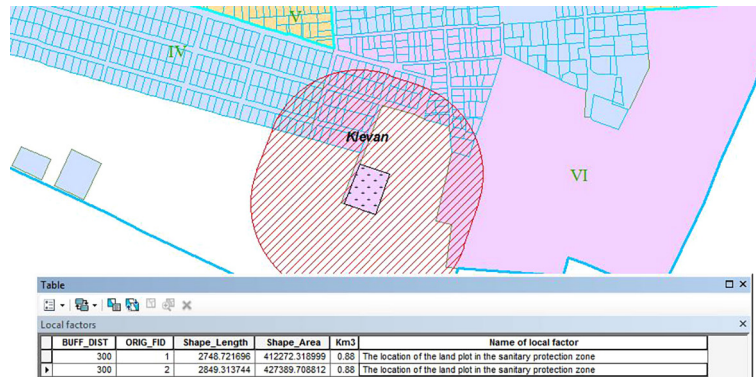Figure 6. Land plots layer with attribute data

Figure 7. A layer of local factors with attribute data

create an expression that can be set at the beginning of the tool to enter the cadastral number of the plot and search for the object of assessment by it. At the second stage, it is necessary to establish in which economic and planning zone the evaluated plot lies, what local factors it has, and copy the value of the base cost and other coefficients to the attribute table of the land plot. This is done using the Intersect tool, which calculates the geometric intersection between the input objects, while spatial objects or parts of objects that intersect in all layers will be written to the output object class. Having selected as input layers the boundaries of the city, economic planning zones, local factors, which intersect with the evaluated land plot, we will get an object with the cut characteristics of the corresponding layers.

The next stage is the calculation of the normative money value of the land plot, for this we will apply the Calculate field tool to the received object, which allows you to perform mathematical calculations between different attributive fields of the table. The last stage is the output of the evaluation results. Given that many extra attributes have been added to the "Evaluated land plot" object, with the help of the "Summary statistics" tool, we will leave only those fields and in such a sequence as required by Procedure (Pro zatverdzhennia…, 2016) when forming an extract from the normative money value of a separate land plot.

Let's add the original layers and connect them and the described tools in the Model Builder window in the set sequence. The newly created NGOzd tool has the following form (Figure 8).

To demonstrate the operation of this tool, open it. As a result, the following window will appear (Figure 9), where you need to enter the cadastral number of the plot you want to evaluate and specify the path to the database where the calculation results will be stored.

The result of the tool is a map window where the evaluated land plot and a table with the evaluation results are highlighted (Figure 10).
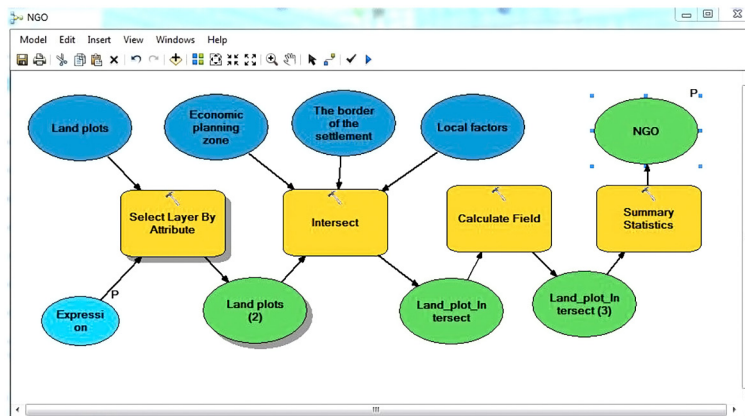

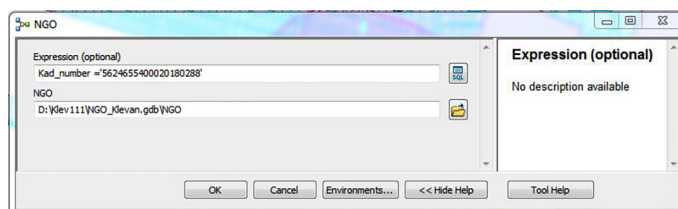Figure 8. Scheme of the normative money value tool of a separate land plot in the Model Builder window

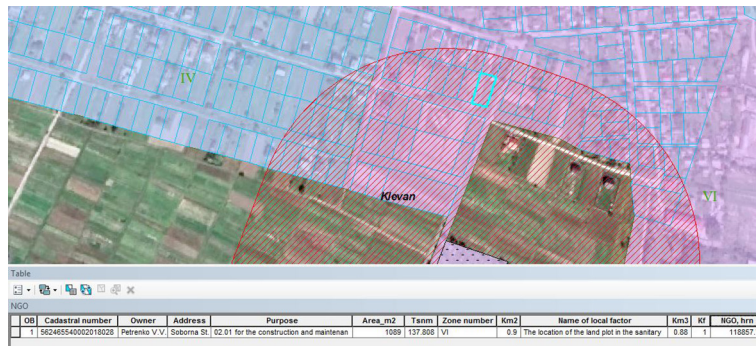Figure 9. Window for entering input data of the developed NGOzd tool

Figure 10. The result of the tool NGOzd

EXTRACT
from the technical documentation on the regulatory
money value of the land plot

Owner:	Petrenko V.V.
Cadastral number of the land plot:	5624655400020180288
The location of the land plot:	Soborna st.
Purpose of the land plot:	02.01 For the construction and maintenance of a residential building, farm buildings and structures
Land plot area, m2:	1089
Basic land value of the settlement, hrn/m2:	137.8
Economic planning zone number:	VI
Coefficient Km2:	0.9
Local coefficients:	The location of the land plot in the sanitary protection zone
Cumulative coefficient Km3:	0.88
Coefficient Kf:	1
NGO of the land plot, hrn:	118850.8

Figure 11. The result of the formation of the Extract from the technical documentation
on the regulatory money value of the land plot

In accordance with the Order (Pro zatverdzhennia…, 2016), a template was created for creating a report in an approved form (Figure 11).

Conclusions

So, as a result of the work, a structure was proposed and a set of geospatial data was formed for the geo-informational provision of the normative money value of the lands of settlements on the example of the lands of the town Klevan. A method of economic and planning zoning based on the theory of fuzzy sets is proposed, namely the method of arranging objects according to a set of features, which allows applying real values of evaluation indicators and calculating their integral values. An example of the operation of the automated zoning algorithm with the use of GIS tools is given. Based on the proposed set of geospatial data, an ArcGIS tool was created using the Model Builder application, which allows you to determine the normative money value of a separate land plot and generate a report.

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