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FORMALIZING THE LAND INVENTORY PROCESS FOR INFORMATION SUPPORT OF LAND PROJECTS MANAGEMENT

The subject *of study in this work is the land inventory process.* ***The work increases*** *the efficiency of the land inventory process by finding the possibility of reducing the amount of topographic surveying work by algorithmizing and systematizing the information flows with a combination of qualitatively different data.* ***Objectives:*** *to analyze the land inventory process within land management projects to identify possible ways of its efficiency improvement; focusing on information flows, to create an information model for the inventory process; to develop scientific-methodological basis for information support of land management projects to reduce the amount of topographic surveying for implementation into decision support systems for land management. The following* ***results*** *were obtained. The requirements of the current legislation on the inventory of land plots and related tasks are generalized. A set-theoretic model of information flows of the inventory process, which combines the approaches of functional modeling, is proposed. It allows us to combine the qualitatively different data, consider their dynamic nature and the logic of interaction. IDEF3-model developed. This model considers remote sensing data as a source of accurate and up-to-date information, algorithmizes the mechanism of their combination with other information about land plots and explains the dynamic nature of its changes with time. A method for creating a database of the working inventory land plan is proposed. It combines information about land plots from several sources, reduces the amount of topographic surveying by selecting plots that needed to be coordinated (determined) with the geospatial data. The developed scientific-methodological basis of information support for land projects forms the structure of information technology for land inventory. Its usage will reduce the number of resources required for the implementation of land projects, at the same time forming reliable conclusions about the state of the land by using geographic information systems (GIS) and combining dissimilar data.* ***Conclusions.*** *The results of the bibliographic search confirmed the following. The effectiveness of the land inventory process, which ensures compliance with legislation in the field of land management, is very difficult because of the need to analyze a large amount of different information appears, which may contain errors, inconsistent and contradictory data. This requires the development of specialized models and method focused on the use of GIS for their implementation into decision support systems for land management. Scientific-methodological basis of information support for land projects during the inventory of land plots has been developed, practical usage of which confirmed that the time costs for obtaining the land plot research data decreased by almost 33% and the accuracy of measuring geometric dimensions of the land plot increased by about 1%.*

Keywords: *model of information flows of the process; functional modeling; IDEF3-model; remote sensing data; inventory plan database.*

Introduction

The acceptance of the Global Environment Facility (GEF) agricultural biodiversity work program in 2000 was a turning point in the management of land projects around the world. The implementation of this program helps to direct efforts in identifying methods, technologies and management policies to ensure the positive impact and/or mitigation of the negative impacts of agriculture on biodiversity, increasing the productivity of lands and their ability to restore the soil fertility through the providing agricultural enterprises with information and awareness of numerous goods and services in agricultural projects [1]. In this sense, understanding the dynamics of changes on land plot and the possibility of using land is an essential source of information for making managerial decisions, which are of paramount importance in the context of land changes associated with the intensification and diversification of land use, the implementation of many ecosystem services, multi-level land management goals, new weather and climatic conditions affecting them, etc. [2 - 4]. These changes can be tracked by land inventory [4].

Article 35 of the Law of Ukraine «About Land Management» notes that land inventory is held in order to establish the location of land management objects,

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their boundaries and sizes, identify lands that are not used or use irrationally (not for their intended purpose), to estimate quantitative and qualitative characteristics of lands, implement state control over the use and protection of land, etc. [5]. At the same time, the process of decentralization of public administration, which in 2020 led to the formation of new united territorial communities, significantly contributed to the aggravation of land inventory issues in Ukraine [3].

In the context of the military conflict, these issues have received a new impulse. So, in the proceeding of the round table of the conference «Environmental Security of the State», which took place in April 2022, the following is emphasized. Military actions significantly complicate the management of land projects, restrict access to territories and information resources, and exacerbate time and financial constraints on the implementation of land inventory processes [6]. In this regard, geoinformation systems (GIS) open up new opportunities for collecting data on inventory objects, identifying them, determining title, evaluating the effectiveness of land use, checking them for compliance with legal requirements, making decisions regarding compliance with land use standards, etc. [3, 4, 7]. However, here the potential of GIS is not fully used: they are not considered as an effective tool that allows you to make informed decisions in land management projects in accordance with the legal requirements, environmental protection, rational land use, etc. [4, 8]. This requires the development of specialized models and methods focused on the use of GIS in land inventory processes for their implementation in decision support systems for land management [2, 7, 8].

Subject area analysis and purpose statement

The process of land inventory in the land management projects is regulated by the Decree of the Cabinet of Ministers of Ukraine dated June 5, 2019, No. 476. It combines research, topographic surveying, and design works. According to Art. 57 of the Law of Ukraine «About Land Management» the process ends with the preparation of technical documentation of land management [5, 9]. This process should be held in compliance with the principles of planning, reliability and completeness of data, consistency and standardization of procedures, accessibility of using information databases, generalization of data in compliance with unified approaches and technologies for their processing [9]. This is what requires a scrupulous study of a large amount of different information (paper, graphic, cartographic, electronic), which, unfortunately, may contain errors and / or inconsistent, contradictory data, etc. [3, 7]. It should be noted that such a picture is typical not only for Ukraine. For example, in the works of M. Musinguzi [10] or H. O. Faxon [11], it is noted that in land management there is a coexistence of cross rights to land, which contributes to its irrational use, significantly hinders the increase in land use productivity, and leads to social tension and conflicts. Also, in some cases, respect for the principle of completeness of data is significantly limited by the impossibility of carrying out full-scale topographic surveying work on the ground. This leads to a lack of understanding of changes in the quality of land resources (their intended use, protection, etc.) [2, 12], to a partial or complete absence of state control over land use [11], to uncontrolled use of forests and violation of natural landscapes [13, 14], promotes aggressive farming, land seizure [15], etc.

Regardless of the considered aspects of the problem of land use, the results of bibliographic searches confirm the following. Effective land inventory and compliance with the law is extremely difficult due to the large size of the geographical areas that need to be tracked [4, 13, 14], the limited number of humans [7, 12, 16] and financial resources [3, 11, 15], that are available for land management organizations. Therefore, in order to increase the transparency and compatibility of inventory results, to make decisions about land management based on the analysis of independent heterogeneous data, it is necessary to implement new approaches and methods within the framework of digitalization of the process that will combine field surveys of land plots with remote sensing of the Earth (RS) data [7, 11, 13] (after all, most of the resources during the inventory are spent on conducting topographical and geodetic works [16]). At the same time, although the use of remote sensing data when conducting an inventory of lands is provided for by the existing legislation of Ukraine [9], the mechanism of their application is not described. Thus, *the purpose* of the article is to increase the efficiency of the land inventory process by finding the possibility of reducing the amount of topographic surveying work through algorithmizing, systematizing the information flows and a combination of qualitatively different data.

Information flows model of the land inventory process

Land project management is not an easy task. On the one hand, the management processes here are defined and regulated by the existing legislation (for example [5, 9]), but their implementation can be significantly complicated due to the features inherent in certain projects (for example, due to the complex geographical location of the land plot, as a key element of land project [13, 16], legal uncertainty about this object [10], the presence of corruption components [15], etc.).

On the other hand, like any information processes performed in land projects, they require algorithmization and formalization to eliminate chaos, determine a clear sequence of work, ease of control over their implementation, etc., as well as systematize data, requirements, norms and rules in one document, arising from the provisions of the existing legislation [7, 18].

Using the author's methodology for the study of information processes, the process of land inventory as a set-theoretic model of its information flows [18 – 20] can be conceptually presented:

$$I\_Pr = (V, Z, \varphi, A, O, \psi). \quad (1)$$

Here, the set $V = \{v_1, v_2, v_3, v_4, v_5, v_6\}$ is considered as the set of input data required for the land plots inventory; $Z = \{z_1, z_2, z_3\}$ means the set of documents regulating the land inventory process; $A = \{a_1, a_2, a_3, a_4\}$ – a set of operations that implement the process; $O = \{o_1, o_2, o_3, o_4\}$ – a set of output data of the process under consideration. At the same time, the internal content of the sets by combined in expression (1) is disclosed on fig. 1. Also, φ means the update function, the need for which is associated with the refinement of the input data of the process in accordance with the requirements of the existing legislation; ψ – an output function that uniquely defines the rules for generating the output data of the land inventory process.

The inventory process is beheld discretely in time. The values of inputs and outputs vary depending on the requirements of regulatory documents, preliminary input data and a set of operations required implementing the process, i.e.:

$$\begin{cases} V(t) = \varphi(V(t-1), Z(t)); \\ O(t) = \psi(V(t), A(t)), \end{cases} \quad (2)$$

that is the input of the process in the present time V(t) depends on the input at the previous moment of time and the set of valid regulatory documents Z(t); the output of the process O(t) determines the sets of input data V(t) and operations A(t) performed at the present time.

The function of exits is the visual representation:

$$\psi : A \times V \rightarrow O, \quad (3)$$

which depends on the complexity of the process, can be presented in tabular, graphical view and as a graph [18]. To determine this visual representation in the land inventory process, we present the function ψ in tabular form (table 1) in accordance with the rules formed in the work [18].

Table 1

Exit Function Tabular View (3)

Operation	Input elements of the set V					
	v_1	v_2	v_3	v_4	v_5	v_6
a_1	$a_1\|o_1$	$a_1\|o_1$	$a_1\|o_1$	$a_1\|o_1$	$a_1\|o_1$	$a_1\|o_1$
a_2	-	-	-	-	$a_2\|o_2$	-
a_3	-	-	-	-	$a_3\|o_3$	$a_3\|o_3$
a_4	-	-	-	-	-	$a_4\|o_4$

In table 1, each row corresponds to one operation of the land inventory process a_j (j=1, …, 4), and the column is one valid input element of the set v_n (n=1, 2, …, 6). The cell at the intersection of a row and a column contains an operation a_j, the execution of which occurs when an element arrives at the input v_n, and the output element o_m (m=1, …, 4), which will appear when the operation is performed a_j.

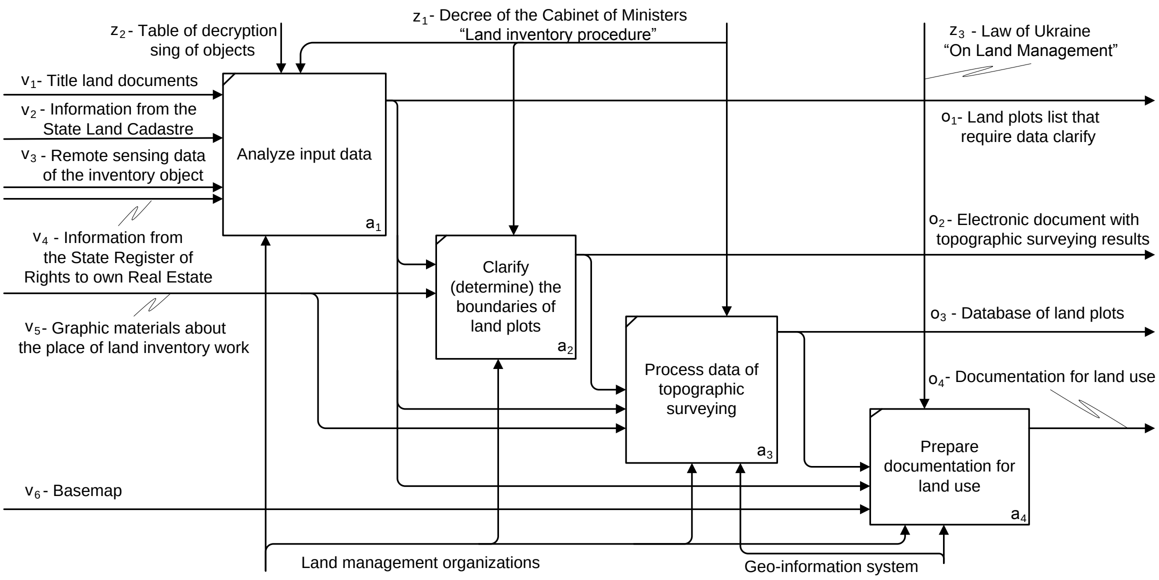

Fig. 1. IDEF0-model as a structure of information technology of land inventory

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For example, in time t upon receipt of an input v_5 to get the output o_3 during operation a_3 is required. In this case, is a necessary output o_1, obtained as a result of the operation a_1 by summarizing input data v_1, v_2, v_3 and v_4 and output o_2, obtained as a result of the operation a_2.

Fig. 1 illustrates a graphical view of the function ψ based on the IDEF0 functional modeling standard, which algorithmizes the land inventory process and defines the structure of information technology that can be used in decision support systems for land management. In it, as a means to perform operations a_3 and a_4 GIS is considered. GIS contains a set of methods and tools for combining geospatial data with the arguments of decision makers [19, 20].

Executing the update function – visual representation [18, 20]:

$$\varphi : V \times Z \rightarrow V \tag{4}$$

associated with the refinement of input data depending on the requirements of regulatory documents Z.

Usually, as the simplest way to represent a function, an enumeration is used, which for each element of the set V forms implementations of the form [17], [18]:

$$\begin{aligned} &v_1 = \varphi(v_1, z_1); \\ &v_2 = \varphi(v_2, z_1); \\ &\ldots\ldots\ldots\ldots\ldots \\ &v_6 = \varphi(v_6, z_3). \end{aligned} \tag{5}$$

However, in the context of digitalization and the need in information support for land projects, this method is subjective, focused on attracting experts and does not correlate with the principles specified in the Decree of the Cabinet of Ministers of Ukraine No. 476 (for example, with the principles of standardization of procedures, generalization of data in compliance with uniform approaches and technologies for their processing [9], etc.). Also, from the first equation of system (2) it follows that the elements of the set of input data are transformed in time, considering the requirements of the regulatory documents. It requires further explanation to reveal such a mechanism.

Dynamic nature of the function φ can be explained by using the methodology IDEF3. It has been chosen due to the following reasons [21, 22]:

- IDEF3 is an extension of the IDEF0 standard, which is used to represent the function of outputs ψ;
- IDEF3 allows you to take into account the logic of the relationships between operations, to present their discrete sequence in the script form that implement in a finite time. It is consistent with the first equation of the system (2);
- IDEF3 provides a tool for creating a set of graphical models that reveal the mechanism for generating realization (5) of the update function φ of the process, while providing simplicity, clarity and ease of perception of the dynamic character of information flows;
- IDEF3 is a part of a structural analysis, has certain semantics for describing information processes, which facilitates their full understanding by developers and end users.

All this, on the one hand, allows us to take into account the dynamic nature of the update function φ according to (2), on the other hand, to reveal the mechanism for obtaining realizations (5) as an operations finite sequence.

For example, consider a fragment of a graphical view of function realizations φ. It based on the IDEF3 methodology, which illustrates the mechanism of forming realizations $v_k = \varphi(v_k, z_l)$ (k=1,…,4; l=1,2) expression (5) for operation a_1, which is held during research works of the land inventory process (fig. 2). According to table 1, while an operation a_1 performs to obtain an outcome o_1 elements v_1, v_2, v_3 and v_4 of set V are combined. They arrive at the input of operation a_1, their refinement is carried out by the elements z_1 and z_2 of set Z.

The main sequence of activities on fig. 2 was formed by algorithmizing of the verbal data of work [9] and systematization of experimental information obtained during the land plots inventory [17]. Here, a temporary designation of the elements of the sets V and Z is additionally introduced to explain the dynamics of their change (this is not typical for the IDEF3 methodology).

In IDEF3-model typical definitions of land management, such as working inventory plan, are used. A working inventory plan is a document that combines various information about the inventory object and the administrative-territorial units that are part of it, the territories defined by the land project, about restrictions on the land rights to use and encumbrance of rights to them [5, 9]. Under such conditions, exit o_1, received from the junction J_{12}, is a database that should combine textual and graphic information in a single description, indicating information about the owner of the land plot, the number of the State Certificates of land, area of the land plot, location of the land plot, etc. The same data is sent to operations a_2, a_3 and a_4 with the difference that some of them are considered as a database that is used for the preparation of documentation for land use, and some require further clarification (determination) by carrying out topographic surveying works. According to Art. 186 of the Law of Ukraine «On Land Management» the land project become valid only after their implementation, data processing and production of documentation for land use (fig. 1) [5].

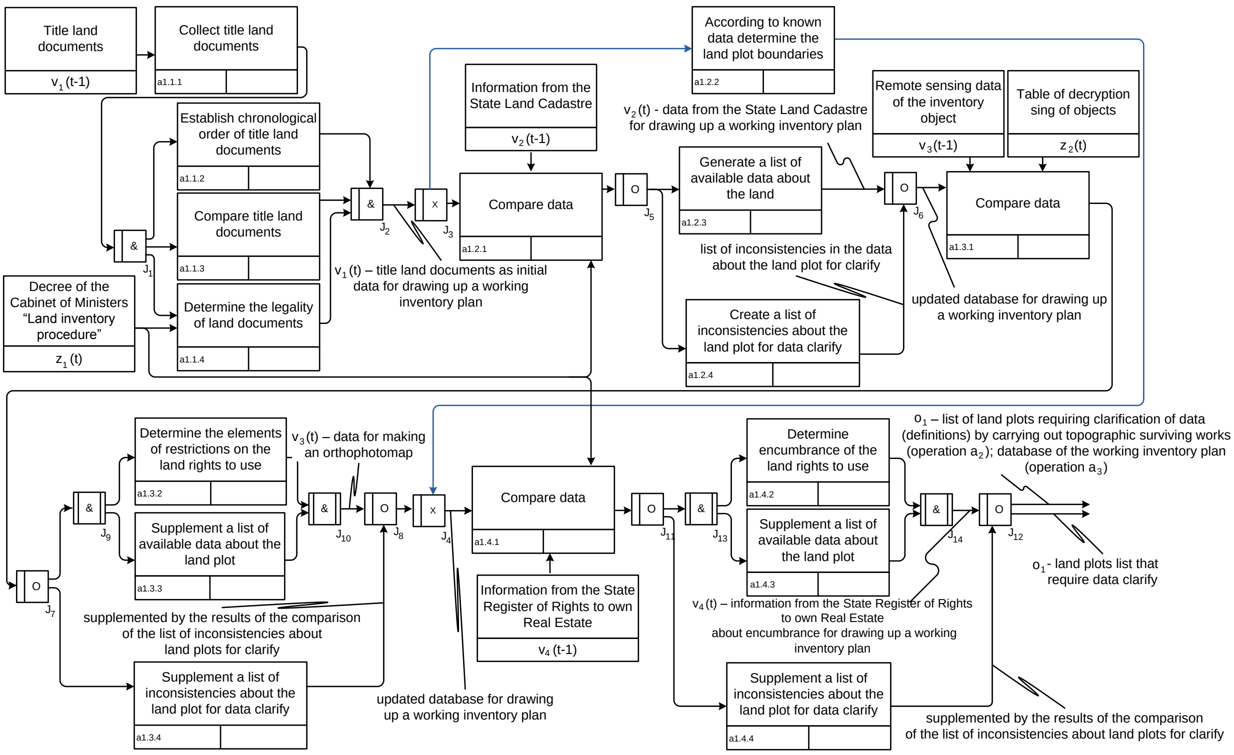

Fig. 2. IDEF3-model of the graphical view of function φ realizations for a_1 operation, which formed by verbal data and experimental information

Method of creating a database of the working inventory land plan

An important stage in implementing different data and the formation of managerial decisions on their basis is their verification or quality assessment [3, 4]. In traditional methods, information about land plots is taken from land management documentation [9]. In the IDEF0-model, land plots are considered as geographical objects with coordinates, area, complex geometric shape, interacting with other geographic objects, the spatial data of which are extracted from several sources. Therefore, in table 1 the sequence of receipt of these data at the input of the operation o_1 is shown. In accordance with the requirements of the ISO 9000:2005 standard, these data are analyzed and verified in the sequence disclosed by the IDEF3-model (fig. 2).

Analyzing the IDEF3-model, we note that in order to draw up a inventory working plan, it is necessary to create a database using elements v_1, v_2, v_3 and v_4 by forming a union of the sets:

$$BD_{IP} = \bigcup_{i=1}^{4} BD_{v_i} , \qquad (6)$$

where BD_{v_i} – sets, that combine information from inputs v_1, v_2, v_3 and v_4.

The method of forming a union of the sets (6) involves the following sequence of actions.

Stage 1. Determine the legal title documents for land plots.

The need in this stage is due to the fact that today in Ukraine there are several types of State Certificates of land plot, each of which confirms the ownership, but contains different information about it. This is due to several reasons, for example, the difference in title land documents of different time periods, possible errors in the transfer / re-registration process of ownership of the land plot, etc. Therefore, it is necessary to establish the chronology of documents, compare their information and determine the legality in accordance with the Decree of the Cabinet of Ministers of Ukraine No. 476 [7, 17]. This allows you to define and enter the input data v_1 into the database (6), that is, to form a set:

$$BD_{v_1} = A \cup B \cup C_{v_1} \cup D_{v_1} \cup E_{v_1} \cup F_{v_1} , \qquad (7)$$

where A = {a: a – number of the State Certificate of land plot};

B = {b: b – full name of the land owner};

$C_{v_1} = \{c_{v_1} : c_{v_1}$ – land plot area in accordance with the State Certificate of land plot};

$D_{v_1} = \{d_{v_1} : d_{v_1}$ – location of the land plot in accordance with the State Certificate of land plot};

$E_{v_1} = \{e_{v_1} : e_{v_1}$ – description of the boundaries of

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the land plot};

$F_{v_1} = \{f_{v_1} : f_{v_1}$ – cadastral number of the land plot according to the State Certificate of land plot}.

Stage 2. According to the data from the State Land Cadaster, to form a set:

$$BD_{v_2} = C_{v_2} \cup F_{v_2} \cup G_{v_2} \cup H, \quad (8)$$

where $C_{v_2} = \{c_{v_2} : c_{v_2}$ – land plot area in accordance to the data from the State Land Cadaster};

$F_{v_2} = \{f_{v_2} : f_{v_2}$ – cadastral number of the land plot according to the data of the State Land Cadaster};

$G_{v_2} = \{g_{v_2} : g_{v_2}$ – purpose of the land plot in accordance with the data of the State Land Cadaster};

H = {h: h – list of security zones and easements of the land plot according to the data of the State Land Cadaster}.

If there is no land plots data in the State Land Cadaster, then the set BD_{v_2} of expression (8) consists of empty sets.

Stage 3. Analyzing remote sensing land plots data, form a set:

$$BD_{v_3} = D_{v_3} \cup E_{v_3} \cup G_{v_3} \cup M, \quad (9)$$

where $D_{v_3} = \{d_{v_3} : d_{v_3}$ – land plot location obtained from the results of remote sensing analysis};

$E_{v_3} = \{e_{v_3} : f_{v_3}$ – description of the boundaries of the land plot obtained by the results of remote sensing analysis};

$G_{v_3} = \{g_{v_3} : g_{v_3}$ – purpose of the land plot obtained by the results of remote sensing analysis}.

M = {m: m – list of restrictions on the land rights obtained by the results of remote sensing analysis}.

Stage 4. According to the State Register of Rights to own Real Estate, form a set:

$$BD_{v_4} = \{bd_{v_4} : bd_{v_4} \text{ – list of encumbrances of the land rights}\}. \quad (10)$$

Stage 5. Due to the fact, may be present of duplicate information, compare the data sets $C_{v_i}, D_{v_i}, E_{v_i}, F_{v_i}$ and G_{v_i}. To do this, it is necessary to find the symmetric difference of sets with duplicate information. For example, you can find a match for the values of the land plot area obtained from different sources using the formula:

$$C_{v_1} \Delta C_{v_2} = (C_{v_1} \setminus C_{v_2}) \cup (C_{v_2} \setminus C_{v_1}).$$

Depending on the results of the comparison the further procedure is given in the table 2.

According to experts, among the land plots officially registered in the State Land Cadaster, a significant part of them are plots with geometry errors that are duplicated as a result of changing the numbers of cadastral quarters, dividing and merging plots, changing their purpose, etc. [17]. This leads to the cases shown in table 2, when information obtained from different sources is contradictory and needs to be reconciled. In this case, remote sensing data (high-resolution aerial, photographic and / or satellite imagery) and orthophotos or digital maps created on their basis, which display the earth's surface with maximum reliability, become a source of accurate and up-to-date information. It makes it possible to obtain grounded decisions to eliminate some contradictions [3, 4, 12].

For example, title documents that were issued in the period 1992 – 2001 may contain data on several land plots with different purposes (for example, for personal agriculture or for the construction and maintenance of a residential building, etc.). In this case, a situation may arise when symmetric set difference is a non-empty set $(D_{v_1} \Delta D_{v_3} = \neg\varnothing)$, i.e., the land plot location according to the documents does not correspond to its actual land plot location (fig. 3, a). It is also common that the purpose of a land plot differs depending on the data source, i.e., $G_{v_2} \Delta G_{v_3} = \neg\varnothing$. For example, in the case shown in fig. 3, b, according to the State Land Cadaster, land plots are intended for personal agriculture, this does not correspond to the actual situation. In these cases, the elements corresponding to the actual information are entered into the database (6), i.e., set elements d_{v_3} or / and g_{v_3}, obtained from the results of remote sensing analysis [12, 13, 17].

In case of detection of such errors, an output o_1 is formed. Further, according to Art. 23 of the Decree of the Cabinet of Ministers of Ukraine No. 476 the procedure for coordinating the data obtained from the results of the inventory process is carried out [9]. In these cases, the inventory process is carried out without topographic surveying works, which significantly reduces the cost of land projects [5, 9].

“Ideal” can be considered a situation, where there are no inconsistencies in the land plot data, received from different sources. This situation is described in the first row of table 2, when the mathematical comparison of the sets elements result (their symmetric difference) corresponds to an empty set. In this case, in accordance with Art. 26 Decree to the Cabinet of Ministers of Ukraine No. 476, according to the results of the input data analysis, documentation for land use is finalized without carrying out topographic surveying works.

Table 2

List of actions depending on the results of comparing duplicate information sets (7) – (10)

The results of comparing sets					The list of actions
$C_{v_1} \Delta C_{v_2}$	$D_{v_1} \Delta D_{v_3}$	$E_{v_1} \Delta E_{v_3}$	$F_{v_1} \Delta F_{v_2}$	$G_{v_2} \Delta G_{v_3}$	
$\varnothing$	$\varnothing$	$\varnothing$	$\varnothing$	$\varnothing$	Form a union of the sets by expression (6) and, in accordance with the IDEF0-process model, proceed to the operation a_4 (Art. 26 of the Decree of the Cabinet of Ministers of Ukraine [9]).
$\neg\varnothing$	$\times$	$\times$	$\times$	$\times$	For land plots for which different data were found as a result of the comparison, carry out topographic surveying works to clarify (determine) the boundaries and areas. In accordance with the IDEF0-process model, proceed to the operations a_2 and a_3. Then, taking into account the obtained data, form a union of sets in accordance with expression (6), proceed to the operation a_4.
$\times$	$\times$	$\neg\varnothing$	$\times$	$\times$	
$\times$	$\neg\varnothing$	$\times$	$\times$	$\times$	Correct data based on the results of remote scanning. In accordance with the IDEF0-process model form an input o_1 and proposals for the matching the data by the State Land Cadaster (Art. 23 of the Decree of the Cabinet of Ministers of Ukraine [9]).
$\times$	$\times$	$\times$	$\neg\varnothing$	$\times$	
$\times$	$\times$	$\times$	$\times$	$\neg\varnothing$	

Note: «×» means an insignificant sets comparison result.

a

b

Fig. 3. Determination of information about land plots based on the analysis of remote sensing data (according to the results of work [17]):
a – finding a land plot location; b – clarifying of the purpose of the land plot

It also reduces the costs of the land project [5, 9].

But the most complex and interesting case is when the result of comparing sets $C_{v_1} \Delta C_{v_2}$ and $E_{v_1} \Delta E_{v_3}$ is not an empty set. And, although it is not possible to eliminate the found contradictions and inconsistencies without carrying out topographic surveying works [9], in this case, the use of remote sensing data also provides certain advantages.

For example, let us consider the case of an inventory of a land plot (fig. 4) located outside the settlements of the Kolomak Village Council of the Bohodukhiv district of the Kharkiv region (cadastral number of the land plot 6323280600:03:000:0326). The area where it is located is swampy (this is due to its proximity to the Kolomak River), grassy with shrubs, electricity lines and field roads are passing through it.

Fig. 4. Land plot on inventory process example

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The difficult geographical location complicates the cadastral survey during topographic surveying works. As a result, on the land plot plan, which was obtained using traditional approaches, the geodesists indicated only the main objects located on the land plot and near it. Agricultural land on the plan is not specified and is separated by a straight line; small shrubs located near it are not marked. The contours of the land plot are depicted by straight, rather long lines (fig. 5).

The main geometric parameters of the land plot, obtained as a result of the cadastral survey, are shown in Table 3. At the same time, only 7 contour points were chosen in the characteristic places of the relief, in the geodesists view. The time spent on the direct cadastral survey of the land plot was one hour.

At the stage of research, using the developed scientific-methodological basis lets upload a satellite image of the land plot to the ArcMap software. Considering the decryption signs decrypt objects located nearby and defines protected zones for them. Taking into account the data of the State Land Cadaster, in particular the Public Cadastral Map, determine the security zones and easements. Information about the existing encumbrances of rights to a land plot was not found according to the State Register of Rights to own Real Estate.

Mutual work with a satellite image, maps and data allows to create a preliminary land plot plan (fig. 6), which becomes the basis for planning a cadastral survey. In particular, taking into account the geometry of the land plot, the number of contour points can be determined, divide the land plot area into sectors for surveying in several stages, planning the sequence of its implementation, etc.

The results of the cadastral survey, obtained using the developed scientific-methodological basis, taking into account the preliminary land plot plan are shown in table 3. An inventory plan with real land plot contours is shown in fig. 7.

As you can see, in the end, the accuracy of obtaining the geometric parameters of the land plot is increased; the time spent on direct cadastral survey of the land plot is reduced. On that basis, it appears possible to perform design works and prepare of documentation for land use, which also reduces the costs of the project.

Conclusions

The results of the bibliographic search confirmed that the effectiveness of the land inventory process in order to ensure compliance with legislation in the field of land management is extremely difficult for a number of reasons [3, 4, 12]. This necessitates the development of models and method focused on the use of GIS for their implementation in decision support systems for land management. Supporting the ideas of the works [3, 9, 11] regarding the need to ensure transparency in the management of land resources, the results of the study are aimed at forming objective conclusions about the state of the land, which are based on theoretical-multiple and functional modeling of information flows of the inventory process for a possible combination of qualitatively different data, taking into account their dynamic nature and the logic of interaction.

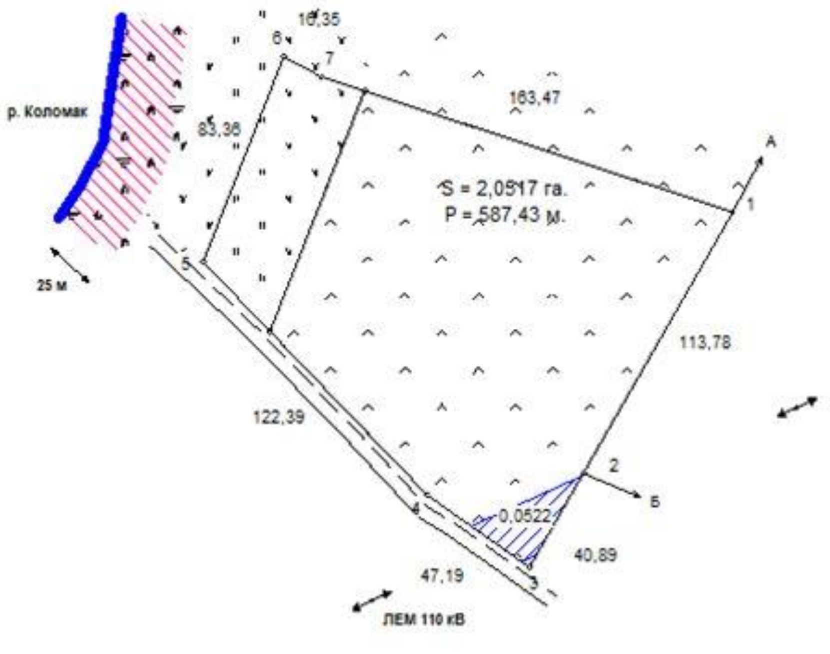

Fig. 5. Land plot plan, which was obtained using traditional approach during inventory process

Table 3

Comparative results of cadastral survey of a land plot (fig. 4) obtained using different approaches

	Use during the inventory process:		Comparison result
	traditional approach	developed scientific-methodological basis	
Land plot area, ga	2,0517	2,0680	+0,79 %
Land plot perimeter, m	587,43	587,55	+0,02 %
The number of contour points used in the cadastral survey	7	12	-
Time spent on cadastral survey, min	60	45	- 33,3 %

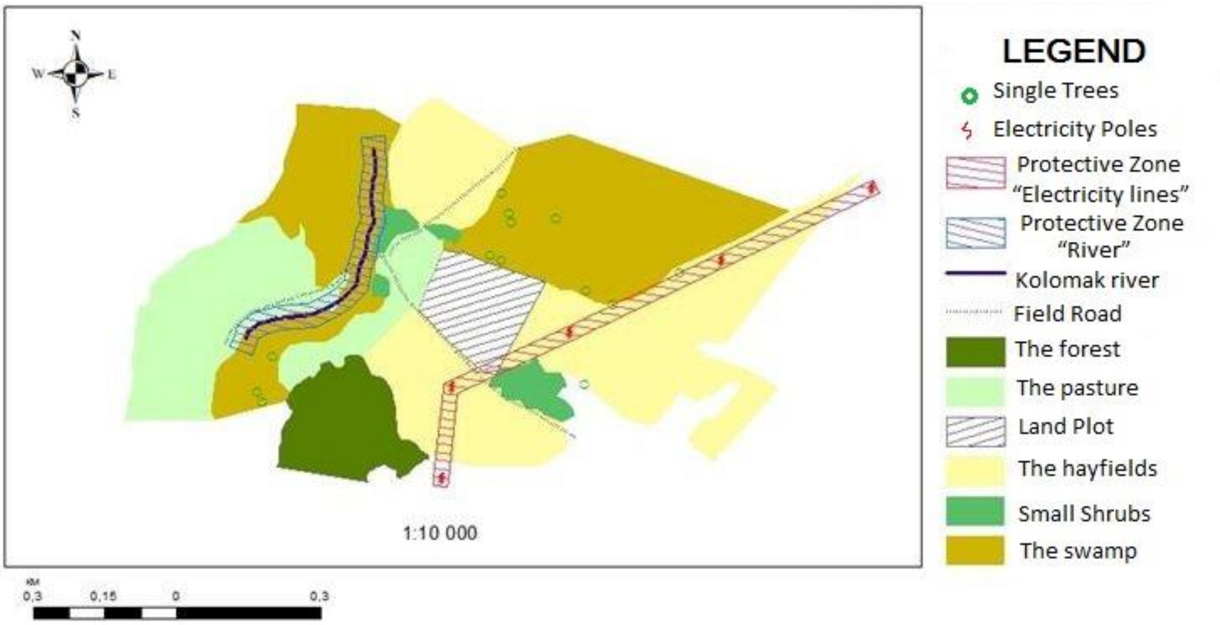

Fig. 6. A preliminary land plot plan obtained using
the developed scientific- methodological basis for planning a cadastral survey

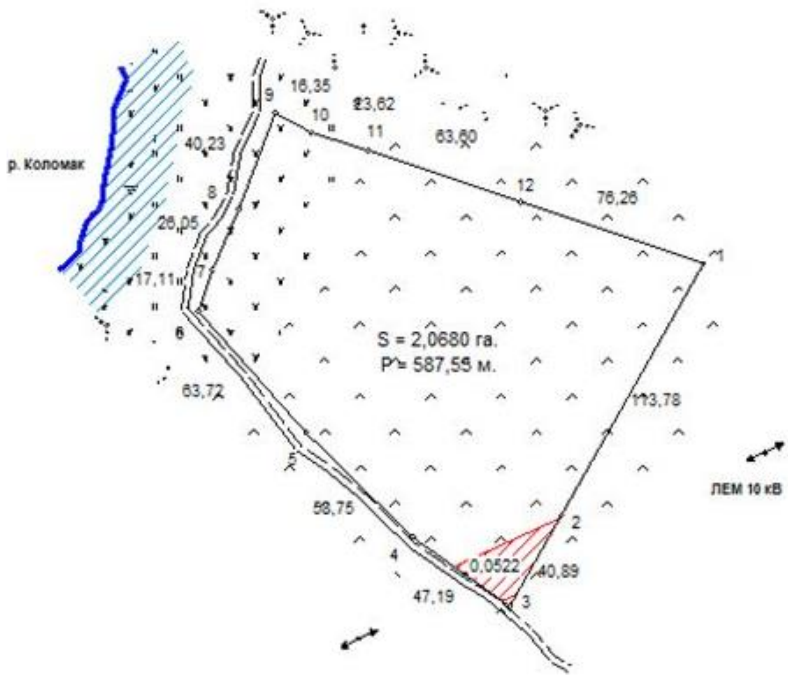

Fig. 7. Refined plan of the land plot, which
was obtained using developed scientific-methodological basis for inventory process

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Unlike work [8, 9, 15], where remote sensing data is considered as an additional tool, the use of which insignificantly affects the inventory results, the developed IDEF3-model considers remote sensing data as a source of accurate and relevant information, algorithmizes the mechanism of their combination with other information, explains the dynamic nature of its change.

Based on the results of the study of work [17] and agreeing with the conclusions of works [4, 12, 14], a method for creating a database of a working inventory plan is proposed, which explains the steps for obtaining information about land plots from several sources, combines field research with remote sensing data, reduces the amount of topographic surveying works by selecting from all land plots only those that require clarify (definitions) of geospatial data.

The developed scientific-methodological basis of information support for land projects creates the structure of land inventory information technology. Its practical use confirmed a reduction the time spent on direct cadastral survey of the land plot by 33.3 %, while increasing the accuracy of the obtained geometric land plot parameters by 0.79 % with a slight increase in the volume of research works.

The results of the study can become an additional tool for promoting the concept of digitalization of cities, considered in [3], by creating consistent datasets on land use in Ukraine.

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Author contributions: review and analysis of references – **V. Cheranovskiy**; development of conceptual provisions and methodology of research – **Svitlana Danshyna**; analysis of research results – **Svitlana Danshyna, Valeriy Cheranovskiy**; writing–original draft – **Svitlana Danshyna**; editing – **Valeriy Cheranovskiy**; project administration – **Svitlana Danshyna**.

All authors have read and agreed to the published version of the manuscript.

Future research directions

Further research should be aimed at solving the issues of automating design work, in particular, the operations of processing, interpreting and visualizing (especially through thematic mapping) the information received about the inventory objects for its analysis by local governments bodies for the purpose of constant monitoring of land use and the formation of decisions on land management based on these data.

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ФОРМАЛІЗАЦІЯ ПРОЦЕСУ ІНВЕНТАРИЗАЦІЇ ЗЕМЕЛЬ ДЛЯ ІНФОРМАЦІЙНОЇ ПІДТРИМКИ ПРОЄКТІВ ЗЕМЛЕУСТРОЮ

С. Ю. Даншина, В. О. Черановський

Предметом дослідження є процес інвентаризації земель. **Метою** статті є підвищення ефективності процесу інвентаризації земельних ділянок шляхом зменшення обсягів топографо-геодезичних робіт через алгоритмізацію, систематизацію інформаційних потоків і поєднання різнорідних даних. **Задачі:** проаналізувати процес інвентаризації земель при управлінні проєктами землеустрою для визначення можливих напрямків підвищення його ефективності. Акцентуючи увагу на інформаційних потоках, розробити інформаційну модель процесу інвентаризації та відповідне науково-методичне забезпечення інформаційної підтримки проєктів землеустрою з метою зменшення обсягів топографо-геодезичних робіт для впровадження до систем підтримки прийняття рішень при управлінні земельними ресурсами. Отримано **результати**. Узагальнено вимоги чинного законодавства щодо інвентаризації земельних ділянок і пов'язані з цим проблеми. Запропоновано теоретико-множинну модель інформаційних потоків процесу інвентаризації, залучення до якої підходів функціонального моделювання дає змогу поєднати якісно різні дані, урахувати їх динамічний характер і логіку взаємодії. Розроблено IDEF3-модель, яка розглядає дані дистанційного зондування як джерело точної й актуальної інформації, алгоритмізує механізм їх поєднання з іншою інформацією про земельні ділянки, пояснює динамічний характер її зміни з часом. Запропоновано метод створення бази даних робочого інвентаризаційного плану, що, поєднуючи інформацію про земельні ділянки з декількох джерел, дає змогу зменшити обсяги топографо-геодезичних робіт шляхом вибору з усіх ділянок лише тих, що потребують узгодження (визначення) геопросторових даних. Розроблене науково-методичне забезпечення інформаційної підтримки проєктів землеустрою створює структуру інформаційної технології інвентаризації земель, використання якої дає змогу зменшити обсяги ресурсів, необхідних для виконання проєктів, при одночасному формуванні об'єктивних висновків про стан земель шляхом використання геоінформаційних систем (ГІС) і поєднання різнорідних даних на обстежувальному етапі. **Висновки**. Результати бібліографічного пошуку підтвердили, що ефективність процедури інвентаризації земель для забезпечення дотримання законодавства у сфері землеустрою ускладнено внаслідок необхідності вивчення великої кількості різнорідної інформації, яка може містити помилки, неузгоджені і суперечливі дані. Це потребує розроблення спеціалізованих моделей і методу, орієнтованих на використання ГІС, для впровадження їх до систем підтримки прийняття рішень при управлінні земельним ресурсами. Розроблено науково-методичне забезпечення інформаційної підтримки проєктів землеустрою при інвентаризації земельних ділянок. Його практичне використання підтвердило зменшення часових витрат майже на 33 % і підвищення точності приблизно на 1% при отриманні геометричних параметрів земельної ділянки.

Ключові слова: модель інформаційних потоків процесу; функціональне моделювання; IDEF3-модель; данні дистанційного зондування; база даних робочого інвентаризаційного плану.

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