LAND MONITORING: MODELING AND EVALUATION

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The natural resources of Ukraine contribute to the development of effective use of land resources. In this context, land monitoring is an analytical basis and is an observation of the land condition fund in order to identify changes in time, assess them, and prevent the consequences of negative processes.

The organization of a land monitoring system in the context of economic globalization requires obtaining new knowledge about the object of the study, identifying the features of the land monitoring system, determining the components of the system, the interconnections, their evaluation and analysis.

The issue of land monitoring was studied by such scientists as A. Tretiak, G. Panas, A. Popova, A. Litvak, A. Dorosh, A. Sozinov, V. Patyk, S. Ryzhuk, M. Lesnoy, P. Pisarenko, A. Rakoyed, I. Yatsuk and others.

In the works of Dorosh A.S., it is noted that the performance at the proper level of the condition's management functions to monitor the use and protection of land depends on objective information. An important source of obtaining such information is the inventory of land [1, p. 24]. At the same time, determining the specificity of land use, it is necessary to take into account the features of lands as a unique natural resource [2, p. 27].

According to scientists Panas R. and Malanchuk M. monitoring of land and soil cover is very popular in Ukraine, considerably this due to the large extent this is due to negative changes in the properties of soils [3, p. 203]. According to

Popova's research, the land conditions resources is estimated to be close to critical [4, p. 93].

In the works of Kingwell R., John M. and Robertson M., the attention was drawn to the land degradation and the need to manage the dryland salinity [5, p. 51].

Anne Vernez Moudon and Michael Hubner conducted land-use monitoring researches in the cities. The research required an extensive review of the literature on the land monitoring, as well as interviews with numerous scientists and practitioners in this field. The processes of urbanization and their negative impact on the urban land conditions were studied. Land use planning and management methods were proposed [6, p. 187].

The intensity of anthropogenic pressure on land resources depends on the level of overall economic development of the territory, negatively affects the condition of the environment [7, p. 288]. Popova O.L. identifies four groups of territorial structures: ecologically unbalanced, unstable vulnerable, medium-balanced and ecologically balanced [4, pp. 97-98].

According to Dorosh A.S., effective monitoring and control over the use and protection of land depends on objective information [1, p. 24]. This is facilitated by the implementation of works on ecological and agrochemical certification of agricultural land.

At present, such methods as "Agro-ecological monitoring and certification of agricultural lands" [8], "Methodology of continuous soil-agrochemical monitoring of agricultural lands of Ukraine" [9], "Methodology of agrochemical certification of agricultural lands" [10] and etc. At the same time, according to Pisarenko P.V., agrochemical monitoring is an integral part of complex agro-ecological monitoring of lands [11, p. 12].

In scientific works Rakoyed A.A. it is proposed a technique for assessing the agro-ecological condition of agricultural land, based on the use of a set of both direct and indirect indicators. The first group includes indicators on which the ecological and agrochemical condition of arable land is determined, to the second, the degree of disturbance of the ecological balance in the ratio of lands in agro-landscapes and the intensity of manifestation of soil degradation processes [12, p. 6]. Research Yatsuk I.P. it is shown a comprehensive evaluation of the condition of soils in administrative areas, based on agrochemical survey, is the basis on which both a regional program for increasing soil fertility and management decisions for their protection and rational use can be based [13, p. 110].

The conducted scientific researches have revealed deterioration of land condition. The developed evaluation methodologies are mainly directed to the analysis of agrochemical and agro-ecological land conditions. They don’t consider evaluations of the land conditions under the multifactor influence of the functioning environment. At the same time, monitoring of the land conditions is not comprehensive and monitoring of land as a system is virtually non-existent [14, p. 55].

Petliuk Yu. S. notes that the existing system for collecting information on the land conditions, either in volume or in content, does not meet modern requirements and tasks of condition land administration [15, p. 247].

There is a need to organize an effective land monitoring system. Despite numerous publications, these studies remain insufficient, since this system is complex and multifactorial.

To further study the land monitoring system, it is first necessary to develop an economic model that will identify the most significant components with their interconnections, as well as determine the characteristic parameters. Then formalize the evaluation and analysis processes by developing appropriate methods.

Monitoring of land is one of the main functions of management in the sphere of land use and protection. Its object is the land fund of Ukraine regardless of the form of ownership of the land, the special purpose and the nature of use.

Land monitoring is carried out in accordance with national and regional programs. It consists of systematic observations of the land conditions and analysis. Information obtained during observations of the land conditions is summarized by districts, cities, regions, and also by individual natural complexes. The results of the evaluation of the land conditions are the basis for the adoption of management decisions regional and local executive authorities, local authorities for the implementation of measures for forecasting, planning, organization of rational use and protection of land.

In practice, the organization of land monitoring is complicated by the influence of various environmental factors. External factors have an indirect impact on the organization of land monitoring. They consist of social, economic, legal, political, technical, and territorial. Direct impact has internal factors: organizational, production and technical, financial. At the same time, land monitoring acts as a system that is formed under the influence of these factors.

The study of the land monitoring system is also complicated by the specifics of its functioning. It is a composite monitoring of the environment and has a characteristic feature - the heterogeneity of land resources.

Land monitoring, depending on the purpose of observations and the degree of coverage of the territories, is conducted at the local, regional and national levels. Financing and logistics are provided from various sources. For example, the organization of measures for soil monitoring on agricultural land is carried out at the expense of condition and local budgets. At the same time, the executive bodies' control over the use and protection of lands is carried out at the expense of the condition budget.

Thus, land monitoring is characterized by multifactor formation and, accordingly, the complexity of the evaluation, which determines the need to use modeling.

To create an economic model, two main features of the formation of a land monitoring system were identified. The first attribute is of a socio-economic nature, since the financing of land monitoring is formed on the basis of the request of the society for information on the land conditions resources, their use. The second group includes organizational measures to conduct observations of land resources. Since the economic attribute dominates, the modeling was aimed at creating an economic model of land monitoring.

When creating a model of the land monitoring system, a set of logical interconnections was used. Such a mapping combines the groups of elements of the object under study into analogous groups of model elements. In other words, the model is a conditional image of an object constructed to simplify its study. The study of this model gives new knowledge about this object.

By definition, the model is abstract. It identifies the most significant factors, determines the patterns of functioning of the object under study and abstracts from other factors that have little effect. The composition of the factors considered in the model and its structure can be improved on the basis of knowledge obtained as a result of the deepening of the study of the object.

Over many years of world experience it has been proved that economic models can be a powerful tool for scientific analysis and forecasting, obtaining results-conclusions that are adequate to the object under study.

For creating the economic model, all interconnections of the land monitoring system can be quantified, which allows obtaining objective data on the condition of functioning of the land monitoring system. Interpretation of modeling results is aimed at changing from information obtained on the basis of model research to describing the components and interconnections of the system. Based on the analysis of modeling results, decisions are made regarding the conditions in which the system will function most effectively.

The economic model of the land monitoring system is considered as a set of enlarged components, fundamentally necessary for the existence and functioning of the system under study.

The unity of the elements of the system, the connections and interactions between them form the integrity of the system, and the components - the structure and economic interests [16, p. 130]. Consider the system of monitoring the land for economic reasons. Government bodies and self-government bodies form a social subsystem, and business structures are, respectively, economic. The operating environment of these subsystems is directly or indirectly linked to land resources.

This system is formed on the requests and opportunities of both the social and economic subsystems. At the same time, the demands are the needs of the society in the rational use and protection of land, and the possibilities are financial support for the organization of monitoring, as well as processes related to improving the efficiency of land use and protection.

As a result of the analysis, the components were identified and the interconnections of the land monitoring system were determined. The enlarged components of this system are the land fund, social and economic subsystems. Between the first two components there are socio-economic interconnections, and between others - economic.

On the basis of this approach, a graph-model is formed, Fig. 1. The presented model has edges (links) and vertices (corresponding subsystems), which are united in a single system (S).

Each subsystem is in accordance with the certain vertex of the graph-model: S_c (social subsystem), S_e (economic) and S_z (land fund).

Edges of the graph-model ($S_e - S_z$) and ($S_e - S_c$) are characterized by economic interconnections, and the edge ($S_z - S_c$) – is socio-economic. Together, the vertices and ribs form a structure that graphically represents the economic model of a land monitoring system.

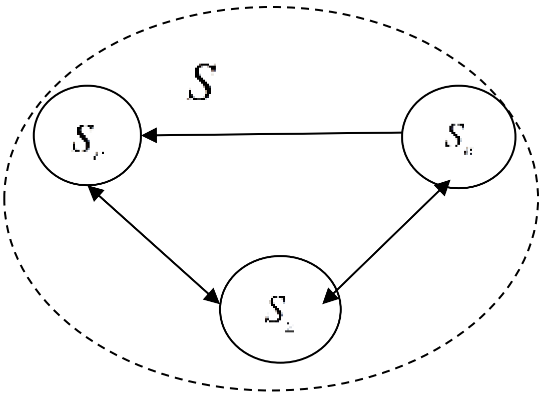

Fig. 1. Graph-model of the land monitoring

The description of the graph-model of the land monitoring system is proposed to be implemented on the basis of the structural-functional approach [17, p. 32–34]. For this purpose, using the methodology of this approach, a study of the land monitoring system was conducted and it was determined:

– identified in the system of the primary element ($S_i \in S$), $i = z, e, c;$

– catalogued subsystems and elements on the basis of the method of structural decomposition;

– identified in the system of the existing links;

– formed a set of influence actions on the processes of the system (U_O);

– defined the mechanism of realization of social, economic and organizational purposes ($F \times U_O \times G \to E_O$);

– identified the functioning system mechanism ($U_O \to E_O$).

As a result, a general economic model of the land monitoring system was obtained. Based on this aproach, the description of the system (S) of the graph-model of the form:

$$S = \langle U_o, E_o, \Phi, G, R \rangle , \tag{1}$$

where U_o – the cost of the resources of the land monitoring system;

E_o – the effectiveness of the land monitoring system;

F – the macro-function of the system;

G – the structure of the system;

R – the emergence ratio.

Emergence–availability the properties of integrity (emergent properties) in the system, are those properties which are not characteristic of its elements and are one of the manifestations of the dialectical principle of the transition of quantity to quality. The emergence of a system is the specific qualities of a given system, each of which is not inherent in its elements, but originates from the unification of these elements into a single, integrated system. The macro-function of the system is a quantitative expression of the main purpose of the system, depends on the value of the resources it consumes. The choice of macro-function ensures the achievement of the required economic efficiency of the land monitoring system. It is connected with the solution of the tasks facing the system. Only for certain resources (U_o) it is possible to ensure system efficiency (E_o). The mathematical expression of a macro function is form of:

$$F : U_o \longrightarrow E_o \, , \tag{2}$$

Achieving the main goal of the system is possible in implementing a macro function (*F*), which should corresponds to the certain system structure (*G*) and its integrity (*R*):

$$R : F \longrightarrow G \, , \tag{3}$$

Emergence ratio (*R*) defines the correspondence between the macro-system (*F*) and represents the structure (*G*). Every time emergence ratio changes in accordance with the macro-function and the deformation structure. The dependence is defined as follows:

$$G = \langle \{S_z, S_e, S_c\}, (S_e, S_c), (S_e, S_z), (S_c, S_z) \rangle \, , \tag{4}$$

where $\{S_z, S_e, S_c\}$ – vertices of the graph-model;

z, e, c – indices, characterizing respectively the land fund, economic and social subsystems;

$(S_e, S_c), (S_e, S_z), (S_c, S_z)$ – the connection between the vertices of the graph-model. The components of the graph-model (Figure 1) are represented by the functions:

$$\begin{aligned} & f_1 : S_e \rightarrow \{U_e, Q_e, D_e\}; \\ & f_2 : S_c \rightarrow \{L_e, E_c\}; \\ & f_3 : S_z \rightarrow \{L_c, E_z\} \\ & f_4 : S_e S_c \rightarrow \{Q_e, L_e\}; \\ & f_5 : S_e S_z \rightarrow \{U_e \;, E_{ez}\}; \\ & f_6 : S_c, S_z \rightarrow \{L_c, E_{cz}\}. \end{aligned} \tag{5}$$

The first function characterizes the economic subsystem, the second one - the social subsystem, the third - the land fund. The economic subsystem is characterized by the cost of resources (U_e), which it consumes, production volumes (Q_e) and incomes (D_e).

The social subsystem depends on the economic subsystem, since for its effective functioning (E_c) the financial resources are needed which are formed on the basis of revenues (L_e) from the economic subsystem, as part of the income (D_e).

The land fund, as an object of land monitoring, is characterized by financial opportunities for conducting observations (L_c), as well as the efficiency of the land use (E_z).

The interconnection between the economic and social subsystems describes the fourth function. The social subsystem is as a consumer, but the economic one is as a subsystem provides demand for production volumes (Q_e) and financial resources (L_e).

The fifth function characterizes the interconnection between the economic subsystem and the land fund through logistical resources (U_e) and economic efficiency of the rational land use (E_{ez}).

The interconnection of the land fund, as a monitoring object, with the social subsystem is characterized by financial receipts for the organization of land monitoring (L_c) and social efficiency of the ration all and use (E_{cz}).

The interaction of the three components, as an integral system, ensures their dynamic development. The proposed economic model of the land monitoring system shows the interdependence of its components and describes the parameters of interaction of subsystems.

To study the model of the land monitoring system is necessary to formalize the processes of analysis and evaluation of the condition of its components, which in the graph-model are represented by functions.

The main component of the land monitoring system is the Land Fund, which is the subject of analysis and evaluation, characterized by the efficiency of land use (E_z). We will develop a methodology for the integrated criterion of the land conditions for it.

The formation basis of such methodology should be based on the system approach whereby takes into account in the interaction and interdependence of characteristics, makes it possible to carry out an integral evaluation and at the same time ensure its maximum objectivity.

The organization and land monitoring conduction are carried out at three levels: local, regional and national. Each level has its own characteristics, which must be taken in to account in the evaluation. First of all, this is a multifactorial influence of the environment on the land conditions, which is formed by natural conditions and the functioning of socio-economic systems.

The validity of the influence of each factor varies depending on the purpose of the evaluation. Therefore, in conducting land monitoring, there is a need to determine the validity of the influence of the attributes on the land condition. In essence, the characteristics have objective and subjective characteristics, which must be taken into account in the evaluation.

At the first stage, the validity of the influence of objective characteristics is determined. It is based on an evaluation of the actual values of the indicators. Since they have different units of measurement, therefore, for evaluation it is necessary to change them into relative values.

It is suggested two approaches to the determination of the relative values of the indicators. The first approach is that the base index is taken as the minimum or maximum value, depending on which one will be desired. An example is land monitoring at the regional level when assessing the land conditions districts. The main indicators that would take into account the influence of the structure of the region's lands on the ecological stability of the territory include the ecological stability of the agro-landscape and anthropogenic impact. Based on these characteristics, the corresponding coefficients are calculated, and then the table is formed. In this case, the maximum value of the ecological stability of the agro-landscape is taken to change the coefficients obtained into relative values for the base indicator, and the minimum value for the anthropogenic impact.

Table 1

Quantitative indicators of the characteristics of the impact on the land conditions

Indicators, *j* / Districts, *i*	j_1	j_2
…	X_{ij}	…
…	…	…
-	$X_j(\max)$	$X_j(\min)$

The conversion of the actual values of the indicators into relative value ones is performed as follows:

a) if the best value of the indicator is the maximum, then the formula is used:

$$\overline{X}_{ij} = \frac{X_{iJ}}{X_j(\max)}, \qquad (6)$$

where $\overline{X}_{ij}$ – the relative value;

X_{ij} – values of indicators;

$X_j(\max)$ – the maximum value.

b) If the best value of the indicator is minimal, then formula:

$$\overline{X}_{ij} = \frac{X_j(\min)}{X_{ij}}, \qquad (7)$$

where $X_j(\min)$ – the minimum values.

The second approach is that when determining the relative indicator, both the minimum and maximum values are used. For example, land monitoring at the national level can be considered, when land is evaluated for indicators for which the maximum and minimum values are not optimal. This can be socio-economic, legal characteristics, etc. Then the relative values are determined by the formula:

$$\overline{X}_{i\,j} = \frac{X_{i\,J} - X_{ij}(\min)}{X_{ij}(\max) - X_{ij}(\min)} \times 100, \tag{8}$$

At the same time, it should be noted that in land monitoring, the choice of the baseline should be the same within a certain aggregate. If the indicators are evaluated, some of which can be translated into relative values by the first approach, and some by the second, then for this set the second approach is chosen, where the base index is the one taking into account the minimum and maximum values.

On the basis of the obtained relative values of the indicators, they are evaluated. For this purpose, it is expedient to use the method of entropy determination. A table of relative values of indicators is generated. Then by this method the sum of each column is found ($\sum_{i=1}^{n} \overline{X}_{ij}$). Further part of each indicator is determined by the total amount of the formula:

$$Q_{ij} = \frac{\overline{X}_{ij}}{\sum_{i=1}^{n} \overline{X}_{ij}}, \tag{9}$$

where Q_{ij} –proportion of the of the *i*-th indicator in the total amount of *j*-th attribute;

$\sum_{i=1}^{n} \overline{X}_{ij}$ – the sum of the values of the *i*-th indicators of the *j*-th attribute.

Results of calculations (Q_{ij}) are reduced to a table on which the entropy values of the j -th characteristic for each table column are determined by the formula:

$$E_j = -\frac{1}{\ln N} \sum_{i=1}^{n} (Q_{ij} \times \ln Q_{ij}), \tag{10}$$

where E_j – an entropy of the j-th attribute.

N – the number of indicators. The objective significance of the *j*-th attribute is determined by the formula:

$$d_j = 1 - E_j, \tag{11}$$

where d_j – the objective significance of the *j*-th attribute.

The reduced objective significance of the *j*-th attribute is determined by the formula:

$$\bar{d}_j = d_j / \sum_{j=1}^{m} E_j, \tag{12}$$

where $\bar{d}_j$ – the reduced objective significance of the *j*-th attribute.

At the second stage, the significance of the subjective attributes influence is determined. It consists of determining by the expert method the advantages of one characteristic with respect to the other. For this they are compared in pairs. The corresponding matrix is formed, where the columns and lines are attributes, and their characteristics are the indices, tab. 2. If the subjective significance of this indicator is greater, then the figure 3 is written to the corresponding cell of the matrix, if less than 1, if they are equivalent to 2. At the same time, the number of indicators (*G)* is equal to m, respectively, ($m = p$; $k = 1 \ldots p$; $j = 1 \ldots m$).

Table 2

Matrix of pairwise attributes influence comparisons on the land condition

Indicators, G_j / Indicators, G_k	G_1	G_2	...	G_m	Sum
G_1	–	…	…	…	$\sum_{j=1}^{m} G_{1j}$
…	…	–	…	…	…
G_p	…	…	–	…	…
Sum	$\sum_{k=1}^{p} G_{p_1}$	…	…	…	$\sum_{k=1}^{p} \sum_{j=1}^{m} G_{kj}$

The next step is to determine the sums of the values of each line, and then the sum of these sums is calculated. According to the obtained data, the subjective significance of each feature is determined by the formula:

$$\bar{g}_j = \frac{\sum_{k=1}^{p} G_{kj}}{\sum_{k=1}^{p}\sum_{j=1}^{m} = G_{k\,j}}, \tag{13}$$

where $\bar{g}_j$ – subjective significance of the *j*-th attribute;

$\sum_{k=1}^{p} G_{kj}$ – the sum of the values of the *j*-th attribute for *k*-th indicators;

$\sum_{k=1}^{p}\sum_{j=1}^{m} G_{k\,j}$ – the sum of values sums of *j*-th attributes for *k*-th indicators.

Such significance has a subjective characteristic, since the evaluation is carried out by an expert method.

At the third stage, on the basis of the objective and subjective significance obtained, the generalized significance (q_j) and their present value ($\bar{q}_j$), according to formulas:

$$q_j = \frac{\bar{g}_j \times \bar{d}_j}{\bar{g}_j + \bar{d}_j} , \tag{14}$$

where q_j – the generalized significance of the *j*-th attribute

$$\bar{q}_j = q_j / \sum_{j=1}^{m} q_j , \tag{15}$$

where $\bar{q}_j$ – reduced of the *j*-th attribute.

At the final stage, the integral indicator of the land conditions is calculated according to the formula:

$$L_i = \sum_{j=1}^{m} (\bar{X}_{ij} \times \bar{q}_j) , \tag{16}$$

where L_i – the integrated indicator of the land conditions.

The obtained value of the integral indicator characterizes the condition of the investigated *i*-th object, which may be a land parcel, a territory of an economy, an populated area, a district, a region, and the like. The value of the integral indicator can vary from 0 to 1. The more indicator values, the better status of the evaluated land within a certain territory.

The result of the study is the economic model of the land monitoring system and the corresponding methodology for the integrated evaluation of the land conditions.

The use of modeling allowed the development of an economic model of a land monitoring system. Identify the most important relationships between the components of the system and characterize the dependencies between the economic parameters of these components.

On the basis of the economic model, a methodology for the integrated evaluation of the land conditions was developed. This technique takes into account the objective and subjective characteristics of the influence of attributes. It makes it possible to combine the results of local, regional and national land monitoring evaluations into the system.

This method allows identifying the most vulnerable land to the impact of external and internal factors of the functioning environment and determining the strategy for their restoration, rational use and protection.

Using the results of the integrated evaluation, it is possible to form a balanced land use structure, develop a strategy for improving the stability and sustainability of ecosystems.

Prospects for further research are the study of the economic model components interaction and the determination the impact of the economic and social subsystems on the land use efficiency.

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