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METHODOLOGY FOR ESTIMATION OF ECOLOGICAL SAFETY IN THE AGRICULTURAL OF UKRAINE

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Abstract

The article is devoted to research and development of methods for estimation of ecological safety in the agricultural area of the region's economy based on a comprehensive analysis of the main criteria and indicators that allow us to make motivated management decisions to prevent environmental threats and risks in this area. The methodology provides for the account of the integral index of ecological safety in the agricultural, which is defined as the sum of the normalized values of indicators (characterized by the corresponding indicator), taking into account the respective weighting coefficients. It is assumed that the difference in the dimensions of the parameters to be measured is eliminated by normalizing (transferring them to a dimensionless form). The estimation of the level of ecological safety in the agricultural of the regions of Ukraine has been carried out on the basis of the developed methodology. The distribution of the territory of Ukraine has been carried out on the following levels of ecological safety: stable, unsatisfactory, critical, crisis and dangerous. In general, the realization of the proposed methodology makes it possible to identify the features and trends of the ecological situation in the agricultural area of the region's economy in order to level out environmental contradictions in the form of a deviation between the actual and target state of agroecosystems in the process of balanced development of agriculture.

Key words: *ecological safety, agricultural, agrarian sector of economy, estimation, criteria, indicators.*

INTRODUCTION

The introduction of intensive methods of agrarian production of Ukraine, focused exclusively on economic development, has entailed a violation of the ecological balance between economic activity and agroecosystems. At the same time, the compensating nature management mechanism in the agricultural, which is currently in force in the country, puts forward only general restrictive environmental requirements for agricultural production and aims at eliminating environmental consequences, rather than preventing environmental threats and risks. Therefore, ensuring ecological safety is an essential element of public agrarian policy, since the most intense pollution of the environment, as well as other negative effects on it, occurs precisely in the process of human economic activity, the damage from which must be minimized.

Effective functioning of the system of ensuring ecological safety in the agricultural is impossible without a comprehensive estimation of the ecological state. Proceeding from this, the main part of the system of its ensuring is the analysis of the existing state and level of the object of research. The need for analytical assessment is indisputable, because it is its results that are the basis for making managerial decisions that allow choosing the optimal strategy, tools and methods in the framework of the organizational-economic mechanism for ensuring ecological safety.

However, taking into account modern theoretical-methodological developments and analytical developments in the field of ecological safety diagnostics in the agrosphere, it is worth noting that there is still no single generally accepted and normatively approved methodology for its assessment at various levels: state, regional, enterprise. Given this, important issues are the choice of methods for assessing the ecological state of the agroecosystems, in particular indicators that most objectively reflect the level of

ecological safety, as well as the corresponding interpretation of the results obtained with a view to selecting, on a certain basis, a strategy for managing ecological safety.

The existing methods of estimation of the ecological safety can be divided into three groups depending on the approaches: ecological safety estimation by the method of rationing, by the method of ecological risk and by the method of integral index. In addition, regardless of the method of ecological safety estimation, its basis is the output criteria for which it will be implemented.

These methods for analyzing ecological safety require the use of different evaluation criteria. Criteria in the framework of standardization techniques provide for an assessment of ecological safety in the following groups of indicators: the amount of emissions and discharges, MAC, soil contamination; the area of disturbed and technologically contaminated lands, plowing, etc. [1]. The advantages of these methods include: officially approved criteria, extensive experience of application, official statistical information illustrating these criteria. Deficiencies include the following characteristics: information bias, non-compliance with the specifics of production, lack of approved standards for all sources of environmental pollution, etc.

Proponents of the method of environmental risk tend to assess ecological safety because of the likelihood of an accident and the amount of damage. With the help of environmental risk assessment of economic activity, E.V. Khlobystov [4] offers to identify the level of ecological safety. He notes "that the assessment of ecological safety is based on an understanding of the specifics of recipients of negative impact", among which the main are man and the basic component of the natural environment – the ecosystem [4]. Some scientists offer additional criteria: the state of flora and fauna, the change in the gene pool of animals as an indicator of the ecological state of the territory, indicators of the quality of environmental management and control, personnel, criteria based on the specifics of production, the level of public health, etc. [2; 10; 14].

The analysis of issues of environmental risk assessment has showed that this method is expedient for applying at the local level. On the scale of the region or the country as a whole, this method is practically not used, since there are no databases for assessing environmental risks that characterize the scale and frequency of their occurrence. In addition, existing methods for assessing environmental damage do not correspond to the economic relations prevailing in the region, and most of them do not have the necessary legal status for use in the agricultural.

It should be noted that theoretical-methodological developments in the sphere of environmental risks are, as a rule, limited by the analysis of situations caused by negative environmental impacts in the event of violation of regulatory regulations. Such situations are also directed to methods for assessing ecological damage. In developed countries, the assessment of ecological damage is directly caused by a disruption in the functioning of the economic system for causing harm to the environment [9; 16].

Representatives of the National Institute of Strategic Studies S.P. Ivaniuta, A.B. Kachinskiy notes [6] that "the level of ecological safety in Ukraine in the future is determined by the magnitude of the risk from both possible natural and man-made disasters, and from negative processes that occur slowly, but in time can lead to social explosions (environmental issues, social conflicts)".

Such a methodology will correspond to the "parameters of determining the grade of ecological safety in the event of emergency situations of natural and technogenic origin, and while ensuring the ecological safety of the regions, we emphasize that it is necessary to pay attention not only to environmental risks [6]". In this connection, it should be noted that S. Lisovskiy [8] offers "a method of an integrated indicator of ecological safety, namely, calculated on the basis of eight indices". In our opinion, the advantage of this technique is its complexity in combination with the relative simplicity of calculations, and the main drawback is the failure of many indicators that reflect the qualitative

parameters of natural resources. Scientists A. Obihod and T. Omelyanenko emphasize that the construction of a certain rating, providing for a sufficient number of indicators, is possible only if the latter is built up to an integral estimate [11]. Thus, the integrated assessment allows, in addition to the study of hazard phenomena, to conduct statistical comparisons, which greatly facilitates the analysis process and makes it objective. It should be noted that in the domestic sphere of environmental, there is a state system for monitoring it, in accordance with which a system for monitoring ecological indicators is being implemented. However, analysis and estimation of the situation based on the results of observations in order to identify negative trends, determine and assess their level of danger, and then develop scientifically sound proposals for their overcoming, requires the use of modern methods of quantitative and qualitative analysis.

In general, the lack of an optimal system for estimation of the level of ecological safety in the agricultural, in our opinion, is caused by the following negative trends: lack of scientifically sound environmental standards, compliance with which could reliably prevent the negative effects of agricultural activities; imperfection of the system of environmental monitoring and, as a result, insufficient objectivity in assessing the existing environmental situation; absence of a reliable and complete assessment of the actual and predicted anthropogenic load. In addition, the available methodological developments in ecological safety assessment take into account the specifics of the predominantly industrial sector or the ecological safety of the country as a whole, focusing exclusively on the level of high-risk facilities.

MATERIALS AND METHODS

Based on the results of the conducted studies and analytical generalizations of existing methodological approaches to ecological safety assessment, we can state that today there are no modern developments that allow us to comprehensively assess its level using the appropriate criteria and indicators in accordance with the current conditions of management and specificity of the agrarian sector. Taking into account the specifics of agriculture, formation of the methodological basis for assessing the level of ecological safety, in our opinion, should be carried out in several stages, namely: characterization of factors that cause environmental issues and threats; definition of integral index; the ranking of objects and zoning of the territory according to the level of ecological safety. An important element of the information-analytical component of the realization of the strategy for ensuring ecological safety is a system of criteria and indicators that provide for the assessment of environmentally-oriented development, quantification of the level of ecological safety and ranking of its species [7; 11; 12].

In our opinion, the criteria for ecological safety are no less important for the sustainable development of the agrarian sector than the economic efficiency that was a priority in a market-based industrial consumer society. As a result, there arises the need to develop and use a small number of integrated environmental criteria and to derive from them a generalized assessment of the state of the facility [5; 13]. Therefore, it is important to distinguish the following main criteria:

– maintenance of health and proper vital activity of the person (ES_1) (to assess the level of ecological safety, this criterion is used by the mortality, fertility, morbidity, disease factors caused by environmental factors, etc., in general, characterize the level of health and quality of life of society);

– preservation, reproduction and productivity of natural resources of the agrosphere (ES_2), in particular, for the ecosphere and its elements – biomes, regions, landscapes, in other words more or less large territorial natural complexes – can be the level of environmental-economic or natural-industrial parity, that is, the degree of compliance of the overall environmental burden in the territory of its assimilation potential;

– balanced development and sustainability of agroecosystems (ES_3), that is, a combination of natural (relief, soil, biota, water objects) and anthropogenic elements, which allows to

maintain resistance to environmental threats). In particular, the integrity, safety of their species composition, biodiversity and the structure of internal interrelations are important indicators of ecological safety.

Each criterion must correspond to a certain set of indicators needed to make management decisions that disclose the natural and anthropogenic characteristics of the factors that trigger the occurrence of environmental issues.

The choice of the system of indicators was carried out taking into account the accumulated domestic and international experience, methods in ensuring ecological safety, as well as the recommendations of state authorities and relevant international organizations, in particular World Economic Forum, United Nations Commission on Sustainable Development, Food and Agriculture Organization of the United Nations, Scientific Committee on Problems of the Environmental.

The selection of indicators is also carried out according to the principles of representativeness (that is, weighty indicators are taken into account that affect the level of ecological safety). These indicators depend on the object (state, region, district, separate territory or agricultural commodity producer), which determines the ecological safety in the agricultural. In their definition, a number of features should also be taken into account, in particular: the efficiency, the availability and reliability of statistical data and laboratory research, the availability of analytical information, timeliness and continuity of its receipt, as well as the costs of obtaining it. The main issue in the choice of the system of ecological safety indicators in agriculture is the contradiction regarding the importance of the indicator and the availability of its information characterizing.

The list of indicators on the criteria and components of ecological safety in the agricultural of Ukraine and its regions in particular has been determined taking into account the existing forms of manifestation of environmental threats. The mentioned indicators characterize the state of agroecosystems and the level of eco-destructive influence of negative factors on the ecosystem data and human activity. Some indicators also characterize the state of the natural resource potential and the assimilating potential of agroecosystems. The system of these indicators has been formed taking into account indicators of the Environmental Performance Index (EPI) [5].

RESULTS AND DISCUSSIONS

The developed list of indicators in order to avoid a double effect of the interrelated factors in the calculation of the integral index by means of the analysis of the matrix of paired correlation coefficients is checked for multicoline (the existence of a linear dependence between factor variables). According to the calculations, and taking into account the above principles, conditions and peculiarities of domestic information support, the author has formed a set of indicators (Table 1), which most fully characterizes the level of ecological safety taking into account the specificity of agroecosystems.

The inconsistency nature of the ecological safety estimation requires the use of various analysis methods. For the purpose of quantitative estimation of ecological safety the agrarian sector include the total number of indices (indicators) in the three main criteria identified as relative indicators indicators of its components. This technique assumes the elimination of the difference in the dimensions of the given parameters by normalizing or translating them into a dimensionless form, that is, reducing to an interval from 0 to 1 (1 corresponds to the best (optimal) value of this index, and 0 – the worst (unacceptable) of its value). To do this, the absolute values of the indicators are compared with the primary (threshold) values of the corresponding indicator.

Therefore, an important step in the account of the ecological safety index is the determination of threshold (limiting) assessment indicators, non-observance of which leads to negative, destructive tendencies in ecological safety and impedes the balanced development of the country's agrarian sector. Determination of threshold

values of indicators depending on the properties of the index is carried out using the following methods: analog (the optimal (basic) (reference) value for a given type is considered optimal, which means the desired value for optimization (maximum or minimum); normative approach (critical or optimal value is determined in regulatory legal acts) of the expert evaluation. The values of the threshold indicators for estimation of the level of ecological safety of the domestic agricultural for the regions and the criteria for their optimality are given in Table 1.

Table 1. The main indicators of ecological safety in the agricultural of the region's economy of Ukraine and their threshold values

№	Indicator name	The threshold values of the indicator	Criterion of optimality of the indicator
x_1	Ecological risk to public health, %	0.05	Min
x_2	Infant mortality rate, unit.	5	Min
x_3	Ecological and agrochemical land evaluation, point	100	Max
x_4	Coefficient of ecological stability of territories, units.	0.51	Max
x_5	Degree of soil erosion, %	10	Min
x_6	Pesticide load, kg / ha a.s. in year	1.2	Min
x_7	Chemical load, kg / ha a.s. in year	90	Min
x_8	Dynamics of humus content in soil, %	100	Max
x_9	The level of implementation of the normative-reasonable rate of application of organic fertilizers, %	100	Max
x_{10}	The area of agricultural lands contaminated with radionuclides, %	1	Min
x_{11}	The level of drinking water contamination in decentralized water supply with nitrates, %	5	Min
x_{12}	The level of expenditures for the conservation of biodiversity and ecosystems in the overall structure of environmental costs, %	10	Max
x_{13}	The share of the components of the ecological network in the overall structure of agricultural land, %	40	Max
x_{14}	Coefficient of coverage of damage caused for environmental pollution, UAH / UAH	1	Max

Source: author's elaboration.

Thus, the translation of factual values into normalized values occurs in the range of normalized values of each indicator from 0 to 1. In this case, the indicators between which there is a direct connection with the integral index (that is, the desired increase in the indicator relative to the base index) are calculated as the ratio of the factual value to the limiting one, and, accordingly, those indices whose optimal decrease is calculated as the ratio of the limit value to the factual:

$$\text{if } x_i \to \max, \quad \text{then } x_i = \begin{Bmatrix} 1, y_i \ge z_i \\ \dfrac{y_i}{z_i} \end{Bmatrix}, \qquad (1)$$

$$\text{if } x_i \to \min, \quad \text{then } x_i = \begin{Bmatrix} 1, y_i \le z_i \\ \dfrac{z_i}{y_i} \end{Bmatrix}, \qquad (2)$$

where y_i – the factual value of the i-th indicator;

z_i – threshold (limiting) value of the i-th indicator;

x_i – normalized value of the i-th indicator.

The next step is to calculate the values of the weight coefficients, which is determined by peer review. We have conducted an expert survey of specialists from the majority of regional departments of agro-industrial development, as well as departments of ecology and natural resources in the regions of Ukraine, with a view to collecting system

information on the level of ecological safety in the agricultural. The results of the survey made it possible to determine expert assessments with characteristics of the weight of each indicator. The organization of the examination was carried out by the method of questioning, the determination of weight coefficients – by the method of direct evaluation [3, p. 49]. The undoubted advantage of this method in comparison with other approaches to determining the weight coefficients of integral indexes of the state of complex systems, in particular ecological safety, can be considered as obtaining a quantitative estimate. At the same time, expert digitizations make a significant element of subjectivism in the values of weight coefficients [15]. According to this method, experts assign points to scores on a certain scale (from 1 to 10). Next, for each indicator, the scores are summed and the average (C_i) [15]:

$$C_i = \frac{\sum_{i=1}^{n} C_{ij}}{n}, \quad (3)$$

where n – number of interviewed experts;
C_{ij} – sum of points for each indicator.

Calculation of (d_i) weighting coefficients for each indicator characterizing the integral index of ecological safety in the agricultural, we propose to implement the following formula:

$$d_i = \frac{C_i}{\sum_{i=1}^{j} C_i}, \quad (4)$$

where j – the number of indicators used in calculating the average score.

The weight coefficients of indices for calculating the integral index of ecological safety in the agricultural of the regions are given in Table 2.
The calculation of the integral index of ecological safety is proposed to be defined as the sum of the normalized values of the above-mentioned indicators, taking into account the corresponding weight coefficients:

$$I_{ES} = \sum_{i=1}^{n} x_i \times d_i, \quad (5)$$

where x_i – normalized value of the i-th indicator;

d_i – weighting factor determining the degree of contribution of the i-th indicator into the integrated index of ecological safety in the agricultural;

n – number of indicators used in the calculation of the integral index of ecological safety into the agricultural.

Table 2. Weighing coefficients of indices for calculating the integral index of ecological safety in the agricultural

№	Indicator name	Weighting factor value
1	Ecological risk to public health,%	0.12
2	Infant mortality rate, unit.	0.11
3	Ecological and agrochemical land evaluation, point	0.08
4	Coefficient of ecological stability of territories, unit.	0.08
5	Degree of soil erosion, %	0.08
6	Pesticide load, kg / ha a.s. in year	0.07
7	Chemical load, kg / ha a.s. in year	0.07
8	Dynamics of humus content in soil, %	0.07
9	The level of implementation of the normative-reasonable rate of application of organic fertilizers, %	0.06
10	The area of agricultural lands contaminated with radionuclides, %	0.06
11	The level of drinking water contamination in decentralized water supply with nitrates, %	0.06
12	The level of expenditures for the conservation of biodiversity and ecosystems in the overall structure of environmental costs, %	0.05
13	The share of the components of the ecological network in the overall structure of agricultural land, %	0.05
14	Coefficient of coverage of damage caused for environmental pollution, UAH / UAH	0.04

Source: author's elaboration.

Based on the results of calculating the integral index of ecological safety in the agricultural, it is possible to assess the facility (region) according with its level in accordance with the proposed classification (Table 3).
Thus, the methodology, including a list of basic indicators, their normalization in

accordance with certain threshold values, as well as the algorithm for calculating the integral index, allow assessing the level of ecological safety in the agricultural.

Table 3. Classification of levels of ecological safety in the agricultural

Levels of ecological safety	The value of the integral index (or a separate indicator) of ecological safety
Stable	0,76–1,00
Unsatisfactory	0,51–0,75
Crisis	0,26–0,50
Critical	0,01–0,25
Dangerous (environmental hazard)	0

Source: author's elaboration.

Also, the proposed system of analytical assessment can be a composite environmental passport that, in addition to assessing the environmental friendliness of production technologies and products, provides an opportunity to consider, in combination and interdependence, the environmental factors that have determined the result of the assessment.

Assessment and diagnostics of the level of ecological safety in the agricultural of the Ukrainian economy were carried out in the context of regions and the country as a whole. The use of the considered methodological approaches made it possible to differentiate the regions of Ukraine depending on the integrated index based on 2017 data (some indicators were averaged over a certain period of time) and ranking them according to the level of ecological safety in the agrarian sector (Table 4).

Table 4. Ranking of the regions of Ukraine according to the level of ecological safety in the agricultural area, 2017

Region	**The value of the integral index of ecological safety**	**Rating of the region by the integral index of ecological safety**	**Level of ecological safety**
Vinnytsia	0.46	24	Stable
Volyn	0.67	2	Unsatisfactory
Dnipropetrovsk	0.50	19	
Donetsk *	0.49	21	
Zhytomyr	0.60	8	
Transcarpathian	0.76	1	
Zaporizhia	0.52	18	
Ivano-Frankivsk	0.57	10	
Kyiv	0.62	4	
Kirovohrad	0.53	16	
Luhansk *	0.56	12	
Lviv	0.53	17	
Mykolayiv	0.54	14	
Odesa	0.57	11	
Poltava	0.54	15	
Rivne	0.50	20	
Sumy	0.62	5	
Ternopil	0.59	9	
Kharkiv	0.55	13	Crisis
Herson	0.61	6	
Khmelnytskyi	0.47	23	
Cherkasy	0.48	22	
Chernivtsi	0.61	7	
Chernihiv	0.66	3	
Ukraine	**0.55**	–	**Unsatisfactory**

* Data without taking into account a part of the territory of the region.
Source: author's elaboration.

The integrated index of ecological safety in the agricultural, as a result of a comprehensive assessment, allows us to evaluate this generalized indicator for the regions of

Ukraine. On average, in Ukraine the value of the integral index is 0.55, which characterizes the level of ecological safety in the agrarian sector of the Ukrainian regions as unsatisfactory, with the approach to the crisis – 0.50. The lowest level of environmental safety – 0.46, which refers to the crisis level, recorded in the Vinnytsia region. In our opinion, this is due, first of all, to the intensity of agricultural production in this region. The pre-crisis level also occurs in five more regions. A stable level of ecological safety (0.76), as of 2014, was recorded only in one region of Ukraine – in Transcarpathian region.

CONCLUSIONS

Thus, the mandatory elements of practical implementation of the methodology for assessing the level of ecological safety in the agrarian sector of the region's economy are: 1) (i) a comprehensive analysis of the main indicators, taking into account regional characteristics of agricultural production; (ii)method of rating these indicators in accordance with certain threshold values; (ii)algorithm for calculating the integral index. The integrated index of ecological safety in the agricultural, as a result of a comprehensive assessment, allows us to assess this aggregate indicator by regions of the country, which in the future will allow us to make motivated management decisions to prevent environmental threats and risks in this area.

The results of the research and analytical data on the level of ecological safety in the agricultural can be used in the development of regional strategies for the sustainable development of agriculture in order to level out environmental contradictions in the form of a deviation between the actual and target state of agroecosystems.

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