UDC 332.2 http://dx.doi.org/10.31548/zemleustriy2022.01.09

METHODICAL APPROACH TO ASSESSING THE LEVEL OF ENVIRONMENTAL SAFETY OF AGRICULTURAL LAND USE

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Abstract. *The article stipulates that in the course of agricultural activity land resources are, first of all, the property of nature, at the same time forming the internal component of the production process, as well as its generalizing aspects. In view of this, land resources are the main means of production in the agricultural sector and the physical basis for agricultural production, as well as an element of natural productive forces.*

The issues of assessing the level of ecological safety of agricultural land use are highlighted and a methodological approach is proposed, based on a comprehensive analysis of a set of criteria and indicators that most fully characterize environmental risks and threats to land use, taking into account the assimilation potential of agroecosystems.

The proposed method of assessing the environmental safety of agricultural land use by ranking regions of the country by integrated index or individual criteria (indicators) allows to classify them by levels of land quality, degradation, anthropogenic impact and eco-destructive load on land. This will identify regions most vulnerable to adverse environmental impacts, which will primarily need assistance and prevention and elimination of environmental threats and risks in order to implement long-term and short-term plans for environmentally friendly agricultural land use at both state and local levels.

Key words: *sustainable development, ecological sustainability, agricultural land use.*

Formulation of the problem.

Every year the demand of the Ukrainian society for overcoming environmental problems grows as well as the understanding of the importance of preserving the quality of the environment and transition to the model of sustainable development, however, strategic directions in the field of environmental protection, in particular, land resources remain unclear and need to be updated.

Given that Ukraine is one of the countries with a high rate of plowed land, agricultural land occupies 70.5% of the total area of the country, of which 57% – arable land (in some areas – up to 86%), one of such priorities is to identify the state and assessing the level of environmental safety of agricultural land use. After all, the ability to manage indicators of environmental safety

in the field of land use through their objective assessment allows timely and sufficient resources to seek resources, especially financial, in areas that contribute to achieving maximum efficiency of environmentally friendly agricultural land use. Therefore, providing land users with sound guidelines for the use of diagnostic and evaluation tools to create conditions that motivate them to achieve the target (expected) results, allow to address issues of improving the performance of environmentally friendly agricultural land use.

The purpose of the article.

The purpose of the article is to substantiate the methodological approaches to assessing the level of environmental safety of agricultural land use as a priority in the field of environmental protection.

Materials and methods.

The theoretical and methodological basis of this study are the provisions of economic theory, land use economics and the concept of sustainable development, which are covered in the works of domestic and foreign scientists on land use issues. The following research methods were also used in the work: system-structural, economic-statistical, groupings, correlation and comparative analysis, expert assessments, indicator, econometric and cluster analysis (to assess the level of ecological safety of agricultural land use).

Presenting main material.

Currently, in the field of environmental safety use a number of evaluation approaches, among which it is necessary to distinguish anthropogenic and environmental [2, 3, 6, 7], which differ in the subjects of their research. Thus, anthropogenic studies the impact of human activities on the environment, and ecological studies the activities of the ecological system.

According to these assessment approaches, it is possible to determine the maximum allowable load on the ecosystem, environmental capacity, technological capacity of the territory, assimilation capacity, etc. The study of these approaches shows their focus on qualitative environmental characteristics, not taking into account indicators that reflect the direct impact on the level of environmental safety, for example, from the activities of agricultural enterprises or the implementation of innovative environmental activities, as well as the state of aquatic ecosystems.

It is worth noting the system of agri-environmental indicators (AEIS), which includes a set of 28 indicators adopted by the European Commission to monitor environmental issues in the Common Agricultural Policy of the European Union. Various systems of agri-environmental indicators have also been developed to identify the state of natural resources, pressures and risks to the environment as a result of the activities of agricultural producers at both national (IRENA) and local (farms) levels [9].

In 1976, at the initiative of an international organization under the auspices of the United Nations - the Food and Agriculture Organization (FAO), it was proposed to use an interdisciplinary approach to assessing the level of sustainability of land use. Therefore, in the process of such assessment, considerable attention is focused on environmental factors (atmosphere, landscape, vegetation, soil cover, degradation pro-

cesses, etc.) [10, 12]. Evaluation under this approach is carried out worldwide in the development of sustainable land use plans, as well as in the process of disclosing the level of suitability of land for agriculture. Over the last few decades, the approach of environmental and economic assessment in the system of environmental management in the field of land management has been widely used in the world.

The assessment process takes place according to a wide range of areas, each of which contains a certain list of criteria: landscape ecology (risk of fire or extinction of certain species of plants and animals, etc.); qualitative state of the environment (GDV, provision of soils with nutrients, level and strengthening of development of degradation processes, etc.); economic component (price of land plots, rent and its distribution, etc.), etc., taking into account which the final index of sustainability (environmental and economic efficiency) is formed, which is used in the certification process.

However, in the FAO methodology, the environmental aspect is examined in the overall set of criteria for sustainable development without taking into account environmental safety as a separate component of land use. In 1992, at the joint initiative of FAO, UNDP, UNEP and the World Bank, the Land Quality Indicators program was proposed to help make better use of existing land quality information and facilitate more systematic data collection. The main goal of the Land Quality Indicators (LQI) program is to develop indicators that identify and characterize the impact of human intervention on the landscape for major agri-environmental zones [12]. The proposed methodological approach to assessing the level of environmental safety of agricultural land use is based on a systematic approach that involves the use of a combination of static and dynamic analysis of the state of the studied object.

The peculiarity of this approach is that static studies are complemented by dynamic in assessing the environmental safety of agricultural land use, ie index indicators. Therefore, the methodological approach to level assessment should be based on a comprehensive analysis of criteria and indicators of environmental safety, which characterize the environmental risks and threats to environmental security in agricultural land use.

The logical scheme of application of techniques and methods for the assessment of environmentally safe land use, which is based on a methodological approach to assessing the level of environmental safety of agricultural land use, is presented in Fig. 1.

Thus, at the first stage the analysis of threats and risks of ecological safety of agricultural land use caused by the influence of eco-destructive factors is carried out. Prevention of risks and threats to the environmental safety of agricultural land use is an important condition for management decisions, which allows to characterize the natural and anthropogenic eco-destructive factors that cause environmental problems. Therefore, a rationally and correctly organized system allows to thoroughly investigate the actual degree of impact of eco-destabilizing factors on the agroecosystem, as well as to reflect the results of such impacts and assess environmental hazards to predict possible transformations in the ecological situation of the environmental safety. [6].

An important issue is the definition of criteria that characterize the environmental threats and risks of environmen-

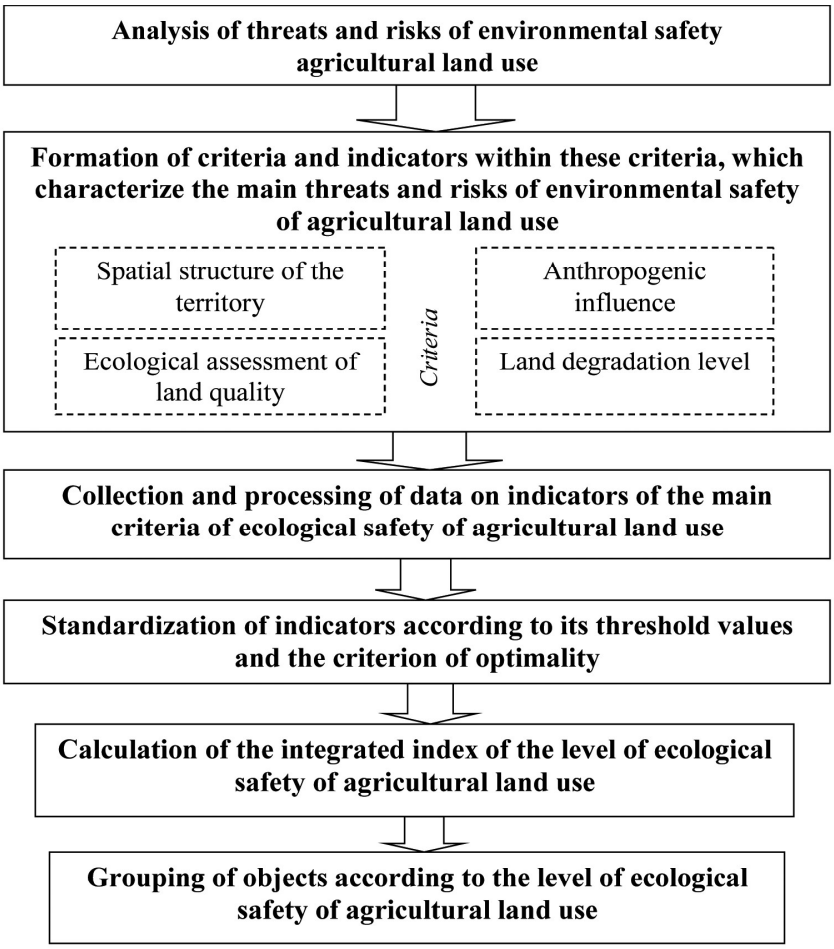

Fig.1. Logical scheme of methodological support for assessing the level of environmental safety of agricultural land use

Data source: Own determination

tal safety of agricultural land use. In our opinion, among the most important criteria for environmental safety of agricultural land use are:

– spatial structure of the territory, characterized by a set of landscapes of a certain territory and their interaction (the optimal is the spatial structure of the territory in which the natural potential of agroecosystems is most effectively realized by organizing and territorial differentiation of functions of certain landscapes);

– level of land degradation, characterized by objective diagnosis of quantitative parameters that reflect the degree of land degradation in order to develop ways to restore their properties and minimize the effects of degradation;

– ecological assessment of soil quality, which significantly affects the state of landscapes and the biosphere as a whole, and through them - the quality of human habitat;

– level of anthropogenic impact on land resources, which characterizes the result of negative environmental impacts of agricultural activities, which cause significant problems in the components of the agroecosystem (abiotic and biotic).

In order to quantify the criteria of environmental safety of agricultural land use, it is necessary to determine the indicators that most fully characterize

these criteria. The set of indicators is determined on the basis of selection of indicators that most fully characterize the criteria of environmental safety of land use, taking into account the specifics of agriculture, as well as previous experience of evaluation, work of Ukrainian and international scientists in the field of land use. sustainable development of the agricultural sector of the economy.

Note that a number of indicators characterizing the level of environmental safety of agricultural land are defined in the methods of the Food and Agriculture Organization of the United Nations, in methodological approaches to calculating the "Environmental Performance Index", developed by the Center for Environmental Policy and Law at Yale University in Columbia University and the World Economic Forum [10, 12]. It should be noted that the list of indicators is based on the principles of representativeness (including the most significant indicators that affect the level of environmental safety of agricultural land use), reliability (adequately reflect the state of the studied object) and accessibility (possibility and economic feasibility) indicators). Next, we grouped the indicators of environmental safety of agricultural land use within the defined criteria groups, which allowed us to identify threats specific to each criterion and to form tools for their neutralization (Table 1).

Table 1. **List of criteria and indicators of ecological safety of agricultural land use**

Criteria and indicators	Threshold values of the indicator	Criterion of optimality of the indicator	Weight
Spatial structure of the territory			**0,25**
Coefficient of ecological stability of the territory, units	0,67	Stimulator	0,11
Coefficient of ecological and technological suitability, units	1,04	Destimulator	0,06
Terrain intensity, %	15	Destimulator	0,08
Level of land degradation			**0,23**
The level of land erosion, %	10	Destimulator	0,15
Intensity of land erosion, %	100	Destimulator	0,08
Ecological assessment of land quality			**0,24**
Ecological and agrochemical assessment of lands, score	100	Stimulator	0,14
Humus content in the soil, %	3,3	Stimulator	0,06
Index of change of humus content in the soil, %	100	Stimulator	0,04
Anthropogenic impact			**0,28**
Pesticide load, kg / ha d.r. for a year	1,2	Destimulator	0,11
Chemical load, kg / ha d.r. for a year	90	Destimulator	0,10
The level of compliance with the normatively justified norm of organic fertilizers application, %	50	Stimulator	0,07

Data source: Own determination

The set of defined indicators most briefly and basic characterizes the environmental safety of agricultural land use at the state level (in terms of its regions). However, this set can be expanded depending on the object of assessment (region, district, land use) and available information materials.

The weight of each indicator and criterion was determined by expert evaluation. To this end, a written survey of specialists and leading scientists in the field of land use was conducted in order to systematize objective data on the level of impact of certain indicators on the environmental safety of agricultural land use. Features of determining the indicators that characterize the identified indicators of environmental safety of agricultural land use, as well as their components are given in Table. 2.

After collecting and systematizing the data by indicators, they were compared by the level of deviation from the threshold values. Determination of optimal (threshold) values of the permissible level of an indicator of ecological safety of agricultural land use is carried out by ecological parameters (the level of conservation of natural ecosystems, the level of humus content, the level of MPC, etc.). Threshold (optimal) values of indicators are quantitative values, violation of which causes unfavorable trends that lead to threats and risks to environmental security of land use.

It should be noted that not all thresholds for real data are the best. Therefore, among the actual criteria that demonstrate the relevant indicator are stimulants (when the best is the maximum value of a certain criterion), ie there is a direct relationship between the stimulus indicator and integrated assessment, and disincentives (where the minimum value of a certain criterion is considered best), when there is feedback between the disincentive and the integrated assessment.

Thus, the value of the stimulus can be calculated by the ratio of actual to optimal data. At the same time, in the case of greater than or equal actual data on optimal values, the stimulant index will be equal to 1. While the disincentive indicator is calculated by the opposite ratio - optimal to real - and, accordingly, equal to 1 under straight portion conditions [5]. When comparing the real evaluation criteria that show the actual state of affairs in the field of land use, with indicators determined during the base period, it is possible to identify a number of both favorable and unfavorable trends in the formation of environmentally friendly agricultural land use.

Determination of reference (threshold) values of evaluation criteria is based on their inherent characteristics and using the appropriate methodological apparatus. Thus, to calculate the reference value of a certain set of criteria using the analog method (optimal is the value of the indicator, which is recognized as a standard in this area; determination of average values, etc.) or regulatory, critical or optimal level is determined according to the limit acts). In some situations, the method of expert evaluation is used [2]. For relative values that reflect the dynamic processes relative to a given baseline, a value of 100 percent is considered best. The values of the optimal evaluation criteria for determining the level of environmental safety of land use in agriculture, as well as the parameters of their optimality are presented in table. 1. Therefore, the indicators contain a number of relevant values that reflect

Table 2. **Indicators of ecological safety of agricultural land use**

№	Indicator	Formula for calculation	Decryption
1	**2**	**3**	**4**
1	Coefficient of ecological stability of the territory (Ke), units	$K_e = \frac{\sum K_{li} \times P_i}{\sum P_i \times K_p}$	Kli - coefficient of ecological stability of lands of the i-th type; Ri - the area of lands of the i-th type; Kr - coefficient of morphological stability of the terrain (Kr = 1 for stable and Kr = 0.7 for unstable areas).
2	Coefficient of ecological and technological suitability (Kets), units	$K_{ets} = \frac{\sum S_i \times Ke_i}{S}$	Si - the area of land of the i-th type of territory on the slope; Kei - the coefficient of erosion of the soil cover for the i-th type of territory on the steepness of the slopes; S - total land area of the study area, ha;
3	Terrain intensity (Nr),%	$N_r = \frac{S_e}{S}$	Se - area of deflation-hazardous and subject to wind erosion (deflation) areas, ha; S - total area of the study area, ha
4	Ecological and agrochemical assessment of land (EACH)	$EACH = \frac{100 \times H_i}{6{,}8 \times k_i}$	Hi - the actual humus content of the i-th period,%; ki - correction factors for: 1) acidity; 2) the content in the soil of mobile forms of cadmium, lead, zinc; 3) contamination with pesticide residues and radionuclides
5	Soil humus content change index (IH)	$IH = \frac{H_i}{H_0} \times 100\%$	Hi - the actual humus content of the i-th period,%; H0 - humus content of the base period,%
6	Chemical load, kg / ha d.r. for a year	$C_l = \frac{Q_l}{S}$	Qof - the actual amount of mineral fertilizers, kg d.r. for a year; S - total land area of the study area, ha;
7	Pesticide load, kg / ha d.r. for a year	$C_p = \frac{Q_p}{S}$	Qof - the actual amount of pesticide application, kg d.r. for a year; S - total land area of the study area, ha;
8	The level of compliance with the normatively justified rate of application of organic fertilizers (Knof),%	$K_{nof} = \frac{Q_{of}}{Q_{nof}} \times 100\%$	Qof - the actual amount of organic fertilizers, t / ha; Qnof - normatively substantiated norm of organic fertilizers application, t / ha
9	Level of land erosion (El),%	$El = \frac{S_{El}}{S_l} \times 100\%$	SEl - area of eroded lands, ha Sl - total area of agricultural land, ha
10	Intensity of soil erosion (Iel),%	$Iel = \frac{E_{li}}{E_{l0}} \times 100\%$	Eli - the actual level of land erosion of the i-th period,% El0 - level of land erosion of the base period,%

Data source: formed on the basis of materials [1, 2, 11].

the state of land use in a given period, and relative dynamic values that should be correlated with the base period.

In the fourth stage, we conducted rationing, as a feature of the original data set is the incompatibility of units and the diversity of their impact on the level of environmental safety of land use. These shortcomings can be eliminated in various ways. In order to level different units of measurement, the procedure of standardization or standardization of indicators is carried out [8,10].

The rationing procedure involves the transformation of the values of all indicators compared to the optimal value, while the normalized indicator is in the range from 0 to 1, and the maximum proximity to one indicates the level of optimality of the actual indicator.

Standardization of indicators is done by comparing the actual and threshold values of indicators as follows [4]:

• for stimulators

$$\hat{x}_i = 1, \text{ when } x_i \geq y_i, \quad (1)$$

$$\hat{x}_i = \frac{x_i}{y_i}, \text{ when } x_i \prec y_i, \quad (2)$$

• for destimulators:

$$\hat{x}_i = 1, \text{ when } x_i \leq y_i, \quad (3)$$

$$\hat{x}_i = \frac{y_i}{x_i}, \text{ when } x_i \succ y_i, \quad (4)$$

when x_i - the actual value of the i-th indicator;

y_i -- optimal (threshold) value of the i-th indicator

(for stimulators → max, destimulators;

$\hat{x}_I$ - is the normalized value of the i-th indicator

The next step is to determine an integrated assessment of the level of environmental safety of agricultural land use, which is based on the calculation of the integrated index, which takes into account a set of indicators and individual criteria for environmental safety assessments. When calculating the integrated index for a certain period in the case of indicators that have a frequency of more than one year (for example, environmental and agrochemical assessment – every five years), the latest available values of these indicators are used.

The values of the integrated index and aggregate indices that characterize the criteria of environmental safety of agricultural land use are shown in Table. 3.

According to the results of calculations of the integrated index of ecological safety of agricultural land use, the regions of Ukraine are ranked depending on the level of this safety (Figure 2).

The results of the analysis show that among the regions of Ukraine the highest level of ecological safety of agricultural land use is characterized by Zhytomyr region (final score 0.77). The indicator of ecological safety is slightly lower in Kyiv (0.76) and Zakarpattia (0.76), which also have a stable level. Other regions of Ukraine are classified as areas with a critical level of environmental safety of agricultural land use. It should be noted that among all regions of Ukraine according to the integrated index of environmental safety of agricultural land use there are no those that are graded to crisis level.

Conclusions.

The results of the environmental safety assessment of agricultural

land use make it possible to take into account the probability of negative consequences in the development and implementation of forecasting policies in the field of land management. Taking such results into account by landowners and land users, as well as land use regulators, makes it possible to develop more specific strategic development plans at different levels: state, regional and local.

In general, the proposed method of assessing the environmental safety of agricultural land use by ranking regions of the country by integrated index or individual criteria (or indicators) allows

Table 3.

Region / Oblast`	Criteria of ecological safety of agricultural land use				Anthropogenic impact Integral index of ecological safety of agricultural land use
	Spatial structure of the territory	The level of degradation	Ecological assessment of land quality	Anthropogenic impact	
Vinnyts′ka	0,71	0,50	0,64	0,58	0,61
Volyns′ka	0,73	0,84	0,50	0,49	0,63
Dnipropetrovs′ka	0,45	0,43	0,74	0,77	0,60
Donets′ka	0,44	0,42	0,75	0,79	0,61
Zhytomyrs′ka	0,87	1,00	0,55	0,67	0,77
Zakarpat•s′ka	0,95	1,00	0,60	0,53	0,76
Zaporiz′ka	0,45	0,47	0,69	0,76	0,60
Ivano-Frankivs′ka	0,92	0,58	0,65	0,60	0,69
Kyyivs′ka	0,68	1,00	0,68	0,69	0,76
Kirovohrads′ka	0,47	0,47	0,81	0,66	0,60
Luhans′ka	0,51	0,42	0,71	0,76	0,61
L′vivs′ka	0,76	0,56	0,62	0,45	0,59
Mykolayivs′ka	0,44	0,47	0,71	0,76	0,60
Odes′ka	0,50	0,48	0,74	0,74	0,62
Poltavs′ka	0,65	0,76	0,68	0,74	0,71
Rivnens′ka	0,73	0,69	0,57	0,50	0,62
Sums′ka	0,68	0,66	0,67	0,56	0,64
Ternopil′s′ka	0,73	0,51	0,74	0,48	0,61
Kharkivs′ka	0,54	0,47	0,79	0,74	0,64
Khersons′ka	0,49	0,49	0,55	0,76	0,58
Khmel′nyts′ka	0,72	0,49	0,66	0,51	0,59
Cherkas′ka	0,67	0,58	0,72	0,67	0,66
Chernivets′ka	0,81	0,47	0,65	0,71	0,66
Chernihivs′ka	0,63	1,00	0,61	0,60	0,70

Note: data without taking into account the Autonomous Republic of Crimea and temporarily occupied territories in Donetsk and Luhansk oblasts.

Data source: Own calculation

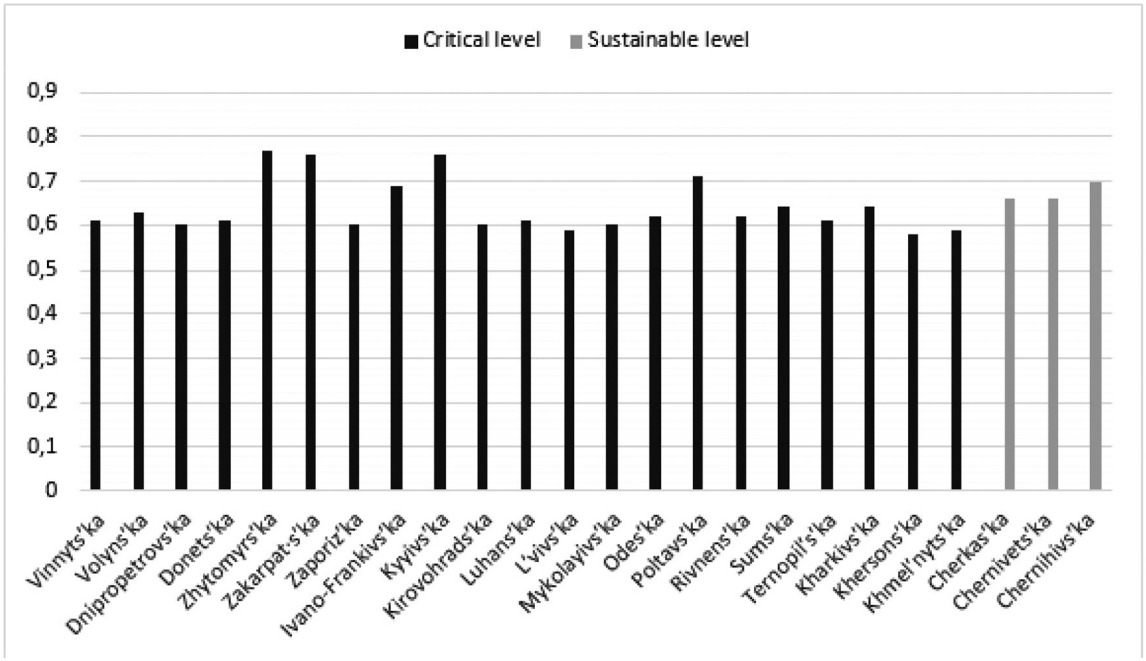

Figure 2. Ranking of regions of Ukraine according to the level of ecological safety of agricultural land usei

to classify them by levels of land quality, degradation, anthropogenic impact and eco-destructive load on land. This will identify the most vulnerable to adverse environmental impacts, which will primarily need assistance and prevention and elimination of adverse environmental effects, as well as provide directions for initiating specific financial instruments and the priority of regional division of public funding to prevent and eliminate adverse impacts due to intensive rural activities. formation and implementation of long- and short-term plans for environmentally friendly agricultural land use at both state and local levels.

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МЕТОДИЧНИЙ ПІДХІД ДО ОЦІНЮВАННЯ РІВНЯ ЕКОЛОГІЧНОЇ БЕЗПЕКИ АГРАРНОГО ЗЕМЛЕКОРИСТУВАННЯ

http://dx.doi.org/10.31548/zemleustriy2022.01.09

Анотація. *У статті визначено, що під час ведення сільськогосподарської діяльності земельні ресурси є, передусім, надбанням природи, водночас формуючи внутрішню складову виробничого процесу, а також його узагальнюючі аспекти. З огляду на це, земельні ресурси виступають основним засобом виробництва в агросфері та фізичною основою для отримуваної сільгосппродукції, а також є елементом природних продуктивних сил.*

Висвітленні питання оцінювання рівня екологічної безпеки аграрного землекористування та запропоновано методичний підхід, базисом якого є комплексний аналіз сукупності критеріїв та індикаторів, які найбільш повно характеризують екологічні ризики та загрози землекористуванню з урахування асиміляційного потенціалу агроекосистем на основі використання інтегрального показника.

Запропонована методика оцінки екологічної безпеки аграрного землекористування шляхом ранжирування регіонів країни за інтегральним індексом чи окремими критеріями (індикаторами) дає змогу класифікувати їх за рівнями якості земель, їх деградації, антропогенного впливу та екодеструктивного навантаження на землі. Вказане дозволить виявити максимально чутливі до несприятливого екологічного впливу регіони, які передусім потребуватимуть допомоги та попередження і ліквідації екологічних загроз і ризиків з метою реалізації довго- та короткострокових планів щодо екологобезпечного аграрного землекористування як на державному так і на локальному рівнях.

Ключові слова: *сталий розвиток, екологічна стійкість, аграрне землекористування.*