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Integral Assessment of the Impact on Ukraine's Environment of Military Actions in the Conditions of Russian Aggression

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ABSTRACT

The article outlines the current issues of environmental security in the context of the escalation of the Russian-Ukrainian war. The purpose of the study is to assess the risks associated with environmental hazards in the context of the escalation of the Russian-Ukrainian war. The article provides an overview of implementations of the economic mechanism of environmental risk assessment and provides quantitative characteristics of integrated threat assessments that characterize the environmental security of the regions of Ukraine. According to the results of the assessment of the integral indicator of ecological danger, the regions of Ukraine are grouped according to the level of safety. Estimated values are identified according to the proposed numerical range of environmental risk values. The obtained results indicate that the regions of Ukraine differ in terms of the integral indicator of ecological danger. To assess the danger of anthropogenic impact on human and environmental safety, the following environmental safety risk assessments were calculated.

Keywords: environmental risk, environmental safety, integral index, threat to the environment, environmental pollution, escalation of the Russian-Ukrainian war, radiation pollution.

INTRODUCTION

At the present stage, more and more attention is paid to environmental safety in connection with the presence of real ecological danger for the environment as a result of the action of many threats of natural, man-made, and socio-political factors. The main technogenic threats include pollution of the Earth's surface with solid household (Popovych et al., 2020, Voytovych et al., 2020) and industrial (Malovanyy et al., 2020, Tymchuk et al., 2020) waste, pollution of surface and groundwater by sewage effluents, as well as hazardous industrial effluents (Malovanyy et al., 2014, Tulaydan et al., 2017), the treatment of which is insufficient at sewage and local treatment facilities, as well as atmospheric pollution by emissions (Ablieieva et al., 2022, Malovanyy et al. al., 2021). It should be emphasized that technogenic development is a characteristic feature of today. It is characterized by rapid and exhausting use of non-renewable types of natural resources and excessive exploitation of renewable ones at a speed that exceeds the possibilities of their reproduction and reconstruction. The scale of environmental pollution is increasing significantly as a result of the escalation of the Russian-Ukrainian war in 2022.

The war did not bypass the environment, natural resource base, and infrastructure. Attacks on forests, terrestrial and marine ecosystems, industrial facilities, transport infrastructure, and homes, as well as water, sanitation, and waste disposal infrastructure, have caused widespread and severe damage with immediate and long-term consequences for human health and ecosystems. Due to the constant barrage of strikes on oil refineries, chemical plants, energy facilities, industrial warehouses, or pipelines, the country's air, water, and soil are polluted with toxic substances, which together pose a danger to the health of the population. Every day, the Ukrainian authorities register cases of exposure to toxic gases released during explosions, fires, and building collapses, which can cause long-term health threats, such as the risk of cancer and respiratory diseases. Many of these problems can be considered cross-border, so the impact will be felt not only in Ukraine but also beyond its borders. Due to damaged water infrastructure, approximately 1.4 million people in Ukraine currently lack access to safe water, and another 4.6 million people have limited access (PAX, 2022).

According to the estimates of the Ministry of Environmental Protection and Natural Resources, the amount of damages from environmental pollution caused by the war is estimated at about 25 billion euros, and about 11.5 billion euros are needed to eliminate the consequences of soil pollution.

In particular, almost a third of the specified amount of estimated damages, namely more than 407.3 billion hryvnias, is the damage caused to the land resources of Ukraine. Among the total amount of losses, more than 176.5 billion hryvnias of losses were caused to the atmospheric air as a result of unorganized emissions of polluting substances rising into the air during fires caused by shelling, including in the territories of forest massifs, objects of the nature reserve fund. Also, according to the Ministry of the Environment, about two thousand specific cases of direct damage to the environment and 244 environmental crimes have been documented to date. As a result of the war, about 30% of the areas of all nature conservation areas of Ukraine are in danger, 17 Ramsar sites with a total area of 627.3 thousand hectares, about 160 territories of the Emerald Network with an area of 2.5 million hectares, and 4 biosphere reserves remain under threat of destruction. This applies to the coasts of the Azov and Black seas, as well as the territories in the lower reaches of the Danube and Dnipro rivers. Currently, as a result of Russian aggression, more than 20 nature and biosphere reserves and national nature parks have been affected, which is about a third of the area of the nature reserve fund of Ukraine. This poses a threat to the strategic goals of preserving biodiversity, leads to a decrease in the potential for absorbing greenhouse gases, and increases the process of desertification. Because of the war, more than 4.6 million people in Ukraine have problems with access to drinking water. Endemic species of plants and animals are under critical threat; their disappearance will have catastrophic consequences for biodiversity on a planetary scale. Almost 3 million hectares of forest in Ukraine were covered by military operations. The war has already led to the burning of 100 thousand hectares of forests and steppes in Ukraine.

MATERIALS AND METHODS

The theoretical and methodological basis of this article is the fundamental provisions of the economy of nature use, the development of productive forces and sustainable development, as well as the systemic approach, which are highlighted in the works of domestic and foreign scientists. To achieve the goal, the following methods of scientific research were used: morphological and abstract-logical – for the analysis and generalization of scientific theories on the economics of nature use and detailing the theoretical and methodological directions of the influence of risk assessment on the formation of environmental safety in international and domestic practices; logical analysis and synthesis – in the course of developing the theoretical and methodological foundations of the structural and dynamic theory of macroeconomic regulation of environmental protection activities; systemic and structural – to determine the main risks at the regional level as a result of military operations; statistical and expert evaluations – to assess risks at the regional level as a result of military operations for the formation of practical recommendations and justification of proposed decisions regarding environmental policy; synthesis and groupings – for research and experimental verification of the adequacy of the theoretical, methodological and practical provisions formed in the article.

The conducted research substantiates the need to develop a new methodology adapted to solving a group of environmental risk management tasks in practice. To ensure rapid assimilation and implementation of the accumulation of knowledge and exchange of experience, to ensure control by one specialist of several risks, and further improvement, they should be standardized within the entire environmental risk management systems. The analysis of works shows that there are the following types of environmental risk assessment methods: qualitative assessments (traditional, based on experts' opinions); quantitative (based on statistics of manifestations and consequences of environmental risks); integral (determining the amount of risk based on several main factors); express assessments; the "delta" method (calculation of the current value of the risk, which dynamically changes based on the previous assessment and the current values of factors affecting the size of the risk); comprehensive (based on special scientific research) (Aleksandrov I.O., Polovyan O.V., Konovalov O.F., Logachova O.V. Tarasov M.Yu., 2010; Taraniuk K.V., 2012). The main disadvantages of the above-mentioned methods include: the need to collect a large amount of primary information for environmental risk assessment; the complexity and long time required for a detailed environmental risk study; the high cost of obtaining relatively accurate estimates of the level of environmental risk; for a large number of risks, relatively accurate statistical sampling can only be carried out for large areas. To avoid these shortcomings, a different approach to environmental risk assessment is proposed. First, the most serious threats are identified and their ranking is carried out. Then they proceed to the actual risk assessment, which takes into account economic losses, mortality, etc. due to natural and man-made emergencies.

Taking into account the requirements of the scientific and methodical literature (Grabovetsky B., 2010, Taraniuk K., 2012, Yakibchu O., 2014), a number of experts – civil servants and specialists on issues of environmental safety in war conditions and their further assessment according to priority significance were involved in conducting this study. It is advisable to use the expert method when the integral indicator that needs to be determined is latent, that is, not amenable to direct quantitative measurement, and the assessments of experts (professionals) offer predictive values of the indicators. The integral assessment of ecological safety is based on a comparison not with the actual (past) state, but with the ideal state, i.e., with its help, it is as if one evaluates not the path that has been taken, but the one that remains to be passed to the ideal (standard) (Muzychenko-Kozlovska, 2019). Among the experts were specialists from all regions of Ukraine with a total number of 131 people, which allows us to assert that the sample is representative and sufficient for approximating the results of the study on the entire general population to obtain results with an accuracy of 95.0% at the level of significance, with an error of 10%. The information base was research of the Kyiv School of Economics (KSE), which, together with the Office of the President, the Ministry of Ecology of Ukraine, are implementing the project "Russia will pay" and the NGO Center for Environmental Initiatives "Ekodiya".

RESULTS AND DISCUSSIONS

An important stage of the integral assessment of the impact on Ukraine's environment of military actions in the conditions of Russian aggression is the selection of indicators that will ensure the comprehensiveness of the study. Since the determination of the level of an integrated assessment of ecological security at the regional level as a result of hostilities is a complex phenomenon, it depends on many factors, therefore it is necessary to aggregate all indicators into one integrated assessment:

- x_1 – radiation contamination in case of Russian shelling and explosions at nuclear power plants;
- x_2 – mining of agricultural lands, forest plantations;
- x_3 – the spread of dangerous poisonous substances due to shelling and fires at oil depots, gas storage facilities, and chemical industry facilities;
- x_4 – pollution of rivers, ponds, and seas due to the sinking of ships, the spread of oil products and explosives;
- x_5 – the destruction of protected areas, destruction of ecosystems, death of animals and birds, forest fires;
- x_6 – the destruction of treatment facilities, dams, and water supply networks;
- x_7 – littering of territories (debris of destroyed buildings, broken cars, remains of household items and appliances, etc.);
- x_8 – significant air pollution;
- x_9 – assessment of death of the population during the year from emergencies as a result of military actions;
- x_{10} – the risk of material losses from emergencies as a result of military actions;
- x_{11} – assessment of ecocrimes committed by Russia on the territory of a certain region.

The evaluation was carried out on a 5-point scale (from 1 to 5 points): 1 point is the lowest rating for the research indicator characterizing the state of security in the region during hostilities;

5 points is the highest score, correspondingly, which characterizes the state of danger in the region during hostilities (see Table 1).

In the second stage, we will assess the impact of risk, and deviations from the planned parameters of indicators characterizing the quantitative parameters of the risk of disruption of the normal functioning of the ecosystem. For this, we took into account indicators x_1–x_8, while we consider indicators $x_9 – x_{11}$ to be the consequences of the previous ones. In this study, we used the SmartPLS3.0 software to check the ratio of the influence of groups of risk factors on environmental hazards in the context of the Russian-Ukrainian escalation war. The partial least squares (PLS) method is a more appropriate statistical method because it can prevent specification errors and improve the reliability of the results, as well as provide better results and minimize structural errors. It has been suggested that the normality of multivariate data can be tested using the web power online tool (https://webpower.psychstat.org/wiki/tools/index) to assess data normality. We ran the web network and the result showed that the data set was not normalized because the multivariate coefficient values were less than 0.05. The result of the Harman univariate test showed that the total method variance is not critical in this study, as the main factor explained 33.45% of the variance, indicating less than the suggested limit of 50%. The predictive accuracy of the model was evaluated based on the explained portion of the variance (R_2), while the R_2 values for risk group Rz_{ij1}–Rz_{ij8} were 0.553, 0.628, 0.523, 0.352, 0.521, 0.454, 0.668, and 0.759 respectively.

Based on studies (Grabovetsky B., 2010), a non-parametric bootstrapping method was used to test the hypotheses. The conclusions revealed that the assessment of the impact on Ukraine's environment of military actions in the conditions of Russian aggression is significantly influenced by the risk of the spread of dangerous toxic substances due to shelling and fires at oil depots, gas storage facilities, and chemical industry facilities (β = 0.727, p<0.01), and the biggest impact is the risk of radiation contamination in the case of Russian shelling and explosions at nuclear power plants (β = 0.743, p< 0.01), followed by pollution of rivers, ponds and seas due to sinking of ships, the spread of oil products and explosives

Table 1. Evaluation of the main indicators of the level of environmental safety of Ukraine of military actions in the conditions of Russian aggression

City	x_{1kj}	x_{2kj}	x_{3kj}	x_{4kj}	x_{5kj}	x_{6kj}	x_{7kj}	x_{8kj}	x_{9kj}	x_{10kj}	x_{11kj}
Vinnytsia	3.0	1.0	3.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	2.0
Volyn	2.0	1.0	2.0	1.0	2.0	1.0	1.0	2.0	2.0	1.0	1.0
Dnipropetrovsk	4.0	2.5	4.0	3.0	3.0	3.0	2.0	3.0	3.0	4.0	2.0
Donetsk	3.5	4.0	4.0	4.0	4.0	4.0	5.0	4.0	4.5	5.0	2.0
Zhytomyr	5.0	2.0	3.0	1.0	2.0	1.0	1.0	2.0	2.0	2.0	2.0
Transcarpathia	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0
Zaporizhzhia	5.0	4.5	4.0	4.0	2.0	4.0	5.0	4.0	4.0	5.0	3.0
Ivano-Frankivsk	2.0	1.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0
Kyiv	4.0	4.0	4.0	3.5	3.0	4.5	5.0	4.0	2.0	5.0	5.0
Kirovohrad	3.5	2.0	3.0	4.0	2.0	2.0	1.0	2.0	5.0	3.0	2.0
Luhansk	4.0	5.0	4.0	5.0	4.0	5.0	5.0	5.0	1.0	5.0	2.0
Lviv	1.5	3.0	2.0	1.0	1.0	1.0	1.0	2.0	1.0	3.0	2.0
Mykolayiv	3.5	3.0	4.0	5.0	3.0	4.5	4.0	4.0	4.5	5.0	1.0
Odesa	3.5	3.0	4.0	4.5	3.0	4.0	3.0	4.0	3.0	4.0	4.0
Poltava	2.0	1.5	3.0	2.0	1.0	2.0	2.0	2.0	2.0	2.0	1.0
Rivne	3.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
Sumy	3.0	3.0	4.0	2.0	3.0	4.0	5.0	3.0	3.0	4.0	1.0
Ternopil	2.0	1.0	2.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	1.0
Kharkiv	3.0	4.0	4.0	3.5	4.0	4.5	5.0	4.0	5.0	5.0	1.0
Kherson	3.0	5.0	4.0	5.0	4.0	3.5	4.0	4.0	5.0	5.0	4.0
Khmelnytskiy	2.5	1.0	3.0	2.5	1.0	2.0	1.5	2.0	1.5	2.0	1.0
Cherkasy	3.5	1.0	3.0	1.0	1.0	2.0	1.0	2.0	1.0	2.0	3.0
Chernivtsi	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0
Chernihiv	2.5	3.0	2.0	1.0	3.0	1.0	4.0	3.0	3.0	3.0	1.0

(β = 0.470, p<0.01), mining of agricultural land, forest plantations (β = 0.481, p<0.01), destruction of sewage treatment facilities, dams, water supply networks (β = 0.261, p<0.01), littering of territories destroyed buildings, broken cars, remnants of household items and appliances, etc.) (β = 0.472, p<0.01), significant air pollution (β = 0.261, p<0.01), as well as destruction of protected areas, destruction of ecosystems, death of animals and birds, forest fires (β = 0.312, p < 0, 01), therefore, the influence of risks regarding the deviation from the planned parameters P_{zij1}–P_{zij8} are accepted (Table 2).

As can be seen from the Table 3, the effect size was estimated using f^2 values were established that $f^2 \geq 0.02$, $f^2 \geq 0.15$, and $f^2 \geq 0.35$ have small, medium, and large effect sizes, respectively. The conclusions showed that R_{zij6} (destruction of water treatment facilities, dams, water supply networks) (f^2 = 0.365), R_{zij4} (pollution of rivers, ponds and seas due to sinking of ships, spread of oil products and explosives) (f^2 = 0.356) and R_{zij3} (spread of dangerous of toxic substances due to shelling and fires of oil depots, gas storage facilities and chemical industry facilities) (f^2 = 0.352) have a large effect, while R_{zij5} (destruction of protected areas, destruction of ecosystems, death of animals and birds, forest fires) (f^2 = 0.283), R_{zij1} (radiation contamination in case of Russian shelling and explosions at nuclear power plants) (f^2 = 0.236) and R_{zij2} (mining of agricultural lands, forest plantations) (f^2 = 0.119) have a medium effect size, R_{zij8} (significant air pollution) (f^2 = 0.112) and R_{zij7} (clogging of territories (debris of destroyed buildings, broken cars, remnants of household items and appliances, etc.) (f^2 = 0.073) have a small effect size. Q^2 values for R_{zij2} (0.349), R_{zij1} (0.350), R_{zij5} (0.160), R_{zij4} (0.166), R_{zij7} (0.036), R_{zij3} (0.141) and R_{zij6} (0.132) were greater than zero, indicating the predictive relevance of the construct. This model is aimed at ensuring the overcoming of risks caused by military actions in Ukraine and preventing their occurrence.

At the next stage of research standardized values of indicators are determined based on the ratio of actual indicators to their reference value. Since there are no standards for individual properties, the basis for comparing the vector of reference values is the reference value of the indicator (1 point), and the general evaluation characterizes the degree of deviation of the actual values from the reference values (see Table 3):

$$z_{ij} = x_r / x_{ij} \tag{1}$$

where: z_{ij} – the standardized value of the indicator;
x_r – the reference value of the indicator that characterizes the integral index of the environmental safety of military actions in the conditions of Russian aggression;
x_{ij} – the value of the indicator that characterizes the integral index of the environmental safety of military actions in the conditions of Russian aggression.

In the next stage, we will calculate the integral index of the environmental safety of military actions in the conditions of Russian aggression for each component standardized value of the indicator, which is carried out according to the following formula:

$$Iij = \sqrt[n]{\prod_{j=1}^{n}\left(1 + z_{ij}\right)} - 1, \tag{2}$$

where: I_{ij} – the integral index of the environmental safety of military actions in the conditions of Russian aggression;
n – the total number of indicators of the index.

Table 2. Trajectory coefficients

Risks	Beta	SD	*t*-value	f^2	Q^2	R^2	Impact of risk, deviation from planned parameters
R_{zij1}	0.743	0.041	18.215	0.236	0.350	0.553	accepted
P_{zij2}	0.727	0.042	17.471	0.119	0.349	0.628	accepted
R_{zij3}	0.472	0.074	6.374	0.352	0.141	0.523	accepted
R_{zij4}	0.481	0.074	6.540	0.356	0.166	0.352	accepted
R_{zij5}	0.470	0.078	6.022	0.283	0.160	0.521	accepted
R_{zij6}	0.312	0.068	4.588	0.365	0.132	0.454	accepted
R_{zij7}	0.261	0.092	2.845	0.073	0.036	0.668	accepted
R_{zij8}	0.281	0.098	2.946	0.112	0.046	0.759	accepted

The value of $I_{ij} \geq 0$ is the extreme state of the system, which will be characterized by a state of sefety due to the reduction of risks of environmental safety at the regional level as a result of military operations.

Calculations of standardized indicators and integral assessment of the level of environmental safety of Ukraine of military actions in the conditions of Russian aggression are presented in Table 3.

To determine the intermediate states that will characterize assessments of the impact on Ukraine's environment of military actions in the conditions of Russian aggression, we will use the formula of the so-called "golden section" (Golden Ratio Calculator, 2022), the essence of which is a proportional ratio close to 0.618:0.382. The patterns of the "golden section" are extremely common in living nature, they are manifested in the harmonious structures of organisms, including humans. This shows that the possibility of applying the principles of the "golden ratio" for determining states seems natural. Therefore, to find the intervals of the assessment of environmental risks at the regional level as a result of military actions, we will obtain a quadratic equation (Golden Ratio Calculator, 2022):

$$x^2 + ax - a^2 = 0 \quad (3)$$

The solution of which allows finding x_1 and x_2:

$$x_{1,2} = -\frac{a}{2} \pm \sqrt{\frac{a^2}{4} + a^2} \quad (4)$$

$x_1 = 0.383$; $x_2 = 0.854$.

Therefore, the states of the integral assessment of the impact on Ukraine's environment of military actions in the conditions of Russian aggression in the interval from 0 to 1 are located as follows (Table 4).

As can be seen from the Fig.1, the value of the Integral assessment of environmental safety of Ukraine of military actions in the conditions of Russian aggression shows that the complex ecological situation that has developed in our country

Table 3. Calculations of standardized indicators (z_{ij}) and integral assessment of the level of environmental safety of Ukraine of military actions in the conditions of Russian aggression (I_{ij})

Region	z_{1ij}	z_{2ij}	z_{3ij}	z_{4ij}	z_{5ij}	z_{6ij}	z_{7ij}	z_{8ij}	z_{9ij}	z_{10ij}	z_{11ij}	I_{ij}
Vinnytsia	0.33	1.00	0.33	1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50	0.70
Volyn	0.50	1.00	0.50	1.00	0.50	1.00	1.00	0.50	0.50	1.00	1.00	0.77
Dnipropetrovsk	0.25	0.40	0.25	0.33	0.33	0.33	0.50	0.33	0.33	0.25	0.50	0.35
Donetsk	0.29	0.25	0.25	0.25	0.25	0.25	0.20	0.25	0.22	0.20	0.50	0.26
Zhytomyr	0.20	0.50	0.33	1.00	0.50	1.00	1.00	0.50	0.50	0.50	0.50	0.59
Transcarpathia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.33	0.94
Zaporizhzhia	0.20	0.22	0.25	0.25	0.50	0.25	0.20	0.25	0.25	0.20	0.33	0.26
Ivano-Frankivsk	0.50	1.00	0.33	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.80
Kyiv	0.25	0.25	0.25	0.29	0.33	0.22	0.20	0.25	0.50	0.20	0.20	0.27
Kirovohrad	0.29	0.50	0.33	0.25	0.50	0.50	1.00	0.50	0.20	0.33	0.50	0.45
Luhansk	0.25	0.20	0.25	0.20	0.25	0.20	0.20	0.20	1.00	0.20	0.50	0.31
Lviv	0.67	0.33	0.50	1.00	1.00	1.00	1.00	0.50	1.00	0.33	0.50	0.71
Mykolayiv	0.29	0.33	0.25	0.20	0.33	0.22	0.25	0.25	0.22	0.20	1.00	0.32
Odesa	0.29	0.33	0.25	0.22	0.33	0.25	0.33	0.25	0.33	0.25	0.25	0.28
Poltava	0.50	0.67	0.33	0.50	1.00	0.50	0.50	0.50	0.50	0.50	1.00	0.59
Rivne	0.33	0.50	0.33	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.00	0.52
Sumy	0.33	0.33	0.25	0.50	0.33	0.25	0.20	0.33	0.33	0.25	1.00	0.37
Ternopil	0.50	1.00	0.50	1.00	1.00	1.00	1.00	0.50	0.50	0.50	1.00	0.77
Kharkiv	0.33	0.25	0.25	0.29	0.25	0.22	0.20	0.25	0.20	0.20	1.00	0.31
Kherson	0.33	0.20	0.25	0.20	0.25	0.29	0.25	0.25	0.20	0.20	0.25	0.24
Khmelnytskiy	0.40	1.00	0.33	0.40	1.00	0.50	0.67	0.50	0.67	0.50	1.00	0.63
Cherkassy	0.29	1.00	0.33	1.00	1.00	0.50	1.00	0.50	1.00	0.50	0.33	0.68
Chernivtsi	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.91
Chernihiv	0.40	0.33	0.50	1.00	0.33	1.00	0.25	0.33	0.33	0.33	1.00	0.53

Table 4. The distribution of regions by the level of the integral index of environmental safety of Ukraine of military actions in the conditions of Russian aggression

Intermediate states	Regions
State of extreme danger $0< I_{ij} < 0.37$	Donetsk (0.26), Dnipropetrovsk (0.35), Zaporizhzhia (0.26), Kyiv (0.27), Mykolayiv (0.32), Luhansk (0.31), Odesa (0.28), Sumy (0.37), Kharkiv (0.31), Kherson (0.24)
	10 regions
Danger $0.38< I_{ij} <0.61$	Zhytomyr (0.59), Kirovohrad (0.45), Poltava (0.59), Rivne (0.52), Chernihiv (0.53)
	5 regions
Threat $0.62< I_{ij} <0.85$	Vinnytsia (0.70), Volyn (0.77), Ivano-Frankivsk (0.80), Lviv (0.71), Ternopil (0.77), Khmelnytskiy (0.63), Cherkasy (0.68)
	7 regions
Risk $0.86 < I_{ij} <1$	Transcarpathia (0.94), Chernivtsi (0.91)
	2 regions
Security $1.1 < I_{ij} <1.68$	–
	Region not represented

Note: the visualization of the obtained results given in Table 4 is shown in Fig. 1.

as a result of the destructive effects of military events has caused no less damage to the environment. Under such circumstances, the search for new tools capable of ensuring a way out of the crisis state of ecological security in the country becomes urgent. This is, first of all, to contribute to the achievement of effective innovative transformation of environmental policy by ensuring the principles of green sustainable development of the national economy. The prerequisite is the definition of the problem field and the main barriers to increasing the level of ecological security in Ukraine, as well as the assessment of the possibilities of overcoming them. The consequences of an armed invasion will have a lasting negative impact on the ability of national economies to prevent and adapt to climate change. Therefore, today, more than ever, it is important not only to improve, to make transparent the procedure for carrying out ecological safety assessment and to establish responsibility for its violation. This methodology will help prepare the groundwork for an ecologically balanced recovery of the country from the consequences of the war with Russia, so that during the reconstruction, not only the possible economic profit, but also the ecological consequences in the long term at the regional level are taken into account.

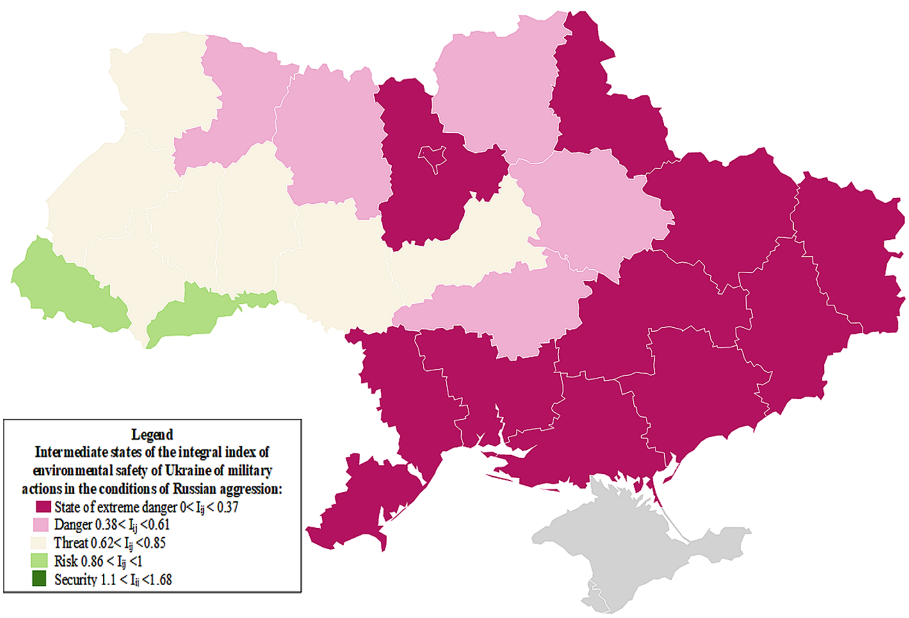

Fig. 1. Resulting map of the integral assessment of the level of environmental safety of Ukraine of military actions in the conditions of Russian aggression

CONCLUSIONS

The assessment of ecological safety and ecological risk analysis, obtained quantitative values of integrated threat assessments characterizing the ecological safety of Ukraine for each of the regions of Ukraine, showed the following: in general, the ecosystem of Ukraine is on the verge of exceeding the permissible impact, especially this applies to the Donetsk-Dnieper region, a number of western, central regions of Ukraine and certain regions of other regions. Therefore, the application of the methodology of environmental safety assessment and environmental risk analysis considered in the work can provide an opportunity to: determine the priority areas of the region's development strategy; to scientifically justify the acceptable level of risk in relation to each of them, to optimize the strategy of ensuring the natural and man-made security of the regions; carry out zoning of the territory of Ukraine according to the degree of internal threats to life.

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