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ECOLOGICAL AND ECONOMIC VALUATION OF LAND IN DE-OCCUPIED TERRITORIES

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ЕКОЛОГО-ЕКОНОМІЧНА ОЦІНКА ЗЕМЕЛЬНИХ УГІДЬ НА ДЕОКУПОВАНИХ ТЕРИТОРІЯХ

Modern challenges associated with the restoration of de-occupied territories necessitate a comprehensive assessment of land resources, accounting for both economic and environmental factors. Therefore, this study aims to develop methodological approaches for the valuation of lands that have been subjected to anthropogenic and technogenic pressure as a result of military actions. During the study, an approach to assessing land in de-occupied territories is proposed: it is based on a comprehensive ecological and economic framework and makes it possible to overcome the limitations of traditional market-based land valuation. In particular, it makes it possible to overcome the limitations of traditional market-based land valuation methods. The formulated provisions demonstrate that, unlike classical approaches that primarily consider current market conditions, the proposed model integrates both economic and environmental parameters of land use functioning. In particular, land value in de-occupied territories is formed both as a market category and owing to the effect of soil degradation processes, technogenic and chemical pollution, physical damage to land (including mine contamination), loss of productive potential, and the need for substantial restoration investments. In light of this, valuation acquires an ecological and economic nature, as it combines: an economic component (market value, income-generating potential), an environmental component (soil quality, pollution, degree of degradation), and a

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restoration component (costs of reclamation, demining, and remediation). Usefulness of the approach to the ecological and economic valuation of land in de-occupied territories lies in the fact that it enables: obtaining a realistic rather than overestimated market value of land; accounting for hidden losses and future costs that are ignored in classical models; forming a substantiated basis for investment decisions, state compensation policies, and territorial recovery programs; ensuring alignment of economic decisions with environmental safety; increasing the reliability of valuation under conditions of high uncertainty and risk.

Сучасні виклики, пов'язані з відновленням деокупованих територій, формують необхідність комплексної оцінки земельних ресурсів з урахуванням як економічних, так і екологічних чинників. Відтак метою дослідження є формування методичних підходів до оцінки земель, які зазнали антропогенного та техногенного навантаження внаслідок активних військових дій. У межах дослідження запропоновано такий підхід до оцінки земельних угідь на деокупованих територіях, що грунтується на комплексному еколого-економічному характері та дозволяє подолати обмеженість традиційної ринкової оцінки земельних ресурсів. Сформовані положення доводять, що на відміну від класичних підходів, які враховують поточну ринкову кон'юнктуру, запропонована система показників інтегрує як економічні, так і екологічні параметри функціонування земельних угідь. Зокрема, йдеться про те, що вартість земель на деокупованих територіях формується не лише як ринкова категорія, але і як результат впливу: деградаційних процесів грунтів, техногенного та хімічного забруднення, фізичного пошкодження земель (у тому числі від мінування), втрати їх продуктивного потенціалу та пов'язаної з цим необхідності здійснення значних відновлювальних інвестицій. У цьому контексті оцінка набуває комплексної природи, зокрема поєднує: економічну складову (ринкова вартість, дохідний потенціал), екологічну складову (якість грунтів, рівень забруднення, ступінь деградації), відновлювальну складову (витрати на рекультивацію, розмінування, очищення). Практична цінність запропонованого підходу до еколого-економічної оцінки земельних угідь на деокупованих територіях в тому, що він дозволяє: отримати реалістичну, а не завищену ринкову вартість земель; врахувати приховані втрати та майбутні витрати (які ігноруються у класичних моделях); сформувати обгрунтовану базу для інвестиційних рішень, державної компенсаційної політики та програм відновлення територій; забезпечити узгодження економічних рішень із екологічною безпекою; підвищити достовірність оцінки в умовах високої невизначеності та ризиків.

Key words: assessment of land resources; economic factors; environmental factors; productive potential; restorative investments; degradation processes; soils; technogenic and chemical pollution; physical damage to land.

Ключові слова: оцінка земельних ресурсів; економічні чинники; екологічні чинники; продуктивний потенціал; відновлювальні інвестиції; деградаційні процеси; грунти; техногенне та хімічне забруднення; фізичне пошкодження земель.

PROBLEM STATEMENT

Modern challenges associated with the restoration of de-occupied territories create the need for a comprehensive assessment of land resources, taking into account both economic and environmental factors. This stems from land affected by military actions is characterized by disruption of soil cover, contamination, degradation processes, and loss of productive potential. Specifically, in the de-occupied territories of southern and eastern Ukraine, significant areas of agricultural land have been affected by landmines, crater formation from explosions, various forms of chemical contamination, and remnants of ammunition. As a result, even after demining, such areas require additional agrochemical analysis, reclamation, and restoration of soil fertility.

In this situation, classical approaches to land valuation prove to be insufficient. They do not adequately account for a wide range of environmental risks, including chemical contamination of soils with heavy metals (lead, cadmium, mercury), petroleum products, and toxic residues of explosive substances; degradation of soil structure and erosion processes; risks of secondary contamination of groundwater and surface water; loss of biodiversity; and the deterioration of ecosystem functions of land resources.

Notably, according to instrumental and laboratory studies conducted by specialists of the Center of Excellence for Mine Action and Environmental Security, elevated concentrations of heavy metals (arsenic, lead, copper, zinc) and explosive residues have been detected in soils in the de-occupied areas of the Mykolaiv region [3]. Moreover, certain plots have suffered significant damage to the soil cover and disruption of its natural state, which will require substantial efforts for reclamation.

In this setting, comprehensive environmental assessment serves as a basis for determining the cost of land restoration, assessing losses, and developing effective policies for the rational use of land resources.

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ACTUAL SCIENTIFIC RESEARCHES AND ISSUES ANALYSIS

Certain issues related to the ecological and economic assessment of land resources in Ukraine are addressed in the works of Kalinchyk M., Slobodyanyk A., Taranenko P., Nastopyrov V. [1], Levandivskyi O.T., Balaniuk I.F., Shelenko D.I., Sas L.S. [4], and Koshkalda I.V., Anopriienko T.V. [2]. Concurrently, existing studies highlight the features of optimizing valuation methods, as well as modern strategies and innovative solutions in the field of land valuation. However, the ecological and economic aspects of land valuation in de-occupied territories have not been sufficiently addressed in the scientific literature.

The principal reason for the limited coverage of ecological and economic issues of land valuation in de-occupied territories in the scientific literature is the novelty of the research object itself, which has emerged as a result of full-scale military actions, as well as the lack of adequate attention to this issue at the legislative level (the most recent methodology is provided in the Resolution of the Cabinet of Ministers of Ukraine "On Approval of the Methodology for Normative Monetary Valuation of Land Plots" dated November 3, 2021, № 1147 [1]).

The vast majority of scientific approaches to land valuation in Ukraine were developed under conditions of relative stability and were focused on traditional value-determining factors, without taking into account large-scale military and technogenic impacts.

RESEARCH AIM

Thus, this study aims is to develop methodological approaches for the assessment of land that has been subjected to anthropogenic and technogenic impacts as a result of military actions.

MAIN FINDINGS OF THE RESEARCH

Within the scope of the present study, the authors emphasize that the ecological and economic assessment of land resources in territories liberated from russian occupation after February 24, 2022, should be regarded as a comprehensive process of determining land value and economic utility, given both productive potential and their environmental condition, degree of degradation, contamination levels, risks of further use, and the necessary costs of restoration.

This is shaped by the specific characteristics of land in de-occupied territories identified by experts of the NGO "Ecology Center of Environmental Initiatives 'Ecoaction'" together with domain experts [7], namely:

1. Physical disturbance of the land surface, evidenced by the presence of craters and depressions (triggered by air strikes and artillery bombardment), trenches, fortification structures, soil compaction resulting from the movement of military equipment and troops, construction of defensive structures, and areas of explosive disturbance.

2. Mine and explosive contamination, characterized by the presence of unexploded ordnance, which restricts or completely prevents land use.

3. Chemical contamination of soils, associated with the presence of heavy metals, petroleum products, residues of explosive substances, and other toxicants.

4. Varying degrees of soil degradation, manifested in the disruption of soil structure, reduced fertility, erosion processes, and loss of the humus layer.

5. Disturbance of the water regime, expressed through altered hydrological conditions and deterioration of surface and groundwater quality.

6. Loss or reduction of biodiversity, resulting from the destruction of natural ecosystems and a decrease in flora and fauna populations.

7. Reduction or loss of productive potential, due to temporary or long-term unsuitability of land for agricultural use.

Every identified characteristic has direct negative consequences. For example, disruption of the soil water balance leads to the development of wind and water erosion. Physical disturbance of land cover results in the destruction of the humus horizon, the loss of the soil's physicochemical properties, and changes in its granulometric composition and aggregate structure [7]. Chemical contamination of soils alters the natural physicochemical parameters of the soil cover (pH, cation exchange capacity, and humus content) [7]. The concentration of toxic chemical substances forms various local landscape-geochemical anomalies.

All these factors affect soil fertility and water retention capacity [7], and in some cases influence the cost of land use and its suitability for long-term utilization. In fact, taken together, these characteristics create a need for significant restoration measures and, consequently, affect the environmental and economic assessment of land resources in de-occupied

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Table 1. Interrelationships among land characteristics, restoration measures, and their influence on the environmental and economic assessment of land resources in de-occupied territories.

Land assessment	Restoration measures in affected territories	Impact on land assessment
Physical disturbance of land cover (craters, trenches, soil compaction)	Land-use planning, filling of craters, deep loosening (deep ripping), land reclamation, and terrain restoration	Decrease in value due to loss of productivity and additional restoration costs
Mine and explosive contamination	Demining, technical inspection of territories, and marking of hazardous areas	Critical decline in value or temporary loss of the land's economic worth
Chemical contamination of soils	Agrochemical analysis, soil decontamination, phytoremediation, application of sorbents, and topsoil replacement	Reduction in value due to environmental risks and substantial remediation costs
Soil degradation (erosion, loss of humus, structural deterioration)	Agro-reclamation measures, application of organic and mineral fertilizers, restoration of the humus layer, and anti-erosion measures	Decrease in rental income and long-term reduction in economic efficiency
Disturbance of the water regime	Restoration of drainage systems, land reclamation, purification of water resources, and regulation of the hydrological regime	Restrictions on land use and reduced investment attractiveness
Loss of biodiversity	Biological reclamation, restoration of natural ecosystems, afforestation, and grassing (conversion to grassland)	Decline in ecosystem value and potential for sustainable use
Reduction or loss of productive potential	Comprehensive reclamation, implementation of adaptive agricultural technologies, and land conservation (where necessary)	Direct reduction in economic valuation and the need to account for the recovery period

Source: compiled based on [7; 3; 1].

territories.Further evidence is provided by the data presented in Table 1.

Environmental diagnostics of land in de-occupied territories is an integrated evaluation of the condition and degree of land degradation. It should combine various ecological characteristics, including the degree of soil disturbance, the level of toxic contamination, and the loss of ecosystem functions

Factually, we consider it appropriate to group the indicators of environmental assessment of land resources into three main blocks: indicators of the physical condition of soils, indicators of chemical and technogenic contamination, and indicators of the ecosystem state of land. In particular [3; 5; 7]:

1. The block of indicators of the physical condition of soils should characterize the degree of mechanical disturbance of land as a result of military actions. It is recommended to include: (i) the level of soil cover disturbance (area and depth of craters, trenches, and pits); (ii) the degree of soil compaction; (iii) disruption of the soil profile structure; (iv) the intensity of erosion processes (active water and wind erosion).

2. The block of indicators of chemical and technogenic contamination should reflect the level of land hazard for further use. It is recommended to include: (i) heavy metal content; (ii) level of petroleum product contamination; (iii) presence of explosive residues, mine and explosive contamination; (iv) exceedance of maximum permissible concentrations of toxic substances.

3. The block of indicators of ecosystem state of land characterizes the functional capacity of land resources as natural systems: (i) humus content and soil fertility indicators; (ii) water regime conditions (quality and availability of water resources); (iii) level of biodiversity; (iv) degree of preservation of ecosystem functions (self-regulation, resilience); (v) level of degradation of natural components.

Such grouping makes it possible to systematically assess the environmental condition of land resources in de-occupied territories and provides a basis for defining a system of indi-

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Table 2. System of indicators and algorithms aimed at identifying environmental constraints in land economic valuation and restoration

Assessment block	System of indicators	Units of measure	Algorithm (methodology) of calculation
Physical condition of soils *(It is important to determine the soil buffering capacity for recovery, humus loss, and reduction of natural fertility).*	Soil cover disturbance level	***% of area***	$K_1 = (Saffected / Stotal) \times 100$, where: *S*(total, affected) – total area of disturbed land (affected land area)
	Depth of disturbances (craters, trenches)	***m***	Weighted average value based on field measurements
	Soil compaction degree	***g/cm³***	$K_2 = \rho_{f/\rho_{optimal}}$, де ρ – soil density
	Soil structure disruption	***points / index***	Expert assessment or share of disturbed horizons (%)
	Intensity of erosion processes	***t/ha/year***	Calculation based on erosion models (e.g., USLE) or field data
Chemical and technogenic contamination *(It is important to identify the presence of various local landscape-geochemical anomalies).**	Heavy metal content (lead, cadmium, mercury, etc.)	***mg/kg***	$K_3 = C_{f/MPC}$, where: C(fact) – actual concentration of the pollutant in soil; *MPC* – maximum permissible concentration of the respective substance.
	Petroleum product contamination	***mg/kg***	Comparison of actual content with regulatory standards
	Explosive residue content	***mg/kg / presence (binary indicator)***	Laboratory analysis or binary assessment (0/1)
	Level of mine contamination risk	***% of area / index***	$K_4 = \frac{S_{неб}}{S_{заг}}$ where: *S*(haz) – area of hazardous land (contaminated with explosive ordnance); *S*(tot) — total area of the study territory.
	Integrated contamination index	***dimension less***	$Z_c = \sum \frac{C_i}{MPC_i}$, where: C_j – actual concentration of the *i*-th pollutant in soil; MPC_j – maximum permissible concentration of the *i*-th substance.
Ecosystem state of land *(It is important to identify pollutants that may migrate and spread within the environment).*	Humus content	***%***	Laboratory analysis
	Soil fertility index	***points***	Humus, pH, and NPK normalization (0–1 or 0–100 scale)
	Water regime condition	***index***	Water quality assessment + level of flooding/drainage condition
	Level of biodiversity	***index***	Shannon index or species richness per unit area
	Ecosystem functions	***points***	Expert assessment (self-regulation, resilience)
	Level of degradation	***% / index***	Share of degraded land or integrated index

Note

* Chemical pollution agents include vehicle fuel, lubricants, solvents, electroplating waste, explosive residues, decontamination substances, heavy metals and their compounds, and radioactive substances.

*Technogenic pollution agents include components and factors arising from the destruction of infrastructure, engineering systems, and military-industrial activities, which alter the physical and functional condition of land.

Source: compiled based on [1; 7; 3].

cators and algorithms aimed at the qualitative aggregation of detailed information on the environmental state of land resources (see Table 2).

Such an assessment should be aimed at substantiating managerial decisions regarding the restoration and rational use of land resources in the post-war period. Therefore, for further formalization, it is appropriate to use:

1. Normalization of the indicators defined in Table 2:

$$K_{norm} = X - \frac{X_{min}}{X_{max}} - X_{min} \qquad (1),$$

where: K(norm) — normalized value of the indicator; X — actual value of the indicator; X(min) — minimum value of the indicator in the sample; X(max) — maximum value of the indicator in the sample.

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It should be noted that normalization of indicators is necessary to transform heterogeneous indicators, differing in units of measurement and scale, into a unified dimensionless scale (typically within the range from 0 to 1). This makes it possible to ensure their comparability and to avoid the dominance of indicators with larger numerical values in the process of further integration.

2. Integration of indicators through an integrated environmental index:

$$I_{eco} = \sum \left(w_i \cdot K_{norm,i} \right) \quad (2),$$

where: w_i — weighting coefficient of the i-th indicator (indicator significance); K(norm,i) — normalized value of the i-th indicator.

The aggregation of indicators, through the calculation of an integrated environmental index, is necessary to synthesize multidimensional information about the condition of land resources into a single composite indicator. This enables a comprehensive assessment of the environmental state of a territory, given the varying significance of individual parameters, as well as the risks of toxic substance migration and their transfer into plant-based agricultural products.

Moreover, the aforementioned approach forms the foundation for the economic valuation of land resources in de-occupied territories, which should be considered through the prism of land value, taking into account the environmental risks and restoration costs identified in Table 2.

Notably, in order to determine the economic (market) value of land resources in de-occupied territories, it is not sufficient to rely solely on conventional valuation approaches. Instead, a hybrid approach should be applied, combining market-based methods with adjustments for environmental losses and restoration expenditures. For this purpose, it is necessary to apply:

1. Calculation of the base market value (as if the land plot were not located in de-occupied territories), defined as the baseline (potential) market value of undamaged land (Vo) [2; 4; 6]. This refers to the standard market price based on a comparative approach (the value of similar land plots in the region).

2. Calculation of the market value of a land plot in de-occupied territories:

$$V=S \cdot P-S(Cm+Cr+Ce) \quad (3),$$

where: S — area (ha); P — average market price per 1 ha (UAH); Cm — demining costs per 1 ha; Cr — land reclamation costs per 1 ha; Ce — environmental remediation costs per 1 ha.

Some scholars [4—5] also propose incorporating Lp into this formula, representing productivity losses due to foregone income (resulting from soil degradation, compaction, erosion, and loss of humus):

$$L_p = \sum_{t=1}^{T} \frac{(Y_0 - Y_t) \cdot P}{(1+r)^t} \quad (4),$$

where: Y_0 — normal (baseline) yield; Y_t — actual/expected yield; P — price of output (agricultural products); r — discount rate; T — recovery period.

Thus, the proposed approach transforms conventional land valuation into an integrated ecological and economic assessment, enabling a more accurate representation of the actual condition and potential of land resources in de-occupied territories and providing a sound basis for managerial, investment, and recovery-oriented decision-making.

CONCLUSIONS

Within the scope of the outlined study, the following approach to the ecological and economic valuation of land on de-occupied territories is proposed. It is based on a comprehensive eco-economic framework and, in particular, makes it possible to overcome the limitations of traditional market-based land valuation. The developed provisions demonstrate that, unlike classical approaches-which primarily take into account current market conditions-the proposed model integrates both economic and environmental parameters of land use.

Specifically, it is argued that the value of land in de-occupied territories is formed not only as a market category, but also as a result of the impact of: soil degradation processes; technogenic and chemical contamination; physical damage to land (including landmines); loss of productive potential; the need for substantial restoration investments.

In this situation, the valuation acquires an ecological and economic nature, as it combines: an economic component (market value, income-generating potential); an environmental component (soil quality, level of contamination, degree of degradation); a restorative component (costs of reclamation, demining, and remediation).

The practical value of the developed approach to the ecological and economic valuation of land in de-occupied territories lies in its ability to: provide a realistic, rather than overstated, market value of land; account for hidden losses and future costs that are ignored in classical models; form a well-grounded basis for investment decisions, state compensation policies, and territorial recovery programs; ensure the alignment of economic decisions with environmental safety; and increase

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the reliability of valuation under conditions of high uncertainty and risk.

Prospects for further research within this thematic area involve deepening the methodological toolkit of ecological and economic valuation. This includes the development of clear algorithms for integrating environmental and economic indicators, the formalization of weighting coefficients for different types of degradation, and the creation of unified indicators applicable across regions. Without this, the model will remain theoretically sound but difficult to implement in practice.

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