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ECOLOGICAL AND ECONOMIC DETERMINANTS OF AGRICULTURAL LAND VALUE IN THE LIBERATED TERRITORIES OF BROVARY DISTRICT

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Abstract: The article presents a comprehensive study aimed at the theoretical substantiation and assessment of the ecological and economic determinants forming the value of agricultural land in de-occupied territories (using the Brovary district of the Kyiv region as a case study). The relevance of the work is driven by the need for an objective assessment of land assets directly affected by military operations. To achieve this goal, a comparative analysis of market prices from the pre-war (2021–2022) and post-occupation (2024–2025) periods was conducted based on secondary market data.

The analysis results revealed a significant decrease in the average value of agricultural land. The findings indicate that land plots with different designated uses

experienced varying degrees of value depreciation. Key ecological and economic factors influencing the change in land value were identified and substantiated, including technogenic pollution resulting from combat operations and shifts in the market supply structure. Also, during the study, the factor of the high cost of demining and, if necessary, recultivation of agricultural lands was taken into account.

The research results highlight the heterogeneous impact of war on different types of agricultural land and underscore the necessity of developing comprehensive programs for recovery, reclamation, and economic stimulation to enhance the investment attractiveness of these territories.

Keywords: ecological and economic assessment, land market value, land market pricing, agricultural land, de-occupied territories, Russian military aggression, technogenic soil pollution, humanitarian demining.

Problem Statement.

This article complements and expands upon the findings of the study published in the author's conference abstracts [3]. The work is dedicated to an in-depth analysis of the factors influencing the market value of agricultural land through the prism of de-occupation processes.

In the context of the full-scale war unleashed by the Russian Federation against Ukraine, an unprecedented impact is observed across all spheres of the country's life, including the real estate market and the land fund in particular. Combat operations, the occupation of territories, and their subsequent liberation fundamentally change economic and environmental conditions, which inevitably affects the value of land assets. The war and its accompanying phenomena—such as production decline, unemployment, financial challenges, and general future uncertainty—serve as significant factors influencing land value.

Despite existing general studies on land market dynamics under martial law, the issue of quantitatively isolating the specific "de-occupation effect" remains insufficiently explored. There is a methodological challenge in developing an approach that would allow for the differentiation between the general economic

decline in agricultural land prices and the specific asset depreciation caused by the environmental consequences of combat operations and the occupation of particular territories.

Purpose of the Study.

The objective of this scientific study is to theoretically substantiate and assess the ecological and economic determinants of agricultural land value formation in de-occupied territories (using the Brovary district of Kyiv region as a case study). Achieving this goal involves addressing the following tasks:

1. To analyze the dynamics of asking prices for agricultural land plots in the Brovary district of Kyiv region during the pre-war (2021–2022) and current (2024–2025) periods;
2. To conduct a comparative analysis with a control region (Boryspil district of Kyiv region) to verify the impact of the occupation factor;
3. To identify and systematize the key ecological and economic factors that constitute the "occupation discount."

The study employs a control group methodology to analyze the agricultural land market in de-occupied territories. This approach has allowed for the mathematical isolation of specific military-related value determinants and established that the additional land depreciation in the de-occupied territories of Brovary district is approximately 20% compared to adjacent non-occupied territories. Furthermore, the consideration of phytotoxicity and mine contamination as direct pricing factors in agricultural land valuation models has been further developed.

The research results can be utilized by local self-government bodies and land management organizations to develop land restoration and reclamation programs. The data regarding median value and the extent of market decline serve as a foundation for an objective assessment of damages incurred by agricultural landowners, as well as for attracting investment in demining and returning degraded lands to economic use. Finally, the study provides sound conclusions for the further development of recovery strategies and the sustainable development of the agricultural sector in the affected regions.

Analysis of Recent Research and Publications.

The problem of land market transformation under martial law and the assessment of incurred damages is a primary focus for many Ukrainian scholars. Existing research can be categorized into the following key areas:

1. Ecological Consequences and Soil Degradation. Issues of chemical pollution (heavy metals, explosive residues) and mechanical damage to the soil cover are examined in detail in the works of both international and Ukrainian scientists, namely: M. Solokha, O. Demyanyuk, L. Symochko, and others.

2. Land Market Economics and Institutional Transformations. Fundamental aspects of the agricultural land market functioning in Ukraine, pricing mechanisms, and the transformation of land relations—particularly under martial law—are studied by A.M. Tretiak, A.H. Martyn, T.O. Yevsiukov, A.O. Koshel, and other representatives of the national school of land management. Their works pay significant attention to the institutional support of the market, the transparency of land auctions, and the regulatory framework of land circulation. Specifically, their research allows for the evaluation of nationwide market trends (e.g., the implementation of automated mass land valuation), providing a necessary basis for further analysis of local markets in de-occupied regions. Analysis of general market trends, transaction volumes, and price dynamics at the national level is conducted by analytical centers (notably KSE Agrocenter) and market researchers. However, these works mostly operate with aggregated data at the regional (oblast) level, without delving into the specifics of de-occupied districts.

3. Methodological Approaches to Damage Assessment. The regulatory framework for assessing damage to land resources is established in the *"Methodology for Determining the Amount of Damage Caused to Land and Soil as a Result of Emergencies and/or Armed Aggression and Combat Operations During Martial Law,"* approved by Order No. 16 of the Ministry of Environmental Protection and Natural Resources of Ukraine on April 4, 2022. Additionally, research is dedicated to improving real estate appraisal methods under conditions of uncertainty.

4. Local Case Studies of De-occupied Territories. Specific aspects of the recovery of the Kyiv and Chernihiv regions are highlighted in reports by international organizations and publications regarding spatial planning. Nonetheless, a comprehensive ecological and economic analysis at the level of specific administrative districts remains fragmentary.

Synthesis of the Review.

What is known: Currently, the catastrophic impact of combat operations on the ecological state of soils has been scientifically proven, and a general decline in agricultural land market activity in Ukraine has been recorded.

What is unknown: There is a lack of clear quantitative indicators regarding the exact extent to which the de-occupation factor (mining, logistics disruption, reputational risks) reduces land value compared to adjacent regions that were not occupied but operate within the same macroeconomic environment.

Proposed in this study: Unlike existing general reviews, this study proposes a targeted analysis of the agricultural land market in the Brovary district using the control group method. This allows for the mathematical isolation of the "military component" of land devaluation by comparing it with the Boryspil district, bridging the gap between ecological measurements of damage and their market reflection.

Materials and Research Methods.

The following methods were employed in this study:

- Method of theoretical generalization and systems analysis – used to study the regulatory framework, scientific works on the ecological and economic assessment of land, and to identify the key determinants of the impact of military actions on the value of land assets;
- Time series comparison method – applied to compare asking prices for agricultural land plots in the Brovary district across two time periods: pre-war (2021–2022) and post-de-occupation (2024–2025);
- Statistical-economic method – used for the collection, grouping, and processing of secondary real estate market data, allowing for the determination

of the average market value of 1 hectare of agricultural land depending on its specific use;

- Graphical and tabular methods – applied to visualize the research results, particularly the dynamics of land value depreciation and the comparison of price indicators for various types of land use;
- Calculation-constructive method – used to assess the impact of environmental factors (pollution, mine hazards) on the economic attractiveness of territories and to substantiate the necessity of costs for reclamation and demining;
- Comparative analysis with a control territory (simplified Difference-in-Differences model) – a quasi-experimental approach used to verify the impact of de-occupation factors. This method allows for the differentiation between general economic factors and the consequences of combat operations and occupation by comparing price dynamics in an adjacent district unaffected by direct military actions.

The article conducts a comparative analysis of the agricultural land market, where the primary object of study is the de-occupied territories of the Brovary district of Kyiv region. To identify the net impact of military and environmental factors, the results were compared with indicators from the Boryspil district, which was not under occupation and served as the control group.

The settlement system of the Brovary district is characterized by a powerful administrative center (Brovary city, with a population of approximately 100,000) and a network of large townships (Velyka Dymerka, Hoholiv, etc.). The total area of the district is 2,888.2 km², encompassing 125 settlements organized into 8 territorial communities with a total population of 242,000. Agricultural lands are dominant in the structure of the land fund, accounting for an estimated 60–70% of the total area (taking into account the change in administrative boundaries in 2020 following the annexation of the Baryshivka and Zghurivka districts). During the active phase of combat operations in February–March 2022, 25 settlements in the district were under temporary occupation.

According to the DeepStateMap monitoring resource, the area of de-occupied territories in the Brovary district amounted to 166.5 km² [1]. This constitutes approximately 5.8% of the district's total area; however, it is within this territory that the primary ecological and economic damages and mine contamination are concentrated, directly affecting the market value of agricultural land.

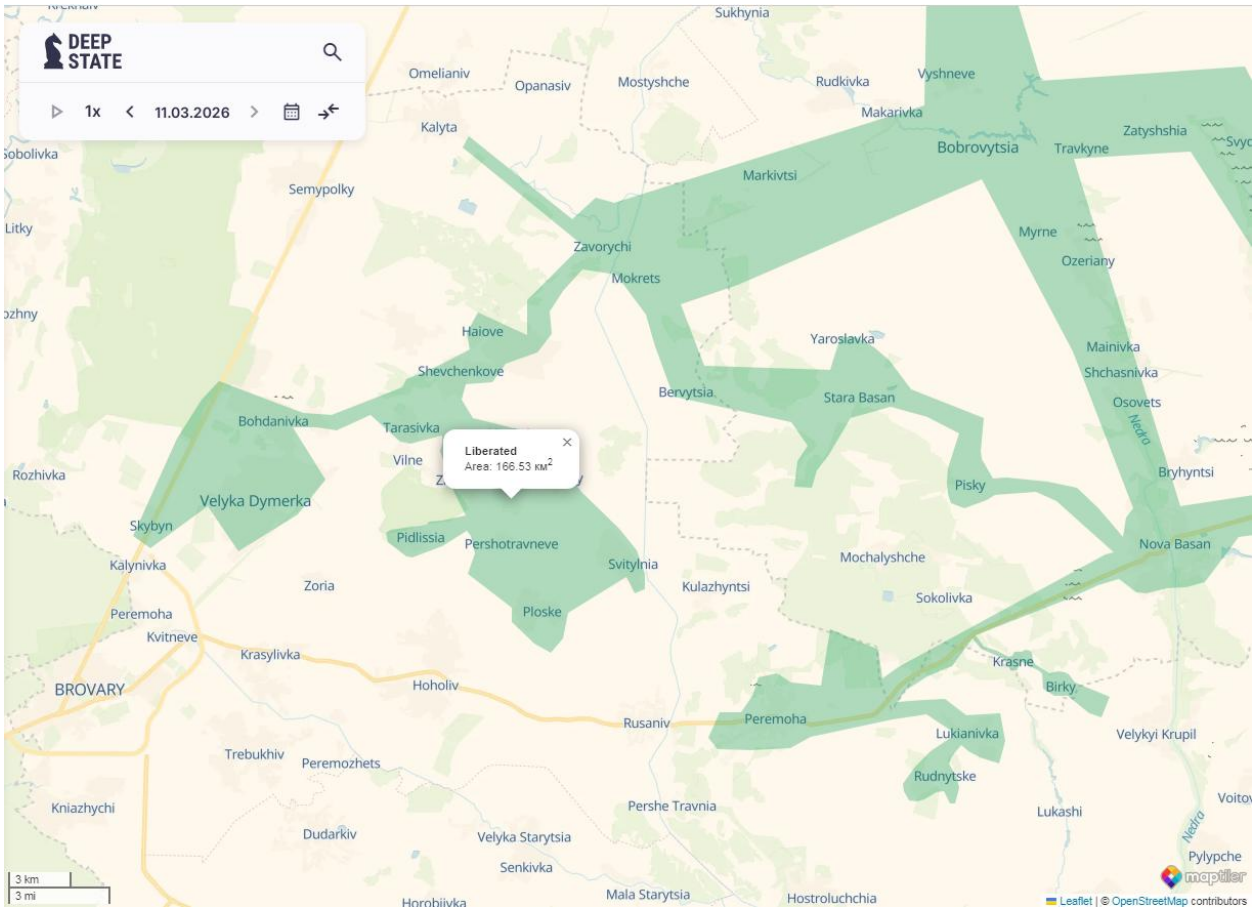

Fig. 1. The extent of occupation in the Brovary district [Source: [1]]

According to the schematic map, it is evident that Russian troops primarily occupied the north-eastern part of the Brovary district. The occupation mainly affected small villages, with the exceptions of Velyka Dymerka, Kalyta, Bohdanivka, and Peremoha. Real estate in this area consists of manor-type residential buildings, land plots for residential construction, and agricultural land.

The research algorithm involved a comprehensive analysis of the local real estate market in the Brovary district across its primary segments: residential, industrial-commercial, and land.

It is worth noting that the residential and industrial-commercial real estate segments are currently well-studied and regularly featured in professional analytical reports. In contrast, the market for agricultural land is in a stage of active formation, as the moratorium on its sale was only lifted in 2021. Prior to the start of the war, this market was in the stage of institutional development, which accounts for the limited amount of scientific research in this field. At the same time, agricultural land forms the basis of the de-occupied territories and plays a strategic role in the economy of the Brovary district. This necessitates focusing this scientific inquiry specifically on the analysis of the ecological and economic determinants of agricultural asset values.

Given that this work focuses on the value of agricultural land plots, the relevant data will be prioritized.

Methodology and Data Collection Protocol

To ensure the objectivity of the study, a protocol for the collection and verification of secondary market data (via the OLX.UA platform) was developed. Data collection was conducted in two stages:

- Retrospective Analysis: Examination of listings from September 2021 to February 2022 (pre-war market state). The initial sample consisted of over 60 objects, from which 25 representative lots were selected after filtering.
- Current Analysis: Examination of listings from September 2024 to June 2025. Out of 50 initial advertisements, 17 objects were included in the final calculation.

Inclusion Criteria for the Sample:

- Geographic Factor: Land plots located exclusively within the territories of the Brovary district that were under occupation or in the immediate combat zone, situated outside settlement boundaries (except for plots designated for gardening, as gardening associations are integrated into settlements).
- Targeted Use: Agricultural land (Code 01 according to the Classification of Types of Land Use [16]). Specifically, plots were selected with the following codes: 01.01 (commercial agricultural production), 01.03 (personal peasant farming), and 01.05/01.06 (individual/collective gardening).

- Financial Factor: Prices indicated in foreign currency (primarily USD) were retained; prices indicated in the national currency (UAH) were converted into USD at the official National Bank of Ukraine (NBU) exchange rate on the date of the advertisement to neutralize the impact of devaluation processes.
- Units of Comparison: The choice of the unit of comparison is driven by the specifics of the local real estate market. Although standard methodology [12] identifies 1 hectare (ha) as the typical unit for agricultural land valuation, in the supply segment of the Brovary and Boryspil districts, the most commonly used unit is the price per 1 are (USD/are), where 1 are = 0.01 ha.

Data Cleaning and Validation Procedure:

To ensure the integrity of the results, the following were excluded from the analysis:

- Duplicate advertisements (identified by contact information or object description);
- Lots with contradictory information (discrepancies in price or area between the title and description);
- Advertisements from real estate agencies showing signs of "bait" listings or objects with abnormally high prices indicating potential future changes in land use.

Only listings with complete information, allowing for the identification of the location and agrophysical characteristics of the plot, were accepted for the calculation of median values.

In addition to technical data cleaning, the validation procedure included an analysis of potential selection bias. Specifically, the risk of the "scale effect" (the correlation between unit price and plot area) was taken into account. A detailed calculation of how changes in the average size of offered objects influenced the median value is presented in the "Results and Discussion" section (sub-section: "Influence of the Quantitative Factor").

The decision to use asking prices from open listings (OLX.UA) instead of public monitoring data from the State Service of Ukraine for Geodesy, Cartography and Cadastre is due to the low elasticity of official transaction prices to market

fluctuations under wartime conditions. This is explained by several institutional and regulatory factors:

- Legislative Price Floor: According to the Transitional Provisions of the Land Code of Ukraine (Clause 22, Section X), "...Until January 1, 2030, the sale price of agricultural land plots allocated in kind to owners of land shares (pats) cannot be lower than their normative monetary evaluation (NME)." The NME often fails to reflect current market realities, serving merely as a fiscal barrier.
- Fiscal Pressure and Financial Monitoring Requirements: The mandatory verification of the buyer's source of income (Article 130 of the Land Code of Ukraine) and the requirement to obtain a "Certificate of Estimated Value" from the State Property Fund of Ukraine (SPFU) Unified Database [13]. This often leads to a concentration of registered prices around the SPFU's calculated values. This reduces the representativeness of official data regarding actual market sentiment and frequently incentivizes transaction parties to declare the minimum permissible price to optimize taxation and simplify verification procedures.

Unlike official statistics, which demonstrate regulatory inertia due to the link to NME, secondary market data (OLX platform, etc.) allow us to record the real amplitude of the price shock caused by military actions and occupation. It should be taken into account that the price of the advertisement usually includes a "bargaining buffer", which in the agricultural land segment is from 5 to 15% (depending on the urgency of the sale and the liquidity of the plot). However, it is the offer prices that react more quickly to changes in the security situation and environmental risks, acting as a leading indicator of the market expectations of the owners.

Results and Discussion.

The study established that the primary structure of the current agricultural land market consists of the following types of land-use purposes: commercial agricultural production, personal peasant farming, and gardening. Due to the proximity of the Brovary district to the city of Kyiv, its geographical location and scenic natural

landscapes have significantly contributed to the intensive development of gardening associations.

Following a comprehensive analysis of the market for land sale offers with agricultural designations (including gardening), the data were carefully examined, verified, and sorted according to the criteria established in the methodology. For clarity of perception, the findings were synthesized into two comparative tables: the first covering the 2021–2022 period and the second covering 2024–2025.

In these tables, the data are categorized by target land-use purpose — gardening and agricultural production (denoted as "agri" in the tables). Furthermore, the median asking price per are (0.01 ha) was calculated for each respective type of land use to identify price trends and the impact of de-occupation processes.

Table 1. Asking Prices for Land Plots (2021–2022) [Source: Compiled by the author based on OLX data].

Settlement Name	Target Use	Area, ha	Value, USD	Price per are, USD	Median asking price per are, USD
Velyka Dymerka	Gardening	0.12	3,000.00	250.00	
Velyka Dymerka	Gardening	0.10	3,000.00	300.00	
Velyka Dymerka	Gardening	0.12	3,999.00	333.25	
Velyka Dymerka	Gardening	0.10	2,000.00	200.00	
Zherdova	Gardening	0.06	2,200.00	366.67	
Zherdova	Gardening	0.10	5,000.00	500.00	
Bohdanivka	Gardening	0.10	4,000.00	400.00	
Rusaniv	Gardening	0.10	900.00	90.00	
Rusaniv	Gardening	0.12	950.00	79.17	
Rusaniv	Gardening	0.10	1,700.00	170.00	
Rusaniv	Gardening	0.10	1,800.00	180.00	
Rusaniv	Gardening	0.10	2,000.00	200.00	
Tarasivka	Gardening	0.06	3,500.00	583.33	**Gardening: 250.00**
Hoholiv	Agri-production	0.95	9,500.00	100.00	
Skybyn	Agri-production	32.00	960,000.00	300.00	
Trebukhiv	Agri-production	янв.50	52,500.00	350.00	
Bobryk	Agri-production	0.20	3,500.00	175.00	
Semypolky	Agri-production	янв.31	13,000.00	99.24	
Semypolky	Agri-production	03.мар	30,000.00	99.01	
Semypolky	Agri-production	фев.78	35,000.00	125.90	
Rudnia	Agri-production	фев.50	10,000.00	40.00	
Zherdova	Agri-production	0.50	2,600.00	52.00	
Zherdova	Agri-production	0.22	1,100.00	50.00	
Zherdova	Agri-production	0.22	4,400.00	200.00	**Agri-production: 100.00**

Table 2. Land Sale Offers for 2024–2025 [Source: Compiled by the author based on OLX data]

Settlement Name	Target Use	Area, ha	Value, USD	Price per are, USD	Median asking price per are, USD
Rudnia	Agri-production	4.00	26,000.00	65.00	
Svitilnia	Agri-production	12.00	42,000.00	35.00	
Zavorichi	Agri-production	2.00	8,500.00	42.50	
Pidlisssia	Agri-production	40.00	220,000.00	55.00	
Shevchenkove	Agri-production	янв.50	4,500.00	30.00	
Svitilnia	Agri-production	10.00	50,000.00	50.00	
Semypolky	Agri-production	фев.78	20,000.00	71.94	
Velyka Dymerka	Agri-production	02.авг	30,000.00	144.23	
Velyka Dymerka	Agri-production	0.85	15,000.00	176.47	
Bohdanivka	Agri-production	янв.96	49,000.00	250.00	
Bohdanivka	Agri-production	0.50	17,500.00	350.00	
Bohdanivka	Agri-production	0.26	10,299.00	396.12	
Zalissia	Agri-production	фев.35	36,000.00	153.19	**Agri-production: 72.00**
Bohdanivka	Gardening	0.10	2,500.00	250.00	
Velyka Dymerka	Gardening	0.65	9,750.00	150.00	
Svitilnia	Gardening	0.12	1,200.00	100.00	**Gardening: 150.00**

Table 3. Statistical Parameters of Agricultural Land Asking Prices Before and After Occupation [Source: Developed by the author]

Land Category (Type of Targeted Use)	Research Period (Years)	Quantity (N)	Median, USD/are	25th Percentile (Q1), USD/are	75th Percentile (Q3), USD/are	Median Change, ΔMe,%
Agricultural (Commercial production, Personal peasant farming)	2021–22	11	100	52	200	**–28**
	2024–25	13	72	50	176	
Agricultural (Gardening)	2021–22	13	250	180	366	**–40**
	2024–25	3	150	100	250	

Notes:

- ***Asking prices*** *originally listed in UAH were converted to USD at the official NBU exchange rate as of the advertisement publication date;*
- ***Q1 and Q3*** *represent the 25th and 75th percentiles, respectively, defining the boundaries of the* ***Interquartile Range (IQR)****;*
- *The calculation of the* ***relative change in median values*** *($\Delta Me, \%$) was performed using the following formula:*

$$\Delta Me = \frac{(Me_{2024-2025} - Me_{2021-2022})}{Me_{2021-2022}} \times 100\%$$

Where:

- *Me is the median price during the pre-war period;*
- *Me is the median price during the current period.*

The calculation of value indicators was carried out in accordance with the provisions of the Methodology for Expert Monetary Valuation of Land Plots [12]. According to paragraph 8 of the methodology [12]: "...when using a methodological approach based on the comparison of sales prices of similar land plots..." (in this case, asking prices) "...in the presence of a large number of sales of similar land plots on the market, mathematical statistics methods may be applied to determine the value through price comparison...".

Given that the purpose of this article is to identify general market trends and assess value dynamics in the region rather than provide an individual appraisal of a specific object, the Median was chosen as the primary statistical indicator. When calculating the median, no adjustments were made for factors that typically influence the value of a specific plot (such as area, shape, access roads, or utilities), as the object of analysis is the market asking price for the segment as a whole, not the valuation of an individual plot. Choosing the median over the arithmetic mean allows for minimizing the impact of outliers (atypical minimums and maximums). To ensure the relevance of the comparison, data arrays with comparable characteristics (location, targeted use) were formed, avoiding subjectivity in applying adjustments.

The analysis of the obtained data (Table 1 and Table 2) demonstrates a steady downward trend in value. Specifically, the median asking price for agricultural land

(commercial production and personal peasant farming) in the de-occupied territories of the Brovary district decreased from 100 USD/are (2021–2022) to 72 USD/are (2024–2025), representing a 28% drop. An even more significant decrease was recorded in the agricultural land segment designated for gardening: the median fell from 250 USD/are (2021–2022) to 150 USD/are (2024–2025) — a 40% difference. This dynamics is visualized in the histogram and graph (Fig. 2 and Fig. 3).

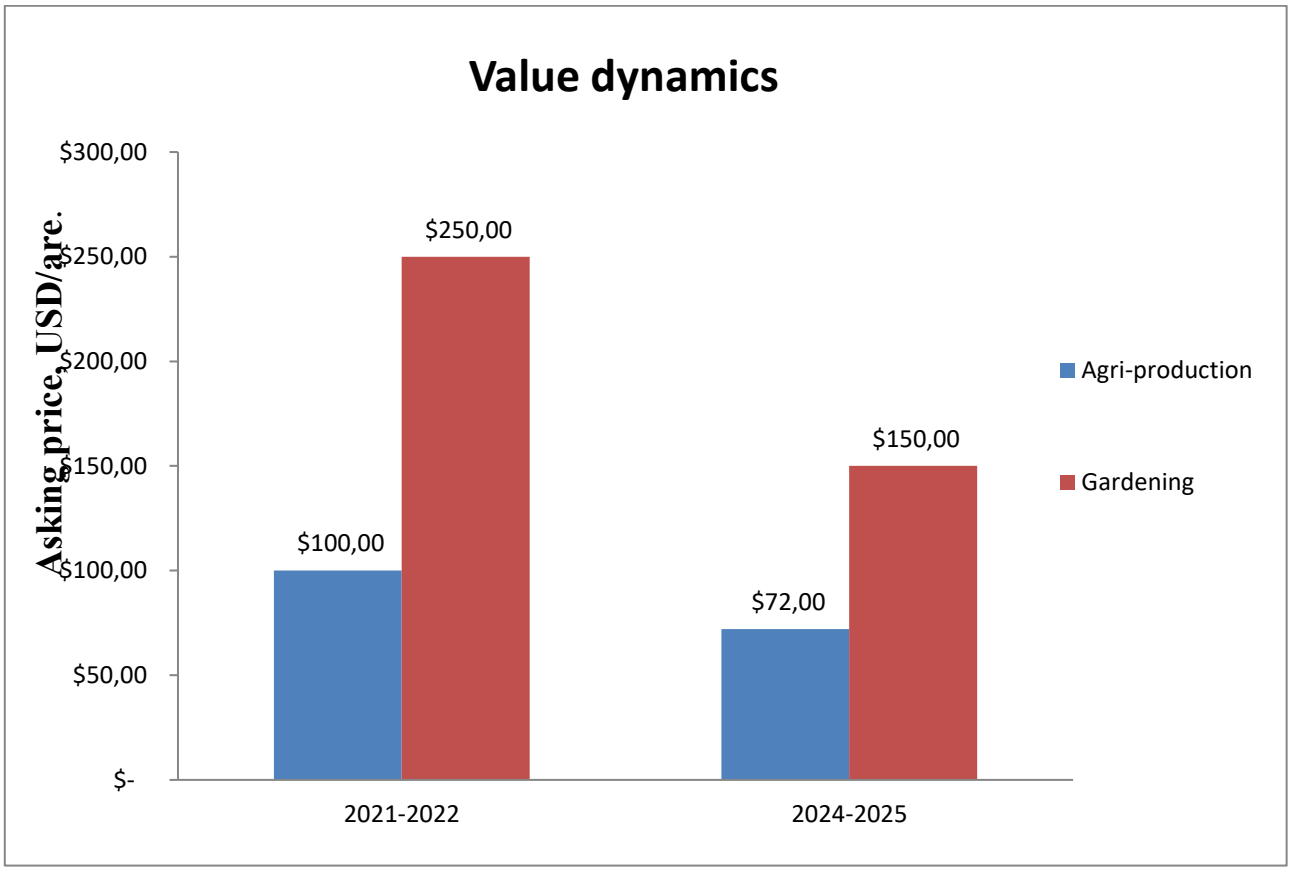

Fig. 2. Dynamics of asking prices for agricultural land [Source: Developed by the author]

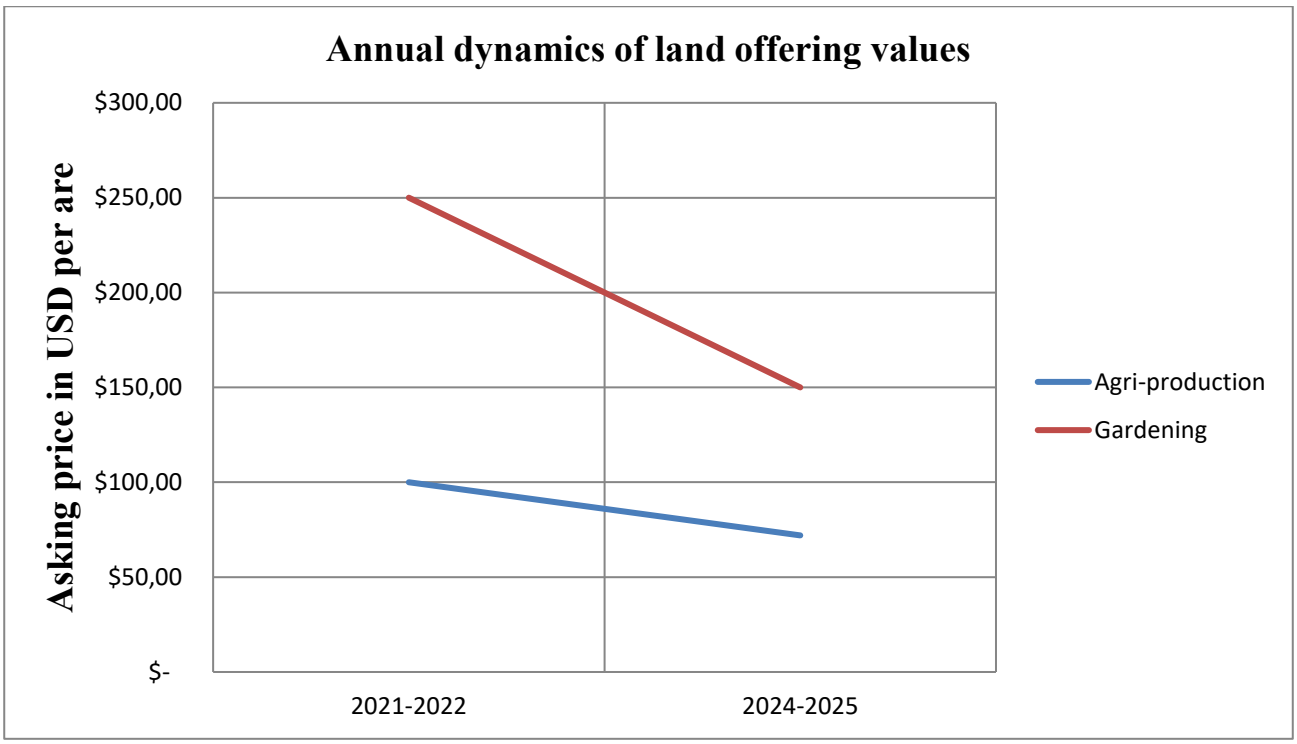

Fig. 3. Annual dynamics of agricultural land asking prices [Source: Developed by the author]

According to the data of the State Service of Ukraine for Geodesy, Cartography and Cadastre, published in the collection [4], the dynamics of weighted average land prices is as follows, according to the graph.

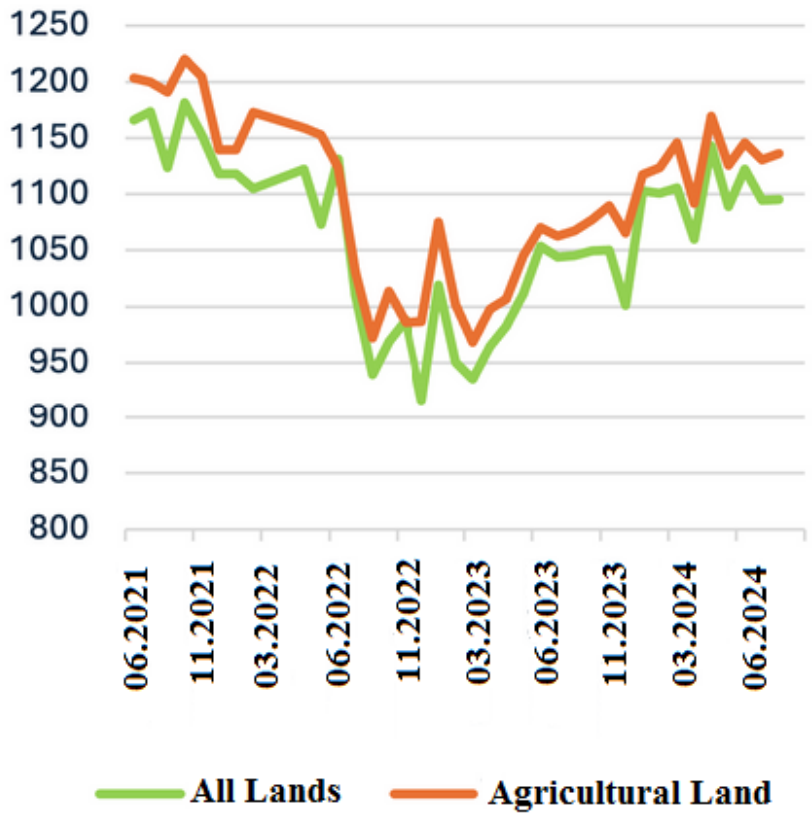

Fig. 4. Dynamics of weighted average prices (in USD per 1 ha) [Source [4]

However, as rightly noted in this analysis [4]: "…it is worth noting that all prices analyzed in the issues of this review are official prices for the purchase and sale of agricultural land, recorded in the agreements. The real value of agricultural land may differ, since most of the purchase and sale transactions are concluded at a price that does not differ from the regulatory monetary assessment (the minimum sale price for former moratorium lands) by more than 2%. Therefore, the true market volume may be significantly larger, as well as the real price. At the same time, due to the fact that the share of transactions concluded at a price equal to the NGO is constant over time - the change in price both in time and in geographical terms reflects the variability of prices in the market. So, while absolute land price values should be treated with caution, the percentage change in price over time accurately reflects market dynamics…".

Official data of the State Service of Ukraine for Geodesy, Cartography and Cadastre on the value of agricultural land are aggregated at the national and regional levels. However, they do not have the necessary spatial differentiation to distinguish

the specifics of deoccupied territories within specific districts. Considering the above-described regulatory restrictions (in particular, the impact of the price minimum at the level of NGOs), it is advisable to use official monitoring data sets to verify general macroeconomic trends, and not to determine the absolute level of prices in local markets. Direct use of generalized indicators of the collection [4] for assessing deoccupied communities of the Brovary district is methodologically incorrect, since it does not allow identifying the local “occupation discount” and specific security risks that directly shape the value in the secondary market.

Comparative analysis of the dynamics of the cost of agricultural land in the control region (using the example of the Boryspil district).

Justification of the choice of the Boryspil district.

The choice of the Boryspil district as a control area (control group) is due to its high degree of homogeneity with the Brovary district in key economic and geographical parameters:

- Logistic factor: both districts are adjacent satellites of the city of Kyiv, have a similar density of transport highways and the level of access to the largest market for agricultural products.

- Natural resource potential: the districts are located within the same natural and climatic zone (Polissya / Forest-steppe) with a similar structure of soil cover (mainly podzolized soils mainly on loess rocks and chernozem-meadow soils).

- Market structure: until 2022, the dynamics of land prices in both districts demonstrated a stable correlation, which allows using the Boryspil district as a "baseline", since it was not under direct occupation;

Limitations and threats to the validity of the comparison.

When using the Boryspil district as a control, the following asymmetries were taken into account that may affect the results:

- Infrastructure factor: the presence of the Boryspil international airport and the specific concentration of logistics hubs creates additional investment demand for land, which may slightly increase the median price in this area regardless of martial law;

- Land use structure: in the Boryspil district, the share of large agricultural holdings is higher, while in the Brovarsky district the market is more diversified due to medium-sized farms and horticulture;

- Security context: despite the absence of occupation, the Boryspil district was subjected to rocket attacks, which creates a regional risk background, but allows us to isolate the "occupation effect" in the Brovary district. Thus, the applied approach allows us to identify the "pure" discount for the occupation by subtracting the overall market decline (recorded in Boryspil) from the deep decline in the Brovary district.

Methodology and data sources when using the comparative method.

To verify the results and ensure the objectivity of the comparison, an independent source was involved - "... aggregated information from the GIS UVEKON database [14] on the average cost of real estate in terms of segments, types, and area by layers, in 4 scale levels is displayed on the map of Ukraine, which in turn is divided into administrative-territorial units and polygons, the borders of which are determined by historically formed features, by type of development or by price features..." This database allows you to aggregate offer prices by specific market sub-segments (agricultural purpose) with a high level of detail by time intervals.

The use of a professional GIS platform allowed us to analyze the aggregated prices of offers in the agricultural land segment for identical time periods.

- Retrospective section (pre-war period): September 2021 - February 2022;

- Current section: September 2024 - June 2025;

Systematization of analytical data by UVEKON [14] allowed us to form comparative tables of market indicators for offers for the sale of agricultural land.

Table 4. Sales offer data for September 2021 - February 2022 [Source: developed by the author based on [14].

Date	Price, USD/are	Number of Listings
30.09.2021	240	49

31.10.2021	281	62
30.11.2021	351	69
31.12.2021	322	69
31.01.2022	303	68
28.02.2022	280	57
Median	**292**	**-**

Table 5. Sales offer data for September 2024 - May 2025 [Source: developed by the author based on [14].

Date	Price, USD/are	Number of Listings
30.09.2024	221	72
31.10.2024	282	69
30.11.2024	223	57
31.12.2024	317	87
31.01.2025	247	65
28.02.2025	220	60
31.03.2025	276	69
30.04.2025	268	77
31.05.2025	344	68
Median	**268**	**-**

Notes to Tables 4 and 5:

- Data on the cost of offers (USD/acre) are generated based on monthly monitoring of the real estate market from the information and analytical platform UVEKON;

- The indicator "Median for the period" is calculated as the median of the average monthly cost values. The author deliberately uses the median of aggregated data to level the impact of extreme price fluctuations within individual months.

- Calculation in USD allows comparing UVEKON data with the author's own data arrays obtained by converting advertisements at the official NBU exchange rate (see the "Methodology" section).

- To verify the results, in addition to calculating the median of average monthly prices, the author calculated the weighted average cost for the entire period using the formula:

$$P_{weighted} = \frac{\Sigma(P_i \times N_i)}{\Sigma N_i}$$

where Pi - is the price for the i-th month, Ni - is the number of offers in the corresponding month. Comparison of indicators (median vs. weighted average) confirms the stability of the identified trend to fluctuations in market activity.

For the comparative analysis of the Brovary and Boryspil districts, data from the UVEKON database [14] were used.

The use of the median of average monthly prices as the resulting indicator for time series (Table 4, Table 5) is justified by the need to stabilize data in conditions of uneven market activity during the war period. This approach allows to level the impact of random price emissions and seasonal fluctuations, ensuring methodological comparability of the results of the Brovary and Boryspil districts.

At the same time, the author is aware that the calculation of the median of aggregated (monthly) data may slightly change the weight of periods with different numbers of announcements (N). To verify the reliability of the conclusions, a control calculation of the weighted average value for the entire period was carried out (the Pweighted formula is given above). A comparison of the results showed that the deviation of the median from the weighted average is minimal (within 3–5%), which confirms the representativeness of the chosen methodology for identifying the market trend. This allows us to assert that the recorded dynamics reflect the real economic expectations of market entities, and are not a consequence of statistical sample bias.

It should also be noted that in order to ensure methodological comparability, for the Brovary district, only data was taken on the type of intended purpose - conducting commercial agricultural production and conducting personal farming, since for the Boryspil district it is indicated that the area of the plots taken exceeds 30 ares, which does not correspond to the type of intended purpose - gardening based on area.

Table 6. Comparative analysis of the dynamics of the cost of agricultural land in the deoccupied (Brovar) and control (Boryspil) districts [Source: developed by the author based on [14].

Region	Retrospective	Current Period	Dynamics, %

	Period (Median), USD/are	(Median), USD/are	
Brovary District	100	72	**–28**
Boryspil District	292	268	**–8**

Analysis of the data of the control region (Boryspil district) using the UVEKON database showed a decrease in the value of offers by only 8%. This trend reflects a general market correction caused by macroeconomic factors and a decrease in purchasing power under martial law. At the same time, the 28% drop in value recorded in the Brovary district creates a gap in dynamics of 20 percentage points. Such a discrepancy is consistent with the hypothesis of a significant impact of specific military and ecological and economic risks (occupation, mining, soil degradation) on the value of land assets. However, it is worth considering that this indicator can also partially accumulate structural differences in local markets. Nevertheless, the significant amplitude of the gap allows us to consider environmental determinants as the dominant factor in the additional depreciation of land in the deoccupied territories of the Brovary region.

The influence of the quantitative factor.

Having analyzed the data on the offers for the sale of agricultural land plots, it should also be noted that the quantitative characteristics of the objects being sold have changed. If before the war in the occupied territories, land plots were mainly offered for sale in sizes that more closely correspond to the size of the land share, then after the deoccupation there were more offers of large areas (from 4 to 40 hectares).

This is one of the factors that affects the decrease in the cost of offers. In appraisal practice, it is generally accepted that there is an inverse relationship between the area and the specific market value of a land plot. That is, the larger the area of the land plot, the lower its specific value. When compiling reports on determining the market value of land plots, this pattern is confirmed in most cases. To take into account the differences in the total area of the valuation object and

comparison objects, the empirical formula of the dependence of the market value on the area of the object is used [5]:

$$K_{area} = \left[\left(\frac{S_{оп}}{S_{оо}}\right)^{k} - 1\right] \times 100\%$$

where: Soo – area of the valuation object, ha.

Soп – area of the comparison object, ha.

k – braking coefficient – from 0.05 to 0.15 (The value of the braking coefficient in most valuation practice is taken at the level of k = 0.1, which corresponds to the established methodological practice of valuation in Ukraine and reflects the average market degree of elasticity of the price of a unit of area relative to the total size of the object).

Let us give as a hypothetical example a possible adjustment for the scale effect: with a coefficient of k=0.05 for land plots of 2 ha and 40 ha, the difference in value according to this formula will be -16%, i.e. if the cost of a land plot of 2 ha was on average 150 USD per are (hundred square meters), then the cost of the same plot but with an area of 40 ha will be 126 USD per are (hundred square meters).

To test the hypothesis of the impact of the scale effect on the study results, the sample structure by area was analyzed. According to Table 1 and Table 2, the median area of plots with uses 01.01 and 01.03 in the 2021 - 2022 sample was 1.31 ha (range from 0.2 to 32 ha), while in 2024 - 2025 it was 2.08 ha (range from 0.26 to 40 ha).

Applying the above formula for the dependence of price on area (with k = 0.1) shows that such consolidation of objects could have led to a technical decrease in the price of a are by approximately 4.6%. Since the actual decrease in value in the Brovary district was 28%, this confirms that about 23 - 24 pp. of the price decrease is due to safety and environmental factors, and not only to changes in the size of plots in the offer.

As noted, the consolidation of objects in the offer (from the median of 1.31 ha to 2.08 ha) creates the prerequisites for a decrease in the price of a are due to the scale effect. However, applying the empirical formula for the dependence of price on area (where k = 0.1) showed that this factor explains only ~5% of the decrease in value.

The remaining 23 pp. of the total price decrease in the Brovary district (28%) is most likely a consequence of environmental and safety determinants.

It should be noted that the issue of the impact of area on the unit cost in the agricultural land segment is the subject of scientific discussion. On the one hand, classical economic theory assumes the presence of a "scale effect", which is expressed in the inverse relationship between the size of the object and its unit price. On the other hand, the specifics of agricultural production form a demand for consolidated land plots, which provide higher technological processing and lower operating costs. In the context of market expectations of agricultural producers, an increase in the median area of plots is often considered as a factor in increasing the liquidity and investment attractiveness of the asset. Under such conditions, the scale effect is offset by the advantages of the production capacity of a single plot. Therefore, the increase in the median area recorded in the study cannot be a fundamental reason for the decrease in value. This allows us to assert that the identified price trend in the period 2021 - 2025 is the result of the direct impact of security and destructive environmental and economic factors, and not a consequence of a structural change in the size of objects in the offer.

Institutional factors of the market (land reform and regulatory changes)

A significant institutional incentive for the transformation of the market environment was the phased implementation of land reform [8]. If in the period 2021 - 2022 the market activity was due to the lifting of the moratorium for individuals, then the period 2024 - 2025 is marked by a new qualitative stage - the admission of legal entities to the market and the increase in property limits to 10 thousand hectares.

From the point of view of political and economic expectations, this step should compensate for the war depression of the market by attracting capital from large agricultural holdings. However, the opposite effect is observed in the Brovary district: institutional liberalization only emphasized market segregation. Large investors (legal entities) demonstrate high sensitivity to security standards. The lack of a clear state policy regarding mass verification of the security of deoccupied territories led to the fact that institutional market expansion worked only for "clean"

regions (for example, Boryspil), while for the Brovary region it fixed the status quo of low supply prices.

Impact of technogenic pollution.

Research results [6] confirm the critical level of technogenic pollution of soils of deoccupied territories with heavy metals (Pb, Zn, Cd) and petroleum products due to explosions and pyrolysis of equipment. The recorded phytotoxicity at the level of 99.8% and degradation of soil mesofauna (mortality of 94.9%) actually exclude such lands from productive agricultural production without carrying out expensive recultivation.

This is also confirmed by the conclusions of the publication [2]:

«…The loss of 32% of arable land as a result of occupation, mining and hostilities will lead, on the one hand, to the destabilization of the world food market, and on the other hand, to the destruction of many valuable natural ecosystems (pastures and hayfields) in the accessible part of Ukraine, which will be plowed up with the hope of compensating for the lost agricultural areas. Unfortunately, among such territories there are also a large number of those that are the last places of distribution of rare species of plants and animals…".

For the land market, this means the transition of the asset from the category of "profitable land" to the category of "burdened capital-intensive object", which forms a fundamental environmental discount in the offer price.

To quantitatively assess the environmental factor within the framework of this study, a system of proxy indicators was used that correlate with the level of potential pollution and mine danger:

- Intensity of hostilities in the community: objects within the territorial communities that were under long-term occupation or on the contact line (Velykodymerska, Baryshivska TG) demonstrate a 15–20% deeper drop in price compared to the rear communities of the district;

- "Contamination" status according to the State Emergency Service: analysis of advertisements shows that the offer price for plots in deoccupied areas, where

according to official reports, humanitarian demining has not yet been completed, is significantly lower than the median, even with a high soil quality assessment;

Distance to active destruction zones: a clear exponential relationship is observed - the closer the site is to the places of mass destruction of equipment, the higher the discount for the risk of chemical contamination and the complexity of future reclamation.

Thus, the recorded degradation of mesofauna and critical phytotoxicity of soils in combat zones [6] indicate the transformation of fertile lands into technogenically contaminated territories. This creates a physical barrier to agricultural activities, since the restoration of agrochemical indicators requires a long period of reclamation. Thus, the technogenic determinant becomes the primary factor that changes the qualitative characteristics of the asset even before it enters the market.

The impact of the environmental factor.

Environmental and technogenic pollution of deoccupied territories is transformed into economic losses due to a number of factors that determine the decrease in the market attractiveness of lands:

- High capital intensity of restoration: the costs of demining and reclamation are often comparable to the market value of the asset, which shifts the financial burden to the participants in the transaction and automatically reduces the offer price;

- Security risks: the threat to the lives of personnel and the integrity of equipment creates a barrier to entry for investors, who are forced to lay a risk premium in the cost of capital;

- Time lag (operational pause): the complexity of permitting procedures and the duration of work postpone the start of economic activity, which is critical for businesses with a long payback cycle.

- Degradation of production potential: chemical pollution and physical compaction of soils reduce productivity for years to come, directly affecting future rental income.

According to online publications, the cost of humanitarian demining of agricultural land ranges from UAH 25,000 per hectare to UAH 64,000 per hectare

[9], [10]. It should be clarified that the specified range corresponds to the full clearance cycle, which includes:

- Non-technical survey (NTS): data collection and visual inspection to determine the boundaries of the probable danger;

- Technical survey: use of metal detectors and search tools;

- Clearance (manual or mechanized): direct removal and neutralization of EHO (explosive hazardous objects).

The lower threshold of cost (UAH 25,000) usually corresponds to areas with a low density of contamination (single EHO), while the upper threshold (UAH 64,000 and above) - to areas with a high density of barriers or cluster munitions. For the Brovary district, where the fighting was of a maneuverable nature with the use of artillery and mortars, these figures are relevant, as they are comparable to (or even exceed) the current median cost of land lease for several years, which makes independent demining for smallholders economically inexpedient.

Analysis of the intensity of fighting in the Brovary district suggests that the costs of land restoration here tend to the lower end of the estimated range (about 25,000 UAH/ha). This is due to the fact that damage to the soil cover in the agricultural areas of the district was mainly fire-related, rather than positional (fewer deep craters compared to areas of prolonged trench fighting), which minimizes the costs of complex technical reclamation.

At the same time, the high level of mine danger remains a determining factor. According to official sources [15], the Brovarsky district is among the three most affected districts of the Kyiv region. As noted by Colonel of the Armed Forces of Ukraine Maksym Komisarov, the range of detected EHO in the district is extremely wide: from anti-personnel and anti-tank mines (MON-50, OZM-72) to elements of the Uragan MLRS and Kh-55 cruise missiles. The presence of about 6,000 explosive objects (according to the Kyiv OVA) detected in the district confirms the significant volume of demining work. Although the absence of massive damage to the soil surface allows for the avoidance of costs for recultivation, the very need for a

comprehensive technical survey of the territories creates financial pressure on landowners.

It should be noted that the real economic pressure on the land owner and, as a result, the market discount, significantly depend on participation in state support programs, which currently provide for two main mechanisms [11], [17]:

- Retrospective compensation (80%): Farmers who independently financed land clearance in the period from February 24, 2022 to April 15, 2024 are entitled to reimbursement of 80% of the costs from the state budget. In this case, provided that there is a certificate from an official operator, the actual financial burden on the owner is reduced to ~5,000 UAH/ha. The presence of such a certificate becomes a key factor in supporting the value of the plot when conducting purchase and sale transactions.

- Full state financing (100%): For entities that are only planning to start clearing contaminated land, the government program "Compensation of costs for humanitarian demining of agricultural lands" provides for coverage of 100% of the costs. The implementation of this mechanism through the public procurement system allows agricultural producers to completely offset the costs of asset restoration.

In view of the above, it can be argued that the market price drop in the Brovary district by 28% is largely caused not only by physical pollution, but also by bureaucratic barriers and information asymmetry. Buyers discount the cost of land by the full amount of demining, since not all owners have certificates or the ability to take advantage of the 100% compensation program. Thus, the presence of a certificate or documentary confirmation of the inclusion of a plot in the state demining program acts in 2024–2025 as a powerful intangible asset that protects the land plot from critical depreciation. It is worth noting that in the scientific and expert environment there is currently an intense debate about the economic feasibility of land reclamation in regions with extremely high intensity of hostilities (for example, the Bakhmut direction). Unlike the Brovary region, where the destruction is mainly localized, in areas of prolonged positional fighting, the cost of capital investments in the restoration of 1 hectare can reach 20,000 USD. This poses a difficult choice for

the state: to invest in the restoration of such territories or to preserve them for the long term. Compared to these indicators, the investment attractiveness of the lands of the Brovary region, despite the 28% discount, looks much higher, which creates the prerequisites for a gradual recovery of the market in the medium term.

Summarizing the results of the study, it should be noted the high speed of adaptation of the agricultural sector of the Brovary region. Most agricultural enterprises and farms began land restoration immediately after deoccupation, using mainly their own resources for recultivation (with the exception of specific demining works).

Empirical analysis of the territories of the district allows us to highlight significant local differentiation in the pace of land restoration:

• Rapid adaptation zones: In the example of the Rudnyanska village council, the restoration of arable land cultivation was recorded in the first sowing season after deoccupation. This indicates a low density of contamination and a high willingness of tenants to resume production.

• Long-term depression zones: In contrast, within the village of Bohdanivka, the process of clearing the territories lasted for over a year. It should be noted that the long-term demining in this settlement concerned mainly non-agricultural lands (buildings and infrastructure facilities), which is confirmed by open source monitoring data [15] and visual inspection of locations by the author in the period 2022–2024.

Such heterogeneity of the situation within one district confirms that the environmental factor acts selectively. It does not simply reduce the value of all lands, but forms "spots" of low liquidity where the threat of EHO is combined with a long waiting time for a security check.

Conclusions and prospects.

The conducted study of the dynamics of the land market of the Brovary and Boryspil districts allows us to draw the following conclusions:

1. Price determination: It was established that the average market value of the land supply of the Brovary district in 2024–2025 decreased by 28% compared to the pre-war period. At the same time, in the Boryspil district, the decrease was only 8%, which confirms the hypothesis of the critical impact of territorial proximity to combat zones and the occupation of the region under study on asset capitalization;

2. Institutional paradox: Despite the second stage of the land reform (opening the market to legal entities from 2024), the expected price increase was leveled by security risks. The presence of programs for 100% state compensation for the cost of demining has not yet become a sufficient driver for price recovery due to high information asymmetry and bureaucratic barriers;

3. Environmental and economic discount: Technogenic soil contamination and mine hazards have translated into a tangible market discount. For the Brovary region, the cost of asset restoration (from 0 - 5,000 UAH/ha taking into account state benefits, from 25,000 UAH excluding them) is comparable to rental income, which creates a "price trap" and forces owners to list objects at the lowest possible cost.

Research limitations and scientific discussion:

The author acknowledges a number of limitations due to the specifics of data collection during the war period:

• Data sources: The analysis was based on offer prices (sales announcements), which may differ significantly from the prices of real deals (transactions) due to a significant “bargaining step” in conditions of low demand;

• Small sample: Due to the limited number of active announcements in some territorial communities of the Brovary region, the results may have a certain statistical error.

• Lack of hedging: In this work, no sample adjustment was made for location, configuration, distance from highways, and level of infrastructure development, which could partially affect the median price values.

• Area distribution: The different structure of lots (small plots versus consolidated arrays) in the compared areas creates an additional impact on the price per 1 hectare, which requires separate mathematical processing.

Directions for further research:

To deepen the obtained results, the following steps are promising:

1. Regression analysis: Building a multivariate model to isolate the net impact of the environmental factor among other price-forming factors.

2. Geospatial risk proxies: Using GIS technologies to compare prices with SES pollution maps and satellite monitoring data of shelling intensity.

3. Comparative verification: Comparing offer prices with State Land Cadastre data on real transactions and the current normative monetary valuation (NGO) to identify the real gap between the market and state standards.

AI Statement:

During the preparation of this manuscript, the author used artificial intelligence tools for literary editing, grammar checking, and translation of the abstract into English. After using these tools, the author personally checked, edited, and revised the content and bears full responsibility for the scientific reliability and originality of the presented material.

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Е. П. Жолкевський

ЕКОЛОГО-ЕКОНОМІЧНІ ДЕТЕРМІНАНТИ ВАРТОСТІ ЗЕМЕЛЬ СІЛЬСЬКОГОСПОДАРСЬКОГО ПРИЗНАЧЕННЯ НА ЗВІЛЬНЕНИХ ТЕРИТОРІЯХ БРОВАРЩИНИ.

Анотація: У статті проведено комплексне дослідження, метою якого є теоретичне обґрунтування та оцінка еколого-економічних детермінант формування вартості земель сільськогосподарського призначення на деокупованих територіях (на прикладі Броварського району Київської області). Актуальність роботи зумовлена потребою в об’єктивній оцінці земельних

активів, що зазнали безпосереднього впливу військових дій. Для досягнення мети реалізовано порівняльний аналіз ринкових цін довоєнного (2021-2022 рр.) та післяокупаційного (2024-2025 рр.) періодів на основі даних вторинного ринку.

Результати аналізу виявили суттєве зниження середньої вартості земель сільськогосподарського призначення. Отримані дані свідчать, що землі різних видів цільового призначення зазнали неоднакового зниження вартості. Зафіксовано та обґрунтовано ключові еколого-економічні фактори, що впливають на зміну вартості земель, зокрема, техногенне забруднення внаслідок бойових дій та зміна структури ринку пропозицій. Також під час проведеня дослідження враховано фактор високої вартості розмінування та проведення при необхідності рекультивації земель сільськогосподарського призначення.

Результати дослідження підкреслюють неоднорідність впливу війни на різні типи земель сільськогосподарського призначення та вказують на необхідність розробки комплексних програм відновлення, рекультивації та економічного стимулювання для підвищення інвестиційної привабливості цих територій.

Ключові слова: еколого-економічна оцінка, ринкова вартість землі, ціноутворення на ринку земель, землі сільськогосподарського призначення, деокуповані території, військова агресія РФ, техногенне забруднення ґрунтів, гуманітарне розмінування.