



Improving the methodology for calculating the average statistical market price of agricultural land

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► **Abstract.** Accurate determination of agricultural land market price was essential for informed economic decisions, yet traditional statistical methods demonstrated unacceptably high discrepancies due to statistical outliers and market structural features. The aim of the study was to develop and validate an improved methodology for calculating the market price of agricultural land that ensured stability and reliability of results through the comprehensive application of multi-level data filtering and an adaptive weighting system. The proposed methodology achieved a threefold reduction in price estimate variability (coefficient of variation 17.2% vs. 54% for traditional methods), while maintaining high representativeness of the sample, this ensured more reliable market price calculations. The analysis revealed that traditional methods produced results ranging from 40.4 to 62.2 thousand UAH per hectare with an amplitude of fluctuations of 54%, whereas the developed methodology provided an estimate of 50.3 thousand UAH per hectare with a coefficient of variation of 17.2%, indicating a threefold improvement in estimation stability. Monthly analysis confirmed the methodology's resilience to seasonal fluctuations and varying intensities of market activity, revealing a price growth trend of 9.3% over 2024-2025 period. Comparison with official calculations of the State Service of Ukraine for Geodesy, Cartography and Cadastre showed a systematic deviation within 17.8%, reflecting objective methodological differences in approaches to processing market information. The practical value of the developed methodology lies in its applicability for analysing the goals of land market monitoring, valuation activities, and state regulation of land relations

► **Keywords:** pricing methodology; transaction data analysis; multilevel filtering; adaptive weighting; price accuracy; land valuation; data outliers

► Introduction

The determination of the average statistical market price of agricultural land based on purchase and sale transaction data was a complex methodological problem that required consideration of both the structural features of the land market and the specifics of statistical data processing. Traditional statistical methods often demonstrated significant discrepancies in results due to the influence of outliers and the heterogeneity of market transactions, which actualised the need to improve existing approaches. C. Leys *et al.* (2013) highlighted that detecting outliers by determining an interval spanning over the mean plus/minus three standard deviations remained a common practice among researchers, however, since both the

mean and the standard deviation were particularly sensitive to outliers, this method was problematic. The authors presented the median absolute deviation as an alternative and more robust measure of dispersion that was easy to implement. P.-L. Loh (2025) provided a theoretical review of modern robust statistics, emphasising that the field had drawn a new surge of attention from 2015 to 2025 due to a desire to recast robust statistical principles in the context of high-dimensional statistics, demonstrating the need for further research in robust estimation that embraced new estimation settings and computational tractability.

The problem of land valuation methodology was directly related to the accuracy of market price calculations.

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H. Cherevko & M. Hryso (2023) identified that the modern methodology for land valuation in Ukraine wasn't ensure an adequate level of assessment for the needs of the real land market, which wasn't allow for a realistic assessment of the land resource potential. Researchers emphasised the need to improve the methodology based on the application of market approaches and the experience of European countries, where mass appraisal methods were widely used. B. Khakhula & N. Svytnous (2024) examined the problem of applying new methodological approaches to the valuation of agricultural land in the conditions of land market formation. Scientists noted that the market value of land depended on supply and demand in the market and the nature of competition between sellers and buyers. The authors emphasised that market value was determined as the most probable price, at which land can be alienated on the open market under competitive conditions, when the parties to the transaction act reasonably with equal access to the necessary information.

The specifics of the agricultural land market in post-socialist countries created additional challenges for price calculation. M. Gorgan & M. Hartvigsen (2022) assessed the modern development stage of land markets in countries in Eastern Europe and Central Asia and discussed the main constraints including informalities, technical errors, and complicated land transaction procedures. The authors noted that agricultural land markets remained weak and still face many constraints, with most countries having farm structures characterised by excessive land fragmentation and small average farm sizes. S. Ibatullin *et al.* (2024) examined the functioning of the agricultural land market in Ukraine and found that prices for land plots remained at the level of their normative monetary value and were still relatively low, indicating significant undercapitalisation of agricultural land as a production factor. The stability of agricultural land prices under the influence of various factors indicated their relative virtuality, which complicated the application of standard statistical methods for calculating average market prices.

M. Kalinchyk & O. Mogylnyi (2024) generalised the experience of EU member states regarding the formation of agricultural land prices and established that the factors increasing land capitalisation included the dominance of high-margin crops in the structure of sown areas, as well as the productivity of crop and livestock production. The author's research demonstrated that price formation in the agricultural land market was influenced by multiple factors that must be taken into account, when developing calculation methodologies. S. Zrobek *et al.* (2020) proposed the application of fuzzy logic theory to perform tasks of determining the market value of agricultural lands, noting that such tasks were of a multi-criteria character as multiple factors were taken into consideration during the land value valuation process. Researchers emphasised that proposed method was particularly useful for countries, where the agricultural real estate market was still in its early stages of development.

Despite the significant volume of research on land valuation and statistical methods, the problem of developing a comprehensive methodology for calculating the average statistical market price of agricultural land based on purchase and sale transaction data, taking into

account statistical outliers and structural heterogeneity of the market, remained insufficiently resolved. Existing approaches either ignored the economic weight of transactions, or were overly sensitive to extreme values, or do not account for the specifics of different market segments. The purpose of this research was to address the critical challenge of obtaining consistent agricultural land price estimates by proposing a novel analytical framework that integrates hierarchical data filtering with dynamic weighting mechanisms. The objectives included: 1) comparative evaluation of traditional statistical methods for land price calculation; 2) development and validation of a multi-method analytical framework with hierarchical filtering and adaptive weighting; 3) empirical testing using official transaction data and comparison with state cadastral estimates. The novelty of the study lies in the proposed integrated approach that combined five complementary calculation methods with an adaptive weighting system, which ensured a threefold reduction in the coefficient of variation compared to traditional statistical approaches.

► Materials and Methods

The empirical basis of this study comprised official data from the State Service of Ukraine for Geodesy, Cartography and Cadastre (n.d.) on purchase and sale transactions of agricultural land plots conducted during January-August of 2025. After data cleaning and verification, 81,026 transactions representing 93% of initially recorded operations were included in the analysis. The geographical coverage encompassed all regions of Ukraine, ensuring sample representativeness and national-level applicability. The temporal scope of eight calendar months enabled consideration of seasonal price fluctuations and evaluation of methodological stability under varying market conditions. The research employed a combination of general scientific and specialised statistical methods. Comparative analysis was applied to evaluate traditional statistical approaches for land price calculation, including arithmetic mean, median, and area-weighted mean methods. Statistical analysis encompassed descriptive statistics, distribution analysis, and variability assessment through standard deviation, coefficient of variation, and range metrics. Systematic approach was utilised in developing the multi-level filtering framework and integrating multiple calculation methods. Empirical validation involved benchmarking the developed methodology against official state cadastral estimates and traditional statistical methods.

The core methodological innovation consisted of five complementary calculation methods, each designed to address specific data characteristics and minimise particular types of statistical anomalies. The hybrid weighted method applied broad filtering boundaries (1-500 thousand UAH per hectare) to eliminate extreme outliers, while preserving sample representativeness, excluding symbolic transactions and speculative deals. The conservative weighted method employed narrower constraints (15-150 thousand UAH per hectare) to focus on typical market transactions under standard conditions. The balanced method with area consideration combined price filtering (8-250 thousand UAH per hectare) with plot size restrictions (0.1-50 hectares), targeting the most

representative market segment that accounted for 89.2% of transactions and 76.4% of total traded area. The ultraconservative method applied the strictest criteria (20-100 thousand UAH per hectare), concentrating on the central price core that comprised 42.8% of operations but demonstrated the lowest variability and highest stability. The adaptive weighting method dynamically adjusted coefficients based on data structure, where methods with larger numbers of valid observations received higher weights, ensuring optimal information utilisation.

The integration framework operated through a dual-level weighting system. The first level combined four basic methods using fixed theoretical weights reflecting each approach's reliability. The second level employed the adaptive method with dynamic coefficients determined by observation counts. Final estimates emerged from equally weighted averaging of both integration levels, balancing theoretical validity with empirical adaptability. Monthly dynamics analysis was conducted to assess the methodology's resilience to temporal fluctuations in market activity. The selection of filtering thresholds was grounded in statistical distribution analysis and expert evaluation of typical agricultural land market conditions, with lower bounds corresponding to minimum economically justified prices and upper bounds covering premium lands, while excluding speculative transactions.

► Results and Discussion

Determining the market price of agricultural land remained a pressing issue for economic analysis of Ukraine's agricultural sector (Cherevko & Hryso, 2023). Traditional statistical methods for processing purchase and sale transaction data often demonstrated significant discrepancies in results due to the influence of outliers and structural features of the land market. The application of an improved methodology to an array of real data allowed for the assessment of the effectiveness of different approaches to calculating the average statistical market price and substantiated the advantages of comprehensive statistical analysis. The structural analysis of the sample demonstrated significant variability in land plot sizes – from minimal shares of 0.0006 hectares to large arrays exceeding 300 hectares. The price range of transactions was characterised by an even greater amplitude of fluctuations: from symbolic amounts to anomalously high values exceeding UAH 2.8 billion per hectare. Such significant variability of price indicators confirmed the relevance of the problem of statistical processing of land market data and the necessity of applying robust analysis methods to minimise the impact of outliers on the final result (Gorgan & Hartvigsen, 2022; Loh, 2025). The arithmetic mean represented the most common and simplest approach to determining central tendency in the statistical analysis of land plot market prices. This method was based on the classical principle of equal weighting of all observations in the sample, regardless of their economic significance or potential representativeness for the general population of transactions. The mathematical formula for the arithmetic mean for calculating the price per hectare was as follows:

$$\bar{x} = (\sum (P_i/S_i))/n, \quad (1)$$

where \bar{x} – arithmetic mean of the price per hectare; P_i – total transaction price; S_i – area of the land plot; n – total number of transactions in the sample.

The application of the arithmetic mean to the dataset of 81,026 purchase and sale transactions yielded a result of 62.2 thousand UAH per hectare. However, a detailed analysis of the distribution of price indicators revealed critical shortcomings of this approach in the context of land market data processing (Hunko *et al.*, 2023). The main problem lay in the excessive sensitivity of the arithmetic mean to extreme values, which in the studied sample were represented by transactions with prices exceeding 500 thousand UAH per hectare, including anomalous cases with values exceeding 2 billion UAH per hectare. Structural analysis showed that only 11.8% of transactions can be classified as statistical outliers according to the interquartile range rule; however, their influence on the arithmetic mean was disproportionately large. This situation led to systematic overestimation of the calculated price compared to actual market conditions, as extremely high prices of individual transactions may reflect specific circumstances (proximity to cities, infrastructural advantages, speculative operations) that were not typical for the majority of agricultural land plots (Leys *et al.*, 2013; Kionka *et al.*, 2021). The median as a statistical indicator represented an alternative approach to determining central tendency, which was theoretically less sensitive to the influence of extreme values compared to the arithmetic mean (Loh, 2025). This method was based on the principle of ranking all observations in ascending order and identifying the middle value that divided the ordered sample in half. The mathematical formula for the median of the price per hectare was as follows:

$$M_e = \{(P_i/S_i)((n+1)/2)\}, \text{ if } n - \text{ odd}; \\ \{((P_i/S_i)(n/2) + (P_i/S_i)((n/2) + 1))/2\}, \text{ is } n - \text{ even}, \quad (2)$$

where M_e – median value of the price per hectare; (P_i/S_i) – price per hectare values arranged in ascending order; n – total number of transactions in the sample.

The application of the median method to the studied dataset yielded a result of 43.7 thousand UAH per hectare, which differed significantly from the arithmetic mean result and demonstrated an opposite tendency. While the arithmetic mean overestimated the value due to the influence of extremely high prices, the median tended to underestimate the result due to the structural features of Ukraine's land market. The critical shortcoming of the median approach in the context of land market price analysis lay in ignoring the economic weight of individual transactions. The median assigns equal significance to the sale of a small plot of 0.1 hectares and a large land array of 100 hectares, which contradicted the economic logic of market price formation. Moreover, the analysis of the distribution of transactions by size showed that a significant proportion of operations involved small land plots, the prices of which were often formed under the influence of specific factors not characteristic of the main segment of agricultural land. Thus, the median estimate may reflect the price level predominantly of small land plots rather than a representative market price for agricultural land in general (Udoenko *et al.*, 2024). The attempt to eliminate the

shortcomings of both the arithmetic mean and the median led to the consideration of a third traditional approach – the area-weighted arithmetic mean. This method represented a compromise solution that took into account both individual transaction prices and their economic weight through the size of land plots. The fundamental concept of the weighted mean was that larger plots had a greater influence on the formation of the overall market price, which corresponded to the economic logic of land market functioning (Yurchenko, 2024). The mathematical formula for the area-weighted arithmetic mean was as follows:

$$\bar{x}_w = (\sum P_i) / (\sum S_i), \quad (3)$$

where \bar{x}_w – area-weighted arithmetic mean of the price per hectare; P_i – total price of the i -th transaction; S_i – area of the i -th land plot; \sum – summation sign across all transactions in the sample.

The application of the area-weighted arithmetic mean method to the studied dataset yielded a result of 40.4 thousand UAH per hectare, which proved to be the lowest value among the three traditional approaches considered. The obtained result confirmed the hypothesis that large land arrays were typically sold at lower unit prices compared to small plots, reflecting the economy of scale effect and the specifics of price formation in different segments of the land market (Kalinchuk & Mogylnyi, 2024). The weighted approach demonstrated an opposite tendency compared to the simple arithmetic mean – it tended to underestimate the market price due to the dominance in the total area structure of large land plots with relatively lower unit prices. At the same time, this method retained sensitivity to outliers in cases, where anomalously high or low prices were characteristic of large land plots. Despite accounting for the economic weight of transactions, the weighted mean does not resolve the fundamental problem of statistical processing of data with a wide range of values and the presence of structural features across different segments of the land market. This necessitated the application of a more sophisticated methodological approach capable of ensuring the robustness of results to various types of anomalies in the source data.

A comparative analysis of the three traditional statistical methods revealed significant discrepancies in the results of calculating the market price of agricultural land: the arithmetic mean showed 62.2 thousand UAH per hectare, the median – 43.7 thousand UAH per hectare, and the weighted mean – 40.4 thousand UAH per hectare. Such an amplitude of fluctuations within 54% from the lowest to the highest value indicated systemic shortcomings of each of the considered approaches and their inability to adequately reflected actual market conditions. Each method demonstrated specific distortions: the arithmetic mean tended to overestimate due to the influence of extreme values, the median ignored the economic weight of transactions, and the weighted mean may underestimate the result due to the dominance of large land arrays with lower unit prices (Khakhula & Svytnous, 2024). The shortcomings of traditional statistical methods necessitated the development of a comprehensive methodological approach that would combine the advantages of different statistical techniques, while mitigating their individual weaknesses

(Yalpir *et al.*, 2021). The conceptual foundation of the improved methodology was the creation of a multi-stage data filtering system with subsequent application of differentiated statistical analysis methods and their integration through a weighting system. The main principle of the developed approach lain in recognising the heterogeneity of the land market and the necessity of applying different analytical tools for different segments of market operations. The methodology provided for the simultaneous use of five complementary calculation methods, each optimised for specific characteristics of the source data and aimed at minimising the impact of specific types of statistical anomalies. The final result was formed through weighted combination of individual estimates, ensuring stability and reliability of the ultimate indicator of land market price (Zrobek *et al.*, 2020).

The hybrid weighted method represented the basic approach in the developed methodology, aimed at eliminating the most obvious statistical anomalies, while preserving the maximum volume of analysed data. The fundamental concept of this method lain in establishing broad limits of acceptable price values that allowed filtering out only extreme outliers, while maintaining sample representativeness. The lower filtering limit was set at 1 thousand UAH per hectare, which excluded from analysis transactions with symbolic prices reflecting intra-family transfers, donations, or technical operations. The upper limit was defined at 500 thousand UAH per hectare, which allowed for the elimination of speculative operations and transactions involving lands with special status or location. The mathematical formula for the hybrid weighted method was as follows:

$$PHH = (\sum P_i) / (\sum S_i), \text{ where } P_i \in [1,000; 500,000] * S_p, \quad (4)$$

where PHH – price per hectare according to the hybrid weighted method; P_i – total price of the i -th transaction that satisfies the price criteria; S_i – area of the i -th land plot; \sum – summation across all transactions that passed the filtering.

The justification for the selection of threshold values was based on statistical analysis of price distribution in the sample and expert assessment of typical market conditions for agricultural land (Veklych & Boiko, 2021). The lower limit of 1 thousand UAH corresponds to the minimum economically justified price for the least fertile lands in remote regions, while the upper limit of 500 thousand UAH covered even the most expensive agricultural lands near large cities, excluding only obviously speculative operations. The conservative weighted method represented a more restrictive approach to filtering source data, aimed at analysing the most typical market operations with agricultural land. This method was based on the hypothesis that the most accurate estimate of the average market price can be obtained by concentrating the analysis on transactions with moderate price characteristics that most likely reflected standard market conditions. The lower filtering limit was set at 15 thousand UAH per hectare, which excluded transactions with potentially underestimated prices caused by specific circumstances of sale. The upper limit was defined at 150 thousand UAH per hectare, which allowed retaining in the analysis the vast

majority of typical market operations, while excluding transactions with premium prices. The mathematical formula for the conservative weighted method was as follows:

$$PHC = (\sum P_i) / (\sum S_i), \text{ where } P_i \in [15,000; 150,000] * S_i \quad (5)$$

where *PHC* – price per hectare according to the conservative weighted method; P_i – total price of the i -th transaction that satisfies the narrowed price criteria; S_i – area of the i -th land plot; \sum – summation across all transactions that passed the conservative filtering.

The justification for threshold values was based on the analysis of interquartile price distribution and the determination of a range that covered the central 70% of transactions by price characteristics. The lower limit of 15 thousand UAH corresponded to the price level below, which transactions may reflect forced sales, intra-corporate operations, or other non-standard market situations. The upper limit of 150 thousand UAH covered even transactions with high-quality lands in economically developed regions, excluding only operations with clearly premium characteristics. The balanced method with area consideration represented an approach that combined price filtering with additional selection criteria based on land plot size. The concept of this method was based on the hypothesis that the most representative market prices were formed in the segment of land plots of typical size, which belong neither to small shares nor to large arrays. Price limits were set in the range from 8 to 250 thousand UAH per hectare, which ensured broad coverage of market operations, while excluding extreme anomalies. Additionally, a filter by land plot area within the range from 0.1 to 50 hectares had been introduced, which allowed focusing the analysis on land use sizes typical for the Ukrainian agricultural sector. The mathematical formula for the balanced method with area consideration was as follows:

$$PHB = (\sum P_i) / (\sum S_i), \text{ where } P_i \in [8,000; 250,000] * S_i \text{ and } P_i \in [0.1; 50], \quad (6)$$

where *PHB* – price per hectare according to the balanced method with area consideration; P_i – total price of the i -th transaction that satisfies both price and area criteria; S_i – area of the i -th land plot within the permissible range; \sum – summation across all transactions that passed the dual filtering.

The justification for filtering parameters was based on structural analysis of the Ukrainian land market and the features of the national model of agricultural land use. Statistical analysis of the distribution of transactions by area showed that land plots ranging from 0.1 to 50 hectares constituted 89.2% of the total number of operations and covered 76.4% of the total area of sold land (State Service of Ukraine for Geodesy, Cartography and Cadastre, n.d.). The lower area limit of 0.1 hectares excluded micro plots (4.7% of transactions), the pricing of which may be influenced by specific factors not characteristic of the main segment of agricultural land. The upper limit of 50 hectares removed from the analysis large agro-industrial arrays (6.1% of transactions), where prices were formed under the influence of corporate strategies and may not reflect general market trends. The expanded

price range compared to the conservative method allowed for accounting for a larger number of legitimate market operations, while maintaining control over statistical outliers. Thus, the balanced method concentrated the analysis on the most representative segment of the land market, which was characterised by both typical plot sizes and standard market pricing mechanisms. The ultraconservative method represented the most restrictive approach to the selection of market data, aimed at analysing exclusively those transactions that most likely reflected standard market conditions without any specific circumstances. The concept of this method was based on the principle of maximum selectivity, where only transactions with price characteristics falling within a narrow range of the most typical market operations were included in the analysis. Price limits were set from 20 to 100 thousand UAH per hectare, which covered the central core of market prices and excluded both potentially underestimated and overestimated land plot valuations. The mathematical formula for the ultraconservative method was as follows:

$$PHU = (\sum P_i) / (\sum S_i), \text{ where } P_i \in [20,000; 100,000] * S_i \quad (7)$$

where *PHU* – price per hectare according to the ultraconservative method; P_i – total price of the i -th transaction that satisfies the strict price criteria; S_i – area of the i -th land plot; \sum – summation across all transactions that passed the most stringent filtering.

The justification for narrow threshold values was based on the analysis of median characteristics of market prices and the identification of a range that covered the central 40% of transactions by price parameters. Statistical analysis showed that transactions in the range of 20-100 thousand UAH per hectare constitute 42.8% of the total number of operations but were characterised by the lowest variability of price indicators and the highest stability of market conditions (State Service of Ukraine for Geodesy, Cartography and Cadastre, n.d.). The lower limit of 20 thousand UAH excluded transactions that may reflect forced sales, technical operations, or lands with limited production characteristics. The upper limit of 100 thousand UAH excluded operations with premium prices caused by special location, infrastructural advantages, or speculative motives of buyers. The adaptive weighting method represented the most sophisticated component of the developed methodology, which dynamically adjusted the weight coefficients of individual methods depending on the structural characteristics of the source data (Sasu *et al.*, 2024). Unlike the previous four approaches that use fixed filtering criteria, the adaptive method was based on the principle of self-regulation, where the importance of each statistical approach was determined by its representativeness in the specific sample. The fundamental concept was that methods with a larger number of valid observations received higher weight coefficients, which ensured optimal use of available information and minimisation of the influence of methods with a limited statistical base. The mathematical formula for the adaptive weighting method was as follows:

$$PHA = (\sum (R_i * B_i * C_i)) / (\sum (B_i * C_i)), \quad (8)$$

where PHA – price per hectare according to the adaptive weighting method; R_i – result of the i -th calculation method; B_i – base weight coefficient of the i -th method; C_i – adjustment coefficient equal to the ratio of the number of transactions in the i -th method to the total number of transactions; Σ – summation across all methods included in the adaptive system.

The system of base weight coefficients was developed taking into account the theoretical advantages and limitations of each method: the hybrid weighted method received a coefficient of 0.8 as a basic approach with broad coverage; the conservative weighted method – 1.4 as the most stable indicator; the balanced method with area consideration – 0.8 given the additional restrictions; the ultraconservative method – 1.2 due to high selectivity. Adjustment coefficients change dynamically depending on the actual number of transactions that satisfied the criteria of each method, ensuring automatic adaptation of the weighting system to the specifics of a particular dataset. The proposed system of five complementary methods created a multidimensional approach to analysing market prices of agricultural land, where each component performed a specific function in the overall architecture of the methodology. The hybrid weighted method ensured broad coverage of market data, the conservative weighted method guarantees stability of results, the balanced method with area consideration accounts for structural features of the national land market, the ultraconservative method minimised the influence of atypical operations, and the adaptive weighting method provided dynamic optimisation of the system. Such a comprehensive approach allowed for the simultaneous utilisation of the advantages of different statistical techniques, while compensating for their individual limitations, creating a synergistic effect, where the integrity of the methodology exceeded the sum of its individual components.

The effectiveness of the developed methodology depended not only on the quality of individual calculation methods but also on the manner of their integration into a unified analytical system. The key task became creating an optimal algorithm for combining the results of five methods that would account for their relative reliability, representativeness, and complementarity. The integration system should ensure not mechanical averaging of obtained values but intelligent weighting that considered both the theoretical advantages of each approach and the practical characteristics of a specific dataset. The developed integration system was based on the principle of double weighting, which combined the advantages of fixed and adaptive weight coefficients (Wu *et al.*, 2024). The first level of integration involved combining four basic methods (hybrid, conservative, balanced, and ultraconservative) through a system of fixed weights reflecting the theoretical reliability of each approach. The second level was represented by the adaptive weighting method, which used the same basic methods but applied dynamic coefficients depending on the number of valid observations in each of them. The final result was formed through equally weighted averaging of the results from both levels of integration, ensuring a balance between theoretical validity and empirical adaptability of the methodology. The mathematical formula for the final integration was as follows:

$$P_{fin} = (P_{fix} + P_{adapt}) / 2, \quad (9)$$

where P_{fin} – final market price per hectare; P_{fix} – result of combining methods with fixed weights; P_{adapt} – result of the adaptive weighting method.

The result with fixed weights was calculated as:

$$P_{fix} = (PHH*0.8 + PHC*1.5 + PHB*0.9 + PHU*1.2) / 4.4, \quad (10)$$

where the coefficients 0.8, 1.5, 0.9, and 1.2 reflected the relative importance of each method in the overall evaluation system.

The application of the developed methodology to the dataset of 81,026 purchase and sale transactions of agricultural land yielded a final result of 50.3 thousand UAH per hectare. This indicator occupied an intermediate position between the results of traditional methods, which confirmed its balance and ability to mitigate extreme tendencies toward overestimation or underestimation. Compared to the arithmetic mean (62.2 thousand UAH per hectare), the developed methodology provided a reduction of 19.1%, reflecting the effectiveness of the extreme value filtering system. At the same time, the result exceeded the weighted mean indicator (40.4 thousand UAH per hectare) by 24.5% and the median (43.7 thousand UAH per hectare) by 15.1%, indicating that the economic weight of transactions was taken into account, while simultaneously eliminating the underestimation effect caused by the dominance of large land arrays. The stability of the developed methodology was confirmed by the insignificant variation in the results of individual system components. The analysis showed that the results of the four basic methods vary within a narrow range, representing a spread of less than 7% from the mean value. This contrasted with the amplitude of fluctuations of traditional methods at 54%, demonstrating a significant improvement in the accuracy and predictability of the estimate. The final result of 50.3 thousand UAH per hectare can be interpreted as the most reliable estimate of the average market price of agricultural land in Ukraine for the study period, which accounted for the structural heterogeneity of the land market and minimised the impact of statistical anomalies. The dynamics of land market prices according to different calculation methods demonstrated significant discrepancies, which confirmed the relevance of the problem of methodological improvement of statistical analysis (Table 1).

The results of the developed methodology demonstrated stable dynamics throughout the study period with gradual growth from 49.8 thousand UAH per hectare in January to 52.5 thousand UAH per hectare in August, reflecting general market trends of rising agricultural land prices. At the same time, traditional methods showed significantly greater variability of results: the arithmetic mean fluctuated from 54 to 72.2 thousand UAH per hectare, the median – from 42 to 45.7 thousand UAH per hectare, and the weighted mean – from 38.5 to 42.2 thousand UAH per hectare. The developed methodology occupied a balanced position between these extreme estimates and demonstrated the smallest amplitude of fluctuations. Particularly, illustrative was April, when the arithmetic mean reached its maximum value of 72.2 thousand UAH per hectare due to the influence of outliers, while the

developed methodology remained at 50.1 thousand UAH per hectare, indicating its resilience to statistical anomalies. A comparison of the developed methodology with official data from the State Service of Ukraine for Geodesy, Cartography and Cadastre (n.d.) showed a high degree of

correlation of results with systematically lower values of the improved approach. The deviation from official calculations ranged from -7.8% to -29.4%, which may indicate the presence of certain methodological differences in calculation approaches (Table 2).

Table 1. Dynamics of the market price of agricultural land according to different calculation methods (January-August 2025)

Month	Number of transactions thousand	Arithmetic mean thousand UAH/ ha	Median thousand UAH/ ha	Weighted mean thousand UAH/ ha	Cadastral data thousand UAH/ ha	New method thousand UAH/ ha
January	4.4	54.7	42.8	38.7	54	49.8
February	12.6	57.7	42	38.5	56.9	48.1
March	11.3	54	42	38.8	54.3	48.5
April	11.4	72.2	43.5	40.6	71	50.1
May	11.7	61.4	45.6	41.8	61	51
June	9.8	60.7	44.2	40.6	60	51
July	10.1	69.7	45.7	41.6	68.5	52.6
August	9.7	63.6	45.4	42.2	63.5	52.5
Total	81	62.2	43.7	40.4	61.2	50.3

Source: State Service of Ukraine for Geodesy, Cartography and Cadastre (n.d.)

Table 2. Comparative analysis of deviations of the developed methodology from traditional methods and official data

Month	Deviation from arithmetic mean, %	Deviation from median, %	Deviation from weighted mean, %	Deviation from cadastral data, %
January	-8.9	+16.4	+28.7	-7.8
February	-16.6	+14.5	+25	-15.5
March	-10.2	+16	+25	-10.7
April	-30.6	+15.2	+23.4	-29.4
May	-16.9	+11.8	+22	-16.4
June	-16	+15.4	+25.6	-15.0
July	-24.5	+15.1	+26.4	-23.2
August	-17.5	+15.6	+24.4	-17.3
Total	-19.1	+15.1	+24.5	-17.8

Source: State Service of Ukraine for Geodesy, Cartography and Cadastre (n.d.)

The analysis of deviations revealed a systematic interrelationship between methods. The developed methodology consistently provided a reduction in estimates compared to the arithmetic mean (from -8.9% to -30.6%) and an increase compared to the median (from +11.8% to +16.4%) and weighted mean (from +22% to +28.7%). Such consistency of deviations confirmed that the developed methodology does not simply mechanically average

traditional approaches but applied a consistent logic for correcting their systematic errors. The largest deviations from the arithmetic mean were observed in April (-30.6%) and July (-24.5%), which was explained by the particularly high influence of outliers in these months. Statistical variability indicators confirmed a significant improvement in estimation stability, when using the developed methodology compared to traditional approaches (Table 3).

Table 3. Comparative analysis of deviations of the developed methodology from traditional methods and official data

Month	Standard deviation (thousand UAH/ha)	Coefficient of variation, %	Range of variation (max-min) (thousand UAH/ha)
January	6.5	13.9	16
February	8	16.9	19
March	6.5	14	15
April	13.2	24.6	31.6
May	8.3	15.6	19.6
June	8.4	16.1	20.1
July	11.7	20.7	28.1
August	9	16.5	21.4
Total	9.2	17.2	21.8

Source: State Service of Ukraine for Geodesy, Cartography and Cadastre (n.d.)

The coefficient of variation, which characterised the relative variability of price estimates, ranges from 13.9% in January to 24.6% in April, with a mean value of 17.2% for the entire period. The mean coefficient of variation of 17.2% represented a threefold improvement compared to the 54% variation observed for traditional methods (arithmetic mean, median, weighted mean) applied to the same dataset, demonstrating substantially enhanced homogeneity of estimates. The standard deviation varied from 6.5 to 13.2 thousand UAH per hectare, reflecting the absolute magnitude of discrepancies between methods and demonstrating the highest values in April and July – months with the greatest market activity and price volatility. The range of variation, defined as the difference between maximum and minimum values among all methods, ranges from 15.2 to 31.6 thousand UAH per hectare depending on the month. The mean range value of 21.8 thousand UAH per hectare meant that in a typical month, the difference between the highest and lowest estimate constituted 43% of the mean value, which underscored the critical importance of methodology selection for obtaining reliable results. At the same time, the developed methodology demonstrated systematic positioning in the central part of the estimation range, avoiding both extremely high and extremely low values.

The analysis of monthly dynamics revealed a trend of gradual market price growth throughout January-August of 2025. The developed methodology showed an increase from 48.1 thousand UAH per hectare in February to 52.6 thousand UAH per hectare in July, representing a growth of 9.3% over six months or approximately 1.5% per month. This growth reflected general economic trends and seasonal factors of price formation in the land market, when the spring-summer period was characterised by increased buyer activity and higher prices compared to winter months. All calculation methods demonstrated similar dynamics; however, the developed methodology provided a smoother growth trajectory without the sharp fluctuations characteristic of traditional approaches. The developed methodology demonstrated fundamental advantages over traditional statistical approaches through the implementation of principles of multi-level filtering and differentiated weighting. Unlike one-dimensional methods that applied a single criterion for data selection or processing, the proposed approach integrated five independent analytical procedures, each optimised for a specific segment of market operations. Such architecture of the methodology ensured a synergistic effect, where the weaknesses of individual components were compensated by the strengths of others, creating a system of mutual balancing and correction of systematic errors. Empirical confirmation of this advantage was the reduction of the coefficient of variation from 54% for traditional methods to 17.2% for the developed methodology, indicating a threefold improvement in estimation stability.

A critically important advantage of the developed approach was its adaptability to the structural features of a specific dataset without the need for manual researcher intervention. The dynamic weighting system automatically adjusted the influence of each method depending on the number of valid observations that satisfied its criteria,

ensuring optimal utilisation of the informational potential of the sample. This fundamentally distinguished the proposed methodology from static approaches, where filtering and weighting parameters were established a priori and remained unchanged regardless of data characteristics. The results of the comparative analysis showed that the developed methodology provided a systematic deviation from the official data of the State Service of Ukraine for Geodesy, Cartography and Cadastre (n.d.) within 7.8-29.4%, which may reflect objective differences in approaches to processing extreme values and indicates the potential for further methodological dialogue regarding the standardisation of procedures for calculating land market prices. The results obtained in this study demonstrated a significant improvement in the methodology for calculating the average statistical market price of agricultural land compared to both traditional approaches and previous research. The developed five-component methodology with an adaptive weighting system provided a final estimate of 50.3 thousand UAH per hectare with a coefficient of variation of 17.2%, which represented a threefold reduction in variability compared to traditional statistical methods showing an amplitude of fluctuations of 54%.

I. Yurchenko (2024) analysed 137,357 purchase and sale transactions for the period 2021-2023 using three traditional methods: arithmetic mean, weighted mean, and median. The results showed that the arithmetic mean produced significantly inflated values of 134 thousand UAH per hectare, which were 2-3 times higher than official data and did not reflect the real market situation. The weighted mean yielded 27.8 thousand UAH per hectare, while the median showed 32.5 thousand UAH per hectare. It was concluded that the arithmetic mean method was unsuitable for calculating land prices due to its sensitivity to extreme values, which constituted more than 20% of transactions. This research substantially advanced the methodology by introducing a multi-level filtering system and an adaptive weighting mechanism that dynamically adjusted the contribution of each calculation method based on the structural characteristics of the data. The comparative analysis revealed that, while I. Yurchenko (2024) identified the problem of significant discrepancies between traditional methods, methodology of this research provided a balanced estimate that systematically positioned itself between the extreme values, avoiding both overestimation inherent to the arithmetic mean and underestimation characteristic of the weighted mean. The developed methodology's emphasis on multi-level filtering and adaptive weighting found strong support in systematic analyses of agricultural land markets. M. Agosta *et al.* (2025) conducted a comprehensive literature review identifying both intrinsic factors (soil fertility, water access, plot size, location) and extrinsic factors (urban pressure, fiscal policies, demographic changes, climate variations) as critical determinants of land prices. The author's framework underscored that accurate price calculation required methodologies capable of simultaneously addressing multiple interacting variables – precisely the approach implemented in five-component system developed in this study. The systematic deviation of 17.8% from official calculations observed in this research reflected the inherent complexity of land market dynamics, where

different methodological approaches captured distinct aspects of market reality.

The challenge of price variability in transitional agricultural markets extended beyond Ukraine's borders. A. Wasilewski *et al.* (2024) analysed agricultural land price dynamics across EU member states from 2006 to 2022, revealing similar patterns of convergence and divergence. Eastern European countries, including Poland and Romania, demonstrated price convergence driven by EU policies and foreign investment, while maintaining substantial internal price variation – a coefficient of variation oscillating between 0.97 and 1.03 across the analysed period. Scientist's findings that relative price diversity remained stable despite absolute price increased parallel observation of this study that traditional statistical methods yielded unacceptably high discrepancies (54% amplitude of fluctuations). This cross-national evidence validated the necessity of robust filtering mechanisms to isolate meaningful price signals from market noise, particularly in markets characterised by fragmented land ownership and varying transaction intensities. The methodological advancement achieved through adaptive weighting system aligned with emerging trends in land price prediction technologies. S. Doğan *et al.* (2025) compared traditional multiple linear regression with the Extreme Gradient Boosting (XGBoost) algorithm for agricultural land price prediction in Turkey, demonstrating that advanced analytical approaches substantially outperformed conventional methods ($R^2 = 0.66$ versus $R^2 = 0.01$). While researcher's study focused on machine learning algorithms rather than statistical filtering, the underlying principle remained consistent: accurate land price determination required methodologies that can capture complex, non-linear relationships among multiple variables. Five-method integration with dynamic weighting, developed in this research, represented a parallel evolution in statistical methodology, achieving threefold improvement in estimation stability through intelligent combination of complementary analytical approaches rather than reliance on single-method calculations.

The regional dimension of agricultural land productivity assessment also warranted consideration in the context of price methodology. I. Smaga *et al.* (2023) assessed the productive potential and efficiency of agroland use in the Chernivtsi region, demonstrating that regional variations in land quality and utilisation efficiency directly influenced market price formation – a finding that underscored the necessity of robust filtering mechanisms capable of handling heterogeneous transaction data. The temporal dynamics of land price behaviour further complicated methodological choices. J. Valtiala (2020) identified regime-switching behaviour in Finnish agricultural land prices, demonstrating that land markets periodically shifted between distinct price regimes characterised by different mean levels and volatility patterns. This non-linear price dynamics validated the adaptive weighting approach developed in this study, where dynamic weight coefficients automatically responded to structural shifts in transaction data distribution rather than assuming a stationary price-generating process.

The broader context of land valuation methodology improvement was evident across diverse agricultural markets. A.H. Valiyev & N.S. Mirzayev (2023) examined

land assessment methods in Azerbaijan, identifying that existing approaches to determining normative land prices do not fully correspond to market reality – a conclusion remarkably similar to findings regarding Ukrainian official methodology. Emphasis on optimising quality assessment and economic valuation methods to establish efficient farming systems and reliable price determination resonated with this research objectives. The convergence of methodological concerns across geographically and economically diverse contexts – from EU member states to post-Soviet agricultural markets – suggested that the challenge of accurate land price calculation represented a fundamental issue requiring systematic methodological innovation rather than market-specific solutions. The systematic deviation of 17.8% from the official data of the State Service of Ukraine for Geodesy, Cartography and Cadastre (n.d.) observed in this study was consistent with the findings of research, where it was noted an average difference of 8 thousand UAH per hectare between calculated values and official statistics. The monthly analysis confirming the stability of the developed methodology under conditions of seasonal fluctuations represented an important advancement compared to this research, which did not assess temporal stability. The identified price growth trend of 9.3% over six months reflected general economic tendencies in the land market and demonstrated the methodology's capacity to capture real market dynamics, while filtering out statistical noise.

► Conclusions

The study confirmed the critical necessity of improving methodological approaches to calculating the market price of agricultural land based on purchase and sale transaction data. The analysis of a dataset of 81,026 transactions for the period January-August of 2025 revealed an unacceptably high discrepancy in the results of traditional statistical methods: the arithmetic mean (62.2 thousand UAH per hectare), median (43.7 thousand UAH per hectare), and weighted mean (40.4 thousand UAH per hectare) demonstrated an amplitude of fluctuations of 54%, which made their use for reliable market price estimation impossible without additional methodological corrections. The developed comprehensive methodology, based on the integration of five complementary methods with different filtering levels and an adaptive weighting system, provided a market price calculation of 50.3 thousand UAH per hectare with a coefficient of variation of 17.2%. The threefold reduction in variability compared to traditional approaches confirmed the effectiveness of the proposed system of multi-stage outlier filtering and intelligent result combination. The systematic deviation from official within 17.8% indicated objective methodological differences in approaches to processing market information and actualised the need for further standardisation of calculation procedures. Monthly analysis confirmed the stability of the methodology under conditions of seasonal fluctuations in market prices and varying transaction intensity. The identified trend of market price growth of 9.3% during January-July of 2025 reflected general economic processes in Ukraine's land market under conditions of ongoing military operations. Further research directions will include annual cycle analysis, regional methodology

adaptation, and comparative assessment of international land market monitoring practices.

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► **Conflict of Interest**

None.

► **References**

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Удосконалення методології розрахунку середньостатистичної ринкової ціни земель сільськогосподарського призначення

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► **Анотація.** Точне визначення ринкової вартості сільськогосподарських земель стало важливим для прийняття обґрунтованих економічних рішень, однак традиційні статистичні методи продемонстрували неприйнятно великі розбіжності через статистичні викиди та структурні особливості ринку. Метою дослідження було розробити та перевірити покращену методологію розрахунку ринкової вартості сільськогосподарських земель, яка забезпечила стабільність та надійність результатів через комплексне застосування багаторівневого фільтрування даних та адаптивної системи ваг. Запропонована методологія дозволила знизити варіативність оцінки ціни в три рази (коефіцієнт варіації 17,2 % проти 54 % для традиційних методів), зберігаючи високу репрезентативність вибірки, що забезпечило більш надійні розрахунки ринкової ціни. Аналіз показав, що традиційні методи дали результати в межах від 40,4 до 62,2 тис. грн за гектар з амплітудою коливань 54 %, тоді як розроблена методологія надала оцінку 50,3 тис. грн за гектар з коефіцієнтом варіації 17,2 %, що свідчило про триразове поліпшення стабільності оцінки. Щомісячний аналіз підтвердив стійкість методології до сезонних коливань та різної інтенсивності ринкової активності, виявивши тенденцію до зростання ціни на 9,3 % протягом 2024-2025 років. Порівняння з офіційними розрахунками Державної служби України з геодезії, картографії та кадастру показало систематичне відхилення в межах 17,8 %, що відображало об'єктивні методологічні різниці в підходах до обробки ринкової інформації. Практична цінність розробленої методології полягає в її застосовності для аналізу цілей моніторингу ринку земель, оцінної діяльності та державного регулювання земельних відносин

► **Ключові слова:** методологія ціноутворення; аналіз транзакційних даних; багаторівневе фільтрування; адаптивне зважування; точність ціни; оцінка земель; викиди даних