Rocznik Ochrona Środowiska

Volume 27 Year 2025 ISSN 2720-7501 pp. 722-737

https://doi.org/10.54740/ros.2025.058 open access

Received: November 2025 Accepted: November 2025 Published: November 2025

Capital Investments in Sustainable Development of Land Resources of Ukrainian Agrarian and Industrial Complex Enterprises: Assessment, Modeling, Optimization

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Abstract: The importance of capital investments for the national economy of Ukraine in general and agriculture in particular is substantiated, since they ensure the formation of tangible and intangible assets of enterprises. It is found that for agricultural production, the main asset for capital investments is agricultural land. At the same time, the activities of agricultural, forestry, and fishery enterprises depend on capital investments in existing buildings, construction of economic structures, purchase of machinery and equipment, as well as in intangible assets – software and concessions, patents, licenses, trademarks, and similar rights. The article reveals the relevance of capital investments as a key tool for ensuring the sustainable development of Ukrainian agro-industrial enterprises in the context of economic and political instability in 2014-2023. The emphasis is on land resources as one of the main factors of production in agriculture, forestry, and fisheries, taking into account the need to increase the efficiency of their use through investment mechanisms. The main objective of the study is to assess the effectiveness of capital investments in the development of land resources of agricultural enterprises, which will allow identifying the potential for increasing the volume of sales and costs of production of products (goods, services) of agricultural, forestry, and fisheries enterprises. The methodological basis of the article includes the use of correlation-regression analysis to establish the relationship between capital investments and key production indicators, as well as the method of analysis of the operating environment, which allows for determining the level of efficiency of investment use in dynamics. Using correlation-regression analysis, a study was conducted of the impact of each type of capital investment on revenue from sales of products (goods, services) and production costs of agricultural, forestry, and fishery enterprises, which allowed us to identify the absence of the impact of an increase in the volume of capital investments on the growth of sales and production costs. At the same time, a relatively significant impact of capital investments is observed on other types of assets, the increase of which ensures an increase in sales and costs for products (goods, services) of agricultural, forestry, and fishery enterprises, in particular, the purchase of software. The paper presents a comprehensive assessment of investments in tangible and intangible assets, including land, buildings, machinery, equipment, and software. The results of the study showed that investments in land do not have a sufficient impact on the economic performance of enterprises, while investments in software and construction have a pronounced positive effect. The method of analysis of the operating environment was used to identify the efficiency of using capital investments for the development of land resources in the context of increasing the volume of sales and costs for the production of products (goods, services) of agricultural, forestry and fishery enterprises, which made it possible to identify the lost potential over the past ten years and to propose approaches to improving production indicators for the following periods. An efficiency line was constructed to identify the most productive periods of investment in the development of land resources, and optimization scenarios were proposed, taking into account the potential for increasing product sales and reducing costs. An assessment of the savings of capital investments in cases of their inefficient use was carried out, and the potential for increasing economic efficiency in the future was calculated. The results of the work are a valuable tool for strategic planning of investment activities of agro-industrial enterprises in conditions of limited resources, market challenges,

and military threats, and the proposed methodology can be adapted to assess the effectiveness of investments in other sectors of the Ukrainian economy.

Keywords: capital investments, sustainable development, land resources, agricultural enterprises, investment efficiency, correlation-regression analysis, operating environment analysis, digitalization in agriculture

1. Introduction

Capital investments are a significant factor in the development of the national economy, as they ensure the creation of fixed assets of enterprises, modernization, and re-equipment of production facilities (Tomashuk et al. 2024). The presence of capital investments emphasizes the development of the state through increased sales of products, increased business activity, and the introduction of innovative business approaches (Hutorov et al. 2021). At the same time, the problem of the efficiency of capital investment requires an optimization approach to its use, which will avoid wasting money on dubious projects.

Agricultural enterprises depend on capital investments, as agriculture is one of the resource-intensive industries, requiring significant funds for construction, purchase and modernization of equipment, development of land resources, environmental safety, creation of infrastructure, formation of intangible assets, etc. (Zamula et al. 2020, Baik et al. 2021, Perevozova et al. 2021, Lupenko et al. 2022, Sirant et al. 2022, Zakharchuk et al. 2022, Denysiuk et al. 2022, Yarmol et al. 2022, Mykhailenko et al. 2023, Lepetan et al. 2023, Jia 2024, von Hegner 2025).

However, simply raising capital does not guarantee sustainable economic growth. The return on investment, its profitability, and overall efficiency are determined by the ability of enterprises to adapt to dynamic market conditions, introduce innovations, and make strategically sound management decisions (Kolesnyk et al. 2018, Kaletnik & Lutkovska 2020, Balanovska et al. 2021, Zhovnirchyk et al. 2023). This, in turn, is a derivative of the ability of business entities to maintain their own competitive positions in the market (Onegina & Vitkovskyi 2020, Andriushchenko et al. 2021, Chikov et al. 2023a). Capital investments, if they are aimed at technological innovation, energy efficiency, and human capital development, form the basis for long-term success in domestic and foreign markets. Moreover, the rational use of capital investments is one of the key factors in ensuring sustainable development of the agricultural sector (Chikov & Titov 2023, Martsynkevych & Danyliak 2023, Dorosh et al. 2024). This includes not only economic feasibility, but also environmental responsibility and social orientation of investment activities (Honcharuk & Tokarchuk 2024). Thus, investment policy in the agricultural sector should be comprehensive, strategically sound, and aimed at achieving a balance between economic efficiency, social justice, and environmental safety.

The article focuses on the study of the role of capital investments in the formation of assets of agricultural, forestry, and fishery enterprises in the context of increasing the volume of sales of products (goods, services). In addition, the need for rationalization of land use through optimization of capital investments of agricultural production enterprises is substantiated (Tretiak et al. 2021, Ostapchuk et al. 2021, Perevozova et al. 2022, Bezdushna et al. 2023, Boussakra et al. 2025).

The purpose of the article is to assess the effectiveness of capital investments in the development of land resources of agricultural enterprises, which will allow identifying the potential for increasing sales and production costs (goods, services) of agricultural, forestry, and fishery enterprises.

2. Methods

The basis of the study is statistical materials on the economic activity of agricultural, forestry, and fishery enterprises of Ukraine during 2014-2023 (State Statistics Service of Ukraine, 2014-2023). Information was systematized according to indicators of capital investments in tangible and intangible assets, as well as sales volume and costs for production of products (goods, services), which allowed conducting correlation-regression analysis, thanks to which regression equations were constructed and indicators of connection density were determined.

To ensure greater analytical validity, the study also involved the calculation of coefficients of determination and elasticity, which made it possible to assess the strength and nature of the influence of investment factors on performance outcomes. The obtained models were tested for statistical significance, and the stability of interdependencies was evaluated over time. This comprehensive approach enabled the formulation of evidence-based conclusions regarding the effectiveness of capital investment in enhancing production efficiency within the sector.

The method of analysis of the operating environment was used to assess the effectiveness of capital investments in land resources over a ten-year period. This method involves the use of the coefficient method and the graphical analysis method.

The combination of parametric (correlation-regression analysis) and non-parametric (operational environment analysis) methods provides a comprehensive approach, where the parametric method identifies key influencing factors, and the non-parametric method allows you to assess the dynamics of efficiency and identify lost potential, which is especially important in the context of uneven investment due to external factors, such as military actions. Thus, the integration of parametric and non-parametric methods is justified, as it provides a comprehensive assessment of the investment activities of agro-industrial enterprises, increasing the reliability and practical value of the conclusions.

The coefficient method is implemented based on the calculation of two groups of coefficients – coefficients of coverage by the volume of products (goods, services) sold by enterprises of capital investments in land (X_1 / Y) and costs of production of products (goods, services) (X_2 / Y), as well as efficiency coefficients, which allows building an efficiency line by positions of the analyzed years in the operating environment. This approach allows us to identify reference years with an optimal ratio of resources and results, which is confirmed by high efficiency coefficients for these periods. To more fully take into account complex influences, such as economic instability, military actions, and changes in market conditions, the efficiency of positions requires additional analysis, in particular by including risk factors (for example, hryvnia volatility or labor migration), which can affect the shape of the efficiency line. This provides a more accurate definition of investment potential and allows us to adapt the method to a changing resource environment, which is critical for strategic planning in conditions of instability (Zhuk 2016, Yermakov et al. 2022, Prib et al. 2022). However, this involves a significant complication of the analysis methodology, as it requires the involvement of multifactor models with a high degree of computational complexity, which goes beyond the scope of the current research topic, which is focused on identifying efficient periods using classical assessment tools, and would require a separate large-scale study focusing on the dynamic stability of economic systems.

The graphical analysis method is implemented by constructing an efficiency line based on ten-year positions, which allows calculating efficiency coefficients and justifying the existing trend in the use of capital investments relative to the unrealized potential for the production of products (goods, services) of agricultural, forestry, and fishery enterprises. In addition, graphical analysis is used to design optimized positions of the efficiency line, which allows constructing an efficiency line as a guideline for planning indicators for the following years – the volume of increased sales of products (goods, services) of agricultural, forestry, and fishery enterprises, and a decrease in capital investments.

This visual tool facilitates intuitive interpretation of sectoral performance dynamics and supports the identification of critical deviations from optimal investment strategies.

The disadvantage of the method of analyzing the operating environment can be considered the absence of a profit indicator in the calculations, which does not allow assessing the return on invested capital investments. However, the presence of a non-parametric component makes the study unbiased and allows introducing various combinations of both effective and factor indicators.

Despite this limitation, the method proves helpful in forming preliminary hypotheses and guiding further econometric modeling, particularly in scenarios where financial reporting data is fragmented or unavailable.

3. Results

Capital investments in agriculture, forestry, and fisheries during 2014-2023 were made in tangible and intangible assets. The formation of tangible assets is the development of land resources, maintenance of existing buildings and structures, construction and reconstruction of buildings, machinery, and equipment. Intangible assets include patents, licenses, trademarks, similar rights, and software (Andriushchenko et al. 2022, Lutkovska & Lebid 2024).

Using correlation and regression analysis methods, we will construct a regression equation and determine the density of the relationship between the impact of capital investments in tangible and intangible assets on the volume of products sold (goods, services) of enterprises and the costs of producing products (goods, services) of enterprises. The feasibility of such an analysis is justified by its ability to clearly identify the statistical significance of dependencies, which is confirmed by testing models for statistical reliability and estimating the coefficients of determination and elasticity. These indicators provide an objective assessment of investment efficiency, allowing us to conclude that land is not very attractive as an investment resource in the context of short-term economic results.

Table 1 shows the regression equations and the density of the relationship for those capital investments where no significant dependence is observed.

Table 1. Dependence of the performance indicator on the resource (capital investment) in the absence of communication density, 2014-2023

№	Performance indicator (Y)	Resource indicator (X)	Regression equation	Communication density
1	Volume of products (goods, services) sold by enterprises	Capital investments in land	$y = 616.86x + 5 \cdot 10^8$	0.07
2	Costs of production of products (goods, services) of enterprises		$y = 561.42x + 4 \cdot 10^8$	0.10
3	Volume of products (goods, services) sold by enterprises	Capital investments in existing buildings and structures	$y = 56.358x + 5 \cdot 10^8$	0.02
4	Costs for the production of products (goods, services) of enterprises		$y = 44.855 + 4 \cdot 10^8$	0.02
5	Volume of products (goods, services) sold by enterprises	Capital investments in concessions, patents, licenses, trademarks, and similar rights	$y = 3399.58x + 5 \cdot 10^8$	0.04
6	Costs for the production of products (goods, services) of enterprises		$y = 4093.59x + 4 \cdot 10^8$	0.11

Source: formed by the authors using (State Statistics Service of Ukraine, 2014-2023)

Thus, it is important to emphasize that there are certain types of capital investments whose implementation does not significantly influence the volume of sales of products (goods, services) or the costs of their production. These capital investments are considered structurally essential but do not directly contribute to short-term improvements in operational performance indicators. Such capital investments include:
– capital investments in land (Chikov et al. 2022),
– capital investments in existing buildings and structures (Vdovenko et al. 2023),
– capital investments in concessions, patents, licenses, trademarks, and similar rights (Dotsiuk et al. 2024).

Although these investments may enhance long-term strategic positioning, asset value, or legal competitiveness, their immediate effect on production efficiency and revenue generation remains limited or delayed. This distinction is critical when evaluating the effectiveness of capital allocation across enterprise categories in the agricultural, forestry, and fishery sectors.

The density of communication in all cases is characterized by a low value of the coefficient of determination, and therefore, the implementation of the corresponding models under these conditions is no longer necessary.

This indicates a weak explanatory power of the independent variables in relation to the dependent ones, suggesting that the modeled relationships lack statistical reliability. As a result, further reliance on these models for predictive or decision-making purposes would be unjustified and may lead to erroneous conclusions regarding the efficiency of capital investment utilization.

At the same time, there are cases of significant impact of capital investments on both the volume of products sold and the costs of their production during 2014-2023. In particular, investments in the construction and reconstruction of buildings ensure an increase in the volume of products sold (goods, services) of enterprises (Fig. 1).

Based on the current dynamics, over the past ten years, there has been a stable need to increase capital investments in the construction and reconstruction of buildings, which will provide an average increase in the volume of sold products (goods, services) of agricultural, forestry, and fishery enterprises by 56.257 times. Even if capital investments are not made ($x = 0$), the volume of sold products (goods, services) of agricultural, forestry, and fishery enterprises will be $80.623 mln.

The growth of capital investments in the construction and reconstruction of buildings leads to an increase in the costs of production (goods, services) of agricultural, forestry, and fishery enterprises (Fig. 2).

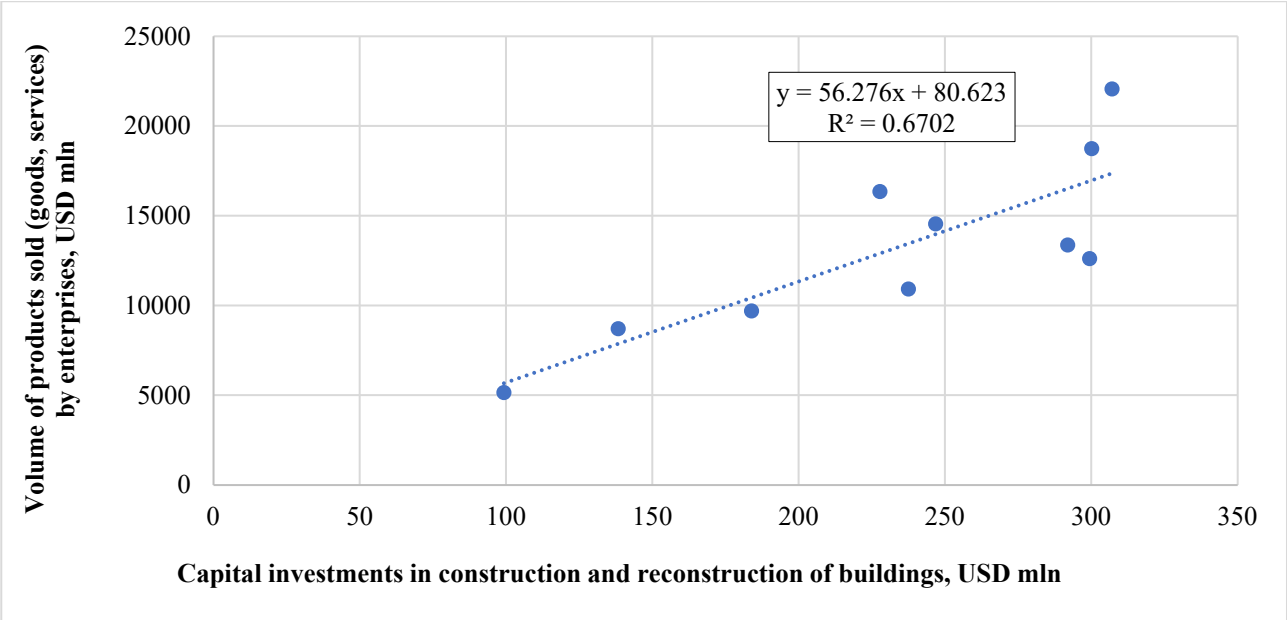

Fig. 1. Correlation-regression dependence of the volume of products sold (goods, services) of enterprises on capital investments in the construction and reconstruction of buildings based on the results of activities in agriculture, forestry, and fisheries, 2014-2023
Source: formed by the authors using (State Statistics Service of Ukraine, 2014-2023)

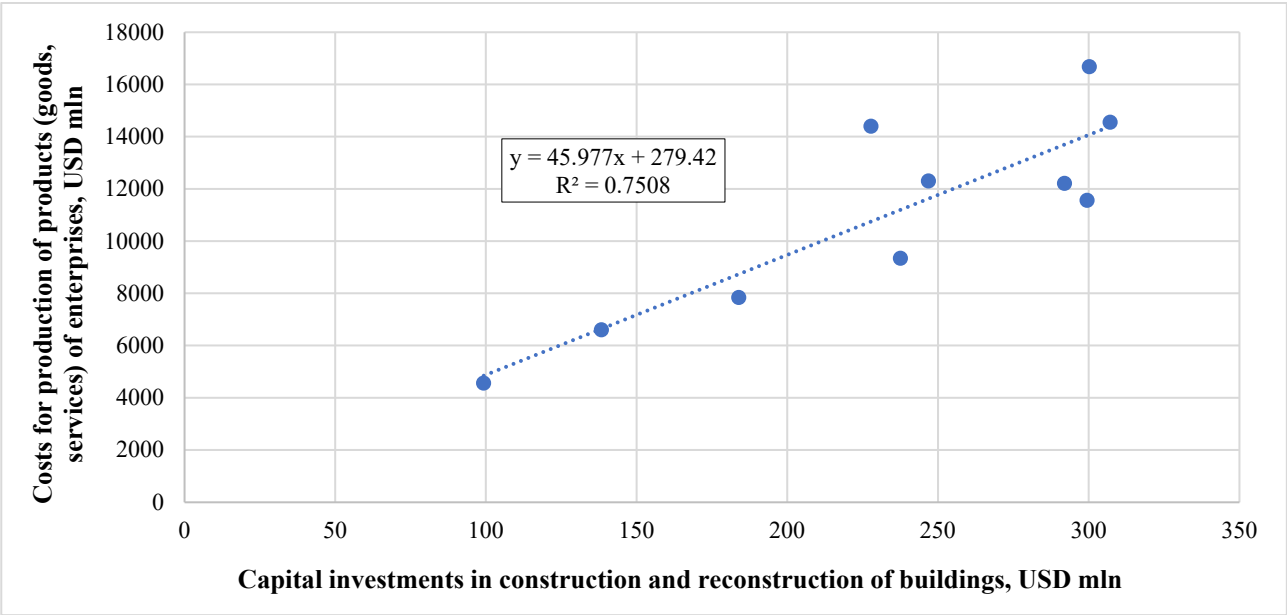

Fig. 2. Correlation-regression dependence of costs for production of products (goods, services) of enterprises on capital investments in construction and reconstruction of buildings based on the results of activities in agriculture, forestry, and fisheries, 2014-2023
Source: formed by the authors using (State Statistics Service of Ukraine, 2014-2023)

The increase in capital investments in the construction and reconstruction of buildings leads to an increase in the costs of production of products (goods, services) of agricultural, forestry, and fishery enterprises by 45.977 times. The absence of capital investments (x = 0) ensures the level of costs of production of products (goods, services) by enterprises by $279.42 mln.

Compared to capital investments in construction and reconstruction of buildings, the impact of capital investments in machinery and equipment on the volume of sold products (goods, services) of enterprises is much smaller, however, based on a sufficiently high level of the correlation coefficient (0.670), it allows us to state the significance of this type of capital investment for increasing the volume of sold products of agricultural, forestry and fishery enterprises (Fig. 3).

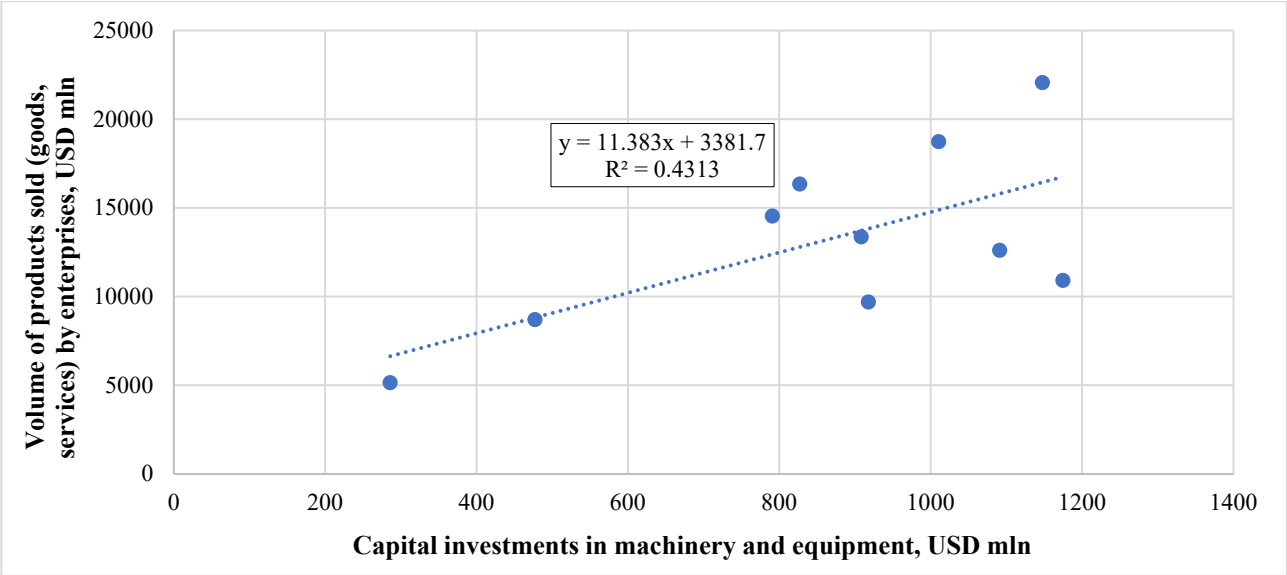

Fig. 3. Correlation-regression dependence of the volume of products sold (goods, services) of enterprises on capital investments in machinery and equipment based on the results of activities in agriculture, forestry, and fisheries, 2014-2023
Source: formed by the authors using (State Statistics Service of Ukraine, 2014-2023)

The increase in the volume of capital investments in machinery and equipment leads to an increase in the volume of sales of products (goods, services) of agricultural, forestry, and fishery enterprises by 11.383 times. At the same time, the absence of capital investments in machinery and equipment will allow to obtain the volume of sales of products (goods, services) of agricultural, forestry, and fishery enterprises by $3381.7 mln.

The dependence of the costs of production of products (goods, services) of enterprises on capital investments in machinery and equipment is also not characterized by high density; however, the level of influence is sufficient to conclude about the significance of this type of capital investment for the development of agricultural production (Fig. 4).

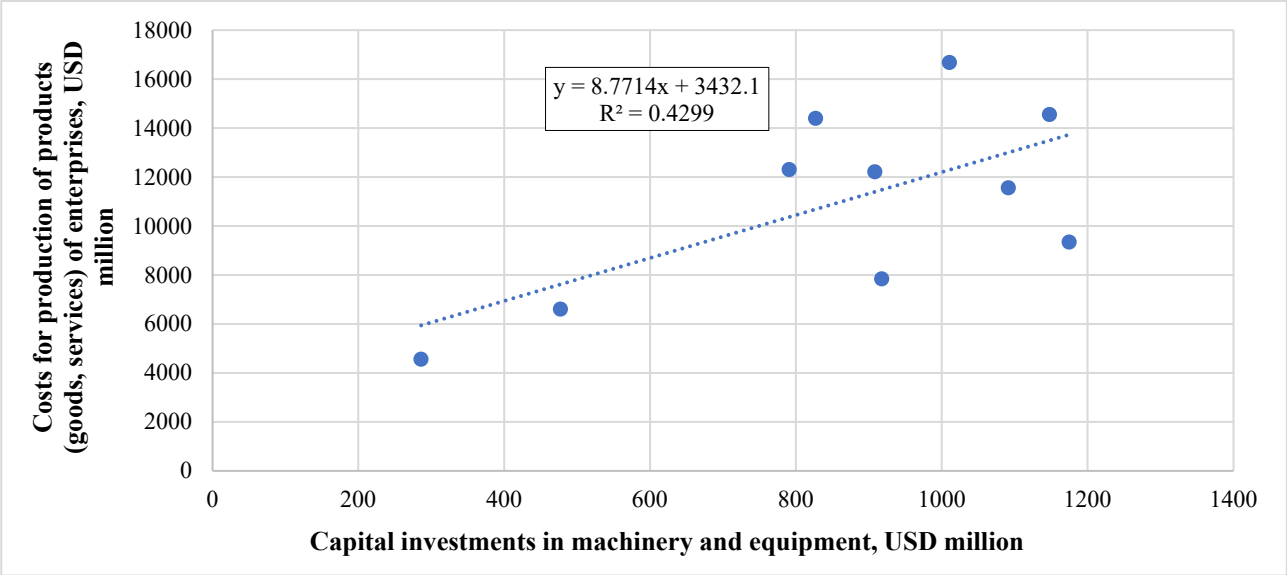

Fig. 4. Correlation-regression dependence of costs for production of products (goods, services) of enterprises on capital investments in machinery and equipment based on the results of activities in agriculture, forestry, and fisheries, 2014-2023
Source: formed by the authors using (State Statistics Service of Ukraine, 2014-2023)

An increase in capital investments in machinery and equipment leads to an increase in the costs of production of products (goods, services) of agricultural, forestry, and fishery enterprises by 8.7714 times. In the absence of capital investments (x = 0), the costs of production of products (goods, services) of enterprises will amount to $3432.1 mln.

Intangible assets play an essential role in the development of agriculture, as they are related to intellectual property and the formation of intellectual businesses (Chikov et al. 2023b). While capital investments in concessions, patents, licenses, trademarks, and similar rights do not significantly affect the increase in sales or production costs, capital investments in software have a close relationship with the sales volume of products (goods, services) of agricultural, forestry, and fishery enterprises (Fig. 5).

Thus, an increase in the volume of capital investments in the purchase of software leads to an increase in the volume of sold products (goods, services) of agricultural, forestry, and fishery enterprises. If capital investments are not made (x = 0), then the volume of sold products (goods, services) of enterprises will be $4369.3 mln.

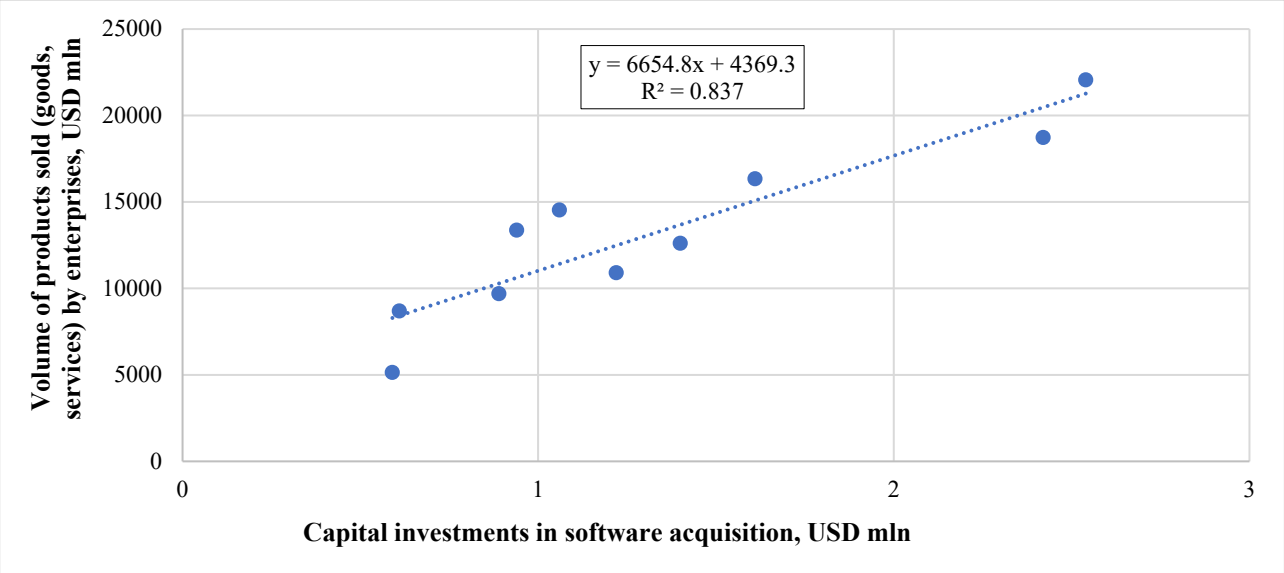

Fig. 5. Correlation-regression dependence of the volume of products sold (goods, services) of enterprises on capital investments in the purchase of software based on the results of activities in agriculture, forestry, and fisheries, 2014-2023
Source: formed by the authors using (State Statistics Service of Ukraine, 2014-2023)

Capital investments in software acquisition also lead to an increase in the costs of production of products (goods, services) of agricultural, forestry and fishery enterprises, since the density of communication is relatively high, and the regression equation characterizes an increase in costs by 4762 times with an increase in capital investments in software acquisition (Fig. 6). If capital investments are not made (x = 0), then the costs of production of products (goods, services) of agricultural, forestry and fishery enterprises will amount to $4678.7 mln.

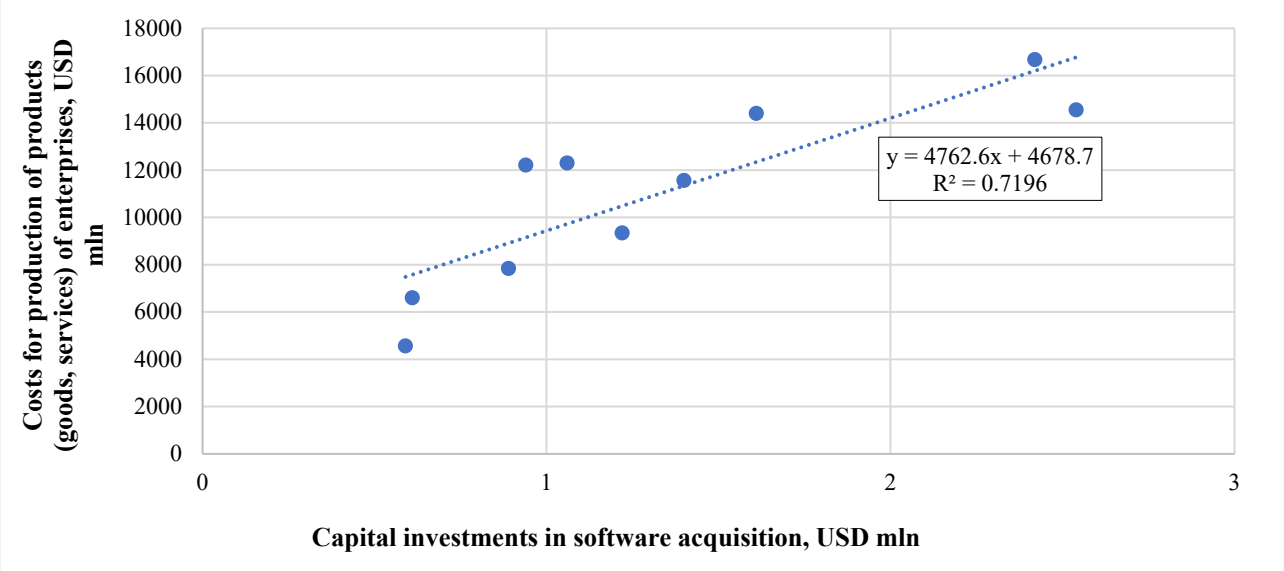

Fig. 6. Correlation-regression dependence of costs for production of products (goods, services) of enterprises on capital investments in the purchase of software based on the results of activities in agriculture, forestry, and fisheries, 2014-2023
Source: formed by the authors using (State Statistics Service of Ukraine, 2014-2023)

Evaluating the results of correlation-regression analysis, we can conclude that it is most advisable to make capital investments in intangible assets – the purchase of software. Such an investment allows you to get a much higher income than when investing in any other type of tangible assets, which indicates a sufficiently high level of implementation of information technologies in the sphere of agricultural production in the period 2014-2023.

At the same time, capital investments in other types of intangible assets: concessions, patents, licenses, trademarks and similar rights have all the possibilities to ensure a high level of income from the activities of agricultural enterprises, however, this potential is not used due to the lack of innovation markets in Ukraine, within which conditions are formed for intellectual business in the agricultural sector in particular and the national economy in general (Tomashuk et al. 2025).

The absence of a structured institutional environment for commercializing intellectual property, combined with limited integration of agricultural enterprises into innovation ecosystems, significantly restrains the transformative impact of such investments. This leads to underutilization of intangible assets that could otherwise enhance competitiveness, promote technology transfer, and stimulate value-added production in agribusiness. Addressing this gap requires coordinated policy efforts aimed at fostering innovation infrastructure, protecting intellectual rights, and stimulating demand for agri-innovations on both domestic and international markets.

Using correlation-regression analysis, we proved the unattractiveness of land as a resource for capital investments in order to increase the volume of product sales and stimulate the production process. On the one hand, this result indicates that although land is the most essential factor for agriculture, it alone does not solve the problem of the development of agricultural production. Buildings, machinery, and equipment are also important in the modern economy.

Furthermore, the empirical findings suggest that land, while foundational, functions primarily as a passive asset that requires active infrastructural and technological augmentation to generate measurable returns.

Intangible assets generally play a decisive role and are able to ensure not only an increase in revenue from product sales but also the market success of the domestic manufacturer (Davydenko et al. 2021, Koval et al. 2021).

These include innovations, proprietary technologies, branding elements, and digital solutions that enhance the adaptive capacity and strategic resilience of agricultural enterprises. As such, future capital investment strategies should prioritize a balanced portfolio that integrates physical and intangible components to maximize value creation and ensure sustainable competitiveness.

On the other hand, investments should ensure improvement of land quality, its reproduction, and productivity (Kaletnik & Lutkovska 2021, Yankovyi et al. 2021, Lozynska et al. 2024). The results obtained indicate the lack of basic approaches to implementing rational land use, since the funds spent during 2014-2023 did not actually ensure the achievement of efficiency from the funds spent.

Thus, there is a need to analyze the effectiveness of capital investments in land over the past ten years based on two factors – capital investments in land (X_1) and costs of production of products (goods, services) of agricultural, forestry and fishery enterprises (X_2), as well as the performance indicator – the volume of products (goods, services) sold by enterprises (Y) (Table 2).

Table 2. Factor (resource) indicators of influence on the volume of sold products (goods, services) of agricultural, forestry, and fishery enterprises, USD mln, 2014-2023

Years	Volume of products (goods, services) sold by enterprises (Y)	Capital investments in land (X_1)	Costs for the production of products (goods, services) of enterprises (X_2)
2014	5137.33	2.13	4559.48
2015	8696.52	1.26	6600.04
2016	9690.25	2.31	7840.45
2017	10,909.99	3.68	9339.21
2018	12,607.45	4.64	11,560.75
2019	13,363.37	7.63	12,211.23
2020	14,536.76	6.53	12,299.89
2021	22,058.85	4.34	14,550.28
2022	16,338.44	1.44	14,396.89
2023	18,729.52	2.70	16,675.44

Source: formed by the authors using (State Statistics Service of Ukraine, 2014-2023)

It should be noted that we study the economic performance of Ukrainian enterprises during the period of maximum political adversity – starting from the beginning of Russia's invasion of Ukraine in 2014 and ending with full-scale hostilities after 2022. These events significantly affected the economy of our state, which allows us to conduct an analysis based on the real state of agriculture, forestry, and fisheries, taking into account the risk factor, which always becomes a significant argument in the event of force majeure circumstances (Honcharuk et al. 2024).

As the results of the data show, the most significant volume of sales of products (goods, services) of agricultural, forestry, and fishery enterprises was observed in the last year before the full-scale invasion, in 2021, reaching $22,058.85 mln. After a significant drop in 2022 by 26% (to $16,338.44 mln), an increase of 15% was recorded in 2023 (to $18,729.52 mln).

Capital investments during 2014-2023 were carried out unevenly – the maximum volume occurred in 2019 ($7.63 mln), while the minimum volumes (2015 at $1.26 mln and 2022 at $1.44 mln) were associated with the consequences of the intensification of hostilities by Russia. The main characteristic of any investment is a significant reduction during periods of military conflict.

The nature of production costs shows a tendency toward consistent increase, indicating an intensification of economic activity. In 2022, production costs decreased by 1% compared to 2021 (from $14,550.28 mln to $14,396.89 mln), which can be considered a consequence of a shock to the entire domestic economy, reflected in reduced business activity across all enterprises. However, after overcoming this situation in 2023, the costs of production of products (goods, services) of agricultural, forestry, and fishery enterprises increased by 15.8%, reaching a record value for the studied period of $16,675.44 mln.

Based on the data in Table 1, we will calculate the coverage ratios of the volume of products (goods, services) sold by enterprises of capital investments in land (X_1 / Y) and the costs of production of products (goods, services) (X_2 / Y) for 2014-2023 (Table 3).

Table 3. Coverage ratios of the volume of sold products (goods, services) of enterprises of capital investments in land (X_1 / Y) and costs of production of products (goods, services) (X_2 / Y), 2014-2023

Years	X_1 / Y	X_2 / Y
2014	0.000415	0.888
2015	0.000145	0.759
2016	0.000238	0.809
2017	0.000338	0.856
2018	0.000368	0.917
2019	0.000571	0.914
2020	0.000449	0.846
2021	0.000197	0.660
2022	0.0000882	0.881
2023	0.000144	0.890

Source: based on Table 2

The most optimal option is to minimize these coefficients. The closer the coverage ratio is to zero, the greater the volume of sales of products (goods, services) of agricultural, forestry, and fishery enterprises. Otherwise, efficiency is achieved by reducing factor indicators – the volume of capital investments and production costs.

This suggests that enterprises reach higher performance levels either by significantly increasing output without a proportional rise in input resources or by streamlining internal operations to reduce expenditures.

In both scenarios, minimizing the coefficients reflects a more efficient use of available resources, pointing to operational models that are either output-driven or cost-conscious. Therefore, tracking the dynamics of these ratios can serve as an effective diagnostic tool for identifying performance trends and making informed investment or optimization decisions within the sector.

Based on the coverage ratios of the volume of products sold (goods, services) of enterprises of capital investments in land during 2014-2023, the best indicator was obtained in 2022, and the worst in 2019. Analyzing the coverage ratios of the volume of products sold (goods, services) of enterprises, of the costs of production of products (goods, services) for 2014-2023, we can conclude that the best indicator was achieved in 2021, and the worst in 2018 and 2019.

Since coverage ratios are relative values, we propose to assess the level of efficiency of capital investments in land using the method of analysis of the operating environment. This method was used (Farrell, 1957) to analyze the efficiency of natural monopolies in order to establish fair pricing for their services. Labor costs and capital costs were proposed as factor indicators. The resulting indicator is the volume of products sold (services provided).

The advantage of this method was that the efficiency was assessed not by the profit indicator, i.e., financial performance, but by an indicator that could influence the company's activities based on the market situation. This was especially important, since profit could not always provide a production result in the context of the potential of other enterprises producing similar products.

Unlike purely financial evaluation tools, this approach allows for a more objective measurement of performance by focusing on operational inputs and outputs, thereby accounting for resource use efficiency rather than income variability influenced by external market distortions.

As a result, at present, the method of analysis of the operating environment is used to assess the efficiency not only of natural monopolies, but also of economic entities of other spheres of activity in the system of competitive relations. In addition, it is used to assess financial indicators and results at the level of the industry (sphere of activity), as well as the national economy as a whole (Pryshliak et al. 2022, Strelbytska et al. 2025).

Its growing application across sectors demonstrates the flexibility and robustness of the method, especially in contexts where profit-based metrics are insufficient or inapplicable due to structural or market-specific constraints.

Unlike parametric methods (in particular, correlation-regression analysis), the method of analyzing the operating environment is not based on determining the dependence of one indicator on another, but on the marginal approach to assessing efficiency.

This method evaluates how closely an enterprise (or a particular observation) approaches the «best practice frontier» formed by the most efficient units within the sample.

As a result, this method can be used to assess efficiency in time space (Fig. 7) during 2014-2023.

Such an approach allows tracking dynamic changes in relative efficiency over time, identifying periods of stagnation or improvement, and detecting structural shifts in resource utilization patterns.

Unlike the example provided by Farrell (1957), we propose to use capital investments and costs of production of products (goods, services) of agricultural, forestry, and fishery enterprises as factor indicators.

This adaptation reflects the sector-specific nature of the study, where the efficiency of enterprises is determined not by general resource inputs like labor and capital alone, but by the actual financial commitments made toward production infrastructure and operational expenditures.

By focusing on capital investments and production costs as input variables, the model captures both long-term strategic and short-term operational resource allocations, making it more suitable for evaluating the productivity dynamics of resource-intensive industries such as agriculture, forestry, and fisheries.

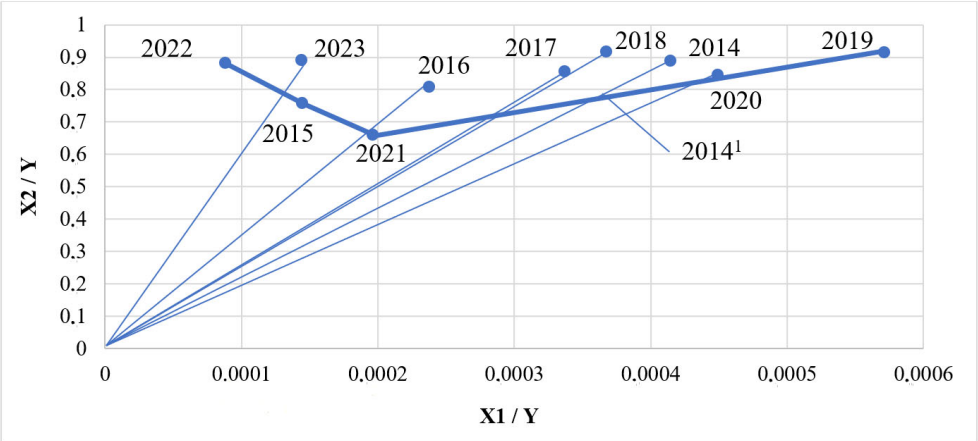

Fig. 7. Evaluating the effectiveness of capital investments in land using the operating environment analysis method, 2014-2023
Source: based on Table 3

The efficiency line is a line connecting the positions of those years that are as close as possible to the abscissa and ordinate axes. It is the limit relative to which the efficiency (inefficiency) of the positions of other years is determined, during which capital investments were used in agricultural, forestry, and fishery enterprises.

In our case, these years are 2019, 2021, and 2022, and the efficiency line looks like: 2019-2021-2022. These years are «reference» for other years of the analyzed period, and therefore, the level of efficiency of capital investments in land during this period will be determined in relation to the given efficiency line.

The efficiency level is determined by calculating the efficiency coefficient based on the application of a graphical method, evaluating the distances between positions and the efficiency line. For example, for a position for 2014, the efficiency coefficient is determined: 0-2014[1]/0-2014. The calculation results for all positions are shown in Table 4.

Table 4. Efficiency (inefficiency) coefficients of capital investments in land, 2014-2023

Years	Efficiency factors	Inefficiencies
2014	0.87	0.13
2015	0.99	0.01
2016	0.81	0.19
2017	0.83	0.17
2018	0.78	0.22
2019	1.00	-
2020	0.99	0.01
2021	1.00	-
2022	1.00	-
2023	0.89	0.11
Sum	6.16	0.84
Sum effective	3.00	-

Source: based on Fig. 7

The positions of the years included in the efficiency line have efficiency coefficients equal to one, and the positions of other years, respectively, range from 0 to 1. The closer the efficiency coefficient is to one, the higher the efficiency. Thus, the most efficient use of capital investments for the development of land resources of agricultural, forestry, and fishery enterprises was carried out in 2015 and 2019, the least efficient in 2016 and 2017. The total efficiency is 7.3 times higher than the total inefficiency (6.16/0.84).

Without paying attention to the rather significant excess of efficiency over inefficiency, it should be noted that there are significant problems with capital investments in 2014-2018, 2020, and 2023. To do this, let us analyze the new positions that formed at the intersection between the efficiency line and the segments 0-2014, 0-2015, 0-2016, 0-2017, 0-2018, 0-2020, 0-2023 (Table 5).

Table 5. Assessment of inefficiently used capital investments in land of agricultural, forestry, and fishery enterprises, 2014-2023

Years	New position covering the volume of products (goods, services) sold by enterprises investing in land	Volume of capital investments under the new position, USD mln	Possible savings on capital investments, USD mln
2014	0.000363	1.86	0.26
2015	0.000139	1.21	0.05
2016	0.000197	1.54	0.76
2017	0.000275	3.00	0.68
2018	0.000294	3.71	0.93
2020	0.000436	6.34	0.20
2023	0.000131	2.45	0.25
Sum			3.12

Source: based on Table 4

Thus, during 2014-2023, it was possible to attract $3.12 mln of capital investments for the development of land resources of Ukraine. At the same time, we believe that in the future there are all opportunities to increase the volume of sales of products (goods, services) by agricultural, forestry, and fishery enterprises by increasing the efficiency of capital investment use.

We propose calculating the potential for increasing product sales by adjusting the efficiency line (Fig. 8).

Based on the approaches to assessing the effectiveness of capital investments in land using the method of analyzing the operating environment for 2014-2023 (Fig. 8), the following graphic actions were carried out to design the potential for increasing the volume of sales of products (goods, services) of agricultural, forestry, and fishery enterprises based on the results of their activities:

– extension of line 2022-2021 towards the abscissa axis,
– extension of the 2019-2021 line towards the ordinate axis,
– construction of a conditional line 0-2019,
– construction of a conditional line 0-2022.

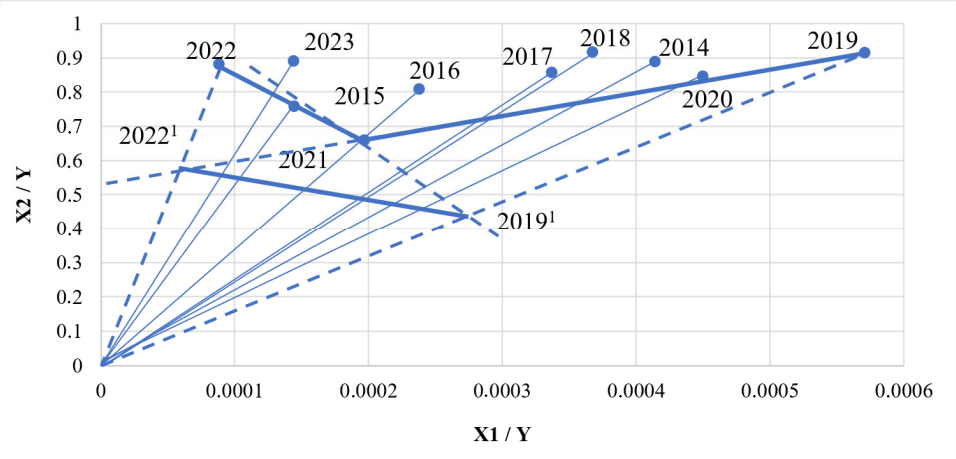

Fig. 8. Assessment of the potential for increasing the volume of sales of products (goods, services) of agricultural, forestry, and fishery enterprises based on the results of their activities during 2014-2023
Source: based on Fig. 6

– formation of the conditional position 2019^1 as the intersection point of the lines 0-2019 and 2021-2022,
– formation of the conditional position 2022^1 as the intersection point of the lines 0-2022 and 2019-2021,
– forming a new line of efficiency 2019^1-2022^1.

Although the shape of the efficiency line is specific due to the use of specific factors (capital investments in land and production costs) and an output indicator (sales volume), the methodological approach is universal and can be adapted for other studies in different sectors of the economy. In particular, the method of operating environment analysis allows for flexible variation of resource and output factors depending on the specifics of the industry, for example, replacing capital investments in land with investments in technology or human capital, and sales volume with profit or productivity indicators. Such universalization is ensured by the non-parametric nature of the method, which does not depend on assumptions about the distribution of data, which makes it suitable for analyzing investment efficiency in any context where it is necessary to assess the relationship between resources and results. Thus, the proposed approach to constructing the efficiency line can be used as a universal tool for assessing the growth potential of economic indicators in other studies, taking into account the specifics of the selected factors and adapting the shape of the efficiency line to the relevant conditions.

Thus, the efficiency line 2019^1-2022^1 defines the limit in the coordinates of the new coverage coefficients, the achievement of which in the following periods will allow for increasing the volume of sales of products (goods, services) of agricultural, forestry, and fishery enterprises with the rational use of capital investments and reduction of production costs. The area 2019-2019^1-2022^1-2022-2021 is the area of potential opportunities relative to the period 2014-2023 for the development of agriculture, forestry, and fishery in the direction of minimizing costs and rationalizing the use of capital investments in land (general direction to zero).

4. Discussion

The results of the study showed that capital investments in the development of land resources of agricultural enterprises in Ukraine during 2014-2023 did not provide the expected increase in product sales and did not lead to a significant increase in economic efficiency. This contrasts with the widespread notion in the literature of land as a key factor of production in the agricultural sector. While land remains an essential input in agriculture, the limited impact of land-based investments suggests that additional strategies, such as

technological advancements or diversification of asset portfolios, are crucial for driving productivity growth.

In particular, the study by Ciaian et al. (2020) shows that investments in land assets in Eastern European countries can have a significant positive impact if accompanied by institutional reforms, land market improvements, and property rights. While Ukrainian agricultural enterprises operated under a moratorium on the sale of agricultural land (until 2021), which significantly limited the incentive to modernize land use and invest in increasing fertility. The absence of a fully functional land market undoubtedly hindered optimal land utilization and stymied capital flow toward land-based improvements, making alternative investments, such as in digital infrastructure and human capital, more critical during this period (Shvets et al. 2021, Kyiv School of Economics, 2023).

One of the main shortcomings of the operating environment analysis method used in the study is the lack of a profit indicator as a key indicator of investment efficiency. This limits the ability to assess the financial return on investment, which is essential for agricultural enterprises in the context of market competition. Thus, a special aspect that requires attention is the limited use of performance indicators. In our work, sales volumes and costs were used; however, profitability, labor productivity, or the level of added value could provide a deeper understanding of the real efficiency of investments. In future analyses, the inclusion of profit margins and productivity metrics could offer a more comprehensive picture of the return on investment and allow for more granular assessments of capital allocation.

In modern studies, in particular, Farrell (1957) and his followers (Pryshliak et al. 2022, Strelbytska et al. 2025), the DEA method is used precisely for a comprehensive assessment of efficiency, taking into account many output and input parameters. Incorporating DEA into future studies would provide a more multifaceted evaluation of efficiency by integrating both financial and operational indicators, offering clearer insights into resource allocation and performance optimization.

Unlike the research of Bokusheva & Čechura (2017), which indicates that the effectiveness of investments in land increases significantly when combined with investments in infrastructure, digital technologies, and education of agricultural workers, ours indicates that investments in software, unlike investments in land, demonstrate a stable positive relationship with the production results of agro-industrial enterprises. This reinforces the idea that the synergy between traditional agricultural inputs and modern technological advancements, such as software and automation, is the key to improving sectoral performance.

Our research highlights the importance of software investments, which do not cover a broader range of digital technologies, such as precision agriculture or automated management systems, which are actively used in developed countries. However, the research of Van der Ploeg et al. (2019) suggests a comprehensive approach to innovation, including not only software but also the integration of IoT and artificial intelligence into agricultural production. This allows for greater productivity and efficiency of land use. The integration of IoT and AI in agriculture represents the next frontier in enhancing land use efficiency, offering real-time data-driven insights that can optimize both decision-making and resource utilization across the supply chain.

The sufficiency of linear models is justified by their effectiveness in identifying key dependencies, as shown in the studies of Dotsiuk et al. (2024) and Strelbytska et al. (2025), where linear regressions were successfully used to analyze socio-economic processes in Ukraine under conditions of economic instability. To check the possibility of improving the results, nonlinear models were also tested, in particular second-order polynomials, which showed a potential increase in accuracy by 3-5% for investments in construction and software, especially during periods of economic instability (2014-2015, 2022). However, this slight improvement is not justified given the complexity of the model in the context of the available data, since linear models already provide a reliable and interpretable basis for analysis, and the additional computational costs of nonlinear modeling do not correspond to the resulting increase in accuracy.

The study confirms the importance of capital investments for the agricultural sector, but points to the need for their rational use, especially in conditions of limited resources and military threats. Comparison with other studies shows that the emphasis on digitalization, environmental responsibility, and innovation ecosystems can significantly increase the effectiveness of investments. As Ukraine moves toward post-conflict recovery, prioritizing investments in digital infrastructure, sustainable practices, and innovative ecosystems could pave the way for long-term growth and resilience in the agricultural sector.

Further research should be aimed at overcoming the identified shortcomings, in particular by integrating a wider range of indicators and taking into account current technological trends. Expanding the scope of research to include broader metrics, such as climate impact, labor quality, and technological adaptation, will enhance the robustness of investment strategies and guide the agricultural sector toward more sustainable and profitable outcomes.

5. Conclusions

According to the results of the study, it can be concluded that capital investments for agricultural production play a significant role. However, the use of capital investments does not always ensure efficient land use. Correlation-regression analysis has shown that capital investments in land do not affect the increase in the volume of sold products (goods, services) of agricultural, forestry, and fishery enterprises and production costs. The absence of a linear relationship indicates the insufficiency of the capital investment factor alone to ensure efficient land use.

This suggests that land, as a primary resource, must be complemented by additional investments in infrastructure, technology, and human capital to leverage its potential for increasing productivity and profitability truly.

The influence of capital investments in other types of assets, the return on which ensures the growth of performance indicators, is substantiated. In particular, investments in modern machinery, technological advancements, and innovations play a crucial role in improving productivity.

Against this background, investing in intangible assets (software, intellectual property, digital infrastructure) allows stimulating agriculture, forestry, and fisheries through an increase in the volume of products sold (goods, services) of enterprises and production costs.

Using the method of analysis of the operating environment, the possibilities of achieving effective land use through capital investments were investigated over a period of ten years, which allowed constructing an efficiency line and proving an acceptable level of efficiency in general under the conditions prevailing during 2014-2023.

The dynamic assessment of efficiency during this period indicates the need for a more adaptive investment strategy, one that aligns with market shifts and evolving production practices.

In addition, an approach was proposed that allows, through the design of the positions of «effective» years, to optimize the efficiency line for future planning of both performance indicators (volume of products sold and production costs) and capital investments for agricultural, forestry, and fishery enterprises.

This strategic approach offers the potential to guide future investments more effectively, ensuring sustainable growth and improving the competitiveness of agricultural enterprises within the broader national economy.

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