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STRATEGIC MANAGEMENT AND ESG IMPACT ASSESSMENT IN SUSTAINABLE AGRIBUSINESS DEVELOPMENT MODEL

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Introduction. Hostilities in Ukraine pose challenges to the agro-industrial complex, including contamination of agricultural land, logistical route complications for the sale of agricultural products, and labour resource shortages. These concerns negatively impact the economic activities of agricultural enterprises, as well as food and environmental security, in Ukraine and globally. To ensure the sustainable operation of agricultural enterprises, it is necessary to conduct a comprehensive study of environmental, social, and governance (ESG) components to develop effective management strategies.

Aim and tasks. This study aims to develop a comprehensive, economically justified, and flexible system of ESG indicators that can enhance the efficiency of integrating environmental, social, and governance components with the strategic aspects of an enterprise's economic activity.

Results. Using the hierarchy analysis method, a three-level model comprising target, criterion, and specific indicator levels was constructed to assess the impact of ESG factors on an enterprise's operations. Calculating ESG indicators for the environmental component revealed the need to reduce CO_2 emissions and decrease the energy intensity. The social component exhibits a strong position in terms of wages and low injury rates, whereas it has a high staff turnover rate. An effective anti-corruption policy characterises the governance component, but there is insufficient implementation of digital management tools. The highest ROIC increase was observed when all the ESG components increased simultaneously. For example, a 0.14% increase in the environmental component (E) results in a combined increase of 0.50-0.63% with the social (S) and governance (G) components. The situation is similar for the social component, where a 10% increase leads to a 0.15% increase in ROIC. The governance component (G) demonstrates the most significant individual effect (0.16%), along with the environmental and social components, which increase by 0.62% and 0.63%, respectively.

Conclusions. A comprehensive system of ESG performance indicators ensures the effectiveness of a company's environmental, social, and corporate social responsibility, as well as its financial performance, competition, innovation, and sustainability. The three-level model enables the assessment of both the direct impact of each ESG component on the enterprise's activities and their interactions, creating a synergistic effect on the agricultural sector.

Keywords: Agribusiness, ESG Factors, Environmental Indicators, Hierarchy Analysis Method, Sustainability.

1. Introduction.

In the current conditions of transformational economic dynamics, environmental, social, and governance (ESG) factors have evolved from an element of corporate social responsibility (CSR) into a strategic, comprehensive tool for risk management, improving operational efficiency, and achieving sustainable development (Cristea et al., 2024). This is especially relevant and necessary for the proper functioning of the agricultural sector, as its operation is directly dependent on natural resources and the social environment, and it serves as a key pillar of food security and environmental security.

However, in Ukraine, as well as at the global level, significant contradictions and challenges remain, particularly the lack of unified standards for assessing ESG factors, the subjectivity of social and governance indicators, the fragmentation of approaches to data aggregation, and the imperfect format of ESG reporting (Zaroni et al., 2025). The effective implementation of ESG principles in the strategic management of enterprises is becoming increasingly complex, which, in turn, reduces its attractiveness to investors and other stakeholders. Insufficient implementation and integration of these principles can lead not only to misalignment with changing market expectations and regulatory requirements but also to reputational risks, lost opportunities for sustainable growth, and potential long-term financial inefficiency.

To overcome these limitations, a science-based, comprehensive system of key performance indicators (KPIs) for ESG factors is currently needed, with particular adaptation to the specifics of agricultural production.

2. Literature Review.

The estimation of social initiatives of more than 4,500 firms provided by the Thomson Reuters ESG database, as well as an investigation into the interrelations between social initiatives and the results of a company's activities, revealed that social investments are a mechanism intended to create value for businesses, which leads to the improvement of financial indicators in terms of operational performance and indicators of the stock market.

It was found that companies with high agency costs often invest in social initiatives to increase labour productivity, ensure compliance, and increase responsibility for product quality (Bhaskaran et al., 2025). Interpreting the determinants of ESG performance is both a key goal of corporate strategic management and a crucial basis for addressing pressing global environmental and social challenges. Most studies focus on the internal determinants of ESG performance rather than external ones (Crace & Gehman, 2023; Wong et al., 2023). This may be since internal determinants are easier to measure and control, whereas external determinants may be more complicated to quantify.

However, ignoring the external determinants of ESG performance may cause problems, as it can lead to an incomplete understanding of the factors that influence long-term sustainable performance (Martiny et al., 2024). ESG reports should expand beyond company-oriented activities and shift from current accounting methods to meet the requirements for disclosing information about ESG. It is proposed to apply digital technology, specifically the "Industry 5.0", to enhance the display of ESG criteria and provide more comprehensive reporting, thereby expanding the decision-making capacity of firms and investors to achieve sustainable development goals (Yadav et al., 2024). Lagodiyenko (2024) identified the main challenges faced by business entities when assessing compliance with ESG parameters.

These challenges primarily include the lack of universal standards, insufficient public accessibility and transparency of data, subjective approaches to evaluating factors under investigation, and the absence of informational, consultative, and technical support necessary for implementing ESG criteria. To overcome these challenges, businesses, government authorities, local self-government bodies, and international institutions have to target their efforts to ensure sustainable development and enhance the long-term competitiveness of enterprises (Lagodiyenko, 2024). Holovchak (2024) considers ESG reporting to be a tool for increasing business transparency.

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Simultaneously, the study highlights several unresolved issues, particularly the uncertainty of the regulatory framework, the lack of standardised methodologies, the weak motivation of business entities to implement ESG requirements, and the low quality of the available data (Holovchak, 2024).

These unresolved issues are crucial for the domestic economy and its business entities, as the practical implementation of the ESG approach is still in its early stages of development. Hence, the study suggests normalising the standards, developing guidelines for investors, and providing recommendations to ensure the objective disclosure of potential risks (Cort & Esty, 2020).

It has been clarified that the E-factor has a positive influence on the performance of agribusiness, as environmental improvement is a fundamental factor in the industry's economic security. Research emphasises the importance of rational utilisation of agrochemical resources, effective soil management, and fertiliser application. Government policies must also target ecological planning and sustainable production. Optimal fertiliser application enhances the economic stability of agricultural enterprises by maintaining ecological balance and promoting effective resource management (Honcharuk et al., 2024; Strelbytska et al., 2025).

In addition, when exploring the principles of a "green" economy, Koval et al. (2025) adhere to the idea that green development can be achieved if environmental and economic policies are combined to achieve social progress, economic growth, and improve the quality of life of the population by reducing threats to the environment.

Digitalisation technologies, such as ESG tools, can systematise technological and production processes, enhance operational efficiency, improve the financial outcomes of a business entity as a whole, and reduce costs. In particular, the highlighted technologies, such as precision agriculture, the use of agricultural drones to monitor field conditions, automatic irrigation systems, and robotic harvesting, have significantly enhanced operational efficiency (Tomashuk et al., 2025).

Research on the strategic development of global CSR in agribusiness (Soloviova et al., 2022) and the analysis of social entrepreneurship in labour employment (Shpykuliak et al., 2024) emphasise the importance of combining economic results with real social benefits. This claim promotes community development, ensures social integration, and fosters economic growth.

In agribusiness, this is manifested, in particular, in the implementation of practices that take into account environmental risks, promote the integration of different social groups and support the long-term economic development of the territories where enterprises operate. This approach helps companies maintain a balance between profitability and the social value of their activities, making business more responsible and sustainable in the long term.

Recent studies focused on the main aspects of sustainable development, in particular, how an integrative comprehension of sustainable development goals (SDGs) affects overall financial performance, which is measured by integrating sustainable development into the company's strategy, business model, and management (Lassala et al., 2021; Schneider et al., 2025).

Hwang (2024) demonstrates a positive relationship between financial performance and ESG indicators, highlighting that integrating ESG principles into corporate activities is both ethically sound and financially beneficial. Therefore, companies must develop clear ESG strategies, engage with stakeholders, invest in data management, seek external advice, and promote the benefits of integrating ESG principles (Hwang, 2024).

Investigating the specifics of ESG reporting and performance indicators, Nielsen (2023) reveals that recent accounting standards have introduced the concept of double materiality in sustainability reporting. A focus on financial materiality drives a financially oriented ESG perspective. This means that investors, analysts, and lenders focus on how climate-related risks may affect the future financial performance of investments and assets, typically measured by Return on Assets (ROA) and Return on Investment (ROI).

The socially oriented perspective of CSR prioritises the well-being of the planet, people, and society. Therefore, it incorporates the perspective of the impact of materiality (Nielsen, 2023). Despite numerous case studies, this issue remains insufficiently examined by scholars. This necessitates in-depth future research focused on assessing existing and developing an integrated system of KPIs for ESG factors to evaluate the environmental, social, and governance performance of companies.

3. Methodology.

3.1.Methods and Framework.

The analysis of the impact of ESG factors on the performance of agricultural enterprises is grounded in a comprehensive methodological framework that synthesises a set of research methods. The monographic method was employed to research the theoretical foundations of the ESG concept, as well as the development of approaches to analysing business sustainability and international standards for reporting sustainable development issues.

The logical-theoretical method provided a theoretical basis for developing a holistic system of performance indicators that addresses the pressing issues of environmental management, ongoing social transformations, and the need for effective corporate governance. System analysis was employed to analyse ESG factors as a multilevel system comprising three interconnected subsystems: environmental, social, and governance, each with specific indicators influencing business performance.

Computational analysis was applied to process empirical data, including the normalisation of selected indicators, calculation of integral indices, and analysis of the sensitivity of financial results to changes in ESG components using scenario modelling.

The abstract-logical method facilitated the substantiation of the theoretical synthesis of research results, identification of synergistic effects arising from the interaction of ESG dimensions, and informed the development of practical recommendations for implementing integrated ESG strategies in enterprises.

The generalisation method of the results collected at different stages of the study into a single methodological basis for assessing the impact of ESG factors on the economic activities of agricultural enterprises.

The specialised mathematical methods applied are as follows:

- The polygon method is a geometric approach to integrating partial key performance indicators into a single comprehensive indicator, an integrated ESG indicator. Unlike simple weighted averages or other scalar aggregation techniques, this method preserves the structural relationships between the individual components of the overall indicator, providing a visual representation of a company’s ESG profile. This approach contributes to a deeper understanding of the spatial configuration of an organisation’s sustainability methods. Hierarchical analysis, also known as the Analytic Hierarchy Process (AHP), was used to formalise the system of ESG indicators, develop a hierarchical model, create matrices of pairwise comparisons, and determine weight coefficients that reflect the relative importance of individual indicators. In contrast to purely statistical methods, such as the principal component method or the -based approach, AHP provides the possibility of integrating subjective expert judgments, which is of fundamental importance in conditions of heterogeneity, high variability, and partial uncertainty in ESG indicator measurement.

- Regression analysis was used to identify, quantitatively measure, and statistically verify the relationship between an integrated ESG index and the financial performance of companies. Compared to more complex algorithmic machine learning approaches or nonlinear models, regression analysis offers a high level of interpretability, enabling the clear identification of the direction, strength, and statistical significance of the impact of ESG components on financial performance while controlling for confounding factors.

3.2. Data Sources.

The research was implemented using the case study methodology (in-depth analysis of a single case) based on Selyshchanske LLC during 2019-2023.

The choice of this research object is driven by the need for access to detailed financial and non-financial data, which can only be obtained through close cooperation with the enterprise's management and access to internal documents.

The enterprise operates under the NACE code 01.11 "Growing grain crops (except rice), legumes and oilseeds", which is the most representative segment of the agricultural sector of Ukraine. This type of activity forms the basis of domestic exports, provides a significant share of the gross added value of agriculture, and plays a crucial role in the state's food security.

To ensure a comprehensive analysis, both primary data from the enterprise's official reporting and information obtained through structured management surveys were utilised. In particular, financial indicators and quantitative ESG indicators were selected from official sources, Form No. 1 "Balance Sheet" (Statement of Financial Position), Form No. 2 "Statement of Financial Results" (Statement of Comprehensive Income), as well as from production reports, agrotechnical documentation and human resources records. Qualitative management indicators were obtained through a survey of the enterprise's management team. All indicators were normalised to a 0-1 scale to ensure comparability and aggregation into an integral ESG index.

3.3. ESG Indicators Assessment.

To ensure the methodological validity of this study, three main research hypotheses were formulated.

H1. Improving the integral ESG indicator has a positive and statistically significant impact on the profitability of the invested capital of an agricultural enterprise (the systematic implementation of ESG practices creates additional economic value by optimising resource use and increasing labour productivity).

H2. ESG components have different strengths of influence on the financial outcomes of an enterprise, with the environmental component demonstrating the highest coefficient of influence in the context of agricultural production (environmental factors directly impact yield and production costs).

H3. Simultaneous improvement of all three ESG components creates a synergistic effect that exceeds the sum of their individual impacts on financial efficiency (testing the presence of a positive correlation between ESG components and the integral quality of the financial efficiency of a business entity).

4. Results.

Over the past few decades, the foundations and principles underlying ESG performance measurements have undergone significant transformation. Early models of corporate social responsibility (CSR) primarily focused on charitable and voluntary activities, as well as adherence to ethical standards and principles.

Simultaneously, performance management and impact assessment issues are often overlooked (Carroll, 1999). With growing attention to sustainable development and the increasing importance of globalisation, the focus of CSR has expanded to include issues of environmental protection and conservation, intergenerational justice, and demographic change, as reflected in concepts such as the triple bottom line (Elkington, 1997). The transition from CSR to ESG entails a more systematic approach to sustainability assessment, with strong integration into an entity's financial and strategic processes. This evolution demonstrates a general transformation in the global perspective on sustainable development, shifting from an external social function to a key component of value creation and risk management (Livoshko, 2022).

Globally, there are some frameworks and standards for ESG reporting and evaluation:

1) Global Reporting Initiative (GRI) as a framework that includes standards for reporting on environmental, social, and governance issues.

2) Sustainability Accounting Standards Board (SASB) focused on financially important ESG factors with indicators intended for investors engaged in decision-making;

3) TCFD is a group dedicated to disclosing financial data on climate change. It invites companies to provide data on how they organise climate risk management.

4) The International Integrated Reporting Council (IIRC) promotes integrated thinking and reporting, connecting financial performance and sustainable development effectiveness through six capitals: financial, production, intellectual, human, social/relational, and natural;

5) The International Sustainability Standards Board (ISSB) is an initiative of the International Financial Reporting Standards Foundation (IFRS Foundation) established to develop global standards for corporate sustainability disclosure. The ISSB aims to provide investors with high-quality, understandable, and comparable information on risks and opportunities related to climate change, resource use, social aspects, and management practices.

6) EU Taxonomy is a classification system developed by the European Commission that establishes standard criteria for identifying economic activities that can be considered environmentally sustainable (Seletska, 2024; Yadav et al., 2024). Its main goal is to create a single, understandable "language field" for all market participants, enabling investors, businesses, and government agencies to determine which projects meet the criteria for sustainable development clearly.

Despite the widespread adoption of frameworks, several problems remain in ESG measurement. In particular, different methodologies use different schemes for weighting and aggregating ESG indicators; there is a factor of incomplete disclosure of information at enterprises; there is a lack of data for specific indicators, especially social ones; the comparability of results is limited due to differentiation in the methods used to calculate integrated ESG indicators; and there is temporal inconsistency of measurement approaches. Thus, availability of equal ESG standards and calculation methodologies has created fragmented methodological uncertainty. Based on the above factors, there is a need to develop a comprehensive, flexible, and economically justified system of ESG performance indicators that can effectively integrate environmental, social, and governance components with the strategic and operational aspects of the economic activities of the enterprise.

The system of ESG performance indicators responds to three forces:

1) Environmental awareness and climate change – current environmental challenges require companies to provide a more transparent and accurate reflection of their impact on the environment. This promotes the development of environmental indicators, such as resource use, reduction of the greenhouse effect, and the use of renewable energy sources (Honcharuk et al., 2024; Okhota et al., 2024).

2) Social transformations and expectations: the growing importance of social issues, including higher living standards, guaranteeing human rights, and inclusion, forces businesses to consider the social effects of their activities. Markets and consumers demand more social responsibility from companies, which pushes them to measure and report on aspects such as workplace quality, community engagement, and support for diversity.

3) The need for effective corporate governance – the growing interest of investors in the stability and ethical standards of corporate governance has contributed to the formation of high requirements for transparency, risk management, and compliance with regulatory requirements.

The modern ESG system enables the integration of indicators that reflect the quality of management processes, corporate ethics, and internal controls, thereby strengthening investor and partner trust.

KPIs are crucial for translating strategic objectives into concrete, measurable indicators that track progress and inform management decisions (Alsayegh et al., 2020; Martiny et al., 2024).

ESG factors are crucial for risk management, attracting investments, introducing innovations, developing and implementing effective strategies, fostering relationships with stakeholders, enhancing brand reputation and image, improving operational efficiency, and ensuring long-term business sustainability. In a dynamic environment, compliance with ESG principles is crucial for meeting regulations and entering new global markets that prioritise sustainability (Folqué et al., 2021; Flaga-Gieruszyńska et al., 2024).

Investors tend to consider ESG indicators, as companies with high ESG ratings are often more resilient and less exposed to various risks (Zumente & Lāce, 2021).

Environmental (E) indicators determine a company's impact on natural systems and its management of environmental risks. These indicators encompass several areas of environmental concern and typically include both absolute and intensity-based values to facilitate meaningful comparisons across businesses of varying sizes and sectors. Social (S) KPIs evaluate the relationship between a business and its employees, customers, suppliers, and community. These indicators encompass issues related to labour relations, respect for human rights, product quality and safety, and interactions with local communities. Governance (G) indicators evaluate the mechanisms of corporate leadership, ethics, and accountability. These indicators evaluate the Board, stakeholder engagement, structures and processes that guide corporate decision-making (Okhota et al., 2024).

The process of choosing partial indicators for ESG KPIs involves identifying aspects of sustainable development. This approach, known as "double materiality", ensures consideration of both financial and non-financial aspects, focusing on the issues that are most important for the enterprise and its stakeholders. Typical evaluation includes the following stages:

• Problem identification for developing a complete list of potentially important topics based on international standards, stakeholder expectations, and industry benchmark analysis.

• Impact assessment to determine the priority of each issue in terms of its economic value and impact on society and the environment.

• Stakeholder consultation for gathering the views of various stakeholder groups on the significance of issues and the level of their impact.

• Prioritising the ranking of identified issues and potential actions based on financial capacity and scale of influence.

• KPI determination for selecting specific indicators to assess performance in the most important areas.

The multi-level ESG performance indicator system proposed below is based on five principles.

– Indicators are selected based on the principle of materiality, and priority is given to those indicators that have a direct impact on the formation of the value of the enterprise and the results that are significant for its stakeholders.

– Preference for quantitative metrics whenever possible; preference is given to quantitative indicators, which promote accurate assessments and ensure their consistency over time and between enterprises.

– Flexibility and adaptability of assessment – attention is paid not only to recording current results but also to analysing the dynamics of changes, which reflects the direction of development and the ability of the enterprise to improve.

– Maintaining a balance between general and sectoral approaches – combining universal ESG indicators with sector-specific ones ensures a deeper understanding of the key challenges of a particular business and a sound assessment of its potential for implementing a sustainable development strategy.

– Focus on achieving results that emphasise actual performance indicators rather than describing the process or methodology.

Considering the principles, the study developed the ESG performance indicator system using the Analytic Hierarchy Process (AHP) proposed by Saaty (2013). This allowed development a three-level model (Table 1), which includes the target level (integral ESG assessment), criteria level (environmental, social, and governance components), and level of specific indicators (quantitatively measured performance indicators):

Level 1. The ESG integral indicator measures the impact of ESG factors on an enterprise's activities.

Level 2. Group ESG indicators include environmental, social, and governance characteristics.

Level 3. Partial ESG indicators comprise a set of quantitative and qualitative indicators tailored to the specific needs of agricultural production.

Table 1. Three-Level Model of Integral ESG Indicator.

Level 1. Integral ESG indicator					
Assessment of ESG performance indicators in agribusiness operation					
Level 2. Group ESG indicators					
Environmental	Symbol	Social	Symbol	Governance	Symbol
Level 3. Partial ESG indicators					
Water consumption per ha (m^3/ha)	e_1	Average salary per month (UAH/month)	s_1	Availability of an anti-corruption policy (yes/no)	g_1
CO_2 emission per ton of production (t CO_2/t)	e_2	Staff turnover (%)	s_2	External audits per year (units)	g_2
Share of land where chemical fertilisers are not applied (%)	e_3	Gender balance ratio, %	s_3	Level of compliance with land-use regulatory norms (yes/no)	g_3
Share of recycled waste (%)	e_4	Employee training (hours/year)	s_4	Level of business process automation, %	g_4
Energy intensity of production (kWh/t)	e_5	Workplace injury rate (cases per 1,000 employees)	s_5	Frequency of updating the enterprise development strategy (times/year)	g_5

Source: based on Okhota et al. (2024), Honcharuk et al. (2024).

The application of the AHP method's tools enables the tailoring of the system of indicators to the specific characteristics of the agricultural industry, considering its unique environmental, social, and governance aspects. In addition, using the matrices of pairwise comparison, weight normalisation, and checks of consistency guarantees the objectivity and consistency of expert opinions.

This system of indicators provides a foundation for quantitative estimation by simplifying the assignment of weight coefficients to each KPI and establishing a basis for calculating integrated ESG performance. The method involves a complex analysis as it determines the relative contribution of each component to the overall ESG profile of the enterprise.

The formalisation of complex relationships between ESG factors and a company's economic efficiency demands consistency and analytical flexibility. A hierarchical structure of the system of indicators can ensure this. Weights obtained through the AHP method can assist in estimating the current state of sustainable development and provide a basis for further integration with other methods of analysis, such as econometric modelling and the polygon method.

An approach should be developed that combines the AHP method, the method of polygons, and econometric modelling of financial indicators, such as ROIC, to analyse and forecast the influence of ESG on financial results.

The tools developed for conducting a quantitative evaluation of the impact of ESG factors on business processes make this approach unique. It combines the capabilities of economic modelling, geometric aggregation, and objective assessment of data quality to provide a holistic view of the relationship between sustainable development and enterprise efficiency.

It predicts the impact of environmental, social and governance initiatives on an enterprise's financial performance and creates a unified, integrated ESG indicator. This approach enables consideration of the complexity of ESG factors, their interactions, and the nonlinear effects they have on a company's competitiveness. The implementation of this method involves a step-by-step data processing process, from basic evaluations of certain indicators to forecasting financial results. The weighting coefficients for each key performance indicator (environmental, social, and governance) are determined using the Saaty method.

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This method is employed to structure the ESG indicator system and assess its relative importance through pairwise comparisons. The area of the polygon created from the normalised, weighted KPI values serves as an indicator of performance, as it reflects how well the different scores balance one another. This polygon method enables the combination of weight KPIs into a single result for each ESG dimension (E, S, and G), ultimately combining them into one overall ESG score. A panel econometric model predicts a financial indicator (ROIC) based on integral ESG indicators, their interactions with, and additional control variables. The AHP method involves defining a hierarchy of indicators and constructing pairwise comparison matrices.

The weighting coefficients are obtained by normalising the eigenvector of the comparison matrix, while the consistency of the judgments is evaluated using the consistency index (CI) and the consistency ratio (CR).

This algorithmic procedure ensures that the resulting weights reflect the priorities of the experts, providing a basis for further aggregation of indicators in a comprehensive ESG assessment.

A square matrix of size $n \times n$, where n is the number of elements (KPIs) in a particular group, forms a pairwise comparison matrix. Due to the use of the Saaty scale, the relative importance of matrix a_{ii} is expressed by matrix elements and in comparison to element j (Table 2).

Table 2. Levels of Relative Importance of Criteria Using the AHP Method.

Degree of significance	Definition	Explanation
1	Equal importance	Two actions contribute equally to achieving the goals
3	Weak importance	There are not sufficiently convincing arguments in favour of one action over another
5	Essential importance	There is reliable evidence to show the advantage of one action over another
7	Obvious importance	Convincing evidence in favour of one action over another
9	Absolute importance	Undeniably convincing evidence supporting the advantage of one action over another
2,4,6,8	Intermediate values between adjacent judgments	A situation when a compromise decision is required
$a_{ji} = \frac{1}{a_{ij}}, a_{ii} = 1$	Reciprocal value when element *j* is more important than element *i*	

The algorithm for constructing and processing a matrix of pairwise comparisons for the partial ESG indicators provided by Selyshchanske LLC is presented below. Given that the methodology for calculating partial ESG indicators and their groups is identical, the same computational procedure applies across all ESG dimensions. Therefore, only the environmental (E) component is presented as an illustrative example in the following section. Thus, the matrices of pairwise comparisons for the ESG indicators are presented in Tables 3-5.

Table 3. Matrix of Pairwise Comparisons of the Environmental Group Indicators.

	e_1	e_2	e_3	e_4	e_5
e_1	1	1/3	1/2	2	1
e_2	3	1	2	4	3
e_3	2	1/2	1	3	2
e_4	1/2	1/4	1/3	1	1/2
e_5	1	1/3	1/2	2	1

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Table 4. Matrix of Pairwise Comparisons of Social Group Indicators.

	s_1	s_2	s_3	s_4	s_5
s_1	1	3	2	4	2
s_2	1/3	1	1/2	2	1/2
s_3	1/2	2	1	3	1
s_4	1/4	1/2	1/3	1	1/3
s_5	1/2	2	1	3	1

Table 5. Matrix of Pairwise Comparisons of Governance Group Indicators.

	g_1	g_2	g_3	g_4	g_5
g_1	1	3	2	4	4
g_2	1/3	1	1/2	2	2
g_3	1/2	2	1	3	3
g_4	1/4	1/2	1/3	1	1
g_5	1/4	1/2	1/3	1	1

In the first step, it is necessary to calculate the sum of all elements for each column of the matrix using the following formula:

$$S_j = \sum_{i=1}^{n} a_{ij} \quad (1)$$

Where:

S_j – the sum of the elements in column j;

a_{ij} – the element in row iii and column j of the pairwise comparison matrix;

n – the total number of indicators.

The sum of the columns shows how “important” each sub-ESG indicator is compared to the others.

A higher column sum indicates a lower importance of the indicator, since higher values in the column mean that other indicators are rated as more important. A lower column sum, on the other hand, indicates that this indicator is often considered more important than others, which increases its priority.

Table 6. Column Sums and Relative Importance of Environmental Group Indicators.

Indicator	Water consumption	CO_2 emissions	Land without chemical fertilisers	Share of recycled waste	Energy intensity
Total	7.5	2.416	4.333	12	7.5

Note: Column sums are calculated based on the pairwise comparison matrix presented in Table 3.

At the second step, the matrix is normalised by its column sums:

$$\tilde{a}_{ij} = \frac{a_{ij}}{S_j} \quad (2)$$

Where:

$\tilde{a}_{ij}$ – the normalised value of the element in row i and column j.

S_j – the sum of the elements in column j.

Table 7. Matrix of Normalised Indicators of the Environmental Group.

	e_1	e_2	e_3	e_4	e_5
e_1	0.133	0.138	0.115	0.167	0.133
e_2	0.400	0.414	0.461	0.333	0.400
e_3	0.267	0,207	0.231	0.250	0.267
e_4	0.067	0.103	0.077	0.083	0.067
e_5	0.133	0.138	0.115	0.167	0.133

For comparison, the normalisation process places all values on a single scale (ranging from 0 to 1). The new matrix of normalised indicators reflects the relative importance of each indicator in each category. Without this action, the further calculation of weights would be incorrect.

When creating an integrated ESG indicator, assessing the sustainability of an agricultural enterprise may be economically unjustified if the normalised values of partial ESG indicators are used without considering their relative significance. This is explained by the fact that all indicators will influence the integrated ESG indicator with the same force; that is, their influence will be balanced:

$$w_i = \frac{1}{n} \quad (3)$$

Where:

w_i – the weight assigned to the i indicator;

n – the number of KPIs in the category.

As different KPIs have varying levels of importance, this level does not always accurately reflect the actual situation in socio-economic systems, such as agricultural enterprises. In addition, since it is not known which indicator has a stimulating or de-stimulating effect on the overall effectiveness of the ESG system, the approach makes it challenging to determine the causes of the system's deterioration or strategies for its improvement.

Although the effect may be appropriate in some situations, it is possible only under the condition of stable system functioning and the expected equal influence on all factors. Neutralising the negative impact of partial ESG indicators is necessary because the assessment of complex socio-economic systems, such as the ESG profile of a company, is based on the accumulation of numerous partial indicators that have different impacts on the overall indicator. To do this, the hierarchy coefficients (weights) obtained using the AHP method are introduced, which allow the KPIs to be distributed according to their level of influence on the overall ESG indicator.

The weight (wi) is a numerical value from 0 to 1, indicating the relative importance of each partial ESG indicator compared to others within the same category. The weight sum of all indicators in a category always equals 1. This makes them comparable to fractions of 100 per cent. The greater the weight, the stronger the KPI influences the final score (integral ESG indicator or financial outcome), since its value has greater "power" in the calculations.

Thus, in the third step, the weights of each studied partial ESG indicator are determined by calculating the average value of the normalised elements in the row:

$$w_i = \frac{1}{n}\sum_{j=1}^{n} \tilde{a}_{ij} \quad (4)$$

Table 8. Matrix of Weighting Coefficients of Indicators of the Environmental Group.

	e_1	e_2	e_3	e_4	e_5	w
e_1	0.133	0.138	0.115	0.167	0.133	0.137
e_2	0.400	0.414	0.461	0.333	0.400	0.402
e_3	0.267	0.207	0.231	0.250	0.267	0.244
e_4	0.067	0.103	0.077	0.083	0.067	0.079
e_5	0.133	0.138	0.115	0.167	0.133	0.137

The obtained weight coefficients are used when combining the econometric model and polygon method. To assess the degree of influence of each indicator on the result, the integral ESG indicator and the forecasted financial indicator (ROIC) were used.

The fourth step is a consistency check. Using the logical relationships between the indicators, the consistency check ensures that the scores in the pairwise comparison matrix do not equal one. This ensures the reliability of the weights used for the partial ESG indicators in calculating the integral ESG indicator, thereby allowing the analysis results to be trusted. If CR < 0.1, the estimates were consistent and could be confidently used for decision-making.

The consistency check includes several stages.

1. Calculating the pairwise comparison vector $(Aw)_i$:

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$$(Aw)_i = \sum_{j=1}^{n} a_{ij}\, w_j \quad (5)$$

Where:

$(Aw)_i$ – the product sum of matrix's i-th row elements of pairwise comparison (a_{ij}) for the corresponding weights (w_j) of all indicators.

This indicator reflects how the matrix "predicts" the importance of the i-th indicator based on the weights.

2. Determining the ratio of the pairwise comparison vector $(Aw)_i$ to the calculated weights

$$P = \frac{(Aw)_i}{w_j} \quad (6)$$

The ratio shows how well the predicted importance ($(Aw)_i$) corresponds to the actual weight (w_j). In an ideal matrix, this ratio equals n (the number of indicators), but in real matrices it slightly deviates due to inaccuracies in the evaluations.

3. Determining the maximum eigenvalue (λ_{max}):

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(Aw)_i}{w_j} \quad (7)$$

In a fully consistent matrix $\lambda_{max} = n$.

If $\lambda_{max} > n$, this indicates a certain level of inconsistency of estimations. The higher the deviation is, the less consistent the matrix is.

4. Determining the consistency index (CI):

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (8)$$

It measures the degree of the deviation of the matrix from ideal consistency. If $CI = 0$, the matrix is perfectly consistent. A positive value of CI indicates the presence of unforeseen factors of influence.

5. Determining the consistence ratio (CR):

$$CR = \frac{CI}{RI} \quad (9)$$

CR compares CI to the random index (RI), which is the average CI for randomly filled matrices of the same size.

For $n = 5$, $RI = 1.12$, if $CR < 0{,}1$ (10%), the matrix is considered sufficiently consistent, and the evaluations can be used. If $CR \geq 0{,}1$, the estimations are too contradictory, and the matrix needs to be revised.

To ensure methodological consistency and avoid excessive detail in identical computational procedures, the following step-by-step calculation algorithm was provided exclusively for environmental component indicators. This approach enables us to clearly demonstrate the logic of applying the hierarchy analysis method without duplicating similar settlement operations for the social and managerial components, which are performed according to an identical scheme.

Thus, for each examined indicator of the environmental component, the pairwise comparison vector $(Aw)_i$ was calculated, and the ratio for each indicator was computed (Table 9).

Table 9. Pairwise Comparison Vectors of Environmental Group Indicators.

	e_1	e_2	e_3	e_4	e_5	$(Aw)_i$	P
e_1	1	1/3	1/2	2	1	0.689	5.021
e_2	3	1	2	4	3	2.032	5.057
e_3	2	1/2	1	3	2	1.233	5.048
e_4	1/2	1/4	1/3	1	1/2	0.399	5.019
e_5	1	1/3	1/2	2	1	0.689	5.021
w	0.137	0.402	0.244	0.079	0.137	-	25.166

The maximum eigenvalue of the matrix (λ_{max}) is calculated based on formula 7 as follows, and is shown in Table 10.

The indicators of the social and managerial components are calculated using an identical methodology: for each indicator, a matrix of pairwise comparisons is formed, a vector of priorities is calculated, the consistency of judgments is verified, and weight coefficients are determined (Table 10).

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Table 10. A System of Weighting Coefficients of Partial KPIs for Determining an Integral ESG Indicator.

Group of indicators	Partial indicators	Weight indicators	Consistency indicators
Environmental	Water consumption	0.137	λ_{max}= 5.033 CI 0.0083 CR 0.0074
	CO_2 emissions	0.402	
	Land share	0.244	
	Waste share	0.079	
	Energy intensity	0.137	
Social	Average salary	0.375	λ_{max}= 5.035 CI 0.0087 CR 0.0078
	Staff turnover	0.121	
	Gender balance	0.215	
	Advanced training	0.074	
	Injury rate	0.215	
Governance	Anti-corruption policy	0.413	λ_{max}= 5.036 CI 0.0091 CR 0.0081
	External audits	0.154	
	Compliance with the regulations	0.257	
	IT-solutions	0.088	
	Strategy updates	0.088	

The polygon method is a tool for assessing complex systems that enables the aggregation of multiple partial ESG indicators into a single comprehensive ESG indicator by calculating the area of a polygon constructed based on the weighted values of the indicators. In the context of ESG, this method is used to evaluate each component (environmental, social, and governance) by constructing a polygon, where each indicator corresponds to an axis of the polygon. The coordinates are determined by the weighted values $z_i=x_i \cdot w_i$, where x_i is a normalised KPI value and w_i is the weight obtained using the Saaty AHP method. The area of the polygon serves as an integral indicator of the corresponding component. The calculated partial integral indicators (E, S, and G) can be used to compare enterprises, assess their sustainability, or serve as input data for an econometric model to forecast ROIC. The formula for calculating the area of a polygon for n KPI is as follows:

$$S = \frac{1}{2}\sum_{i=1}^{n} z_i\, z_{i+1} sin\left(\frac{360^{\circ}}{n}\right) \quad (10)$$

Where:

$z_i = x_i * w_i$ – a weight value of i-th KPI, where x_i is the normalised KPI value (0-1);

w_i – the weight from the Saaty AHP;

z_{i+1} –a weight value of the next KPI, with $z_{i+1} = z_1$, which closes the polygon;

$sin\left(\frac{360^{\circ}}{n}\right)$ – the sine of the angle between adjacent vertices of the polygon, which depends on the number of indicators n. This angle reflects the uniform distribution of vertices along a circle;

1/2 – a coefficient arising from the triangulation method (dividing the polygon into triangles from the centre).

The formula considers the geometry representing the polygon, where the vertices are located on the circle, and the weight values determine their coordinates.

The products $z_i z_{i+1}$ represent the contribution of each pair of adjacent indicators, while multiplication by $sin\left(\frac{360^{\circ}}{n}\right)$ takes into account the angle between the axes, which influences the area.

For n=5 (KPI number in each component):

$$\sin\left(\frac{360^{\circ}}{\mathrm{n}}\right)=\sin\left(\frac{360^{\circ}}{5}\right), \sin(72^{\circ})\approx 0.951$$

To apply the polygon method, KPI values were normalised to the range 0-1 to unify different units of measurement, and their weighted values were calculated according to their relative importance (Table 11).

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Table 11. Normalised Partial KPIs (2023).

	e_i	w_i	z_i
e_1	0.8	0.137	0.110
e_2	0.6	0.402	0.241
e_3	0.7	0.244	0.171
e_4	0.9	0.079	0.071
e_5	0.5	0.137	0.069
s_1	0.9	0.375	0.338
s_2	0.4	0.121	0.048
s_3	0.7	0.215	0.151
s_4	0.6	0.074	0.044
s_5	0.8	0.215	0.172
g_1	1	0.413	0.413
g_2	0.6	0.154	0.092
g_3	0.9	0.257	0.231
g_4	0.5	0.088	0.044
g_5	0.7	0.088	0.062

The formula for the polygon area involves calculating the sum of the products of neighbouring weighted values according to the formula $\sum_{i=1}^{n} z_i z_{i+1}, z_{n+1} = z_1$ that reflects the relationship between neighbouring indicators, which affects the shape of the polygon.

The "interaction" of partial ESG indicators in a polygon will have the following form (Table 12).

Table 12. Matrices of Interaction Effects of Partial ESG Indicators in a Polygon.

Environmental indicators						
	e_1	e_2	e_3	e_4	e_5	sum
e_1	0.110				0.110	
e_2	0.241	0.241				
e_3		0.171	0.171			
e_4			0.071	0.071		
e_5				0.069	0.069	
	0.027	0.041	0.012	0.005	0.008	0.092
Social indicators						
	s_1	s_2	s_3	s_4	s_5	sum
s_1	0.338				0.338	
s_2	0.048	0.048				
s_3		0.151	0.151			
s_4			0.044	0.044		
s_5				0.172	0.172	
	0.016	0.007	0.007	0.008	0.058	0.096
Governance indicators						
	g_1	g_2	g_3	g_4	g_5	sum
g_1	0.413				0.413	
g_2	0.092	0.092				
g_3		0.231	0.231			
g_4			0.044	0.044		
g_5				0.062	0.062	
	0.038	0.021	0.010	0.003	0.025	0.098

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Based on the obtained data, the area of the polygon for each KPI was calculated (Table 13).

At this stage, several key conclusions can be drawn: the environmental component (E) – a low area ($S_E = 0.0438$) indicates the need to improve CO_2 emissions and energy intensity.

Agricultural enterprises can invest in emission-reducing technologies (e.g. biogas plants) and energy-efficient equipment. Social component (S) – the area ($S_S = 0.0456$) reflects strong positions in wages and injury rates, but high staff turnover requires attention.

Table 13. Results of Polygon Area Calculation for KPIs.

Component	Calculation	Result
Environmental (E)	$S_E=\frac{1}{2}\cdot 0.0921\cdot 0.951$	0.0438
Social (S)	$S_S=\frac{1}{2}\cdot 0.0960\cdot 0.951$	0.0456
Governance (G)	$S_G=\frac{1}{2}\cdot 0.0979\cdot 0.951$	0.0466

Possible measures include improving working conditions and fostering a positive corporate culture. The governance component (G) – the most significant area – ($S_G = 0.0466$) indicates strong management, particularly in anti-corruption measures. However, IT solutions and strategies have development potential, for example, through the implementation of digital management systems. Comparing the partial indicators with the benchmark helps understand what the area would like in case all KPIs had ideal, normalised values ($x_i = 1$), and the weights were as follows. Table 14 presents the results of this comparison for the Environmental ESG components**.**

The maximum (ideal) area for (5 KPIs in each category) is as follows.

$$S_{max} = \frac{1}{2} * 5 * 1 * 1 * sin(72^{\circ}) \approx 2.3778$$

The actual areas are compared with the benchmark using two formats:

– the difference: $S_{max} - S$ is to see how much smaller the actual area is compared to the ideal one.

– percentage of the maximum: $\frac{S}{S_{max}} * 100\%$ to assess what proportion of the ideal value has been achieved.

A graphical interpretation of the obtained data is given below (Fig. 1).

Table 14. Differences and Relative Achievement of ESG Partial Indicators (2023).

Component	$S_{max} - S$	$\frac{S}{S_{max}} \cdot 100\%$
Environmental component (E)	2.3340	1.84%
Social component (S)	2.3322	1.92%
Governance component (G)	2.3312	1.96%

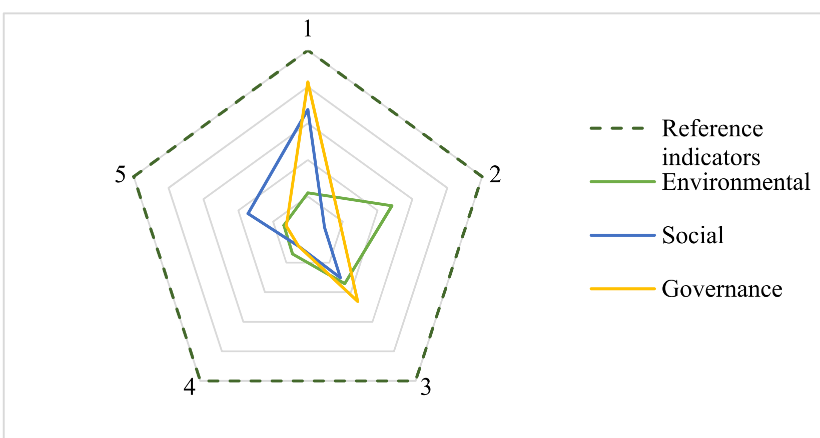

Fig. 1. Polygon of the Integral ESG Indicator (2023).

The polygon for the three components (E, S, G) is constructed using the vertices S_E, S_S, S_G according to the following formula:

$$S_{ESG}=\frac{1}{2}\sum_{i=1}^{3} S_i S_{i+1} \sin\left(\frac{360^\circ}{3}\right),\ S_4=S_1 \quad (11)$$

where $n = 3$ (three components).

The "interaction" of three ESG components in the polygon can be represented as follows (Table 15). Based on the data obtained, the area of the polygon of ESG components is calculated $S_{ESG} \approx 0{,}0026$ is an integral indicator that aggregates all three ESG components.

Table 15. Matrix of Effects of Mutual Influences of ESG Components.

	S_e	S_s	S_g	E
S_e	0.0438		0.0438	
S_s	0.0456	0.0456		
S_g		0.0466	0.0466	
z_4			0.071	
z_5				
	0.0020	0.0021	0.0020	0.0061

The small value of the area is explained by low values of the partial indicators, which are far from ideal. By analogy with the calculation of the "ideal" area for partial ESG KPIs, the ideal area of the polygon for ESG components (n = 3) is calculated as S_{ESG}=1.299.

As shown, the overall ESG indicator is only 0.20% ($S_{ESG} \approx 0{,}0026$) of the ideal value, and the difference of 1.299 units emphasises the significant gap between the current and ideal states. A graphical interpretation of the obtained data is presented in Fig. 2.

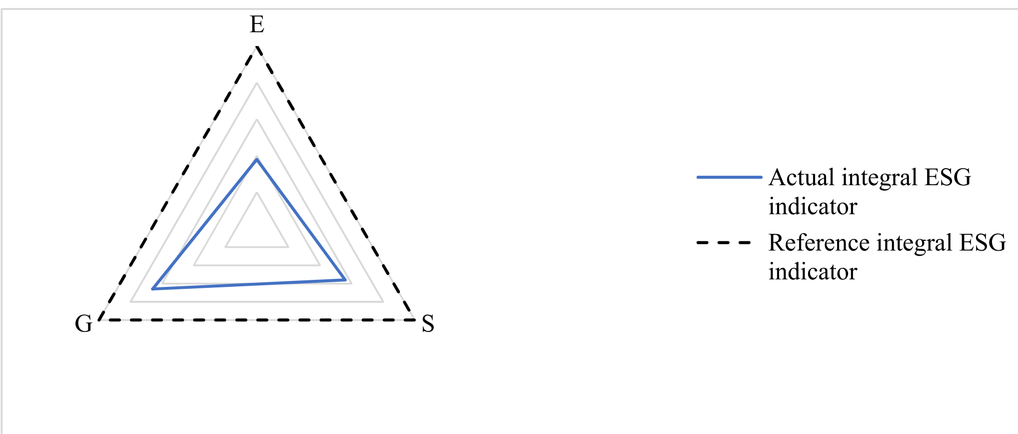

Fig. 2. Polygon of the Integral ESG Indicator.

The data obtained reflect the level of sustainability of enterprises in the environmental, social, and governance spheres, as well as their complex impact. However, to assess the impact of sustainability on the financial performance of the enterprise, an econometric model was developed that allows us to predict a key financial indicator, such as ROIC, considering the obtained ESG indicators.

To forecast the financial performance of an enterprise, an original econometric model was proposed that considers both the direct effects of ESG components and their interactions to assess the synergistic effect:

$$ROIC_{i,t}=\alpha+\beta_1 E_{i,t}+\beta_2 S_{i,t}+\beta_3 G_{i,t}+\beta_4 (E\times S)_{i,t}+\beta_5 (E\times G)_{i,t}+\beta_6 (S\times G)_{i,t}+\beta_7 ESG_{i,t}+\varepsilon_{i,t} \quad (12)$$

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Where:

$ROIC_{i,t}$ – dependent variable representing the financial indicator (ROIC) of the enterprise i at time t; $E_{i,t}, S_{i,t}, G_{i,t}$ are integral indicators of environmental, social, and governance components (S_E, S_S, S_G); $(E \times S)_{i,t}$, $(E \times G)_{i,t}$, $(S \times G)_{i,t}$ is a synergistic effect between ESG components;

$ESG_{i,t}$ – a general integral indicator; α is the constant; $\beta_{1,\dots,7}$ are regression coefficients; $\varepsilon_{i,t}$ is an error.

This is because the model enables us to assess both the direct impact of each ESG component on financial performance and its interaction, which is crucial for the agricultural sector. The agricultural industry has a significant impact on the environment, society, and economy. It also depends on the availability of natural resources and the social conditions. Therefore, sustainability is a key factor in ensuring long-term financial progress.

When interacting, ESG components may have a synergistic effect, such that the joint advancement of certain components yields a more profound result than the sum of their individual contributions.

This is particularly important for the agricultural sector due to its complexity. For example, the introduction of biogas plants not only reduces emissions (E) but also creates jobs and improves conditions in rural areas (S); governance quality (G) ensures the effective implementation of environmental technologies (E), increasing the “green” renewal of business processes; transparent governance (G) optimises social programs (S), for example, by involving employees in decision-making, which reduces staff turnover and increases efficiency.

Therefore, to estimate the model coefficients, data for 2019-2023 were used, reflecting the dynamics of ROIC and ESG indicators. The data is presented in the table given below (Table 16).

Table 16. Dynamics of ROIC and ESG indicators of Selyshchanske LLC.

Year	ROIC (%)	E	S	G	$E \times S$	$E \times G$	$S \times G$	ESG
2019	5.0	0.0350	0.0380	0.0400	0.0013	0.0014	0.0015	0.0018
2020	5.5	0.0370	0.0390	0.0410	0.0014	0.0015	0.0016	0.0019
2021	6.0	0.0390	0.0410	0.0420	0.0016	0.0016	0.0017	0.0021
2022	6.5	0.0410	0.0430	0.0440	0.0018	0.0018	0.0019	0.0023
2023	7.0	0.0430	0.0440	0.0450	0.0019	0.0019	0.0020	0.0025

To assess the impact of changes in ESG components on ROIC, a sensitivity analysis was also performed through scenario modelling, a 10% change in group ESG indicators (Table 17). The highest increase in ROIC was observed under conditions of simultaneous improvement in all ESG components, indicating a strong synergistic effect. The promotion of environmental, social, and governance practices does not simply add value “piece by piece”, whereas the interaction of these factors significantly enhances the financial impact.

Table 17. Scenario Analysis of ESG Indicator Changes and Their Effect on ROIC (2024).

Scenario	ROIC (%)	Increase (%)
Basic scenario	7.84	-
$E + 10\%$	7.98	0.14
$S + 10\%$	7.99	0.15
$G + 10\%$	8.00	0.16
$ESG + 10\%$	8.75	0.91
$E, S, G + 10\%$	8.34	0.50
$E, S, G, ESG + 10\%$	9.25	1.41
$E, S + 10\%$	8.34	0.50
$E, G + 10\%$	8.46	0.62
$S, G + 10\%$	8.47	0.63

In particular, a 1.41% increase (from 7.84% to 9.25%) in the "E, S, G +10%" and "ESG +10%" scenarios demonstrates that investments in all areas of an organisation's sustainable development can generate premium investment returns.

The environmental component (E) enhances the manufacturer's reputation, reduces environmental risks and restoration costs, and can also make "green" financial instruments more accessible to investors. However, its influence (a 0.14% increase) increased sharply when combined with other elements, resulting in a total increase of 0.50-0.63% when combined with S and G.

Social (S) initiatives offer the dual benefits of attracting talented employees and increasing customer loyalty, which in turn reduces the operating costs and staff turnover.

The impact of S+10% resulted in a 0.15% increase; however, when combined with other factors, it effectively doubled the effect compared to the impact of a single factor.

Corporate governance directly reduces risk and the cost of capital. The governance component (G), specifically transparency, ethics, quality management, and internal control, demonstrates the most significant individual effect (0.16%). However, in combination with E or S, it had an even more substantial multiplicative effect (increased by 0.62% and 0.63%, respectively).

5. Conclusions.

The implementation of ESG principles in corporate economic activities is still in its early stages in Ukraine. Legislative contradictions and a lack of unified ESG reporting complicate practical implementation. Due to the entry of domestic agricultural producers and service providers into EU markets, as well as international obligations in compliance with Ukraine's intention for European integration, large agricultural enterprises are gradually implementing ESG principles. This promotes the implementation of innovations and risk management, improves relations with stakeholders, enhances productivity, and increases operational efficiency, ensuring long-term business resilience.

It also makes them more competitive and ensures access to international markets, investments, and donor funds, which are necessary for sustainable development. Small- and medium-sized agricultural enterprises should develop their own ESG strategies to ensure financial sustainability and competitiveness. Because there are no unified standards for assessing ESG factors, and some subjectivity exists in social and management indicators, as well as fragmentation of approaches to data aggregation, we propose a comprehensive system of ESG performance indicators to assess the impact of environmental, social, and governance components on the economic activities of enterprises.

A three-level model was developed, comprising a target level, a criteria level, and a specific indicator level. This approach enables the calculation of a unified, integrated ESG indicator that considers the complexities of ESG factors, their interactions, and their impact on financial outcomes. Selyshchanske LLC was used as a model enterprise, and based on the calculations, proposals for improving its activities were recommended to be scaled to small- and medium-sized agricultural enterprises. To achieve the maximum effect on ROIC, enterprises must develop integrated ESG strategies.

1. Set clear KPIs for each ESG direction and coordinate them through a single risk management system.
2. Ensure cross-functional interaction: combine environmental initiatives with financial processes and implement "green" standards in internal reporting and control procedures.
3. Implement ESG reporting according to international standards and involve external auditors to increase investor confidence.

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