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Enhancing Innovative Potential in Ukraine's Agro-Industrial Complex: Leveraging Information Technologies for Sustainable Growth and Efficiency

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Abstract

The article analyzes key trends in enhancing the innovation potential of enterprises in Ukraine's agro-industrial complex and proposes strategies for their improvement. A model has been developed for the effective use of innovative capabilities of the regional agro-industrial pool, which adapts to various conditions. The research emphasizes significant progress in innovative processes that optimize resource management and increase productivity. It includes calculations and presents the obtained results. The study also examines the practical application of these achievements, focusing on agro-industrial companies that have successfully implemented information technologies to enhance operational efficiency, reduce costs, and promote sustainable agricultural practices. To facilitate growth and efficiency in Ukraine's agro-industrial sector, the research emphasizes the need to create a robust innovation ecosystem that combines theoretical concepts with real-world applications. Additionally, it proposes using the MS Excel FORECAST tool for analyzing future economic dynamics models. The implementation of a structured approach to strengthening innovation potential at all levels of the agro-industrial complex is expected to lead to increased investment, competitive advantages, and overall economic effectiveness for enterprises.

Keywords

Innovative potential, agro-industrial complex, information technologies, resource management, sustainable agriculture, economic efficiency.

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Introduction

The agricultural sector has traditionally been a cornerstone of Ukraine's economy, holding leading positions in global exports (State Statistics Service of Ukraine, n.d.). However, the development of the agro-industrial complex is constrained by internal management challenges, outdated technologies, and, critically, the destruction of infrastructure due to the ongoing war. Despite these threats, the sector's recovery relies on enhancing the innovation potential of enterprises. The objective of this research is to analyze key trends in the agro-industrial complex and identify strategies for strengthening its innovation potential to ensure competitiveness and economic resilience.

The concept of innovation potential is widely explored through resource theory (Lavrenenko et al., 2021; Stræte et al., 2022) and various assessment methodologies (Savytskyi, 2019; Hryhoruk et al., 2020; Piletska and Tkachenko, 2020; Saunila, 2020; Shvets and Dubei, 2021). The integration of innovations is recognized as a crucial factor for competitiveness in both classical and contemporary literature (Schumpeter, 1912; Thompson, 1965; Ansoff et al., 2019; Harkema, 2003; Heiets, 2009; Ferreira et al., 2020; Puzyrova, 2020; Akhtar, 2023), as well as for profit growth (Faivishenko et al., 2020; Cherep et al., 2021; Hlubish, 2021).

In the Ukrainian context, scholars have analyzed the economic development of agricultural enterprises (Andriichuk, 2013; Balanovska et al., 2021; Sabluk, 2008; Skotsyk, 2017; Smulka, 2020; Ragaza et al., 2022), regional economic security (Trusova et al., 2020), and strategic resource management (Ulyanchenko et al., 2021). Particular attention is paid to managerial aspects of innovation (Blikhar et al., 2022; Kychko et al., 2021) and the formation of cluster structures (Lis et al., 2021; Hrosul et al., 2021; Kovalial et al., 2022).

Innovations in agriculture encompass the systematic implementation of new technologies (Karnaushenko et al., 2023). "Innovation potential" is interpreted as untapped resource opportunities (Shulhina et al., 2011), readiness for innovation (Mykytiuk, 2015), or a dynamic system of transforming ideas into products (Harbar, 2021; Goodman and Wilkinson, 2023). However, current political and economic conditions—including funding deficits, logistics disruptions, and war damage (Ministry of Agrarian Policy and Food of Ukraine, 2022b)—significantly hinder this development. Therefore, further research is required to develop new forms of organizational interaction and digital models to optimize the use of limited resources (Kyrylov et al., 2024).

Materials and methods

Research objectives. The main objective of this research is to analyze the innovation potential of production enterprises in Ukraine's agro-industrial complex, focusing on agricultural machinery, processing, and agricultural enterprises. The purpose of the study is to identify the current state of innovation activities, assess enterprise development dynamics, and propose a comprehensive mechanism for activating innovation potential.

Research design. This study employs a mixed-methods approach that combines quantitative and qualitative methods of data collection and analysis to ensure a comprehensive understanding of the innovation landscape in Ukraine's agro-industrial complex.

Data collection. Quantitative data:

- Data on the number of enterprises in the agro-industrial complex from 2017 to 2023 were collected from the State Statistics Service of Ukraine. These data include the number of production enterprises (agricultural, machinery manufacturing, and processing) and their respective shares in the overall industry.
- A structured questionnaire was developed and distributed among agricultural enterprises in Kirovohrad, Ternopil, and Cherkasy regions. The survey aimed to collect data on enterprise size, types of machinery used, and the scale of innovation activities. A representative sample of 7% of agricultural enterprises from these regions was targeted.

Qualitative data:

- In-depth interviews were conducted with key stakeholders, including managers and decision-makers from selected agricultural enterprises. The interviews aimed to explore challenges and opportunities related to innovation, investment, and machinery utilization.
- Specific cases of enterprises that exemplify successful or unsuccessful innovation practices were analyzed to provide contextual understanding of agro-industrial complex dynamics.

Data Analysis. The collected quantitative data were analyzed using descriptive statistics to summarize the characteristics of the studied enterprises, including their size distribution and machinery usage. The dynamics of enterprise numbers and their innovation activities over the specified period (2016-2024) were analyzed to identify trends and fluctuations.

Qualitative data from interviews and case studies were analyzed using thematic analysis to identify common themes and patterns related to innovation potential, challenges, and improvement strategies. A comparative analysis of Kirovohrad, Ternopil, and Cherkasy regions was conducted to identify regional differences in innovation activities and enterprise operations.

Model development. A model for utilizing the innovation potential of the agro-industrial regional enterprise pool was developed. This model includes:

- Synergistic effect: Potential benefits from enterprise integration to enhance innovation potential and reduce costs.
- Innovation cycles: A framework for creating innovation cycles that promote continuous improvement and adaptation to market requirements.

Validation of findings. Data from various sources (surveys, interviews, and statistical data) were triangulated to confirm findings and enhance credibility. Preliminary results and proposed models were presented to stakeholders in the agro-industrial complex for feedback and validation, ensuring that the research addresses real challenges and opportunities.

Limitations. The research focuses on three regions, which may limit the generalizability of findings to other regions of Ukraine. Reliance on data obtained through surveys and interviews may introduce bias, as respondents may have incentives to present their enterprises in a more favorable light.

Results and discussion

Ukraine's agro-industrial complex encompasses diverse business entities, including agricultural machinery manufacturing enterprises (Am), agricultural enterprises (Ae), processing enterprises (e.g., in the food industry (Fd)), intermediary enterprises (traders), and others. This study focuses on production enterprises, particularly in agriculture, machinery manufacturing, and processing, as their innovation potential is crucial for the country's strategic development.

Table 1 presents an analysis of changes in the number of production enterprises within Ukraine's agro-industrial complex from 2017 to 2023.

From 2017 to 2023, the share of agricultural machinery manufacturing enterprises (M) in the industry and agro-industrial complex experienced moderate growth, averaging 3.67% and fluctuating from (-97) to 38 units. The dynamics of processing enterprises (F) and agricultural enterprises (A): F fluctuated between (-1%) and (+4.7%), while A ranged from (-24.7%) to (+2.7%). This information is vital for understanding the evolution of Ukraine's agro-industrial complex.

During the analyzed period, notable regional and national fluctuations in the number of agro-industrial enterprises were observed. Overall, in Ukraine, agricultural machinery enterprises increased by (+16.45%), and processing enterprises by (+6.22%), while agricultural enterprises experienced a decline of (-5.29%). This uneven dynamics among agricultural enterprises is a common trend for many regions of Ukraine, reflecting the complexity and diversity of the situation. Before the war, from 2017 to 2021, only four out of 25 regions of Ukraine reported growth in the total number of agro-industrial enterprises: Poltava (+4.3%), Sumy (+3.7%), Khmelnytskyi (+62.8%), and Chernihiv (+1.8%). In contrast, two regions - Volyn (-20.1%)

Enterprises \ Year		2017	2018	2019	2020	2021	2022	2023
Industry, including (M, F)		123,876	125,859	130,324	126,337	126,386	102,500	114,155
The agro-industrial complex	**M**	545	561	591	616	626	529	567
	F	15,119	15,544	16,275	16,222	16,206	13,937	16,406
	Share (M, F) in the industry / Share (M, F) in the agro-industr. complex, %	12.6/17.1	12.8/17.5	12.9/18.4	13.3/19.4	13.3/19.2	14.11/21.4	14.87/21.2
	A	75,992	75,730	74,858	70,059	70,803	53,281	62,960
	Total the agro-industrial complex (manufact. sector)	91,656	91,835	91,724	86,897	87,635	67,747	79,933
Manufact. enterprises of the total		199,868	201,589	222,048	196,396	197,189	155,781	177,115
The share of A (%)		38	37.6	33.7	35.7	35.9	34.2	35.55

Note: The presented statistics do not include activities of budgetary institutions or regions temporarily occupied by the Russian Federation, offering a thorough overview of Ukraine's agro-industrial complex.

Source: Prepared by authors using statistical data from the State Statistics Service of Ukraine (n.d.), (Petrova et al., 2024).

Table 1: Study of enterprise number trends within Ukraine's agro-industrial complex from 2017 to 2023.

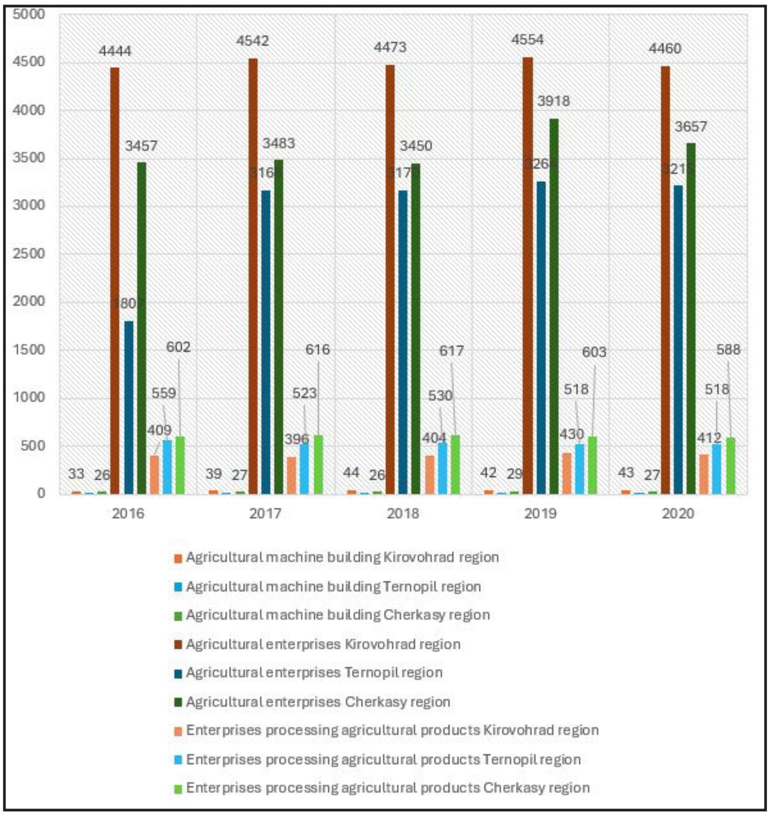
and Chernivtsi (-18.3%) - experienced decline. In most regions (19), the dynamics of agro-industrial enterprise activities differed significantly by type. This variability was particularly evident in Kirovohrad, Ternopil, and Cherkasy regions, which were selected for more detailed analysis. It can be concluded that the trends observed in these regions are representative of broader patterns throughout Ukraine.

In Kirovohrad region during the analyzed period, the number of agricultural machinery manufacturing enterprises increased by 30.30%, processing enterprises by 0.73%, while agricultural enterprises experienced a decline of 0.58%. In Ternopil region, the number of agricultural machinery manufacturing enterprises doubled (100% growth), but food industry enterprises decreased by 7.32%, and agricultural enterprises fell by 10.50%. In Cherkasy region, the number of agricultural machinery manufacturing enterprises increased by 3.85%, processing enterprises by 2.33%, and agricultural enterprises by 1.61%. Overall, the period from 2017 to 2021 was characterized by unstable dynamics in the development of agro-industrial enterprises.

In 2019, driven by expectations of positive changes after elections, there was a surge in the creation of new agricultural enterprises, with their number in Cherkasy region increasing by 78. However, this growth was short-lived, as a decline of 123 units was observed in 2020 (State Statistics Service of Ukraine, n.d.).

Figure 1 illustrates the disproportionate structure of the agro-industrial complex in almost all regions of Ukraine. Moreover, the number of agricultural machinery manufacturing enterprises, which are crucial for innovation implementation, remains low, accounting for only 0.18% to 0.87% of the total number of agro-industrial enterprises in the studied regions.

The Kirovohrad, Ternopil, and Cherkasy regions as of 2020 together account for 13.7% of Ukraine's total area allocated to grain and legume crops (with a production share of 15.4% of the total harvest in Ukraine). According to data on gross agricultural production for 2020, the combined share of Kirovohrad, Ternopil, and Cherkasy regions was



Source: Prepared by authors using statistical data from the State Statistics Service of Ukraine (n.d.)

Figure 1: Trends in the number of active enterprises within the agro-industrial complex in the Kirovohrad, Ternopil, and Cherkasy regions from 2016 to 2020.

approximately 15.1% of the country's total volume (State Statistics Service of Ukraine). These regions primarily focus on crop production, particularly the cultivation of grain and technical crops. However, quantitative analysis of agro-industrial enterprises must also include a comprehensive assessment of their innovation potential. Qualitative indicators related to the development of these enterprises are closely linked to their innovation activities. Currently, the average innovation activity of agricultural machinery manufacturing enterprises in Ukraine is 15.7%, which is lower than the approximately 20% observed in the industrial sector (State Statistics Service of Ukraine). Therefore, these enterprises are unable to adequately meet the demand for innovative products from agricultural producers.

In the agro-industrial complex processing sector, sunflower oil production is developing most rapidly, supported by state protection of sunflower seed exports. Sunflower oil exports are highly profitable for Ukraine, generating revenue of $6.4 billion in 2021 (Agronews, 2021), and constitute a significant portion of the country's processed product exports. In 2019, the implementation of new technological processes at processing enterprises was 6.8%, and the level of innovation activity among agricultural processing enterprises was 14.7% (State Statistics Service of Ukraine, n.d.). Overall, from 2016 to 2019, research and development expenditures in Ukraine demonstrated positive growth (2016 – 11,530.7 million UAH, 2017 – 13,379.3 million UAH, 2018 – 16,773.7 million UAH, 2019 – 17,254.6 million UAH), but a decline was observed in 2020 (2020 – 17,022.4 million UAH) (Tomashuk, 2023).

The authors' analysis of the innovation potential of agro-industrial enterprises revealed a number of development problems:

- Many machinery manufacturing and processing enterprises of Ukraine's agro-industrial complex do not meet the current level of innovation development and are balancing on the edge of bankruptcy.
- Equipment for soil cultivation, sowing, and fertilizers largely attempts to compete with products from developed countries, with production having decreased almost 30-50 times since Ukraine's independence (Ministry of Agrarian Policy and Food of Ukraine, 2022a).
- Most manufactured agricultural machinery belongs to the 1st or 2nd generation, characterized by low technological efficiency and single-operation capabilities (Ministry of Agrarian Policy and Food of Ukraine, 2022a).
- Some enterprises have been completely liquidated (for example, JSC "Ternopil Combine Plant," which manufactured sugar beet harvesters, went bankrupt), while others have been dismantled for scrap metal (for example, sugar processing plants, canning facilities, etc.).
- Ukrainian enterprises predominantly produce goods in single batches or small batches. For example, JSC "Elvorti" in Kropyvnytskyi (Kirovohrad region) produces seeders, cultivators, and disc harrows in limited quantities.

Thus, in the pre-war period, both agricultural machinery and processing enterprises experienced decline due to the erosion of their production capabilities. The ongoing hostilities exacerbate the situation in the agro-industrial complex. Positive transformations in the agricultural sector are possible through strengthening production and innovation potential, which is extremely necessary for producing high-quality modern products, including agricultural machinery. This necessitates a radical renewal of the sector. A crucial factor in stimulating innovation in the agro-industrial complex is the readiness of agricultural producers to implement new technologies.

During the period from 2019 to 2023, the authors conducted interviews with agricultural enterprises in Kirovohrad, Ternopil, and Cherkasy regions, using a representative sample of 7%. Respondents possessed characteristics reflecting broader population segments. The survey included agricultural enterprises of various sizes (see Table 2).

Regions	**Size**		
	Large	**Medium**	**Small**
Kirovohrad	0.96	0.87	1.23
Ternopil	6.41	4.35	5.35
Cherkasy	92.72	94.78	93.42

Source: Prepared by the authors using data from the interviews.

Table 2: Percentage distribution of agricultural enterprises in Kirovohrad, Ternopil, and Cherkasy regions by size.

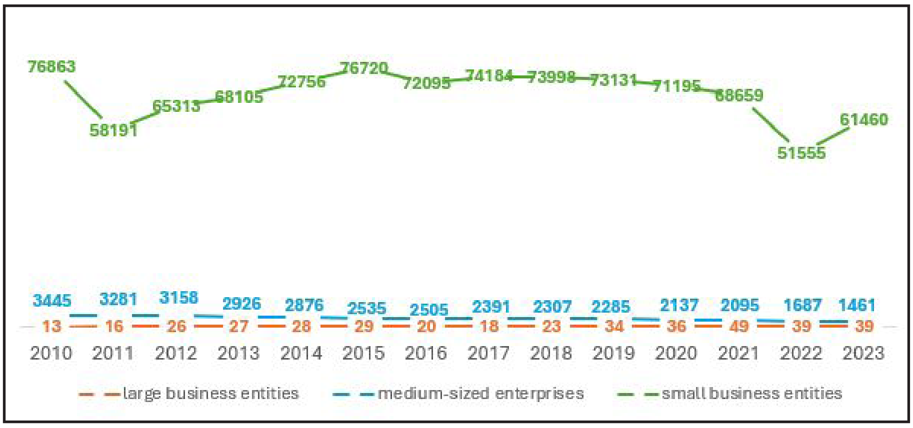
The study indicates that small agricultural enterprises predominate in Kirovohrad, Ternopil, and Cherkasy regions, which corresponds to the nationwide distribution shown in Figure 2.

Over the past thirteen years, small agricultural enterprises have comprised the "lion's share" of Ukraine's agricultural enterprises (more than 96% from 2010-2023). During the study, we developed a questionnaire and conducted interviews, the results of which are summarized and presented in Table 3.

The research results showed that during the period from 2019 to 2023, agricultural producers demonstrated a specific set of characteristics (Table 3).

The process of machinery modernization is influenced by enterprise size. Agricultural holdings are in the most advantageous position, as they replace at least 50% of their machinery and equipment and possess 75% to 100% modern foreign agricultural machinery. In contrast, small and medium agricultural enterprises are in a worse position.

The study showed that Kirovohrad region faces the lowest rates of agricultural machinery fleet renewal. Thus, 55.5% of the fleet either updates very slowly or does not update at all. The main factor affecting this problem, as noted in interview responses, is the financial constraints faced by respondents, which significantly limit their purchasing capabilities.



Source: Compiled by the authors based on statistical data (State Statistics Service of Ukraine, n.d.)

Figure 2: Dynamics of the number of active subjects of small and micro enterprises of agriculture, forestry and fisheries in 2010-2023.

Equipment Load Indicators	Cherkasy	Ternopil	Kirovohrad
Agricultural machinery fleet	Updated in the range of 10-30%, mainly through imported used agricultural machinery	Relatively updated for large and most medium agricultural enterprises, and can practically be considered updated for small ones, but in this case it is conditioned by imported used agricultural machinery	Not updated at significant rates (mainly 5-10%), and there are enterprises where no updates have occurred at all in recent years (Figure 4)
New generations of agricultural machinery	Used by 80% of respondents. At the same time, if small agricultural enterprises cannot afford to buy certain agricultural machinery, they cooperate	Used by 95% of respondents	Used by 50% of respondents
Agricultural machinery in farms	Imports predominate in percentage terms	All farms use imported multi-profile machinery, as production diversification strategies are being implemented in the region	The percentage of domestic products is higher

Source: Grouped based on questionnaire data, Petrova et al., 2024

Table 3: Comparative analysis of machinery use in the studied regions.

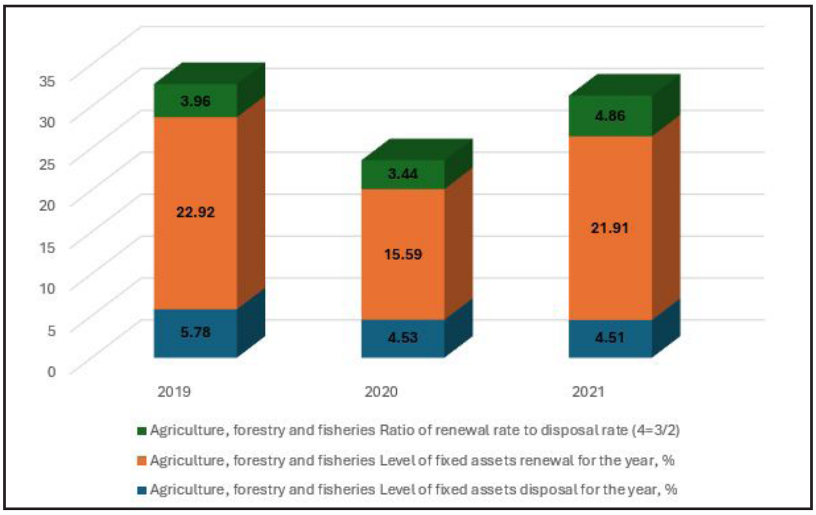
The survey results lead to the following conclusions:

- The complexity and diversity of agricultural machinery on farms is increasing, as reported by 80% of respondents. However, financial constraints prevent them from updating equipment.
- High costs hinder the transition to growing "clean" agricultural products that contain minimal amounts of health-harmful chemical compounds and are GMO-free.
- Enterprises predominantly rely on traditional technologies, and only some use no-till methods, agricultural drones, or tractors with autopilot.
- Almost all enterprises have their own, albeit outdated, machinery and do not engage in agricultural machinery leasing.

The cost of updating fixed assets in Ukraine's agriculture, especially in the studied regions, is increasing due to high prices associated with purchasing agricultural machinery (Figure 3).

During the period from 2019 to 2021, fixed asset disposal rates varied from 4.5% to 5.8%, while renewal rates fluctuated from 15.6% to 22.9%. Notably, renewal rates exceeded disposal levels by an average of 3.95 times, indicating the sector's commitment to modernization and growth. However, in 2022, combine harvester purchases fell by 2.4 times compared to the previous year, and tractor purchases were halved (Agravery, 2022, 2023).

This decline occurs during a period when Ukraine, including its agro-industrial complex, is experiencing significant losses due to military conflicts. Specifically, 84.2 thousand units of machinery and equipment have been destroyed or damaged (11% of the total available as of February 24, 2022) (Ministry of Agrarian Policy and Food of Ukraine, 2022b). The study also examined additional factors affecting the attraction of investment and labor resources to enhance the potential of agricultural enterprises (Table 4).



Source: Prepared by the authors using statistical data (State Statistics Service of Ukraine, n.d.). (the last update of this indicator on the Ukrstat website was in 2021)

Figure 3: Trends in fixed assets development of agricultural enterprises in Ukraine from 2019 to 2021.

Indicators	2017	2018	2019	2020	2021	2022	2023
Capital investments in agriculture, hunting and related services, million UAH	64084.08	66576.32	59910.06	50634.30	69966.30	51355.69	65150.63
Including machinery and equipment, million UAH (%)	48934.47 (76.36)	45460.35 (68.28)	37835.06 (63.15)	32941.86 (65.06)	47802.59 (68.32)	34446.34 (67.07)	42093.23 (64,61)
Labor costs at agricultural enterprises, million UAH	36028.21	45243.12	51830.75	53765.67	64335.68	61201.39	66012.30
Volume of agricultural, forestry and fishery products sold, million UAH	454380.10	525096.89	556325.87	605483.12	918661.15	680489.94	780089.52

Source: Prepared by authors using statistical data (State Statistics Service of Ukraine, n.d.).

Table 4: Trends in investment attraction, labor costs, and sales volumes of agricultural enterprises in Ukraine from 2017 to 2023.

Various factors influence the volume of products sold. Analysis of Table 4 shows how investment growth and labor costs affect final results. In 2023 compared to 2017, capital investments increased by only 1.66%, but were characterized by unstable dynamics during the analyzed period. During this period, labor costs increased by 83.22% (primarily due to minimum wage increases), leading to a 71.68% increase in product sales volume.

To attract investment, it is important to understand the dynamics of future behavior of economic entities, characterized by growth rates and trends during the specified period. Next, we examine the dynamics of economic entities' activities using the example of three typical small agricultural enterprises A, B, C (Table 5).

Table 6 presents forecast indicators for small agricultural enterprises (A, B, C) for 2025–2027, based on 2016–2024 data, calculated using the FORECAST function in Microsoft Excel.

While small enterprises benefit from operational flexibility and local knowledge, they face critical economic limitations when scaling. Under resource

Indicators	2016	2017	2018	2019	2020	2021	2022	2023	2024
Agricultural Enterprise A									
Enterprise capital	4930.8	5454.9	6276.5	6751.9	7616.7	9736	15129.1	13549.8	15328
Labor costs	429.42	691.5	917.67	908.43	930.2	1090.12	1020.1	1140.3	1223.6
Net revenue from product sales	2688.2	3111.5	4428.5	4166.3	4621.6	7532.7	8968	6861.4	9177.34
Innovation development costs	-	90	130	100	200	290	310	390	430
Agricultural Enterprise B									
Enterprise capital	-	-	-	40207	46293	81360	104027	121432	147981
Labor costs	-	-	-	2288	1726	1878	2194	4580	6023
Net revenue from product sales	-	-	-	55466	41893	56820	49609	44238	99058
Innovation development costs	-	-	-	470	500	680	420	630	780
Agricultural Enterprise C									
Enterprise capital	-	-	-	-	8947	8069	7802	19346	62010
Labor costs	-	-	-	-	5212	8086	9714	11087	10498
Net revenue from product sales	-	-	-	-	43281	65740	66645	96132	84069
Innovation development costs	-	-	-	-	150	190	180	510	540

Source: prepared by authors using data from enterprises A, B, C

Table 5: Performance indicators of small agricultural enterprises in 2016-2024, thousand UAH.

Indicators	MS Excel FORECAST			Function
	2025	2026	2027	
Agricultural Enterprise A				
Enterprise capital	16806.5	18244.9	19683.3	y = 1442.7x + 2205.7
Labor costs	1305.2	1387.2	1469.2	y = 0.5179x - 1043.9
Net revenue from product sales	10119.2	10944.3	11769.5	y = 827.53x + 1590.8
Innovation development costs	480.0	531.7	583.4	y = 0.5179x + 0.0857
Agricultural Enterprise B				
Enterprise capital	172222.0	195343.8	218465.5	y = 22484x + 11521
Labor costs	6863.9	7772.4	8681.0	y = 787.23x + 359.53
Net revenue from product sales	87443.1	95022.7	102602.3	y = 6222.4x + 36069
Innovation development costs	764.0	813.0	862.0	y = 0.48x + 4.12
Agricultural Enterprise C				
Enterprise capital	62700.1	75517.1	88334.2	y = 11740x - 13986
Labor costs	12566.7	13856.8	15147.0	y = 1357.3x + 4847.5
Net revenue from product sales	117571.0	116448.4	142378.3	y = 11197x + 37583
Innovation development costs	725.3	816.7	989.6	y = 1.1x - 0.16

Source: prepared by authors using data from enterprises A, B, C

Table 6: Forecast performance indicators of small agricultural enterprises A, B, C for 2025-2027, thousand UAH.

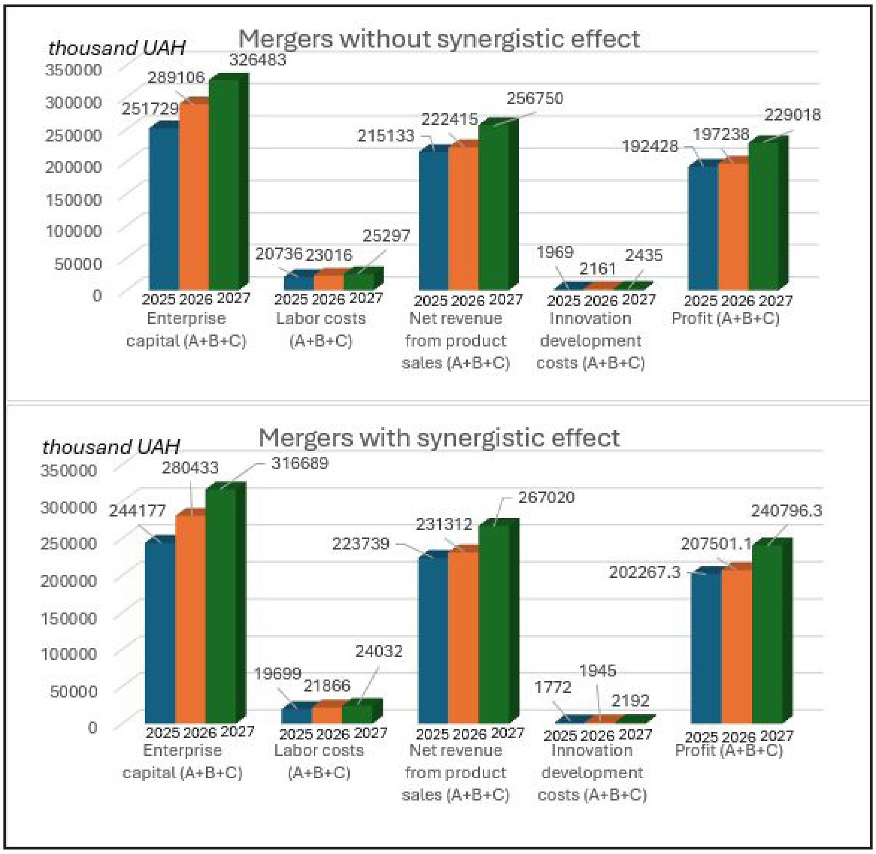
constraints, cooperation becomes the primary pathway to competitiveness. This study examines synergistic effects in two key areas: resource optimization and revenue growth, applying conservative estimates of savings and additional revenue at the level of 3–10%.

The most significant impact is observed in **capital resource savings** (estimated at ~11–13%), which enables the shared use of high-cost machinery. For instance, a modern grain harvester ($300–400 thousand) is economically unfeasible for a single 200-hectare farm due to low utilization (<10% of time). However, a cooperative of three farms (600–900 ha) can effectively utilize one unit, generating absolute savings of up to $800 thousand. This principle extends to infrastructure projects, such as grain elevators, where a joint investment of $2–3 million becomes viable. Simultaneously, **labor cost optimization** (~5%) arises from eliminating role duplication; instead of separate administrative staffs, a cooperative can employ fewer, higher-qualified specialists and optimize seasonal labor redistribution. Regarding **innovation implementation** (~10%), cooperation makes advanced technologies like precision farming ($50–100 thousand) financially accessible, reducing the investment burden from 10–20% of a single farm's revenue to a manageable 3–7% for the group. Finally, the synergistic effect contributes to a projected ~4% increase in **marketing and sales** revenue by enabling direct negotiations with exporters and optimizing logistics.

A comparative analysis of the enterprises (A+B+C) with and without cooperation effects was modeled using custom software. The calculations reveal that in 2025 alone, synergistic processes generate an additional profit of approximately **9.8 million UAH ($240 thousand)**. Figure 4 illustrates the stable growth of this indicator to 11.7 million UAH by 2027.

However, it is crucial to note that successful consolidation requires careful management, as ignoring compatibility factors can lead to "negative synergy" and integration failure.

To build a mathematical model of innovation potential for individual and consolidated



Source: Predicted and prepared by the authors using data from enterprises A, B, and C.

Figure 4: Impact of synergistic effect on cooperation between agricultural enterprises A, B, and C.

enterprises depending on investment volume, we define limitations and assumptions.

Mathematical limitations:

1. Function monotonicity – the model does not account for possible inflection points in real economic processes;
2. Exponential character – may lead to unrealistically large values during extrapolation;
3. Determinism – does not account for stochastic factors of the real economy.

Economic assumptions:

1. Stability of external conditions – the model assumes unchanged market environment;
2. Absence of competition – competitive reactions are not considered;
3. Cost linearity – proportionality between investments and potential results is assumed.

The model is based on a linear function of investment scaling:

Investment Size = Maximum Investment × (i/100)

where *i* – variable from 0 to 100 with step 10, i.e., *i* takes values (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100).

This relationship creates uniform distribution of analysis points from 0% to 100% of maximum investment. The linearity of this function ensures objective comparison of efficiency at different capital investment levels, which is critically important for correct economic analysis.

Mathematical model for individual enterprises. This formula reflects the law of diminishing marginal efficiency, a fundamental principle of economic theory. Mathematically, this is expressed through an exponential function with base less than one (0.98<1). The efficiency function for individual enterprises is described by the following exponential relationship:

$$\textit{Efficiency for individual enterprise} = E_{base} \times 0.98^{(i/10)}$$

where:

E_{base} – initial efficiency reflecting the basic level of innovative productivity of a small enterprise. Accepted as 0.12 (12%);

0.98 – efficiency reduction coefficient, meaning 2% efficiency loss at each scaling stage;

(*i*/10) – exponent ensuring gradual efficiency reduction.

The physical meaning of this relationship is that small enterprises face resource limitations and inability to effectively utilize large investment volumes.

Mathematical model for consolidated enterprises. This formula demonstrates the economy of scale effect through an exponential function with base greater than one (1.02>1). The efficiency function for consolidated enterprises has the opposite trend:

$$\textit{Efficiency for cooperation} = E_{base} \times 1.02^{(i/10)}$$

where:

E_{base} – initial efficiency reflecting the basic level of innovative productivity of a small enterprise. Accepted as 0.15 (15%);

1.02 – efficiency growth coefficient, meaning 2% efficiency increase at each scaling stage;

(*i*/10) – exponent ensuring progressive efficiency growth.

Innovation potential calculations. Innovation potential for individual enterprises is determined by:

Innovation Potential = Investment Size × Efficiency for individual enterprise

Innovation potential for consolidated enterprises is determined by:

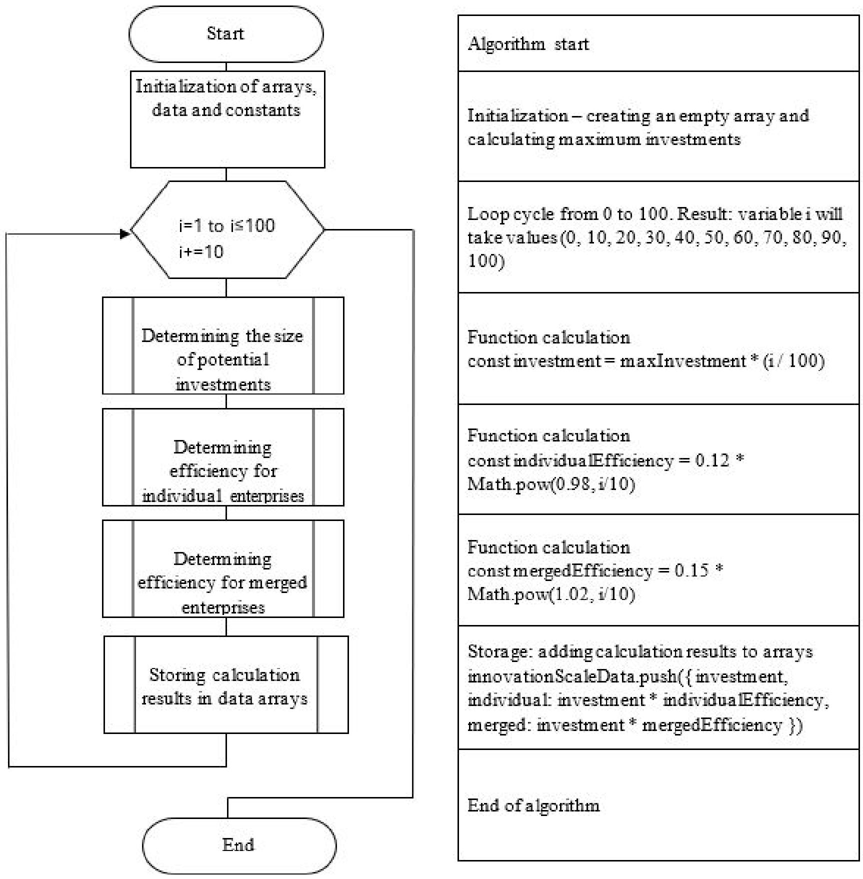
Innovation Potential = Investment Size × Efficiency for cooperation

The algorithm flowchart for calculating innovation potential is shown in Figure 5.

An innovative approach to modeling synergistic effects through the use of exponential functions with opposite trends has been developed. This allowed quantitative description of qualitative differences in behavior of different organizational structures and ensured mathematical rigor of analysis.

The key value of the developed model is its ability to determine critical points for making strategic decisions about enterprise consolidation. The model combines mathematical objectivity with economic justification, guaranteeing practical applicability of results in real conditions.

Further model development may include

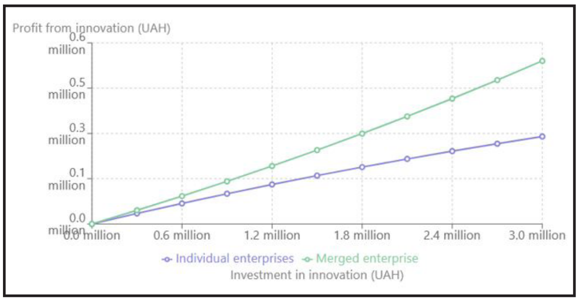


Source: Constructed by authors.

Figure 5: Algorithm flowchart for calculating innovation potential.

consideration of stochastic factors to improve forecasting accuracy, nonlinear effects, and dynamic market environment changes, making it even more realistic and useful for practical application in innovation process management.

The calculation results are presented as a graph in Figure 6, and the complete simulation was performed in Visual Studio Code environment – the result of which is shown in Analysis of the effectiveness.



Source: Constructed by authors.

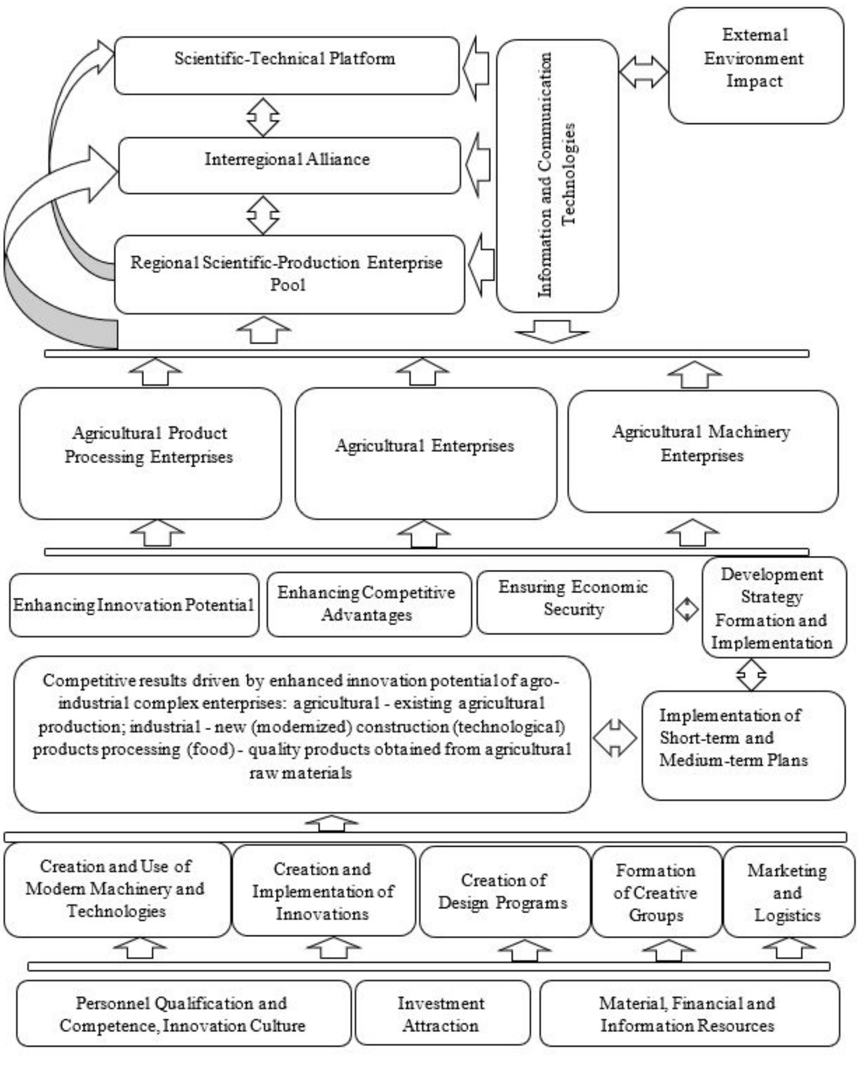
Figure 6: Innovation efficiency depending on scale.

Figure 6 indicates that while large and medium agricultural enterprises possess significant development opportunities, small enterprises have yet to utilize their hidden innovation potential. Our surveys in Kirovohrad, Cherkasy, and Ternopil regions revealed that unlocking this potential requires investment, management optimization, and, crucially, the development of cooperative relationships. To address these challenges, we propose a multi-level modernization strategy.

At the state level, the role should shift from direct subsidies to creating institutional conditions for small producers. A promising direction is establishing public-private partnerships that leverage the trend toward decentralization. Partnerships between local communities and businesses can strengthen local governance capabilities, where the state acts as a partner ensuring coordinated actions and priority setting. Furthermore, we propose the creation of interregional alliances, which are temporary scientific-technical associations uniting several regions. For example, an alliance between Kirovohrad, Ternopil, and Cherkasy regions is viable due to their complementary characteristics, such as the presence of agricultural universities, similar soil quality, and high grain yields. Such alliances would facilitate investment attraction, scientific exchange, and logistics optimization.

At the regional level, given the unstable economic situation and lack of trust, a direct transition to full-scale cooperation is difficult. Therefore, we recommend a phased approach starting with "pool"-type associations. These temporary associations allow enterprises to solve specific tasks, such as joint procurement, sales coordination, or innovation sharing, without a full legal merger. Even at this initial stage, pools generate significant synergistic effects, including reduced unit costs, shared access to new technologies, and stronger negotiating positions. In this structure, profits can be contributed to common funds and distributed proportionally, integrating local community structures with universities and production units.

Finally, a state-level scientific-technical platform should be created to integrate management bodies with business and science, promoting the self-synchronization of agricultural enterprises. A successful example of such cooperation is the testing of experimental seeders by JSC "Elvorty" in partnership with scientific institutes. The innovative potential of such an enterprise pool functions as a probabilistic dynamic system, where effective management relies on the optimal combination of informational, intellectual, financial, and technological resources. The system must be open and dynamic to respond to external changes, aligning with the law of requisite variety. Based on this analysis, we have structured the components of a comprehensive mechanism for activating innovation potential (see Figure 7).



Source: Constructed by authors.

Figure 7: Mechanism for activating innovative potential of key agricultural enterprises.

Effective development requires a market-oriented strategy focused on high-quality innovative products. To minimize risks and optimize resources, the management structure must shift from rigid hierarchy to **project teams** and creative groups led by process owners (Petrova et al., 2010). This approach stimulates "idea generators" and enhances flexibility.

Given that innovation in agricultural machinery is capital-intensive, the priority should be attracting investments to modernize existing equipment, followed by modeling the optimal level of innovative expenditures.

Forming regional associations generates "**second-level synergistic effects.**" While scaling may increase coordination costs, it significantly strengthens innovative potential. Furthermore, integrating these associations into state-supported platforms facilitates access to grants, promotes **circular economy** principles, and delivers socio-economic benefits such as job creation and environmental protection.

Conclusion

The post-war recovery of Ukraine's agro-industrial complex requires a fundamental shift toward innovative technologies. The analysis of agricultural enterprises revealed a low level of readiness for innovation due to a lack of investment and effective management. To address this, the study proposes a flexible model for forming regional agro-industrial associations (covering 3–5 regions) that integrate territorial communities, universities, and industry.

A key finding is the mathematical demonstration of the synergistic effect: while individual enterprises face diminishing returns on investment due to resource limitations, integrated structures show growing efficiency through economies of scale. Therefore, the priority for further research is the development of specialized information systems and software. These IT solutions will allow agricultural producers to transition from empirical estimates to scientifically grounded calculations, modeling investment scenarios and justifying the economic feasibility of cooperation.

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References

[1] Adamchuk, V. V., Kvasha, Y. L., Savchenko, I. F., Borys, A. M., Rykhlivskyi, P. A., Lysaniuk, V. H. and Shynkevych, Y. B. (2021) "Peculiarities in the design of the cutting apparatus for universal sowing of seeded and small-scale vegetable crops", *Mechanization and Electrification of Agriculture: Nationwide Collection*, Vol. 14, No. 113, pp. 105-112. ISSN 2603-3704.

[2] Agronews (2021) "*The largest importers of Ukrainian oils have been introduced*". [Online]. Available: https://agronews.ua/news/nazvano-najbilshyh-importeriv-ukrayinskyh-olij [Accessed: Jan 12, 2024].

[3] Akhtar, N. (2023) "Unlocking the Potential: The Impact of Innovative Capability on Process, Product, and Market Innovation and Firm Performance", *Marketing and Management of Innovations*, Vol. 14, No. 2, pp. 19-33. ISSN 2451-1668. DOI 10.21272/mmi.2023.2-03.

[4] Andriichuk, V. H. (2013) "Economics of enterprises of the agro-industrial complex", KNEU, Kyiv, 779 p. (In Ukrainian).

[5] Ansoff, H. I., Kipley, D., Lewis, A. O., Stevens, H. and Ansoff, R. (2019) "Implanting Strategic Management", Palgrave Macmillan, Cham, Switzerland, 592 p. ISBN 978-3-319-99598-4. DOI 10.1007/978-3-319-99599-1.

[6] Balanovska, T., Mykhailichenko, M., Holik, V., Dramaretska, K. and Troian, A. (2021) "Development management of agricultural enterprises", *Financial and Credit Activity: Problems of Theory and Practice*, Vol. 3, No. 38, pp. 134-143. E-ISSN 2310-8770, ISSN 2306-4994. DOI 10.18371/fcaptp.v3i38.237434.

[7] Blikhar, V., Kopytko, M., Patsula, O., Synenkyi, V. and Bulachek, V. (2022) "Management and legal aspects of economic security of enterprises in the process of innovation", *Financial and Credit Activity: Problems of Theory and Practice*, Vol. 6, No. 41, pp. 360-368. E-ISSN 2310-8770, ISSN 2306-4994. DOI 10.18371/fcaptp.v6i41.251445.

[8] Cherep, A., Beridze, T., Baranik, Z., Korenyev, V. and Dashko, I. (2021) "Assessment of the competitiveness of industrial enterprise activities", *Financial and Credit Activity: Problems of Theory and Practice*, Vol. 3, No. 38, pp. 272-280. E-ISSN 2310-8770, ISSN 2306-4994. DOI 10.18371/fcaptp.v3i38.237457.

[9] Faivishenko, D., Dubovyk, T., Savchuk, A. and Romanchenko, T. (2020) "Strategic impact of innovations on enterprises financial state", *Financial and Credit Activity: Problems of Theory and Practice*, Vol. 4, No. 35, pp. 411-417. E-ISSN 2310-8770, ISSN 2306-4994. DOI 10.18371/fcaptp.v4i35.222442.

[10] Ferreira, J., Coelho, A. and Moutinho, L. (2020) "Dynamic capabilities, creativity and innovation capability and their impact on competitive advantage and firm performance: The moderating role of entrepreneurial orientation", *Technovation*, Vol. 92, p. 102061. ISSN 0166-4972. DOI 10.1016/j.technovation.2018.11.004.

[11] Goodman, D. and Wilkinson, J. (2023) "Patterns of research and innovation in the modern agro-food system", In: *Technological Change and the Rural Environment*, 1st ed., Routledge, pp. 127-146. ISBN 9781003394624.

[12] Government Portal. (2024) "*Denys Shmyhal: Our priority is to support domestic producers*". [Online]. Available: https://www.kmu.gov.ua/en/news/denys-shmyhal-nash-priorytet-pidtrymka-vitchyznianoho-vyrobnyka [Accessed: Feb 10, 2024].

[13] Harbar, V. (2021) "The essence and structure of the innovative potential of the enterprise", In: *2020: Theoretical and methodological approaches to the formation of a modern system of national and international enterprises, organizations and institutions' development: Collective Scientific Monograph*, pp. 2-12. DOI 10.36074/tmafmseoid.ed-2.05.

[14] Harkema, S. (2003) "A complex adaptive perspective on learning within innovation projects", *The Learning Organization*, Vol. 10, No. 6, pp. 340-346. E-ISSN 1758-7905, ISSN 0969-6474. DOI 10.1108/09696470310497177.

[15] Heiets, V. M. (2009) "Society, state, economy: The phenomenology of interaction and development", Kyiv, 864 p.

[16] Hlubish, L. (2021) "Obstacles to the formation of competitive advantages in the sectors of food security of Ukraine", *Agricultural and Resource Economics: International Scientific E-Journal*, Vol. 7, No. 1, pp. 115-136. E-ISSN 2414-584X. DOI 10.51599/are.2021.07.01.07. (In Ukrainian).

[17] Hrosul, V., Kruhlova, O., Mkrtchyan, T., Zubkov, S. and Timchenko, O. (2021) "Enterprise integration and formation of cluster structures in the field of food sector", *Agricultural and Resource Economics: International Scientific E-Journal*, Vol. 7, No. 2, pp. 119-140. E-ISSN 2414-584X. DOI 10.51599/are.2021.07.02.07.

[18] Hryhoruk, P. M., Paionk, O. P., Savchuk, O. P. and Khrushch, V. O. (2020) "Characteristics of processes of formation and implementation of the innovative potential of small and medium enterprises", *Visnyk*, Vol. 6. pp. 54-62. ISSN 2414-987X. DOI 10.31891/2307-5740-2020-288-6-8. (In Ukrainian).

[19] Karnaushenko, A., Tanklevska, N., Povod, T., Kononenko, L. and Savchenko, V. (2023) "Implementation of blockchain technology in agriculture: fashionable trends or requirements of the modern economy", *Agricultural and Resource Economics: International Scientific E-Journal*, Vol. 9, No. 3, pp. 124-149. E-ISSN 2414-584X. DOI 10.51599/are.2023.09.03.06.

[20] Kovalyov, A., Babii, O. and Tymchenko, K. (2022) "Clustering of winegrowing and winemaking industry as an effective form of management", *Financial and Credit Activity: Problems of Theory and Practice*, Vol. 6, No. 47, pp. 480-490. E-ISSN 2310-8770. DOI 10.55643/fcaptp.6.47.2022.3870.

[21] Kychko, I., Parubets, O., Kholodnytska, A., Perminova, V. and Lytvyn, S. (2021) "Formation of managerial competencies of managers and their impact on the competitiveness of the firm and the labor market in Ukraine", *Financial and Credit Activity: Problems of Theory and Practice*, Vol. 4, No. 39, pp. 284-293. E-ISSN 2310-8770. DOI 10.18371/fcaptp.v4i39.241317.

[22] Kyrylov, Y., Hranovska, V., Savchenko, V., Kononenko, L., Gai, O. and Kononenko, S. (2024) "Sustainable Rural Development in the Context of the Implementation of Digital Technologies and Nanotechnology in Education and Business", *Nanotechnology Perceptions*, Vol. 20, No. S8, pp. 297-323. ISSN 1660-6795. DOI 10.62441/nano-ntp.v20iS8.25.

[23] Lavrenenko, V., Makhova, H. and Vostriakova, V. (2021) "Development of the enterprise's innovative potential on the basis of resource theory", *Financial and Credit Activity: Problems of Theory and Practice*, Vol. 3, No. 38, pp. 397-408. E-ISSN 2310-8770. DOI 10.18371/fcaptp.v3i38.237473.

[24] Lis, A. and Lis, A. (2021) "Relationships Between Geographical and Virtual Proximity in Cluster Organisations", *Studia Regionalne i Lokalne*, Vol. 3, No. 85, pp. 142-161. ISSN 1509-4995. DOI 10.7366/1509499538506.

[25] Ministry of Agrarian Policy and Food of Ukraine. (2022a) *"Concept of the State Target Economic Program for the Development of Domestic Machine Engineering for the Agro-Industrial Complex until 2020*". [Online]. Available: https://www.minagro.gov.ua [Accessed: Jan 12,2022].

[26] Ministry of Agrarian Policy and Food of Ukraine. (2022b) "*Overview of war damage in Ukraine agriculture. Indirect damage assessment*". [Online]. Available: https://minagro.gov.ua/storage/app/sites/1/uploaded-files/damagesreportissue2ua-1.pdf. [Accessed: Jan 12,2022].

[27] Mykytiuk, P. P. (Ed.) (2015) "Innovative development of enterprises: A textbook", Printer Inform, Ternopil, 224 p.

[28] NISS (2023) "*The agricultural sector of Ukraine in 2023: components of sustainability, problems and promising tasks*". [Online]. Available: https://niss.gov.ua/doslidzhennya/ekonomika/ahrarnyy-sektor-ukrayiny-u-2023-rotsi-skladovi-stiykosti-problemy-ta [Accessed: March 21, 2024].

[29] Petrova, I., Sysolina, N., Kononenko, L., Sysolina, I. and Savelenko, H. (2024) "Increasing the Innovative Potential of the Enterprises of the Agro-Industrial Complex of Ukraine: Fundamental Developments", *The International Journal of Multiphysics*, Vol. 18, No. 3, pp. 1320-1340. ISSN 1750-9548.

[30] Petrova, I. L., Shpylova, T. I. and Sysolina, N. P. (2010) "Innovative activity: Incentives and obstacles", In: Petrova, I. L. (ed.) "*Innovative activity",* Dorado, Kyiv, 320 p. (In Ukrainian).

[31] Piletska, S. T. and Tkachenko, Y. (2020) "Innovative potential of the enterprise in the anti-crisis management system", *Oblik i Finansi*, No. 87, pp. 178-184. e-ISSN 2518-1181. DOI 10.33146/2307-9878-2020-1(87)-178-184. (In Ukrainian).

[32] Puzyrova, P. V. (2020) "Main factors influencing the process of forming and developing the innovative potential of integrated business structures", *Formation of Market Relations in Ukraine*. E-ISSN 1728-662X. DOI 10.5281/zenodo.4415456. (In Ukrainian).

[33] Ragazou, K., Garefalakis, A., Zafeiriou, E. and Passas, I. (2022) "Agriculture 5.0: A new strategic management mode for a cut cost and an energy efficient agriculture sector", *Energies*, Vol. 15, No. 9, p. 3113. ISSN 1996-1073. DOI 10.3390/en15093113.

[34] Sabluk, P. T. (2008) "Problems of ensuring the profitability of agro-industrial production in Ukraine during the post-industrial period", *Economics of Agro-Industrial Complex*, pp. 19-37. E-ISSN 2413-2322.

[35] Saunila, M. (2020) "Innovation capability in SMEs: A systematic review of the literature", *Journal of Innovation & Knowledge*, Vol. 5, No. 4, pp. 260-265. E-ISSN 2444-569X. DOI 10.1016/j.jik.2019.11.002.

[36] Savytskyi, E. E. (2019) "Evaluation of the level of innovative potential of the enterprise", *Financial and Credit Activity: Problems of Theory and Practice*, Vol. 2, No. 29, pp. 204-211. E-ISSN 2310-8770. DOI 10.18371/fcaptp.v2i29.171779.

[37] Schumpeter, J. A. (2004) "*The Theory of Economic Development*", 10th ed., Transaction Publishers, New Brunswick, New Jersey.

[38] Shulhina, L. M., Shulhyna, L. M., Yukhymenko, V. V. and Yukhymenko, V. V. (2011) "The modern concept of strategic management of innovation development of enterprises", *Marketing and Management of Innovations*, Vol. 2, No. 3, pp. 79-84. E-ISSN 2227-6718.

[39] Shvets, V. I. and Dubiei, D. I. (2021) "Management of the innovative potential of Ukrainian industrial enterprises", *Economic Bulletin of Dnipro University of Technology,* Vol. 75, pp.106-113. ISSN 2709-6459. DOI 10.33271/ebdut/76.106.

[40] Skotsyk, V. I. (2017) "Organizational and economic mechanism for the formation and functioning of agricultural machinery in Ukraine", Ph.D. Thesis, Vinnytsia.

[41] Smulka, O. (2020) "Formation of the innovative potential of agricultural enterprises", *Agrarian Economy*, Vol. 13, No. 1-2, pp. 45-54. ISSN 2313-3627.

[42] Solohub, I. (2023) "*The impact of war on capital investments in Ukraine*", Economics. [Online]. Available at: https://voxukraine.org/vplyv-vijny-na-kapitalni-investytsiyi-v-ukrayini [Accessed: Sept 10,2025]. (In Ukrainian).

[43] State Statistics Service of Ukraine (n.d.) Statistical data. [Online]. Available: https://www.ukrstat.gov.ua. [Accessed: June 5,2025]. (In Ukrainian).

[44] Stræte, E. P., Vik, J., Fuglestad, E. M., Gjefsen, M. D., Melås, A. M. and Søraa, R. A. (2022) "Critical support for different stages of innovation in agriculture: What, when, how?", *Agricultural Systems*, Vol. 203, p. 103526. ISSN 0308-521X. DOI 10.1016/j.agsy.2022.103526.

[45] Sysolina, N. P., Savelenko, H. V. and Sysolina, I. P. (2018) "Problematic aspects and prospects of innovative development of agricultural machinery", *Central Ukrainian Scientific Bulletin. Economic Sciences*, Vol. 1, No. 34, pp. 280-287. ISSN 2663-1636. DOI 10.32515/2663-1636.2018.1(34).208-287. (In Ukrainian).

[46] Team Ensol (2024) "*Analysis of the effectiveness of the consolidation of agricultural enterprises. The working model*". [Online]. Available: https://economic-grygoriy.ensol.team/ [Accessed: June 5, 2025].

[47] Thompson, V. A. (1965) "Bureaucracy and Innovation", *Administrative Science Quarterly,* Vol. 10, No. 1, pp. 1-20. ISSN 0001-8392. DOI 10.2307/2391646.

[48] Tomashuk, I. (2023) "Competitiveness of agricultural enterprises in market conditions and ways of its increase", *Green, Blue and Digital Economy Journal*, Vol. 4, No. 1, pp. 64-81. E-ISSN 2661-5282. DOI 10.30525/2661-5169/2023-1-7.

[49] Trusova, N. V., Hryvkivska, O. V., Yavorska, T. I., Prystemskyi, O. S., Kepko, V. N. and Prus, Y. O. (2020) "Innovative development and competitiveness of agribusiness subjects in the system of ensuring of economic security of the regions of Ukraine", *Rivista di Studi sulla Sostenibilita*, Vol. 10, No. 2, pp. 141-156. ISSN: 2239-7221.

[50] Ulyanchenko, O., Vasyurenko, L., Litvinov, A., Utenkova, K., Filimonov, Y. and Kuksa, I. (2021) "Strategic management of resource potential as a measure to increase the competitiveness of the enterprise in the agricultural sector", *Financial and Credit Activity: Problems of Theory and Practice*, Vol. 4, No. 39, pp. 276-283. E-ISSN 2310-8770. DOI 10.18371/fcaptp.v4i39.241316.