

## MANAGEMENT OF CLUSTER DEVELOPMENT OF AGRICULTURAL ENTERPRISES IN CONDITIONS OF DIGITALIZATION, LEGAL RISKS, INNOVATIVE EDUCATION AND SMART ECONOMY

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### Abstract

The article examines the management of cluster development of agricultural enterprises in the conditions of digitalization, legal risks, innovative education and Smart economy. The need to implement digital technologies, automation and digital resource management, which contributes to increasing the productivity and competitiveness of agricultural enterprises, is substantiated. Legal risks associated with data protection and intellectual property management are considered, as well as the need to integrate innovative education to train specialists capable of working in the conditions of the Smart economy. It has been proven that the clustering of enterprises makes it possible to implement innovations more efficiently, optimize production processes and minimize costs, which contributes to the sustainable development of the agricultural sector. It is recognized that the use of the modified distribution method of the closed type allows to optimize the comparison of the forecasted volumes of production with the available actual resources of agricultural enterprises. In the conditions of growing digitalization, this approach contributes to increasing the efficiency of resource allocation due to more accurate accounting of actual indicators and forecasted needs. It was emphasized that the model of cluster development of agricultural enterprises in combination with new technologies, such as Smart economy, allows enterprises to join forces to increase competitiveness and optimize production processes.

**Keywords:** cluster development, smart economy, agricultural enterprises, management, digitalization, legal risks, innovative education.

**JEL Codes:** I29, O33, Q10.

### Introduction

Management of cluster development of agricultural enterprises is one of the key tasks of the modern economy in conditions of rapid digital transformation. The introduction of innovative

technologies and digitalization of agriculture open up new opportunities for increasing production efficiency, optimizing resources and improving product quality. However, the digitization process

carries a number of legal risks related to data privacy, compliance with cybersecurity standards, and the introduction of new regulatory requirements. In this context, there is a need for innovative education that will help prepare qualified specialists capable of working in a smart economy based on new principles of production organization and management.

### **Literature review**

In scientific literature, the topic of cluster development of agricultural enterprises is actively explored in the context of globalization and digital transformations. Many authors emphasize the importance of clustering for increasing the competitiveness of the agricultural sector, as it contributes to the unification of efforts of enterprises, scientific institutions and government bodies for more efficient use of resources and the introduction of innovations. In particular, works [1-4] emphasize the importance of innovations, clusters, for stimulating innovation and increasing the productivity of enterprises.

Digitalization is one of the central topics of modern research in the field of agriculture [5-6]. According to many researchers, digital technologies such as artificial intelligence and big data analysis provide new opportunities for the development of clusters. For example, works [7-10] analyze the advantages of using digital solutions to increase the efficiency of production processes and improve interaction between participants.

Important attention in the literature is paid to the basics of modeling, which can be implemented in our article [11-12]. Some scientists [13] focus on the growth of legal risks associated with the use of digital technologies in agriculture, in particular on issues of cyber security, protection of personal data and regulation of digital interaction between enterprises. Scientists [14-15] propose innovative directions of financial management and resource conservation, necessary for rapid adaptation of agribusiness enterprises.

Innovative education is also an integral part of cluster development [16-17]. It ensures the training of personnel who have the necessary

knowledge to work in the conditions of the smart economy.

A detailed consideration of the evolution and conditions of the development of the smart economy is depicted in works [18-19], which emphasize the functional features of the smart economy as a near future.

In works [20-24] attention is focused on the need for an innovative approach in the production process, including in the agricultural sector.

Researchers [25] offer the basics of modeling complex economic, ecological and social processes that can be applied in our research.

For a more practical implementation of the modeling basis, we used the websites of the "Stfalcon" Company [26], the Cadastre UA resource [27], the reporting activities of Farms in the Kirovohrad region [28] and the Debit-Credit information resource [29].

Thus, the literature on the topic of cluster development of agricultural enterprises covers a wide range of issues, including digitalization, legal risks, and innovative education, which together create a basis for modeling effective and sustainable cluster structures in the context of a smart economy.

### **Methodical approach**

Management of the cluster development of agricultural enterprises in the conditions of digitalization, legal risks, innovative education and smart economy is proposed to be implemented using the distribution problem method. It can be presented as an optimization problem that takes into account a number of factors that affect the effective use of resources and interaction between cluster members. The goal is to maximize the efficiency of cluster development through the optimal distribution of resources between enterprises. The problem of such modeling is solved by linear or non-linear programming methods, depending on the complexity of the profit and risk functions. The optimal distribution of resources allows to maximize the economic effect, minimizing legal risks, while ensuring the integration of modern technologies and the development of personnel through innovative education. Such a model takes into account enterprises, resources that can

be both material and informational, educational and innovative programs that contribute to increasing the level of digital competences, as well as various legal risks that can affect the activities of the cluster. The optimal allocation of resources involves taking into account the potential economic profit of each enterprise from the use of these resources, as well as the need to minimize legal risks and ensure access to innovative technologies and training programs. Limitations in such a model arise from the limited amount of resources that can be provided to enterprises, the need to comply with legal norms and standards, and the need to ensure that enterprises can integrate only those technologies and educational programs that correspond to their current level of technical and personnel training. The solution to this problem allows to create a balance between the economic efficiency of the cluster, the minimization of legal risks and the development of innovative competences in the context of digitalization and smart economy.

### Results

To study, research, analyze, model and forecast the cluster development of agricultural enterprises in the conditions of digitalization, legal risks, innovative education and smart economy, we use general informative and statistical data of three economic entities of the agrarian sphere of the Kirovohrad region. These

agricultural enterprises have similar production capacities, similar areas for growing agricultural crops, are engaged in the production of strategically important and ecologically clean products, and also actively implement innovations by updating equipment and plant varieties. They are distinguished by high efficiency, success and stable profitability, occupying leading positions in the region. Let's briefly consider them. LLC "Agro-osnova" of the Kirovohrad region - is engaged in the cultivation of grain and technical crops (wheat, corn, sunflower and soybeans). LLC "Agrarian Company Zorya" of Kirovohrad region also grows similar grain and technical crops. The main type of activity of LLC Agro-industrial company "Rozkishna" of Kirovohrad region is plant and animal husbandry.

So, let's move on to the practical implementation of management modeling of cluster development of agricultural enterprises using distribution problems. Let's name the optimal areas of each of the crops that must be grown on each of the fields:  $x_{11}$ ,  $x_{12}$ ,  $x_{13}$ ,  $x_{21}$ ,  $x_{22}$ ,  $x_{23}$ . Moreover, the first number is the type of agricultural product of the crop that should be produced, the second is the field where the agricultural product will be grown. We will calculate the objective function of the maximum production of agricultural products for the enterprises analyzed by us. Then, taking into account clustering, we have the following form of the optimization problem (Table 1).

**Table 1. Modeling of the objective function with the optimal location of agricultural areas at maximum production in the process of clustering three agricultural enterprises, 2025**

Agricultural enterprises	An objective function with the optimal distribution of cultivated areas for the maximum production of agricultural products, taking into account clustering
	Cereal crops
LLC "Agro-Osvana" of the Kirovohrad region	$Z_{\max}=34,60X_{11}+35,80X_{12}+33,90X_{13}+78,60X_{21}+79,40X_{22}+77,60X_{23}$
LLC Agrarian company "Zorya" of Kirovohrad region	$Z_{\max}=35,00X_{11}+34,80X_{12}+35,20X_{13}+77,00X_{21}+76,20X_{22}+77,10X_{23}$
LLC Agro-industrial company "Rozkishna" of Kirovohrad region	$Z_{\max}=35,16X_{11}+34,80X_{12}+35,80X_{13}+79,16X_{21}+79,00X_{22}+78,90X_{23}$
Technical agricultural crops	
LLC "Agro-Osvana" of the Kirovohrad region	$Z_{\max}=31,90X_{11}+32,10X_{12}+32,30X_{13}+24,80X_{21}+25,50X_{22}+25,80X_{23}$
LLC Agrarian company "Zorya" of Kirovohrad region	$Z_{\max}=32,00X_{11}+35,60X_{12}+33,00X_{13}+26,20X_{21}+26,10X_{22}+26,90X_{23}$
LLC Agro-industrial company "Rozkishna" of Kirovohrad region	$Z_{\max}=32,46X_{11}+33,00X_{12}+33,50X_{13}+25,36X_{21}+26,00X_{22}+25,80X_{23}$

\*Source: Developed from [23; 28].

At the next stage, we will apply the simplex method, which is particularly effective for optimizing profit, minimizing costs or distributing limited resources between different options. So, as a result of the simulation, we obtained the optimal

placement of technical crops on three fields, taking into account the clustering of three enterprises of the Kirovohrad region, 2025, the results are summarized in the table 2.

**Table 2. Optimizing the location of agricultural crops to obtain the maximum yield in agricultural enterprises of the Kirovohrad region, 2025**

Agricultural enterprises	Optimization results using the modified distribution method of the closed type
Cereal crops	
LLC “Agro-Osvana” of the Kirovohrad region	Maximum production of agricultural products, t $Z_{max}=79701.20$ t The total area of winter wheat and corn for grain is 1,434 hectares. The area of three fields under these crops is 1,434 hectares. Distribution problem of closed type
LLC Agrarian company “Zorya” of Kirovohrad region	Maximum production of agricultural products, t $Z_{max}=73202.26$ t The total area of winter wheat and corn for grain is 1,334 ha. The area of three fields under these crops is 1,334 hectares. Distribution problem of closed type
LLC Agro-industrial company “Rozkishna” of Kirovohrad region	Maximum production of agricultural products, t $Z_{max}=76664.60$ t The total area of winter wheat and corn for grain is 1,353 ha. The area of three fields under these crops is 1,353 hectares. Distribution problem of closed type
Technical agricultural crops	
LLC “Agro-Osvana” of the Kirovohrad region	Maximum production of agricultural products, t $Z_{max}=29722.63$ t The total area of sunflower and soybean crops is 1,019 ha. The area of three fields under these crops is 1,019 hectares. Distribution problem of closed type
LLC Agrarian company “Zorya” of Kirovohrad region	Maximum production of agricultural products, ts $Z_{max}=29286.99$ ts The total area of sunflower and soybean crops is 948 ha. The area of three fields under these crops is 948 hectares. Distribution problem of closed type
LLC Agro-industrial company “Rozkishna” of Kirovohrad region	Maximum production of agricultural products, ts $Z_{max}=29901.00$ ts The total area of sunflower and soybean crops is 1,003 ha. The area of three fields under these crops is 1,003 hectares. Distribution problem of closed type

\*Source: Developed from [23; 28].

Next, we will carry out a comparative cluster analysis of the results, comparing the predicted indicators of the production of agricultural products in physical volumes for 2025 with the actual volumes of production of these products in 2023. Moreover, the actual indicators of the volume of production were

obtained by us based on the data of the annual financial and accounting reports of the three investigated agricultural enterprises No. 29-sg (annual) “Report on the area and gross harvest of agricultural crops, fruits, berries and grapes” (Table 3) [17].

**Table 3. Comparative cluster analysis of agricultural production in the physical mass of agricultural enterprises, 2023, 2025**

Agricultural enterprises	Comparative cluster analysis
Cereal crops	
LLC “Agro-Osvana” of the Kirovohrad region	Production of grain crops, ts, 2023 74489.56 ts Increase (decrease) in production (+,-) 2025 from 2023 + 5211.64 ts
LLC Agrarian company “Zorya” of Kirovohrad region	Production of grain crops, ts, 2023. 69218.60 ts Increase (decrease) in production (+,-) 2025 from 2023 + 3983.66 ts
LLC Agro-industrial company “Rozkishna” of Kirovohrad region	Production of grain crops, ts, 2023 67417.60 ts Increase (decrease) in production (+,-) 2025 from 2023 + 9247.00 ts

Technical agricultural crops	
LLC “Agro-Osvana” of the Kirovohrad region	Production of industrial crops, ts, 2023 27282.25 ts Increase (decrease) in production (+,-) 2025 from 2023 + 2440.38 ts
LLC Agrarian company “Zorya” of Kirovohrad region	Production of industrial crops, ts, 2023 26483.44 ts Increase (decrease) in production (+,-) 2025 from 2023 + 2803.55 ts
LLC Agro-industrial company “Rozkishna” of Kirovohrad region	Production of industrial crops, ts, 2023 24835.2 ts Increase (decrease) in production (+,-) 2025 from 2023 + 5065.80 ts

\*Source: developed by the author based on [23; 28].

At the next stage, we will carry out a comparative analysis of the forecasted volumes of production of grain and technical crops in physical units for 2025 with the actual indicators

for 2023 for the three studied agricultural enterprises, and also compare these data with the results of clustering (Table 4).

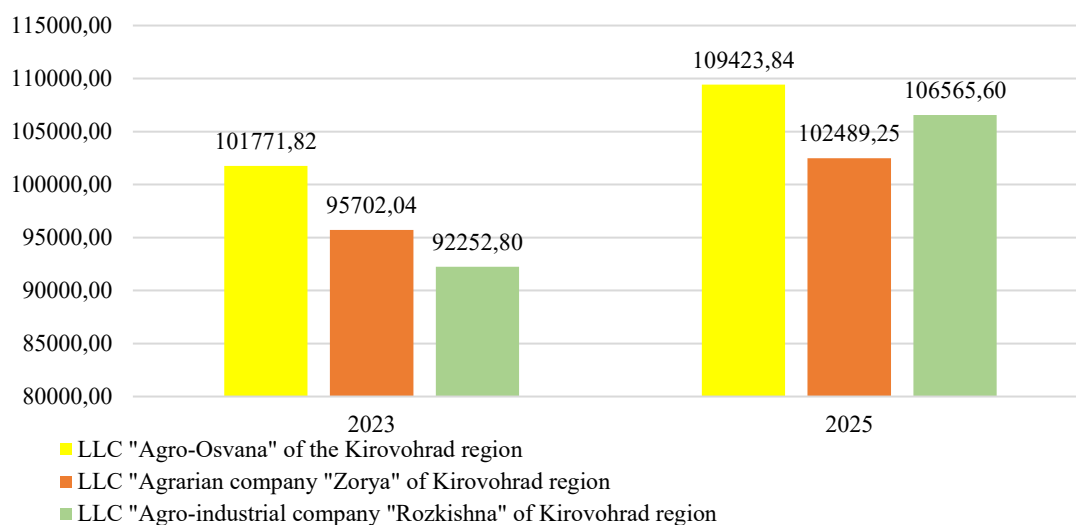
**Table 4. Comparative analysis of forecasted volumes of production of grain and technical crops in physical units for 2025 with actual indicators for 2023**

Agricultural enterprises	The total area of grain and technical agricultural crops	Production grain and technical agricultural crops, ts		Increase (decrease) production of grain and industrial crops (+,-) 2025 from 2023	Increase (decrease) in the production of grain and technical crops (+,-) 2025 from 2023 (compared with the result of clustering)
		2023	2025		
LLC “Agro-Osvana” of the Kirovohrad region	2453	101771,82	109423,84	7652,02	7652,02
LLC Agrarian company “Zorya” of Kirovohrad region	2282	95702,04	102489,25	6787,21	6787,21
LLC Agro-industrial company “Rozkishna” of Kirovohrad region	2356	92252,80	106565,60	14312,80	14312,80

\*Source: developed by the author based on [23; 28-29].

Table 4 presents a comparative analysis of the forecasted production volumes of grain and technical crops for 2025 with actual indicators for 2023 for three agricultural enterprises of the Kirovohrad region: Agro-Osvana LLC, Zorya Agricultural Company LLC, and Rozkishna Agro-industrial Company LLC. For each enterprise, the total area of crops, actual production volumes in 2023, forecasted for 2025, as well as the expected increase in production in physical units (quintals) are given. From the analysis, it can be seen that an increase in production volumes is expected for all enterprises in 2025. The greatest growth is predicted for Rozkishna Agro-industrial Company LLC, which

plans to increase production by 14,312.8 quintals compared to 2023. Positive dynamics are also predicted for “Agro-Osvana” LLC and “Zorya” Agrarian Company LLC, but to a lesser extent - by 7,652.02 and 6,787.21 quintals, respectively. Such a trend indicates an improvement in the efficiency of agricultural production and possible investments in technologies contributing to an increase in productivity. Graphically, the forecast values of the production of agricultural products in physical mass for 2025 and the actual values of the production of agricultural products in physical mass in 2023 of grain and technical crops of the three studied agricultural enterprises are presented in Fig. 1.



**Figure 1. Actual and forecast values of the production of grain and technical crops in physical weight of the three studied agricultural enterprises, 2023, 2025**

\*Source: suggested by the authors.

Next, we continue the comparative analysis of the economic indicators of the studied economic entities, taking into account clustering, innovativeness and Smart-economy. We will calculate the production of gross products in

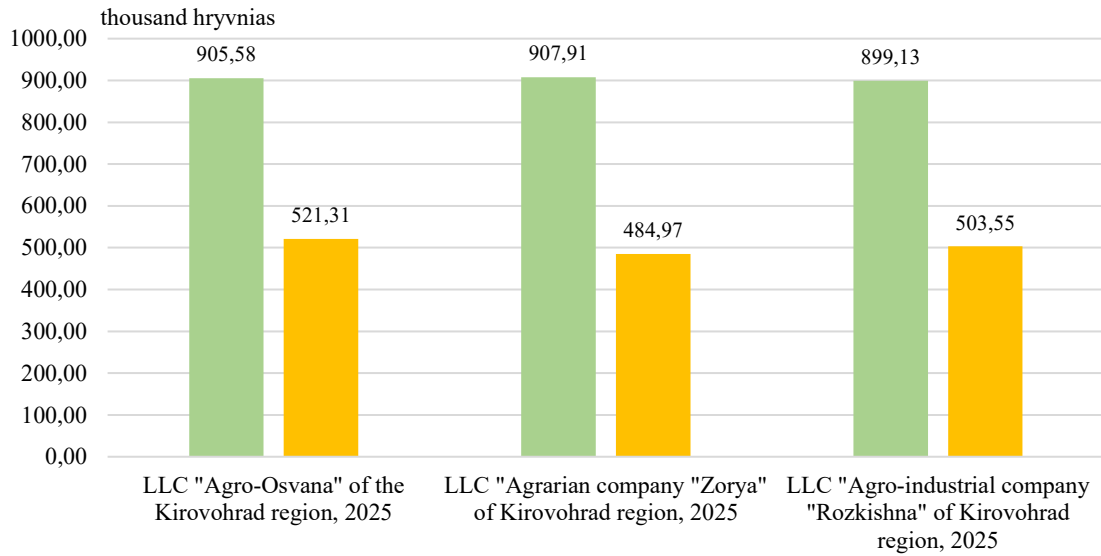
monetary terms for 2025 (at the average prices of 2022) from the obtained optimized sowing areas and gross harvests of agricultural crops of the studied agricultural enterprises (Table 5).

**Table 5. Forecast optimal production of gross products in monetary terms, taking into account the clustering of three agricultural enterprises, 2025**

Agricultural enterprises	Production of gross products, thousand hryvnias for 2025 (at average prices of 2022)		
	Winter wheat	Corn for grain	Total, thousand UAH
LLC "Agro-Osvana" of the Kirovohrad region, 2025	905,58	521,31	1426,89
LLC Agrarian company "Zorya" of Kirovohrad region, 2025	907,91	484,97	1392,88
LLC Agro-industrial company "Rozkishna" of Kirovohrad region, 2025	899,13	503,55	1402,68
Agricultural enterprises	Production of gross products, thousand hryvnias for 2025 (at average prices of 2022)		
	Sunflower	Soy	Total, thousand UAH
LLC "Agro-Osvana" of the Kirovohrad region, 2025	707,44	697,25	1404,69
LLC Agrarian company "Zorya" of Kirovohrad region, 2025	658,13	648,65	1306,77
LLC Agro-industrial company "Rozkishna" of Kirovohrad region, 2025	687,50	697,62	1385,12

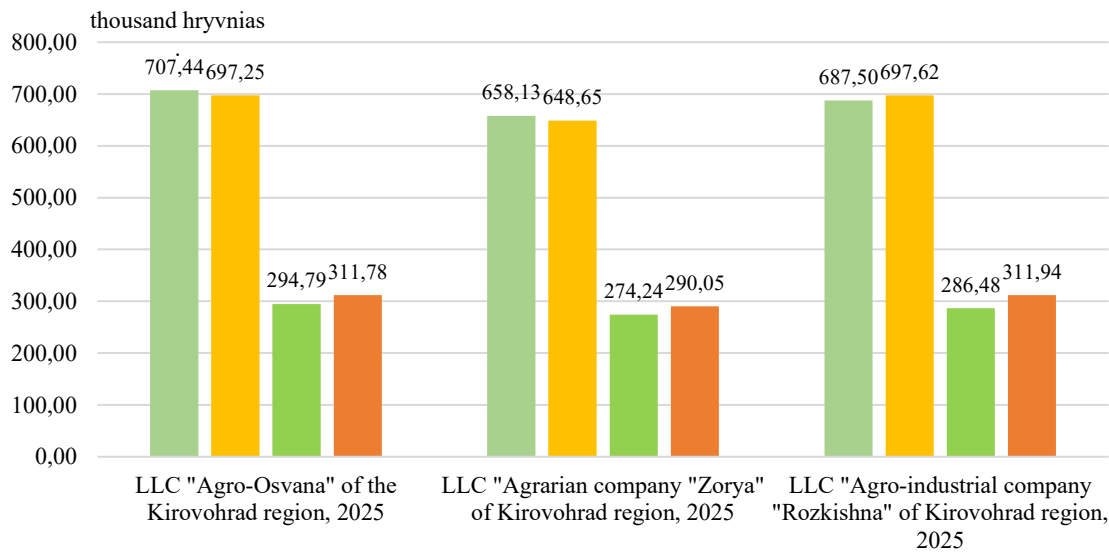
\*Source: suggested by the authors.

Graphically, the forecast optimal production of gross products in monetary terms, taking into account the clustering of three agricultural enterprises for the next period, is presented in fig. 2 and fig. 3.



**Figure 2. Forecast production of gross production of grain crops in monetary terms, taking into account the clustering of three agricultural enterprises, 2025**

\*Source: suggested by the authors.



**Figure 3. Forecast production of gross production of industrial crops in monetary terms, taking into account the clustering of three agricultural enterprises, 2025**

\*Source: suggested by the authors.

As a result of all calculations, this is the calculation of the profit from the collected optimization acreage of three business entities of the Kirovohrad region, taking into account clustering for the next period (Table 6).

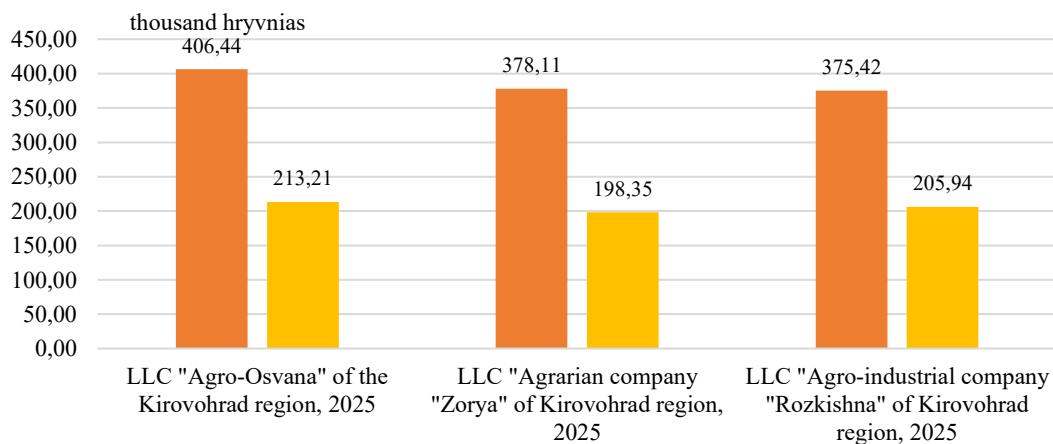


**Table 6. Forecast value of profit taking into account the clustering of three agricultural enterprises, 2025**

Agricultural enterprises	Profit, thousand UAH 2025		
	Winter wheat	Corn for grain	Total, thousand UAH
LLC "Agro-Osvana" of the Kirovohrad region, 2025	406,44	213,21	619,65
LLC Agrarian company "Zorya" of Kirovohrad region, 2025	378,11	198,35	576,46
LLC Agro-industrial company "Rozkishna" of Kirovohrad region, 2025	375,42	205,94	581,36
Agricultural enterprises	Profit, thousand UAH 2025		
	Sunflower	Soy	Total, thousand UAH
LLC "Agro-Osvana" of the Kirovohrad region, 2025	294,79	311,78	606,57
LLC Agrarian company "Zorya" of Kirovohrad region, 2025	274,24	290,05	564,29
LLC Agro-industrial company "Rozkishna" of Kirovohrad region, 2025	286,48	311,94	598,43

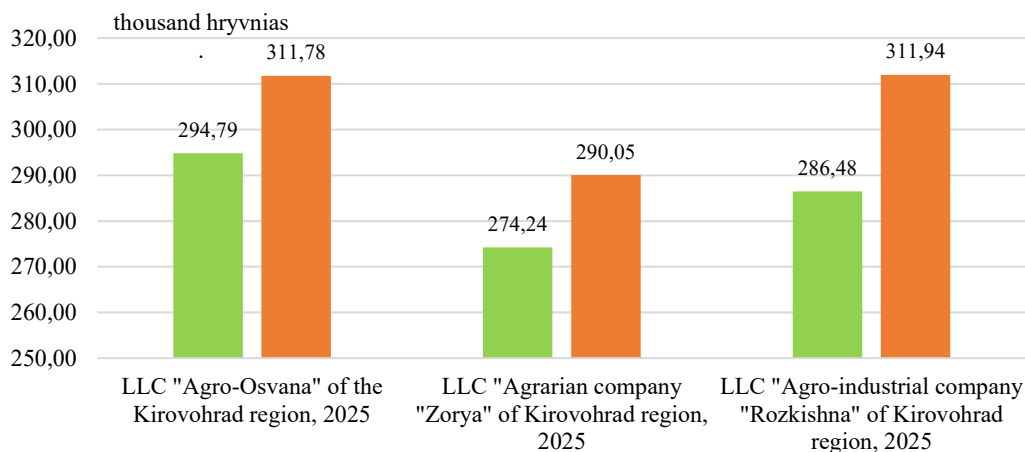
\*Source: suggested by the authors.

Graphically, the forecast value of profit taking into account the clustering of three agricultural enterprises for the next period is presented in fig. 4 and fig. 5.



**Figure 4. The forecast value of the profit of grain crops taking into account the clustering of three agricultural enterprises, 2025**

\*Source: suggested by the authors.



**Figure 5. Forecast value of the profit of industrial crops taking into account the clustering of three agricultural enterprises, 2025**

\*Source: suggested by the authors.



The last stage of research and modeling of cluster development of agricultural enterprises in conditions of digitalization, legal risks. of innovative education and Smart-economy - generalization and comparison of

actual and forecast values of production of gross products in the field of crop production and profit of the field of crop production of the studied agricultural enterprises, taking into account the clustering carried out (Table 7).

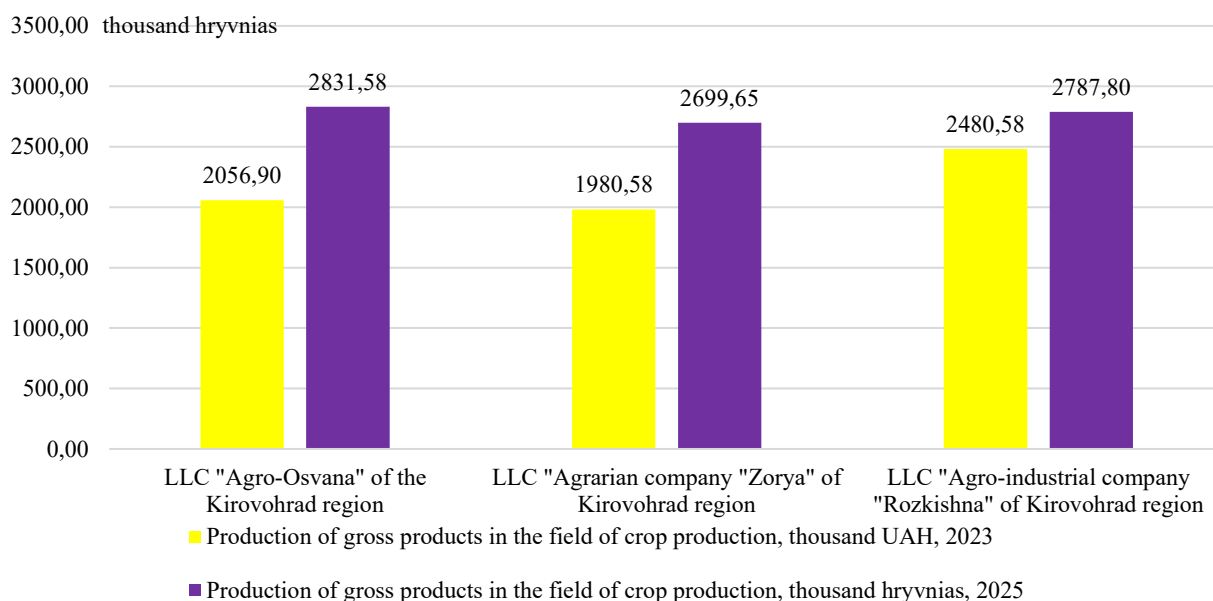
**Table 7. Actual and forecast values of production of gross products and profit of the crop production industry of the investigated agricultural enterprises, taking into account clustering, 2023, 2025**

Agricultural enterprises	Production of gross products in the field of crop production, thousand UAH, 2023	Production of gross products in the field of crop production, thousand hryvnias, 2025	Absolute deviation of 2025 from 2023, +,-	Relative deviation of 2025 from 2023, %
LLC "Agro-Osvana" of the Kirovohrad region	2056,90	2831,58	774,68	37,66%
LLC Agrarian company "Zorya" of Kirovohrad region	1980,58	2699,65	719,07	36,31%
LLC Agro-industrial company "Rozkishna" of Kirovohrad region	2480,58	2787,80	307,21	12,38%
Agricultural enterprises	Profit (loss) in crop production, thousand UAH, 2023	Profit (loss) in the field of crop production, thousand hryvnias, 2025	Absolute deviation of 2025 from 2023, +,-	Relative deviation of 2025 from 2023, %
LLC "Agro-Osvana" of the Kirovohrad region	1119,44	1226,22	106,78	9,54%
LLC Agrarian company "Zorya" of Kirovohrad region	754,62	1140,75	386,13	51,17%
LLC Agro-industrial company "Rozkishna" of Kirovohrad region	954,62	1179,79	225,17	23,59%

*\*Source: suggested by the authors.*

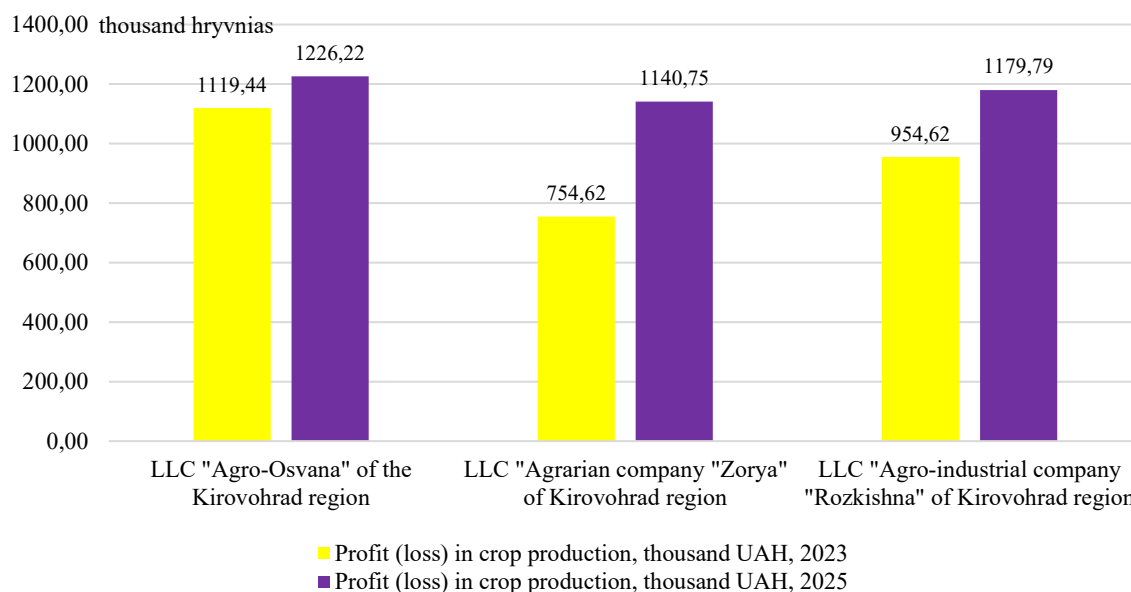
Analyzing the calculated economic indicators of agricultural enterprises, it is necessary to note the growth in the forecast period of the production of gross products and the profit of the crop industry, which can be a positive phenomenon of management, taking into account the processes of digitalization and

legal risks. innovative education and Smart economy. Graphically, the actual and forecast values of the production of gross products and profit of the crop production industry of the investigated agricultural enterprises, taking into account clustering for the last and next period, are presented in fig. 6 and fig. 7.



**Figure 6. Actual and forecast values of the production of gross products of the field of crop production of the investigated agricultural enterprises, taking into account clustering, 2023, 2025**

\*Source: suggested by the authors.



**Figure 7. Actual and forecast values of the crop industry profit of the studied agricultural enterprises, taking into account clustering, 2023, 2025**

\*Source: suggested by the authors.

The use of the modified distribution method of the closed type allows to optimize the comparison of the forecasted production volumes with the available actual resources of agricultural enterprises. In the conditions of growing digitalization, this approach contributes to increasing the efficiency of resource allocation due to more accurate accounting of actual

indicators and forecasted needs. The model of cluster development of agricultural enterprises in combination with new technologies, such as Smart economy, allows enterprises to join forces to increase competitiveness and optimize production processes. In addition to technical innovations, it is important to consider the legal risks that accompany the implementation of

digital technologies. Legal aspects related to data protection, intellectual property and digital resource management are becoming key factors in enterprise development strategies. Innovative education, which integrates knowledge of the latest digital and technological processes, provides the necessary training of personnel capable of working effectively in the conditions of the Smart economy. Thus, the integration of digitalization, legal risk management and the implementation of innovative education within the framework of a cluster approach contributes to increasing the overall productivity and sustainability of agricultural enterprises.

### Conclusions

The proposed modeling demonstrates the dynamics of the development of agricultural enterprises in the field of crop production based on actual and forecasted data on the production of gross products and profit for 2023 and 2025. In the context of the cluster development of agricultural enterprises in the conditions of digitalization, legal risks, innovative education and Smart economy, these indicators indicate the potential for increasing the efficiency and profitability of the industry. Enterprises such as Agro-Osvana LLC, Zorya Agrarian Company

LLC, and Rozkishna Agro-Industrial Company LLC demonstrate growth in gross output and profit, indicating optimization of production processes. In conditions of digitization, enterprises can implement modern technologies for precision farming and analysis of market trends, which will ensure effective management of resources and increase their competitiveness. Cluster development involves the association of enterprises for the joint use of technological innovations and management practices. This reduces risks related to legal aspects, as clusters can work on common standards for legal protection of data and contracts. Innovative education will help provide enterprises with highly qualified personnel who will be able to implement digital technologies and adapt to changes in the legal environment. The significant relative growth of profit in LLC “Zorya” and “Roskishna” indicates the perspective of the introduction of innovative technologies and the cluster model. The integration of the Smart economy will further increase the efficiency of operations due to automation, digital process management and cost reduction, which will contribute to the stable growth of enterprise revenues.

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