Case study on Ukrainian farm gross margin and direct cost analysis of wheat production

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Abstract. The paper aims to present a case study of profitability analysis based on gross margin calculations to evaluate agricultural measures' financial impact on the final economic figures at Korystivske LLC Farming Company. Based on the information collected from annual financial statements, statistical reports and accounting data from 2011-2023, the analysis relies on the gross margin method compared to the yield statistics of the main crops grown. The mathematical modelling in correlation and regression models shows the relationship between using fertilizers and pesticides and the resulting yields. Temporary reduction of fertilizer and plant protection intensity will reduce yields to some extent but will avoid deterioration of the financial situation of the analyzed farm. The model shows that intensification of agricultural technologies will not directly increase profits. The relationship between the use of mineral and organic fertilizers, pesticides, herbicides and fungicides and the dynamics of marginal profit is insignificant. It cannot give us specific recommendations on the direct impact of the intensity of agricultural practices on farm profitability. Further modelling of the relationship between agricultural technology and gross margins did not show any acceptable correlation, which proves the importance of forecasting final prices when intensifying fertilizer and pesticide use. The study results showed that high input prices are the most acute problem, and lower output prices are the last obstacle to further intensification of wheat production.

1 Introduction

The ongoing conflict in Eastern Ukraine, which began in 2014 and intensified in 2022, has had a significant impact on the country's agricultural sector. It has disrupted farming activities, caused damage to infrastructure, and displaced people from their homes and farmland. If the conflict continued or escalated in 2024-2025, it would likely continue to affect Ukrainian agriculture negatively.

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Ukraine is a major exporter of agricultural products, including wheat, corn, and sunflower oil. International trade relationships, sanctions, and export restrictions can have a substantial impact on the country's agricultural exports. Any changes in trade dynamics, especially with key trading partners, could affect the agricultural sector.

Ukrainian agricultural exports are sensitive to global commodity price fluctuations. Changes in prices for key commodities like wheat, rapeseed etc. can impact the income of Ukrainian farmers and the country's overall agricultural sector. The war and low prices can slow down the investments.

Ukraine has been a significant player in the global wheat market. The country experienced notable growth in wheat production over the years leading up to 2022. Favorable weather conditions and the expansion of cultivated land contributed to this growth. Ukraine has consistently been one of the world's largest wheat exporters. It exports a significant portion of its wheat production to international markets, including countries in Europe, North Africa, the Middle East, and Asia.

Like all agricultural commodities, Ukrainian wheat exports are subject to fluctuations in global demand, currency exchange rates, and international trade conditions. Changes in these factors can influence the export performance of Ukrainian wheat. To understand how the Ukrainian wheat production suffers from the full scaled Russian invasion we propose to analyze the outcome, gross margins and their dynamics during the period before and after war outbreak. Gross margin in crop planting is a financial indicator used in agriculture to assess the profitability of cultivating specific crops. It represents the difference between the total revenue generated from selling the harvested crops and the total variable costs incurred in producing those crops within a specific area or for a specific crop variety. Gross margin is expressed as a monetary value and is a crucial tool for farmers and agricultural businesses to evaluate the financial performance of their crop production.

Variable costs are the expenses directly associated with crop production and can vary depending on the crop type, location, and farming practices. Variable costs include items such as: Seed and Planting Material, Fertilizers and Nutrients, Pesticides and Herbicides, Labor and Machinery, Irrigation and Water Management, Fuel and Energy, Miscellaneous Costs.

The formula for calculating gross margin in crop planting is as follows:

$$\textit{Gross Margin} = \textit{Total Revenue} - \textit{Total Variable Costs} \qquad (1)$$

The resulting gross margin figure represents the amount of money that remains after covering the variable costs associated with crop production. It provides insight into whether the crop production is financially viable and if it can cover both variable and fixed costs, such as land rental or depreciation of equipment. A positive gross margin indicates profitability, while a negative gross margin suggests that the crop production may not be economically sustainable without adjustments.

Many publications focus on defining and explaining the concept of gross margin, emphasizing its role as a financial indicator in agriculture, such as F. Kasonga [1], G. Coppola [2].

Researchers often discuss the components of gross margin, such as total revenue and variable costs, and how they relate to farm economics. Numerous studies explore the application of gross margin analysis at the farm level making Cost-benefit analysis, for example publication of Yrjölä, Tapani & Kola, Jukka [3]. These analyses help farmers and policymakers understand the financial viability of various crops and farming practices.

Publications of M. Lizot, F. Trojan, P. Afonso examine various factors that influence gross margins in agriculture, including market prices, input costs, technology adoption, weather conditions, and government policies to support the decision making in farming [4].

Studies often use statistical models and regression analyses to identify the key drivers of gross margin variability, for example well known research of accounting applied to farming by M. Devkota [6].

Haixia Wu [7] investigates how farmers make crop selection decisions based on gross margin analysis. This includes evaluating the relative profitability of different crop choices.

R. Sharma Mina Devkota, Yigezu Atnafe Yigezu [5, 6] assess the relationship between sustainable farming practices and gross margin. They examine how factors like organic farming, conservation tillage, or precision agriculture can impact both profitability and environmental sustainability.

Publications very rare address the role of risk and uncertainty, especially under war conditions during gross margin analysis [7-9]. However, researcher consider geographical and regional differences in gross margins, recognizing that factors such as climate, soil quality, and local market conditions can significantly influence profitability, but the impact of war stays still open [11-13].

Many publications provide empirical case studies from specific regions or farming systems, offering practical insights into the application of gross margin analysis in real-world contexts [14-17]. The current publication aids to show how the impacts of war such as price fluctuations, logistic problems and high risk of destruction and both material and financial losses mirror on Ukrainian middle sized farm, for Ukraine is one of the largest suppliers of agricultural products, primarily grains and oilseeds, to the global market. Ukraine is the world's 2nd largest exporter of grains and 7th largest exporter of oilseeds worldwide [11].

The study's objective is to analyze the financial trends of Ukrainian agricultural enterprises in terms of individual crops and to find approaches to the optimal level of use of expensive mineral fertilizers and pesticides in the context of high prices for them and low prices for the final product. The specific objectives of the study are to estimate the profitability of the selected agricultural enterprise during the study period; to analyze the dynamics and structure of direct costs associated with the farm's operations per 1 ha of fields; to study the gross margin by crops and for the farm as a whole and identify individual influencing factors.

The calculation aims to predict whether the same level of wheat supplies from Ukraine can be expected in the face of difficult logistics and high input prices.

2 Proposed model and methodology

This study is generally based on both primary and secondary data. The primary data sources include farm accounting and data collected interviewing the farm management, the secondary data comes from the profit and loss account, balance sheet and agricultural statements of Korystivske LTD. The period of study extends over financial years from 2011 to 2023, the data taken to the modelling approaches considers the period from 2015 to 2023. The data collected refers to the profitability of the enterprise especially the profitability based on gross margin calculation. The Gross Margin analysis include main crops and is related to the whole farm too.

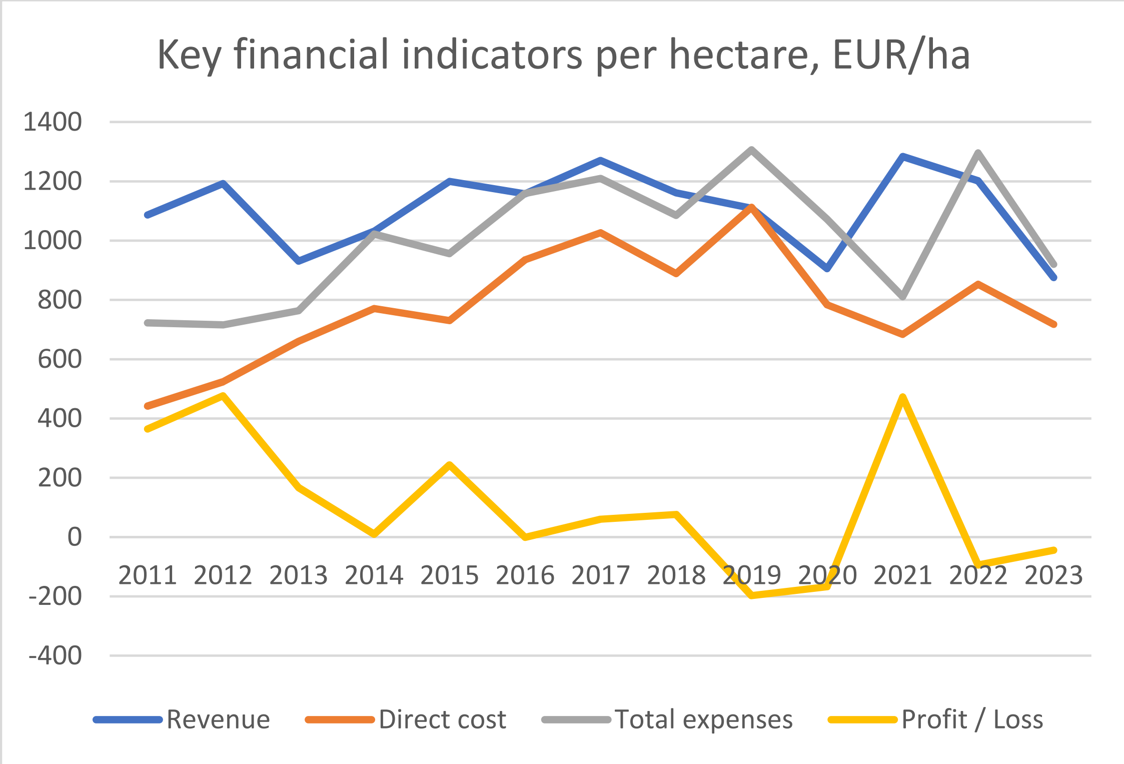


Figure 1. Key financial indicators per hectare, EUR/ha.

The company has fairly stable financial performance. However, the period from 2019 to 2023 is unprofitable for the company, except for 2021, when the economic conditions and output prices were objectively very favorable. In 2019-2020, the reason was low yields due to unfavorable weather conditions, and in 2022-2023, high logistics costs and low final selling prices.

Table 1. Yields of the main crops grown, to/ha.

Crop / Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Winter wheat	51	54	54	62	62	56	71	78	86	49	105	90	85
Corn	82	77	80	64	64	98							
Winter barley	46	37	44					75	67	61	95	72	67
Winter rapeseed	31	39	35	43	47	43	52	42	38	29	40	40	39
Sugar beet		411	331	375	341	523							

Source: calculations based on statistical reports, 29sg-formular 2011 – 2023.

The period 2022 - 2023 is a special one, as high yields were accompanied by a significant increase in production costs, which, in terms of both direct costs and total cost, significantly exceeded revenue growth, resulting in losses of €94 per hectare in 2022 and €44 per hectare in 2023 [8].

We believe that this was due to high prices for transporting products to the market in 2022, which increased due to the blocking of sea export corridors through Ukrainian. As a result, Ukrainian companies were forced to export their products by road and partially by rail, which is much more expensive. In 2023 occurred both – expensive logistic and falling world prices for crops.

Analysing the data by individual crops, we note that in each of the unprofitable years, one crop was responsible for the negative result: barley was unprofitable in 2019, rapeseed in 2020, winter barley in 2022, and winter wheat in 2023.

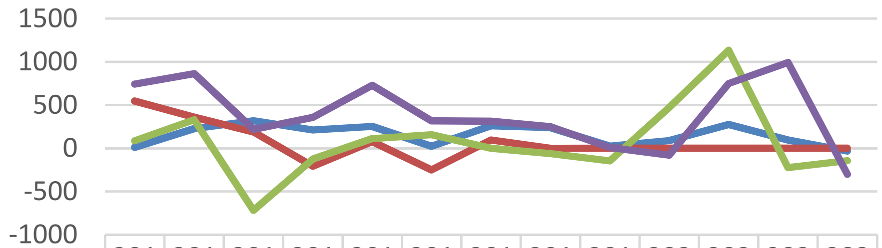
According to the results of the study of the correlation level between the indicators under consideration, we can conclude that for the main crops, Gross Margin is less determined by the level of yield and more by other factors. In particular, for wheat, the correlation coefficient is -0,02, which indicates that there is practically no correlation between the change in marginal profit and the yield of this crop. All other things being equal, the main, if not the decisive, factor affecting gross profit is the market price of the crops produced.

Table 2. Pearson's correlation coefficient.

Crop	Pearson's correlation coefficient	Degree of relationship
Winterwheat	-0,02	Non-significant inverse relationship
Corn	0,62	Medium direct relationship
Winter Barley	0,56	Medium direct relationship
Winter Rapeseed	0,19	Weak direct relationship

Therefore, for a more detailed analysis of the factors, we will estimate the marginal income for the main agricultural crops grown by the company. As we can see from the previous data, these crops are winter wheat, winter barley and winter rapeseed, and in previous periods - corn. The use of gross profit over standard profit measurement, especially in agriculture, has some advantages that make it a preferred measure for assessing the financial performance of agricultural businesses [17-20]. Here are a few reasons why gross profit calculation is often considered better in agriculture:

1. Gross profit is a straightforward measure that focuses on the direct costs associated with production, such as the cost of seeds, fertilizers, labor, and other inputs, subtracted from the revenue generated from selling the agricultural products. This simplicity makes it easy to calculate and understand which is particularly important in the agricultural sector, where operations can vary widely in scale and complexity.
2. Agriculture often involves many variable costs, such as the price of inputs (e.g., fertilizers, pesticides, and fuel) and labor. Gross profit allows farmers to track and control these variable costs efficiently. Monitoring gross profit margins can help farmers make informed decisions about resource allocation and cost management.
3. Agricultural income can be highly seasonal, with most revenue generated during specific planting and harvesting periods. Gross profit helps capture the income and expenses associated with these seasonal variations, providing a more accurate picture of short-term profitability.



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Winter wheat	10	226	318	211	252	23	258	239	24	87	276	95	-33
Corn	546	360	188	-208	77	-251	95	0	0	0	0	0	0
Winter barley	85	331	-719	-125	110	156	0	-62	-148	471	1135	-223	-145
Winter rapeseed	743	863	218	357	728	316	310	250	8	-80	749	993	-302

Figure 2. Gross Margins, EUR/ha.

It should be noted that the calculation of Gross margins does not take into account transportation costs to the consumer. In all previous periods, these costs were not significant and did not affect financial performance. However, in 2022, these costs increased extremely rapidly. In particular, the cost of transporting 1 tonne of crop to the consumer for exports to German ports was up to EUR 260 per tonne, and to consumers in Poland - about EUR 150 per tonne. If these figures were taken into account in the calculation of Gross margins, all crops would show negative Gross Marginability. Expensive logistics in 2022 resulted in a discrepancy between positive gross margin and negative bottom line.

The gross margin fluctuated during the reporting period. A high level of gross margin indicates that management is making a concerted effort to reduce production costs. The significance test showed that the gross margin was uniform over the period under review

Thus, it is hypothesised that yield maximisation in times of financial and political instability does not lead to profit maximisation due to two factors - low commodity prices and high prices for mineral and organic fertilisers and pesticides.

Therefore, we propose to analyze the impact of agricultural inputs on yields and Gross Margins.

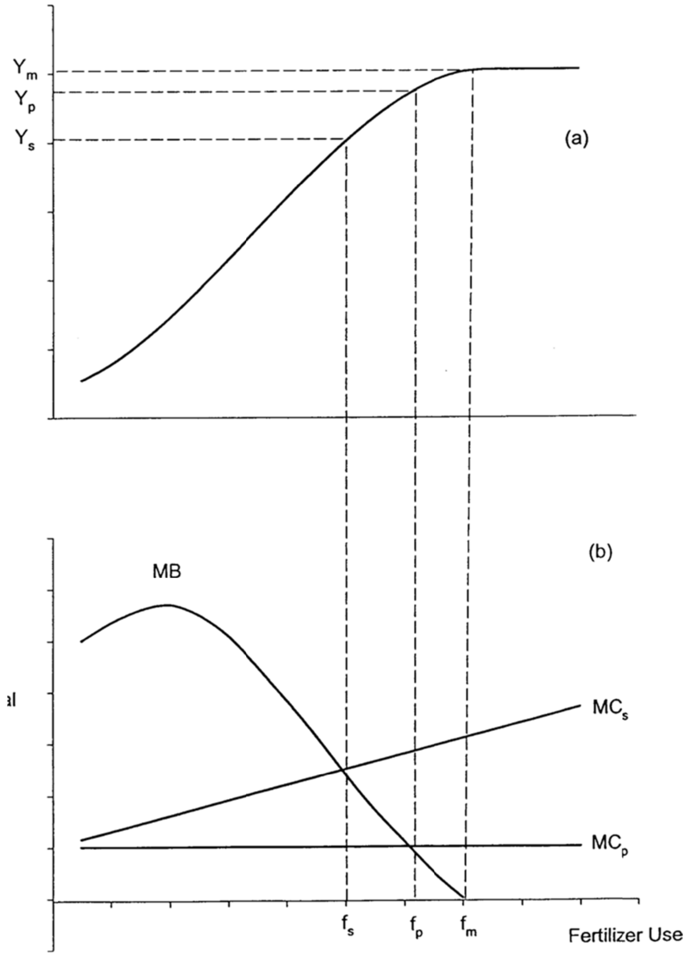


Figure 3. The relationship between yield, marginal benefit / cost, and fertilizer use [10, 11].

In agricultural economics, Profit could be maximised equaling the marginal value of the input product to its price. Thus, examining whether the ratio between the marginal value of mineral fertilisers and pesticides product and the mineral fertilisers and pesticides price is less than one, we are able to identify the deviation in the use of mineral fertilisers and pesticides [10, 12]. Based on the above information, in this article we first chose the classic logarithmic Cobb-Douglas production function model to measure the price elasticity of fertiliser and pesticide application:

$$\ln Y=\beta_0+\beta_1\times\ln F+\beta_2\times\ln L+\beta_3\times\ln M+\beta_4\times\ln S+\beta_i\times Farmer+\beta_j\times Land+\varepsilon_1 \quad (2)$$

where Y – the wheat yield per hectare as an dependent variable. Independent variables are represented by fertilizer per hectare (F), labor input (L), machinery use (M), seeding material input (S), the farmer business talent and land plot quality ($Farmer$ and $Land$). $\varepsilon 1$ represents a random disturbance term. The elasticity of output of fertilizer and pesticides refers to β_1.

However, additional to this, if the aim is the profit maximisation, the goal is to calculate the optimal level of fertiliser and pesticide application. As already mentioned, the farmer's profit is maximised when the marginal benefit equals the marginal cost. Thus, the marginal effect of applying mineral fertilisers and pesticides to wheat crops should be equal to the ratio of the price of mineral fertilisers to the price of wheat.

At the same time, if we take into account the marginal effect of applying mineral fertilisers and pesticides in terms of wheat yield, calculated using formula (2), the optimal amount of mineral fertilisers per hectare will be equal to

$$F_{optimal}=(\beta_1 \times Y)/(P_F Y_Y) \quad (3)$$

Precisely, by deducting the ideal application rate from the actual application rate per hectare, one can determine the degree of deviation of the application rate per hectare after calculating the optimal application rate per hectare using formula (3).

$$F_{deviate}=F_{actual}-F_{optimal} \quad (4)$$

Since one of the goals of the analysis in this article was the extrapolation of the results of the analysis of a typical farm to the state of Ukrainian agriculture as a whole, in order to find the economic optimum of fertilizer application, in the next part of the article we will construct production functions separately for the selected main agricultural crop, which is decisive for the farm .

In our case, the idea is to analyse how the level of farming intensity, which is designed to maximise yields, affects the level of Gross Margin received per hectare of land. The purpose of the study is to test the hypothesis that maximum production does not bring maximum profit, because sooner or later, the production of an additional unit of product will cost you more than it will bring in profit. Thus, we plan to analyse whether intensive fertilisation and crop protection products are justified for the enterprise in question, or whether, given the low price and high costs forecast, the enterprise should temporarily abandon intensive farming, thus reducing yields but also reducing potential losses. We propose to calculate the economic efficiency the enterprise should temporarily reduce the intensity of farming using the aforementioned Gross Margin indicator. For example, we will take the wheat production during the period 2015 - 2023 of the above-mentioned medium-sized farm. For the analysed enterprise, wheat production is crucial, as during the analysis period, the area under this crop accounted for more than half of the total area under crops annually. Then the model will look like this:

Factors influencing the output factor (Gross margin and yield):

1. Cost of planting material (X1).
2. Fertiliser costs (organic and mineral) (X2, X3).
3. Application of so-called plant protection products (pesticides, herbicides and fungicides), and the level of expenditures on them (X4).

Table 3. Input data by year.

Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Area, ha	537	709	540	695	681	838	730	708	780
Gross Margin for Wheat, EUR/ha	253	23	258	239	24	87	276	95	-33
Yeald, to/ha	6	6	7	8	9	5	11	9	8,5
Seeding material cost, EUR/ha	18	11	20	19	32	27	25	22	25
Fertilizer, EUR/ha	129	81	102	81	160	65	62	1	48
Organic fertilizer, EUR/ha	49	31	38	18	20	10	8	11	10
Pesticides, EUR/ha	18	12	93	92	118	124	64	152	120

Based on the collected statistical data, several models of the dependence of marginal income and yield on the above factors were developed: the logarithmic production function model, the linear model, and the hyperbolic model:

$$Y = a_0 + \frac{a_1}{x_1} + \frac{a_2}{x_2} + \cdots + \frac{a_n}{x_n} \quad (5)$$

The results of this modelling are presented in the tables below:

Table 4. Modelling the dependence of Gross Margin on production factors.

Model	Resulting equation	Correlation index	The option with the closest connection
Logarithmic	ln Y = 3,67-0,27lnx1-0,04lnx2+0,13lnx3+0,29lnx4	0,492	+
linear	Y= 2,57+10,04*x1-1,25*x2+5,15*x3-1,12*x4	0,438	
Hyperbolic	Y=192,8+533,5/x1-47,2/x2-743,7/x3-1209,7/x4	0,255	

Table 5. Modelling the dependence of yields on production factors.

Model	Resulting equation	Correlation index	The option with the closest connection
Logarithmic	ln Y = 1,72+0,26lnx1-0,032lnx2-0,10lnx3-0,02lnx4	0,517	
linear	Y= 7,41+0,15*X_1-0,01*X_2-0,05*X_3-0,01*X_4	0,573	
Hyperbolic	Y=7,25-12,1/x1+0,73/x2+17,87/x3-9,24/x4	0,575	+

Based on the results of modelling the Gross Margin, we see that the most appropriate model is the logarithmic model, however, even it shows that the level of this indicator by only 49% is determined by production factors, where determination by other market factors is 51%. At the same time, the most appropriate model for predicting yields based on the same factors is the hyperbolic model, which shows that 57.5% of this parameter is determined by production factors. Thus we conclude that intensification of production through agricultural inputs has a greater impact on yields and a much smaller impact on financial results.

The application of the methodology of partial factor productivity, described in more detail in our previous article, also helps to confirm the previous conclusions [11]. According to this methodology, we estimate the extent to which partial input factors (in our case, the cost of seeds, fertilisers and protection products) affect changes in Gross Margin and yield.

As can be seen from the table 6, in some years fertiliser application had a certain impact on the gross margin dynamics, while in most cases this impact was rather insignificant (except for 2022, when a 1% increase in fertiliser costs led to a 21% increase in gross margin). Instead, in 2023, the increase in costs for mineral fertilizers and plant protection products led to an increase in the unprofitability of the company's activities. At the same time, the impact of the same factors on the yield level (Table 7) is more stable, which confirms the stable dependence of the latter on these production factors. However, as the analysis for the same year 2022 showed, the impact of fertiliser application on yields was more intense (for every single percent of mineral fertilizers cost growth, there was a 50% crop increase).

Table 6. Results of partial factor productivity calculation (by Gross Margin).

Years	X1	X2	X3	X4
2016	0,15	0,14	0,14	0,14
2017	6,17	8,91	9,15	1,45
2018	0,98	1,17	1,96	0,94
2019	0,06	0,05	0,09	0,08
2020	4,30	8,92	7,25	3,45
2021	3,43	3,33	3,97	6,15
2022	0,39	21,34	0,25	0,14
2023	-0,31	-0,01	-0,38	-0,44

Table 7. Results of the calculation of partial factor productivity indicators (by Yield).

Years	X1	X2	X3	X4
2016	1,64	1,59	1,58	1,50
2017	0,64	0,93	0,95	0,15
2018	1,20	1,44	2,41	1,16
2019	0,67	0,57	1,01	0,88
2020	0,66	1,37	1,11	0,53
2021	2,38	2,31	2,75	4,26
2022	0,93	50,73	0,60	0,34
2023	0,83	0,02	1,04	1,20

This research confirms the previous conclusions that a temporary reduction in intensity of farming will reduce yields to some extent, but will protect the significant drop of farm's financial position. The belief that the generous agricultural technology will directly increase Gross Margin was not confirmed. The relationship between the growth rate of mineral and organic fertilisers and plant protection use and Gross Margins is insignificant and cannot give us specific recommendations on the direct impact of the intensity of agrotechnical measures on the farm profitability level.

On the other hand, the results of calculations have shown that for an average agricultural enterprise, the most significant risk is primarily the risk of low yields, which is also confirmed by the modelling results. In turn, if yields are achieved, it is the level of prices for final products, which would also take into account the costs of transporting the products to the end consumer, that is crucial for the formation of Gross Margin. It was in years with high prices that gross margin was the highest, and vice versa, in years with low prices and high logistics costs, gross margin, as well as profit in general, was negative.

3 Results

An agricultural enterprise faces the difficult task of determining within what limits it can manoeuvre direct costs to maintain the required profit level on the one hand and to ensure that cost savings do not critically affect yields on the other. In this study, a model for optimising direct costs was proposed.

Variables are entered next: X1, X_2, X_3, X_4 – components of direct costs that correspond to the cost of production factors affecting yield (respectively, X_1 – cost of seeds and planting material, euro/ha; X_2 – cost of mineral fertilisers, EUR/ha; X_3 – cost of organic fertilisers, EUR/ha; X_4 – cost of plant protection products, EUR/ha. It was used the correlation model presented above to determine the yield, taking into account the influence of production factors (the calculations in this study are given for winter wheat). The Gross margin function is then defined as the difference between revenue (the result of price, yield and area) and total direct costs of growing wheat. In the system of constraints, we take into account that the yield should not be below the critical level when the costs of growing are not covered by the sales revenue. In addition, the total amount of direct costs of growing a crop for a certain period is limited by the financial position of the enterprise and available working capital. That is, the maximum cost is B_T^{max}.

An important indicator for building the model is the output price, which only depends on the market situation and which we have no influence on. To ensure the accuracy of the model, it is additionally proposed to use price forecasting methods that take into account the risks of price fluctuations. To take into account the risk of price fluctuations, a series of price dynamics for the selected culture have to be built first. Then, we are able to develop the price trend for the crop analyzed, which depends on the fluctuations of the corresponding price for each crop:

$$\hat{P}_{t+1} = f(t+1) \tag{6}$$

The expected income will be:

$$GM = P*(7{,}25-12{,}1/X_1+0{,}73/X_2+17{,}87/X_3-9{,}24/X_4)*S - (X_1+X_2+X_3+X_4) * S \rightarrow max$$

$$\text{Limitations: } \begin{cases} S*X_1 + S*X_2 + \ldots + S*X_n \leq B_m^{max}; \\ 7{,}25-12{,}13/X1+0{,}73/X2+17{,}83/X3-9{,}21/X4 > Y_{cr} \end{cases} \tag{7}$$

This model can be solved by using the Excel Solver. As a result, the agricultural enterprise will receive such a distribution of direct costs that will ensure maximum gross margin (GM). The model can be improved and detailed by adding several crops according to a predefined crop structure.

4 Conclusions

Thus, was proved that the application of plant protection products and mineral fertilisers should be calculated based not only on the maximising yields criteria, but on the maximising profitability as well. For this purpose, we propose to use the Gross Margin indicator, which avoids result distortions due to the inclusion of overhead expenses, which are relatively constant and cannot be regulated, unlike direct production costs. In periods when prices for the final products of agricultural enterprises are expected to be low due to market conditions, such as the current military aggression of the Russian Federation and the general instability of the agricultural market that has resulted from it, the intensity of crop cultivation should be adjusted to minimise costs.

The correlation and regression models built by the authors showed a correlation between the use of fertilisers and pesticides and the yields obtained, so a decrease or increase in the intensity of fertiliser and pesticide use will to some extent reduce or increase yields. However, at the same time, the modelling results show that the level of intensity of agricultural technologies will not lead to changes in the level of profit.

The direct relationship between the use of mineral and organic fertilisers, pesticides, herbicides and fungicides and the dynamics of marginal profit is not significant, as modelling the relationship between agricultural technology and gross profit did not reveal an acceptable correlation. This proves the importance of forecasting final prices when planning the use of fertilisers and pesticides. The market price of agricultural products has a much greater impact on the final results. Given the high prices for these resources, the most acute problem is optimising their use, so the authors propose a model for optimising agronomic approaches depending on the expected market price. In this case, it is the reliability of price forecasting that will answer the question of whether a particular enterprise should invest significant funds in increasing yields. If the price of the final product is suspected to be unstable, the enterprise should pursue a safer investment policy that takes into account the possibility of low market prices. This would allow the company to maintain its profitability despite the decline in yields or at least minimise losses arising from such market events. In the context of significant market volatility caused by political instability and military actioni, such a policy could make sense and save farmers from significant losses, allowing them to survive the crisis and intensify production in a more stable market.

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