Modelling Agricultural Productivity in the Management of the Production Component of Economic Security of Agribusiness

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Abstract. *The article carries out an intersectoral study of the influence of meteorological and agrotechnical factors on the productivity of agricultural production (on the example of sugar beet) as a key indicator of the production component of the economic security of agribusiness. It is determined that in the framework of the experiments carried out to increase the productivity of sugar beet, insufficient attention is paid to the impact of meteorological conditions prevailing in the year of the experiments, which, in turn, may cast doubt on the reliability of the results obtained, for example, in the year of abnormal weather conditions. That is why the article outlines a methodological and practical approach to modelling and assessing the impact of meteorological conditions (uncontrollable factors) and agrotechnical practices – liming and organic fertilisation (controllable factors) – on sugar beet yield. It has been substantiated that the results of the carried-out correlation-regression analysis of the influence of meteorological conditions on the productivity of sugar beet are suitable for practical use and can be useful for conducting an experiment and obtaining a more accurate result of assessing the impact of agrotechnical practices of various nature, considering the factors of influence of weather conditions on the yield of sugar beet. As part of modelling and analysing the impact of agronomic practices – liming and organic fertilisation (controlled factors) – on sugar beet yields, it was proposed to apply such agronomic practices as defecate application (50% of the full rate depending on the hydrolytic acidity of the soil). Based on the results obtained, the models (equations) of dependence of sugar beet yield and digestibility on different doses of defecate and organic fertiliser were built, which will allow making effective management decisions in the field of managing the production component of economic security of agribusiness. Thus, the study identified, evaluated and modelled the impact of meteorological conditions and agrotechnical methods of soil liming and organic fertilisation on the productivity of sugar beet as a key indicator of production security of agribusiness. When conducting research with the use of agrotechnical techniques and determining their effectiveness based on the proposed models, it is important for the operational director (agribusiness director) to assess the meteorological conditions that prevailed in the year of the study.*

Keywords: *agribusiness, economic security, production component of economic security, agricultural productivity, modelling.*
JEL Classification: *D02, M21*

1 Introduction

The production component of the economic security of agribusiness is fundamental to ensuring the efficient and continuous operation of agricultural enterprises. It covers all aspects related to the production process, from growing crops to harvesting and primary processing of products (Bohdan S., 2024). One of the key elements of the production safety system is production risk management, which includes forecasting and minimising the impact of adverse weather conditions, pests, plant diseases, and other factors that may adversely affect yields and productivity. An important aspect is the optimisation of the use of resources such as land, water, seeds, fertilisers and plant protection products. Effective management of these resources helps to increase yields and product quality, as well as reduce costs. Production safety also includes the introduction of modern technologies and innovations, such as automation and mechanisation of production processes, the use of precision farming systems, and information and communication technologies to monitor and manage production processes. Compliance with industrial safety standards and norms is critical to ensuring high quality and safety of products. The production component of the economic security of agribusiness also includes measures to increase the resilience of production to external challenges, such as climate change, economic crises and geopolitical risks (Tytenko L., 2018). In general, the production component of agribusiness economic security is a comprehensive system that includes risk management, optimisation of resource use, introduction of technologies and innovations, compliance with safety and quality standards, and ensuring resilience to external challenges. This allows agricultural enterprises to ensure stable and efficient production, while maintaining their competitiveness and economic sustainability.

At the same time, in the system of managing the production security of agricultural enterprises in terms of ensuring the productivity of agricultural production, special attention should be paid to uncontrollable and controllable factors – meteorological conditions and the use of specialised agricultural techniques. It is possible to assess the impact of these two factors on the state of production security of agribusiness by means of modelling.

The aim of the study is to identify, assess and model the impact of meteorological conditions and agrotechnical practices (for example, soil liming and organic fertilisation) on the state of production security, which is determined by the productivity of sugar beet production. This goal was achieved on the basis of the conclusions obtained from the results of solving the following scientific and practical tasks on modelling and assessing the impact of: meteorological conditions (uncontrollable factors) and agrotechnical practices – liming and organic fertilisation (controlled factors) on sugar beet yield as a key indicator of production security of agribusiness.

The research was carried out in 2023 using the desk method (as part of the study of the influence of meteorological factors) and the field method (as part of the study of the influence of agrotechnical factors) on a farm located in the Podillia region. The data for modelling the influence of meteorological conditions on sugar beet productivity were obtained from meteorological stations located in Vinnytsia region in the settlements of Haisyn, Horodkivka, Kryklyvets, Savchyne, Bondurivka. The data for modelling the impact of agronomic practices on sugar beet productivity were obtained after the implementation of certain agronomic practices for liming soils with defecate and applying organic fertilisers – compost. The sugar beet yield was determined using the weighing complex of the sugar beet station, and its technological qualities (digestibility) were determined in the raw material laboratory. The results were processed, aggregated, and visualised using the R data analysis software (Novytska N. et al., 2021).

2 Modelling and Assessment of the Influence of Meteorological Conditions (Uncontrollable Factors) on the Productivity of Sugar Beet as a Key Indicator of Production Security of Agribusiness

According to the data of meteorological stations located in Vinnytsia region on the territory of the settlements of Haisyn, Horodkivka, Kryklyvets, Savchyne, Bondurivka, an array of information was formed – the amount of precipitation and average temperature by months (from March to October) with a total of 474 observations. Having constructed scatter diagrams for the following indicators: endogenous variable – sugar beet yield, exogenous variables – precipitation and temperature by month, it was determined that the array of observations contains a significant number of "anomalous" points. Accordingly, there was a need to reduce the array to obtain more adequate data for modelling (Fig. 1).

By sampling 20% of the central values – 96 observations – by excluding "anomalous" observation points from the array, descriptive statistics can be determined for further use in interpreting the modelling results (Table 1).

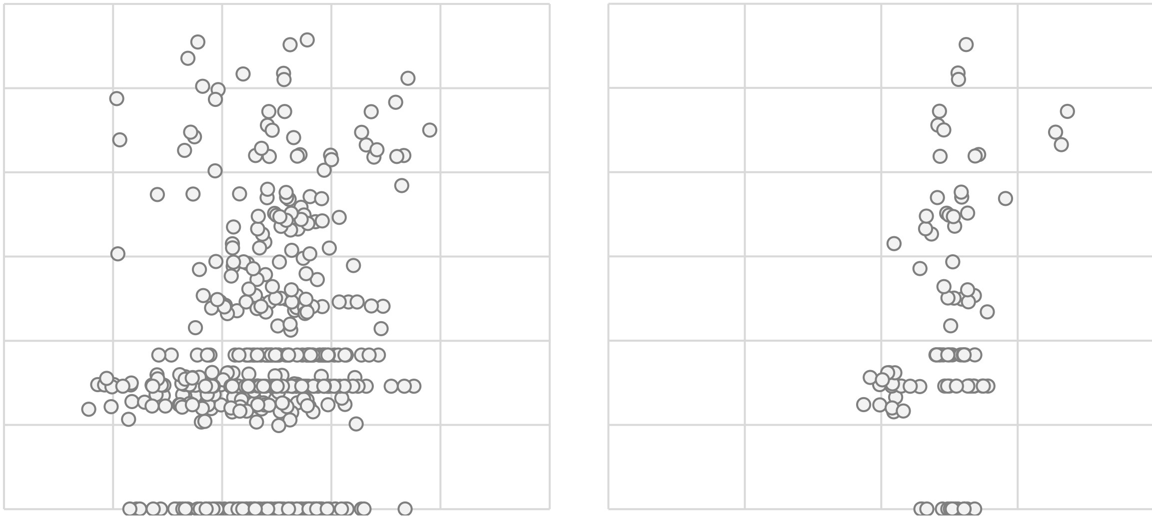

Figure 1 Scatter diagrams: dependence of sugar beet yield of sugar beet on meteorological conditions (left figure – full sample, right figure – sample excluding "anomalous" points)

Source: created using R software

Table 1 Descriptive statistics of the model of sugar beet yield dependence on meteorological conditions

Variable	Name of the indicator	Descriptive statistics				
		$\bar{x}$	*Me*	σ^2	*Es*	*As*
Y	**Yields**	49.65	50.22	28.40	1.93	0.35
X_1	Precipitation – March	20.57	18.30	203.36	-0.45	0.44
X_2	Average temperature – March	3.43	4.54	5.42	-1.11	-0.54
X_3	Average rainfall – April	38.79	34.82	171.50	-0.80	0.63
X_4	Average temperature – April	10.68	10.41	5.76	-1.15	-0.32
X_5	Average rainfall – May	80.63	78.10	760.01	0.29	-0.01
X_6	Average temperature – May	14.96	14.90	1.05	1.84	0.65
X_7	Average rainfall – June	115.83	83.27	1 838.45	16.50	3.94
X_8	Average temperature – June	20.36	20.11	0.94	0.57	1.32
X_9	Average rainfall – July	84.86	33.31	4 162.63	18.11	4.21
X_{10}	Average temperature – July	21.39	21.59	0.85	-0.57	0.05
X_{11}	Average rainfall – August	39.90	32.18	471.39	0.61	1.24
X_{12}	Average temperature – August	20.49	20.70	5.11	72.59	-7.94
X_{13}	Average rainfall – September	16.86	9.15	273.92	0.12	1.19
X_{14}	Average temperature – September	15.55	16.10	4.20	3.44	-1.76
X_{15}	Average rainfall – October	40.01	36.54	1 045.67	-1.17	0.34
X_{16}	Average temperature – October	7.83	6.71	3.71	-0.51	0.93

Source: calculated using R software

Further, a correlation and regression analysis of the impact of precipitation and average temperature per month on sugar beet yield in the Podillia region was carried out. The correlation analysis by "central" values does not differ significantly from the full correlation analysis. Accordingly, it can be assumed that only the average temperature in June has a separate effect on the yield. The results of the correlation analysis are shown in Table 2.

Considering the results of the correlation analysis, it can be said that all indicators have an additive effect on yield, which is confirmed by the correlation coefficient of the regression model for 20% of the "central values" – 0.9613, obtained because of the regression analysis.

The nature of the relationship between the variables included in the model is strong. In particular, the adequacy of the built regression model is evidenced by the coefficient of determination obtained at the level of 0.9242, which is interpreted as the explanation of the variation in sugar beet yield by the variation in

Table 2 Correlation analysis of sugar beet yield dependence on precipitation and temperature by months

Variable	Name of the indicator	Y – X	Type of correlation
Y	**Yields**		
X_1	Precipitation – March	0.2876	there is no correlation
X_2	Average temperature – March	-0.3689	weak correlation
X_3	Average rainfall – April	0.1687	there is no correlation
X_4	Average temperature – April	0.2234	there is no correlation
X_5	Average rainfall – May	-0.3758	weak correlation
X_6	Average temperature – May	-0.0906	there is no correlation
X_7	Average rainfall – June	0.1856	there is no correlation
X_8	Average temperature – June	-0.7471	strong inverse correlation
X_9	Average rainfall – July	0.1943	there is no correlation
X_{10}	Average temperature – July	0.2762	there is no correlation
X_{11}	Average rainfall – August	0.0106	there is no correlation
X_{12}	Average temperature – August	-0.1593	there is no correlation
X_{13}	Average rainfall – September	-0.0252	there is no correlation
X_{14}	Average temperature – September	-0.1286	there is no correlation
X_{15}	Average rainfall – October	0.1474	there is no correlation
X_{16}	Average temperature – October	-0.4648	weak correlation

Source: calculated using R software

Table 3 Results of regression analysis of sugar beet yield dependence on precipitation and temperature by month

Regression statistics

Multiple R	0.9613
R–squared	0.9242
Normalised R–squared	0.9088
Standard error	1.6093
Number of observations	96

Analysis of variance

	df	SS	MS	F	The value of F
Regression	16	2493.4352	155.8397	60.1746	1.92361E-37
Residuals	79	204.5936	2.5898		
Total	95	2698.0287			

Regression coefficients and their adequacy

	Coefficient	***Standard error***	***t–statistic***	***P–value***
Yields	**55.2748**	**15.6320**	**3.5360**	**0.0007**
Precipitation – March	0.1726	0.0510	3.3810	0.0011
Average temperature – March	0.2084	0.1556	1.3394	0.1843
Average rainfall – April	0.0848	0.0212	3.9969	0.0001
Average temperature – April	3.3197	0.4506	7.3671	0.0000
Average rainfall – May	-0.0377	0.0148	-2.5455	0.0129
Average temperature – May	-1.3344	0.7042	-1.8948	0.0618
Average rainfall – June	-0.0296	0.0085	-3.4857	0.0008
Average temperature – June	-1.8008	0.8780	-2.0509	0.0436
Average rainfall – July	0.0272	0.0058	4.6648	0.0000
Average temperature – July	1.6020	0.6194	2.5863	0.0115
Average rainfall – August	-0.0676	0.0177	-3.8125	0.0003
Average temperature – August	0.0168	0.0913	0.1841	0.8544
Average rainfall – September	0.0781	0.0226	3.4607	0.0009
Average temperature – September	-1.1558	0.2586	-4.4699	0.0000
Average rainfall – October	-0.0830	0.0247	-3.3562	0.0012
Average temperature – October	0.0255	0.3913	0.0651	0.9483

Source: calculated using R software

precipitation and average temperature at the level of 92.42%. The variation of other factors not included in the model determines the impact on sugar beet yield in this analysis at the level of 7.58%. The suitability of the model for forecasting and use in practice is confirmed by the Fisher's F-test and the level of significance of this coefficient.

The interpretation of the results of the regression analysis is shown in Table 4.

The reliability of the coefficients that determine the impact of monthly precipitation and temperature on sugar beet yield is confirmed by the Student's t-test.

Thus, the results of the correlation and regression analysis are suitable for practical use and can be useful for conducting experiments and obtaining a more accurate result of assessing the impact of various agrotechnical practices, considering the factors of weather conditions on sugar beet yield.

3 Modelling and Analysis of the Impact of Agronomic Practices – Liming and Organic Fertilisation (Controlled Factors) on Sugar Beet Yield as a Key Indicator of Agribusiness Production Security

Significant anthropogenic and human impact, intensification of agricultural production has significantly affected the state of soil acidification in Ukraine. The Podillia region is characterised by a catastrophic level of soil acidification, where acidic soils account for more than 80% of the total arable land. In addition to significant soil acidification, it is the saturated beetroot crop rotation that negatively affects soil health and condition, leading to:

– Accumulation of pathogens and an increase in the population of cyst nematodes (100% yield loss in infected areas and up to 26% loss of yield potential over the entire sugar beet area)

– reduction of soil moisture reserves due to the cultivation of crops with intensive development, moisture consumption and late harvesting (reduced yields of subsequent crops in the crop rotation);

– loss of yields in fields with low productivity potential.

In this context, to improve the soil and reduce its acidity, it is proposed to carry out liming by applying defecate and organic fertilisers (compost), which will ensure the productivity of sugar beet.

The experimental scheme was implemented as follows: control; application of defecate (50% of the full norm depending on the hydrolytic acidity of the soil): defecate 0.8 tons per hectare (0.5 Hr), defecate 1.6 tons per hectare (1.0 Hr), defecate 2.4 tons per hectare (1.5 Hr), defecate 3.2 tons per hectare (2.0 Hr); compost application: 6 tons per hectare, 8 tons per hectare, 10 tons per hectare, 12 tons per hectare with different doses by plots – 6 tons per hectare, 12 tons per hectare; compost and defecate application: defecate 0.8 tons per hectare (0.5 Hr), defecate 1.6 tons per hectare (1.0 Hr), defecate 2.4 tons per hectare (1.5 Hr), defecate 3.2 tons per hectare (2.0 Hr) with different doses of compost application – 6 tons per hectare, 8 tons per hectare, 10 tons per hectare, 12 tons per hectare.

The results of the experiments are shown in the form of graphs of the dependence of sugar beet yield and its digestion on the doses of defecate and compost.

Table 4 Interpretation of the regression analysis of the dependence of sugar beet yield on precipitation and temperature by month

Variable	Coefficient	Explanation	Nature of the impact	Quantitative impact	Condition
Y	55.2748	with an increase in the indicator by: – 1 mm (precipitation); – 1°C (temperature) the yield ...	–	–	*provided that other factors remain constant*
X_1	0.1726		will increase by	0.173 tonnes	
X_2	0.2084		will increase by	0.208 tonnes	
X_3	0.0848		will increase by	0.085 tonnes	
X_4	3.3197		will increase by	3.320 tonnes	
X_5	-0.0377		will decrease by	0.038 tonnes	
X_6	-1.3344		will decrease by	1.334 tonnes	
X_7	-0.0296		will decrease by	0.030 tonnes	
X_8	-1.8008		will decrease by	1.801 tonnes	
X_9	0.0272		will increase by	0.027 tonnes	
X_{10}	1.6020		will increase by	1.602 tonnes	
X_{11}	-0.0676		will decrease by	0.068 tonnes	
X_{12}	0.0168		will increase by	0.017 tonnes	
X_{13}	0.0781		will increase by	0.078 tonnes	
X_{14}	-1.1558		will decrease by	1.156 tonnes	
X_{15}	-0.0830		will decrease by	0.083 tonnes	
X_{16}	0.0255		will increase by	0.025 tonnes	

Source: compiled by the authors based on the results of the analysis

Scheme 1: Application of faeces (50% of the full rate depending on the hydrolytic acidity of the soil) (Figure 2–3).

Scheme 2. Application of compost with different doses by plot (Figure 4–5).

Scheme 3: Application of 0.8 tons per hectare (0.5 Hr) of faeces and compost with different doses by plot (Figure 6–7).

Scheme 4. Application of 1.6 tons per hectare (1.0 Hr) of faeces and compost with different doses by plot (Figure 8–9).

Scheme 5. Application of 2.4 tons per hectare (1.5 Hr) of faeces and compost with different doses by plot (Figure 10–11).

Scheme 6: Application of 3.2 tons per hectare (2.0 Hr) of faeces and compost at different doses by plot (Figure 12–13).

Thus, according to the results of the above modelling of the impact of different schemes of application of defecate (with an increase in the dose of application by 0.8 tons per hectare) and organic fertiliser – compost (with an increase in the dose of application by 2 tons per hectare), there is an increase in both yield and digestibility of sugar beet.

The developed dependence equations are characterised by an appropriate level of determination, which confirms their suitability for practical use, and the results obtained are adequate. For more accurate results, it is proposed to further expand the scale of the experiment and determine the threshold values of suboptimal applications of faeces and organic fertiliser.

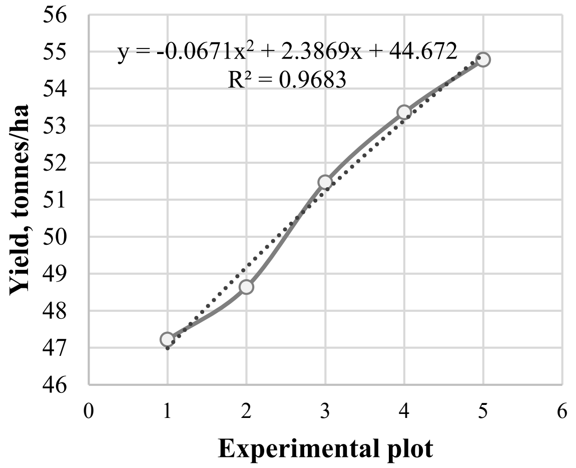

Figure 2 Dependence of yield on the dose of defecate application (scheme 1)

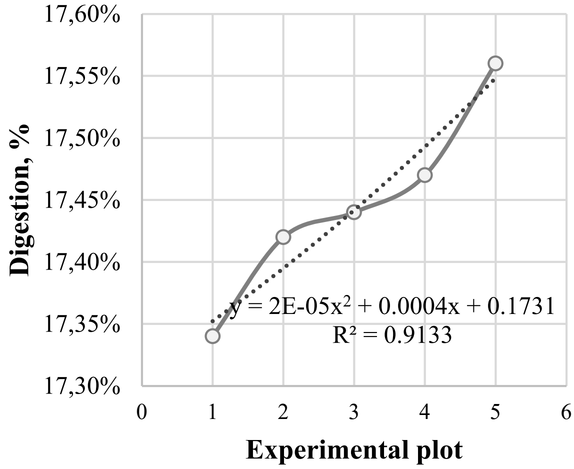

Figure 3 Dependence of digestion on faeces application doses (scheme 1)

Source: compiled by the authors based on the results of the study

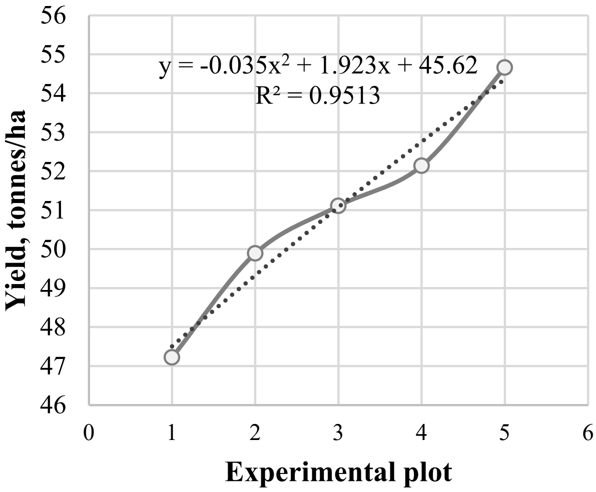

Figure 4 Dependence of yield on the dose of defecate application (scheme 2)

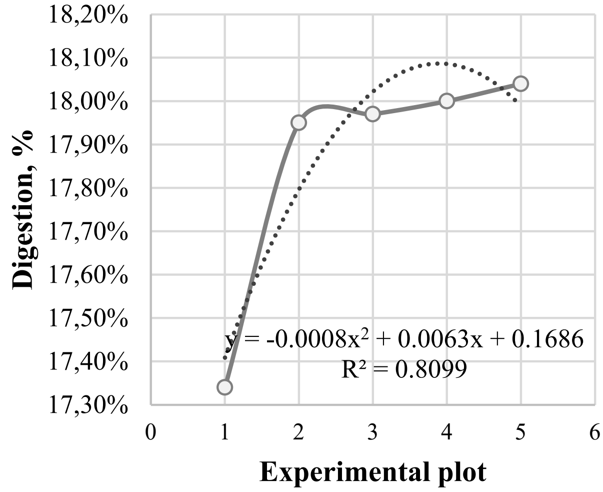

Figure 5 Dependence of digestion on faeces application doses (scheme 2)

Source: compiled by the authors based on the results of the study

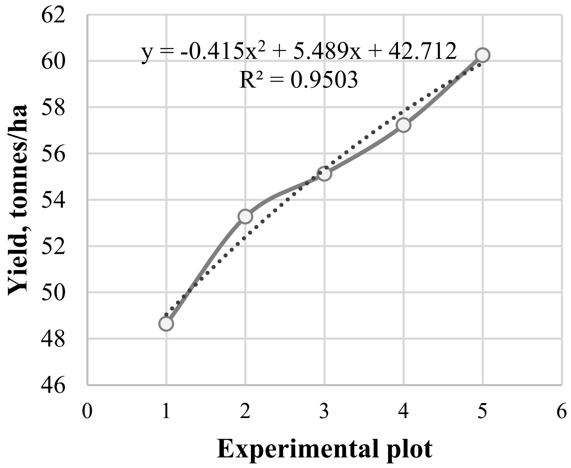

Figure 6 Dependence of yield on the dose of defecate application (scheme 3)

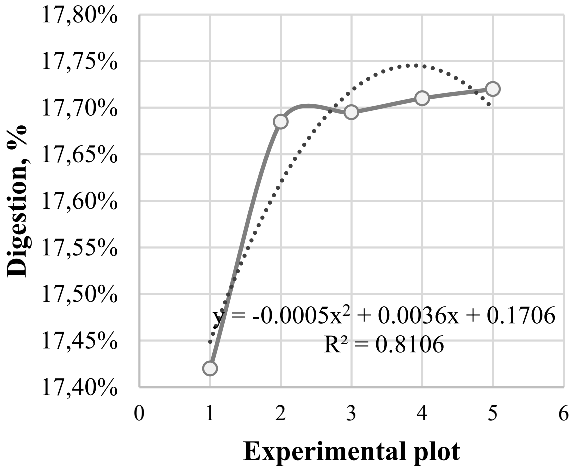

Figure 7 Dependence of digestion on faeces application doses (scheme 3)

Source: compiled by the authors based on the results of the study

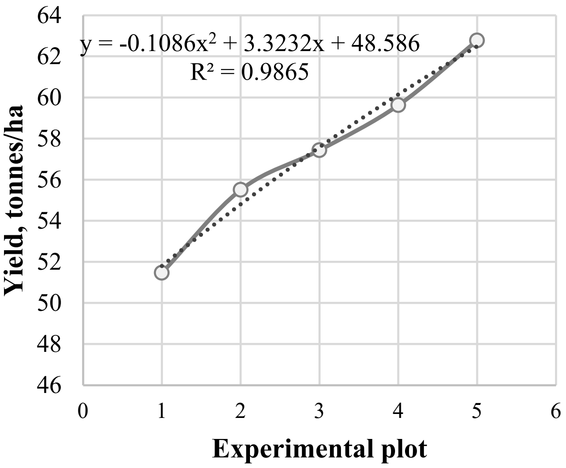

Figure 8 Dependence of yield on the dose of defecate application (scheme 4)

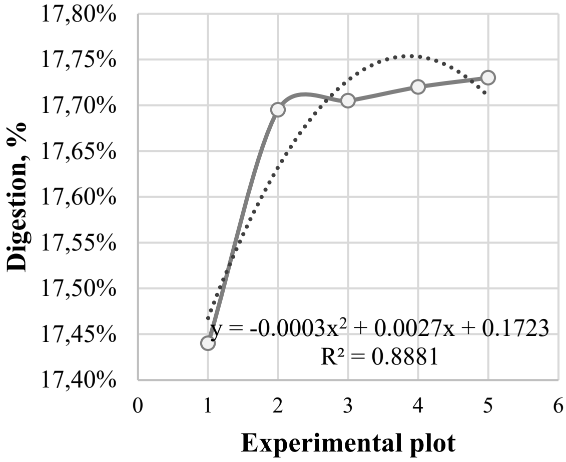

Figure 9 Dependence of digestion on faeces application doses (scheme 4)

Source: compiled by the authors based on the results of the study

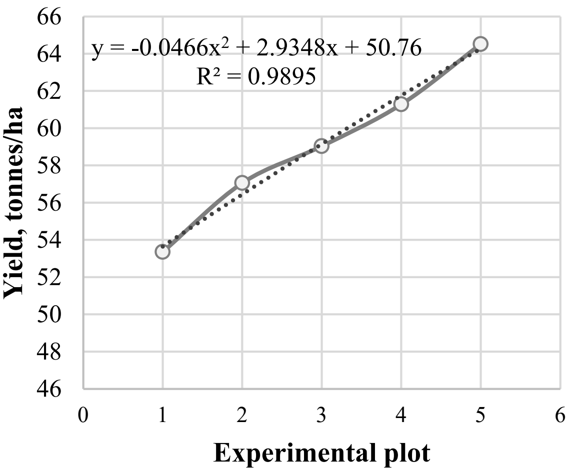

Figure 10 Dependence of yield on the dose of defecate application (scheme 5)

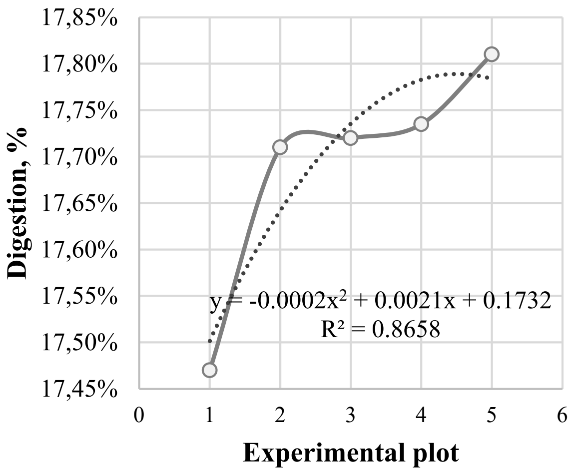

Figure 11 Dependence of digestion on faeces application doses (scheme 5)

Source: compiled by the authors based on the results of the study

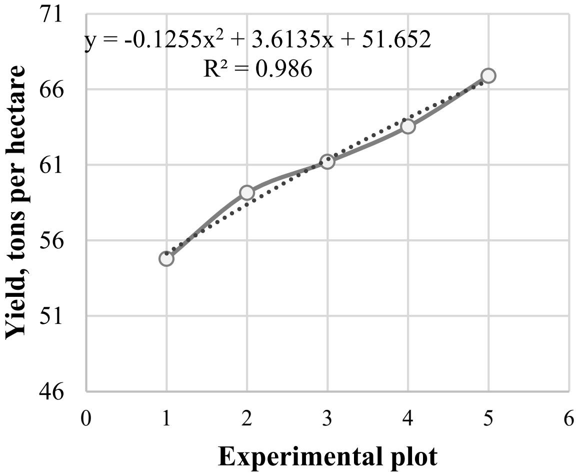

Figure 12 Dependence of yield on the dose of defecate application (scheme 6)

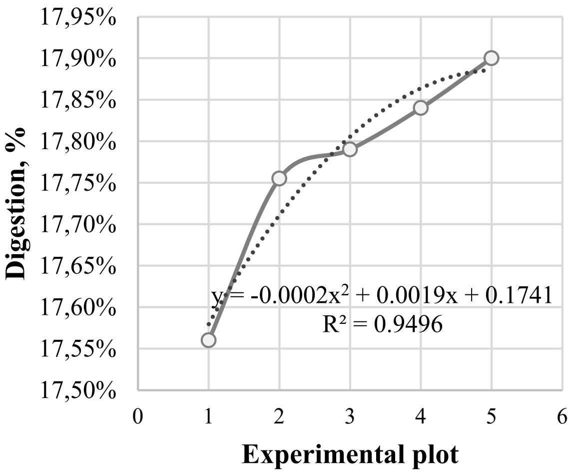

Figure 13 Dependence of digestion on faeces application doses (scheme 6)

Source: compiled by the authors based on the results of the study

Table 5 Interpretation of the results of modelling the impact of agronomic practices on sugar beet yield

Scheme №	Scheme of application of faeces and organic fertilisers	Amount of change (increase) on average		R^2 of yield and digestion models	
		yields, tonnes per hectare	digestion, %		
1	Application of defecate: *with an increase in the dose of faeces application by 0.8 tons per hectare*	1.86	0.06%	0.9683	0.9133
2	Composting: *with an increase in the dose of compost application by 2 tons per hectare*	1.89	0.18%	0.9513	0.8099
3	Application of faeces 0.8 tons per hectare (0.5 Hr) and compost: *with the application of 0.8 tons per hectare of faeces and an increase in the dose of compost by 2 tons per hectare*	2.79	0.08%	0.9503	0.8106
4	Application of faeces 1.6 tons per hectare (1.0 Hr) and compost: *with the application of 0.8 tons per hectare of faeces and an increase in the dose of compost by 2 tons per hectare*	2.83	0.07%	0.9865	0.8881
5	Application of faeces 2.4 tons per hectare (1.5 Hr) and compost: *with the application of 0.8 tons per hectare of faeces and an increase in the dose of compost by 2 tons per hectare*	2.90	0.09%	0.9895	0.8658
6	Application of faeces 3.2 tons per hectare (2.0 Hr) and compost: *with the application of 0.8 tons per hectare of faeces and an increase in the dose of compost by 2 tons per hectare*	3.03	0.08%	0.9860	0.9496

Source: built by the authors based on the results of the experiment

4 Conclusions

Thus, the study identified, evaluated and modelled the impact of meteorological conditions and agrotechnical methods of soil liming and organic fertilisation on the productivity of sugar beet as a key indicator of production security of agribusiness. When conducting research with the use of agrotechnical techniques and determining their effectiveness based on the proposed models, it is important for the operational director (agribusiness director) to assess the meteorological conditions that prevailed in the year of the study. It is in the years of "abnormal" weather and climate conditions that the results of modelling the effectiveness of agricultural practices should be adjusted for the impact of meteorological factors by comparing model data with the actual data obtained during the calendar year. This will allow to level the influence of uncontrollable factors and ensure the optimal decision-making for the application of the most optimal and effective agrotechnical scheme in the following seasons of sugar beet cultivation.

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