Correlation and regression modeling of the grain production cost

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Abstract. The study of the efficiency of the grain economy has shown that its level is determined by production costs. Correlation and regression analysis of the factors of the production cost of 100 kg of grain has revealed that its value is determined, first of all, by the level of intensification of the industry and the yield capacity of grain and leguminous crops. According to the obtained result, in order to lower level the production cost of 100 kg of grain, the value of production costs per hectare of area under crops should not exceed 10.5 thousand rubles (the level of intensification) and the yield of grain and leguminous crops should not be less than 17.5 dt/ha. Otherwise, the production cost of 100 kg of grain will be too high, which will lead to a decrease in the profitability of the grain economy.

1 Introduction

The efficiency of agricultural production, including the grain industry, depends on rational cost management, cost-conscious usage of labor, material and financial resources to optimize the cost of production. The indicator of the cost of goods manufactured is interconnected with the indicators of production efficiency and influences formation of the financial result [1–4].

The production cost is the main component of the output price and is affected by the changes in the conditions of agricultural production and the sales. The cost of goods level affects the profits of agricultural enterprises, the rate of expanded reproduction, the financial status of economic entities [5–7]. The financial and economic status of an enterprise and its competitiveness under a free market economy largely depend on how to solve the cost management problems of the production and sales.

The evidence from practice shows that to provide an increase in the efficiency of grain production, it is necessary to develop a resource-saving mechanism [8-10]. In this regard, the development of theoretical concepts and recommended practices in the costs management of grain production to increase the efficiency of the grain industry is of particular importance.

2 Materials and Methods

Cost level significantly affects formation of financial results and the efficiency of the grain industry.

In order to define the influence of various types of costs on the efficiency of grain production, a statistical grouping of 158 agricultural enterprises cultivating grain crops in the Ulyanovsk region was carried out by the labor remuneration, seed costs, fertilizer, plant protection agents, maintenance of fixed assets.

Table 1. Grouping of agricultural organizations of the Ulyanovsk region by the production costs for labor remuneration per 1 ha of grain crops

Indicators	Groups by production costs for labour remuneration per 1 ha of grain crops, thousand RUB				
	Up to 1.0	**1.0–2.0**	**2.0–4.0**	**Over 4.0**	**Total. on average**
Number of Enterprises	71	46	25	16	158
Production costs for labour remuneration per ha, thousand RUB	0.55	1.31	2.58	5.03	1.39
Crop yield dt/ ha	16.7	23.1	20.8	20.6	19.2
Production costs of 1dt, RUB	591.03	702.14	778.02	865.67	673.39
Full prime cost 1dt, RUB	583.92	675.77	777.21	763.01	655.57
Sale price, 1dt, RUB	736.87	845.83	865.61	804.11	795.22
Gross profits per 100 ha of grain crops, thousand RUB	265.9	383.4	187.6	85.7	273.6
Grain profitability level, %	26.2	25.2	11.4	5.4	21.3

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The grouping of enterprises by the production costs for labor remuneration per 1 ha of grain crops showed that with an increase in wage costs, the production cost of 1 dt of grain increases, the level of profitability of the grain industry decreases (Table 1).

With an increase in labor remuneration costs, the gross profit per 100 ha of grain crops decreases. At the same time, no direct correlation between production labor remuneration costs per ha of grain crops and yield has been revealed.

Table 2. Grouping of agricultural organizations of the Ulyanovsk region by the production costs for seeds per 1 ha of grain crops

Indicators	Groups by production costs for seeds per 1 ha of grain crops, thousand RUB				
	Up to 1.0	1.0–2.0	2.0–3.0	Over 3.0	Total. on average
Number of enterprises	46	67	35	10	158
Production costs for seeds per ha, thousand RUB	0.55	1.37	2.32	3.51	1.42
Crop yield dt/ ha	17	18.5	23.9	21.7	19.2
Production costs of 1dt, RUB	633.79	617.8	714.1	984.67	673.39
Full prime cost 1dt, RUB	656.91	595.04	650.65	951.67	655.57
Sale price, 1dt, RUB	817.38	737.2	814.72	931.37	795.22
Gross profits per 100 ha of grain crops, thousand RUB	260.6	273.7	408.9	-46.5	273.6
Grain profitability level, %	24.4	23.9	25.2	-2.1	21.3

The grouping of enterprises according to the value of seeds production costs per 1 ha of grain crops has made it possible to reveal the direct correlation between the level of seeds costs for the yield of grain crops (Table 2).

With the increase by 6.4 times in the cost of seeds, the production costs of 1 dt of grain increases 1.6 times, as a result of which the level of profitability of grain decreases.

The grouping of agricultural organizations of the Ulyanovsk region by the value of production costs for fertilizers per 1 ha of grain crops also has shown the direct correlation between the value of fertilizing costs and the level of the yield. The progressive costs of fertilizers, despite the increase in the yield of grain crops, leads to the increase in the production costs of 1dt of grain, and the gross profit per 100 ha of grain crops increases (Table 3).

Table 3. Grouping of agricultural organizations of the Ulyanovsk region by the production costs for fertilizers per 1 ha of grain crops

Indicators	Groups by production costs for fertilizers per 1 ha of grain crops, thousand RUB					
	Not applied	Up to 1.0	1.0–2.0	2.0–4.0	Over 4.0	Total. on average
Number of enterprises	34	37	47	31	9	158
Production costs for plant protection agents per ha, thousand RUB	0	0.65	1.5	2.74	6.47	1.95
Crop yield dt/ ha	12.6	13.5	19.7	24.1	29.9	19.2
Production costs of 1dt, RUB	577.99	648.34	614.25	684.45	835.7	673.39
Full prime cost 1dt, RUB	561.96	624.1	610.29	674.62	797.82	655.57
Sale price, 1dt, RUB	699.11	744.59	772.27	795.65	951.06	795.22
Gross profits per 100 ha of grain crops, thousand RUB	187.1	188.7	307.9	286.1	424.2	273.6
Grain profitability level, %	24.4	19.3	26.5	17.9	19.2	21.3

Table 4. Grouping of agricultural organizations of the Ulyanovsk region by the production costs for plant protection agents per 1 hectare of grain crops

Indicators	Groups by the production costs for plant protection agents per 1 ha of grain crops, thousand					
	Not applied	Up to 1.0	1.0–2.0	2.0–3.0	Over 3.0	Total. on average
Number of enterprises	22	72	38	14	12	158
Production costs for plant protection agents per ha, thousand RUB.	0	0.6	1.36	2.28	4.4	1.15
Crop yield dt/ ha	24.2	14.7	19.7	25.7	31.7	19.2
Production costs of 1dt, RUB	746.26	570.14	684.54	799.35	748.42	673.39
Full prime cost 1dt, RUB	744.18	574.92	644.86	741.18	725.98	655.57
Sale price, 1dt, RUB	892.92	707.77	787.2	870.33	880.85	795.22
Gross profits per 100 ha of grain crops, thousand RUB	306.9	204.1	284.8	343.5	515	273.6
Grain profitability level, %	20	23.1	22.1	17.4	21.3	21.3

Grouping of enterprises by the value of production costs for plant protection agents per 1 ha made it possible to determine that in 22 farms where plant protection agents are not used, the average yield of grain crops was 24.2 dt/ha, while the level of profitability of the industry was 20.0 %. In the same farms where plant

protection agents are used, there is a direct relationship between the level of these types of costs and the yield of grain crops. The largest amount of gross profit received per 100 ha of grain crops is observed in farms with a high level of costs for plant protection agents (Table 1).

The grouping of enterprises by the value of production costs for the maintenance of fixed assets per 1 ha of crops of grain crops made it possible to identify the relationship between the costs of fixed assets and the level of grain yield (Table 5).

Table 5. Grouping of agricultural organizations of the Ulyanovsk region by the value of production costs for the maintenance of fixed assets per 1 ha of grain crops

Indicators	Groups by production costs for labour remuneration per 1 ha of grain crops, thousand RUB				
	Up to 1.0	1.0–2.0	2.0–3.0	Over 3.0	Total. on average
Number of enterprises	80	48	15	15	158
Production costs for the maintenance of fixed assets per ha, thousand RUB	0.51	1.48	2.38	5.41	1.15
Crop yield dt/ ha	14.8	23.3	21.6	26.1	19.2
Production costs of 1dt, RUB	578.47	712.56	773.59	765.67	673.39
Full prime cost 1dt, RUB	592.71	676.89	713.57	726.6	655.57
Sale price, 1dt, RUB	724.35	842.07	851.26	81.15	795.22
Gross profits per 100 ha of grain crops, thousand RUB	206.8	372.1	266.4	234.7	273.6
Grain profitability level, %	22.2	24.4	19.3	11.5	21.3

The research made it possible to determine a strong direct dependence of the profitability of production costs on the amount of costs for seeds, the maintenance of fixed assets, a weak direct dependence on the amount of costs for fertilizers, and inverse dependence on the labor costs and plant protection agents.

In order to identify the most significant factors affecting the production cost of 100 kg of grain in the Ulyanovsk region, a correlation and regression analysis of data from 158 agricultural enterprises was carried out.

Effectiveness indicator:

Y is the production cost of 100 kg of grain, RUB.

Variable factors:

X1 – yield of grain and leguminous crops, kg/ha

X2 – ratio of labor to output, 100 kg of grain, man-h

X3 – intensification level, thousand RUB/ha

X4 – concentration level, ha

X5 – the cost of fertilizers applied per hectare of sowing grain and leguminous crops, thousand RUB.

X6 – the cost of seeds per hectare of sowing grain and leguminous crops, thousand RUB.

X7 – the cost of plant protection agents per 1 ha of sowing of grain and leguminous crops, thousand RUB.

X8 – the cost of fixed assets maintaining per 1 ha of sowing of grain and leguminous crops, thousand RUB.

The "Multiple Regression" feature of the analytical program Statistica was used during the analysis. The results of the correlation analysis of the production cost of 100 kg of grain in agricultural enterprises are presented in the form of a matrix of partial coefficients characterizing the strength of the relationship between the effective and factorial characteristics (Table 6).

Level (rx3y = 0.320), ratio of labour to output (rx2y = 0.0.277) and the costs of seeds per 1 ha of sown area (rx6y = 0.267). A weak direct correlation between the production cost of 100 kg of grain and the cost of plant protection agents, the maintenance of fixed assets, a weak reverse – with the yield. There is no connection between the production cost of 100 kg of grain, the level of concentration of production and the cost of fertilizer. In accordance with the obtained results, factorial characteristics X4 and X5 were excluded.

Table 6. The matrix of partial coefficients of the correlation-regression model of the production cost of 100 kg of grain

Factorial characteristics	Partial coefficients of the correlation-regression r_{xiy}	Relation pattern
Yield of grain and leguminous crops	–0.187	weak, reverse
Ratio of labour to output 100 kg of grain	0.277	noticeable, direct
Intensification level	0.320	noticeable, direct
Concentration level	–0.001	absent
The cost of fertilizers applied per hectare of sowing grain and leguminous crops	0.081	absent
The cost of seeds per hectare of sowing grain and leguminous crops	0.267	noticeable, direct
The cost of plant protection agents per 1 ha of sowing of grain and leguminous crops	0.156	weak, direct
The cost of fixed assets maintaining per 1 ha of sowing of grain and leguminous crops	0.142	weak, direct

3 Results and discussion

In accordance with the presented results of the correlation and regression analysis (Fig. 1), the equation of the regression model of the production cost of 100 kg of grain can be presented as follows:

$$Y = 659.33 - 32.34X_1 + 30.29X_2 + 51.37X_3 + + 5.16X_6 - 14.80X_7 - 10.20X_8$$

R= .82688878 R2= .68374506 Adjusted R2= .67117864
F(6,151)=54,410 p<0,0000 Standard Error 130,51

N=158	Beta	St. Error Beta	B	St. Error	t(151)	p-знач.
			659,3278	32,32919	20,3942	0,000000
X1 - yield of grain and leguminous crops, kg / ha	-1,13241	0,078170	-32,3362	2,23214	-14,4866	0,000000
X2 - ratio of labour to output, 1 centner of grain, man-h	0,20098	0,048582	30,2859	7,32097	4,1369	0,000058
X3 - intensification level, thousand rubles / ha	1,34964	0,098400	51,3732	3,74554	13,7159	0,000000
X6 - the cost of seeds per hectare of sowing grain and leguminous crops, th. rub.	0,01992	0,052994	5,1615	13,72825	0,3760	0,707460
X7 - the cost of plant protection agents per 1 ha of sowing of grain and leguminous	-0,07841	0,063539	-14,7991	11,99191	-1,2341	0,219088
X8 - the cost of fixed assets maintaining per 1 ha of sowing grain and leguminous	-0,06813	0,056649	-10,2005	8,48220	-1,2026	0,231020

Fig. 1. The results of multiple regression of the production cost of 100 kg of grain

The regression coefficient a1 shows that with an increase in the yield of grain and leguminous crops by 100 kg/ha, the production cost of 100 kg of grain decreases to 32.34 RUB. The regression coefficient a2 indicates that with an increase in ratio of labour to output by 1 person-hour, the production cost of 100 kg of grain increases by 30.27 RUB.

With an increase in the level of intensification by 1 thousand RUB per 1 hectare the value of the production cost of 100 kg of grain increases by an average of 51.37 RUB. A linear direct effect on the formation of the production cost of 100 kg of grain is also exerted by the cost of seeds: with an increase in the cost of seeds per 1 ha of crops of grain and leguminous crops by 1 thousand RUB the cost of 100 kg of grain increases on average 5.16 RUB.

An increase in the cost of plant protection agents and the maintenance of fixed assets by 1 thousand RUB/ha, on the contrary, leads to a decrease in the level of production cost of 100 kg of grain, respectively, by 14.80 and 10.20 RUB.

The study of the strength of relationship is of great importance for assessment of the quality of the developed equation. The importance of the correlation-regression equation for the production cost of 100 kg of grain is determined by using the multiple correlation coefficient and the coefficient of determination (Table 7).

Table 7. Coefficients of multiple correlation and determination of the regression model of production cost of 100 kg of grain

Multifactorial model	Multiple correlation coefficient (R)	Determination coefficient (R^2)
Production cost of 100 kg of grain	0.827	0.684

The correlation coefficient R = 0.827 shows that the correlation between the production cost of 100 kg of grain and the factors included in the model is sufficient, the determination coefficient R2 = 0.684 or 68.4 % indicates that the production cost of 100 kg of grain by 68.4 % is under the influence factors included in the model, and by 31.6 % – under the influence of other factors.

Therefore, this model can be recommended to agricultural organizations for implementation, since the coefficient of determination is more than 60 %.

The significance of the developed multiple regression equation has been assessed with Fisher's F-test. The actual value of the F-criterion (F fact = 54.41) exceeds the tabulated value (F table = 2.16 with a = 0.05). Therefore, with a probability of 0.95, one can determine the statistical significance of the compiled equation of multiple regression of the production cost of 100 kg of grain, which were formed under the influence of the factors under study.

Validation of the significance and reliability of the regression coefficients is carried out in accordance with the Student's test [8]. The analyzed coefficient is considered significant if its t-criterion in absolute value exceeds 2.00, which corresponds to a significance level of 0.05.

In our example, we have for the coefficients b1–b3 the following indicators of the Student's test: tb1 = 14.487; tb2 = 4.137; tb3 = 13.715. Therefore, only these variables are significant. The indicator of the Student's test for b6–b8 is tb6 = 0.376, tb7 = –1.234, tb8 = –1.203, which is below 2.0, therefore, these factors are not statistically significant.

Beta correlation coefficients shows that of all the factors included in the model, yield, costs of plant protection agents and maintenance of fixed assets per 1 ha are inversely correlated with the production cost of 1 dt of grain.

The beta coefficient, which is in the range from 0 to –1, indicates a low sensitivity of the reaction of the effective feature to a change in X2, X6–X8. The beta coefficient above 1 indicates a high sensitivity of production costs to changes in X1 and X3.

The rest of the factors X1 and X3 correlate with the dynamics of the production cost of 1 dt of grain. At the same time, the level of intensification of the industry (1.34) has the most influence on the development of an effective factor. The yield of grain and leguminous crops take second place in terms of influence on the level of production cost of 1 dt of grain (–1.13).

The linear graph of the dependence of the production cost of 1 dt of grain on the level of intensification of the industry is presented in Figure 2 and indicates that an increase in the level of intensification of the industry by 1 thousand RUB/ha leads to an increase in the production cost of 1 dt of production by an average of 12.20 RUB.

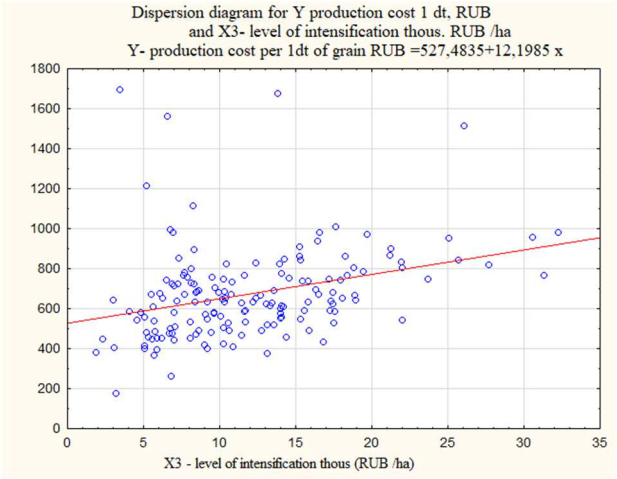

Fig. 2. Dependency diagram of the production cost of 1 dt of grain on the level of intensification of the industry

In accordance with dependency diagram of the production cost of 1 dt of grain on the yield of grain and leguminous crops (Fig. 3), it follows that with an

increase in the latter by 1 dt/ha, the effective indicator decreases by an average of 5.35 rubles/dt.

The cumulative effect of the two most important factors, according to beta coefficients, is shown as a 3d graph in Figure 4.

The residual analysis showed that 58 agricultural enterprises (36.7 %) have reserves for reducing the production cost of 1 dt of grain.

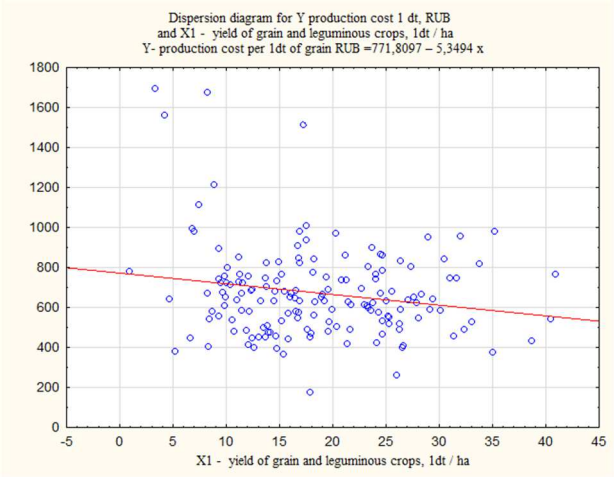

Fig. 3. Dependency diagram of the production cost of 100 kg of grain on the yield of grain and leguminous crops

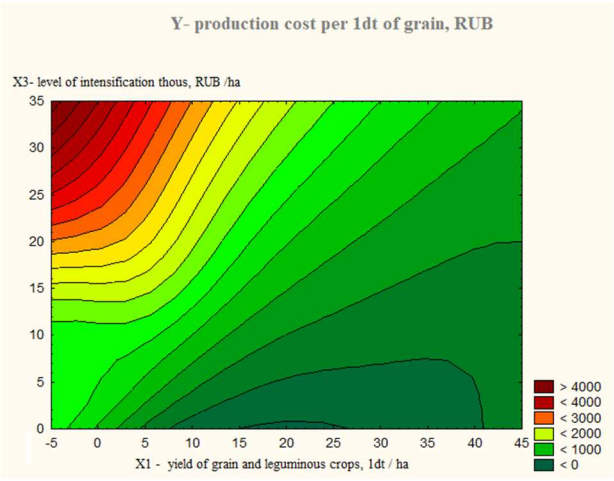

Fig. 4. 3-d dependency diagram of the production cost of 1 dt of grain on the level of intensification of the industry and the yield of grain crops

The decision tree, built in the analytical program Deductor, made it possible to determine the boundaries (conditions) of achieving the low level of production cost of 1 dt of grain for agricultural enterprises of the Ulyanovsk region.

According to the obtained result, in order to get a low level of production cost of 1 dt of grain (up to 578.41 rubles), it is necessary that the value of production costs of area under crops per 1 ha does not exceed 10.58 thousand RUB. (level of intensification), the yield of grain and leguminous crops should not be less than 17.53 dt/ha.

Otherwise, the production cost of 1 dt of grain will be over 726.43 RUB for 1dt, which will lead to a decrease in the profitability of the grain industry.

4 Conclusion

To sum up, the regression and correlation analysis has shown that the production cost of 1 dt of grain in agricultural enterprises of the Ulyanovsk region is determined, first of all, by the level of intensification of the industry and the yield of grain and leguminous crops.

References

1. O.V. Solntseva, N.E. Bunina, O.A. Zazhivnova, M.A. Viderker, Forecasting of self-sufficiency in grain in Russia, *Agricultural science and education at the present stage of development: experience, problems and ways to solve them, Mat. of the VIII Int. sci. and pract. Conf.* (2017), pp. 175–181
2. S.V. Chelnokova, Dynamics and forecasting of indicators of development of the grain industry of the Ulyanovsk region, *Topical issues and priorities of the socio-economic development of the region in the context of digital transformation, Coll. of art. of the All-Russ. res. and pract. Conf.* (2019), pp. 62–65
3. S.Yu. Petryakova, Assessment of the production potential of the grain industry in the region, *Agrarian potential in the food supply system: theory and practice, Mat. of the All-Russ. res. and pract. Conf.* (2016), pp. 237–241
4. O.V. Sidorenko, I.V. Ilyina, Sustainability of grain production in the regions of the Russian Federation, Bull. of Agrar. Sci., **1(82)**, 135–144 (2020).
5. N.A. Ivanova, A.E. Anoshina, Analysis of grain production in the Ulyanovsk region, *Problems of the development of modern science, Mat. of the Int. res. and pract. Conf.* (2015), pp. 92–96
6. S.V. Basenkova, E.A. Smirnova, Efficiency of grain production: regional aspect, Econ. and Entrepren., **1–2(42)**, 304–307 (2014)
7. G.G. Zotova, N.V. Karpova, Analysis of the influence of factor changes on grain production in the Ulyanovsk region, *Innovative activities of science and education in agricultural production, Mat. of the Int. res. and pract. Conf.* (2019), pp. 329–334
8. D.A. Zyukin, R.V. Soloshenko, Scenarios for the development of grain production and the state of the grain market in the short-term and med-term, Econ. Sci., **183**, 51–56 (2020)
9. S.V. Basenkov, G.G. Zotova, Climatic factor and efficiency of grain production in the Ulyanovsk region, Econ. and Entrepren., **11-2(76)**, 249–252 (2016)
10. N.R. Alexandrova, O.I. Khamzina, Information technologies as a means of increasing the efficiency of grain production, Econ. and Entrepren., **10(123)**, 966–972 (2020)