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OPTIMIZATION OF PRODUCTIVE COSTS ON THE BASIS OF THE MARGINAL UTILITY

G.A. Beznosov [a*], N.V. Ziablitckaia [b], L.A. Novopashin [a], L.V. Denyozhko [a], A.A. Sadov [a], and N.K. Pryadilina [c]

[a] *Federal State Budgetary Educational Establish of Higher Education, Ural State Agrarian University, (FGBOU VO Uralsky GAU) Ekaterinburg, Karl Liebknecht ul.,42, RUSSIA*

[b] *South Ural State University, Chelyabinsk, pr.Lenina, 76, RUSSIA.*

[c] *Ural State Forest Engineering University, Ekaterinburg, 620100, Siberian tract, 37, RUSSIAN FEDERATION.*

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ABSTRACT

After analyzing trends and patterns of development of the economic mechanism of resource saving in agricultural production an inverse dependence relationship has been established between the efficiency of agricultural production from the level of its resource intensity; and it has been proved that it is reasonable to reduce not all production costs, but only those types that affect the efficiency indicators of production in a negative way, and, conversely, it is reasonable to increase those types of production costs that are able to ensure the growth of productive indicators of economic activity at an agricultural enterprise. The conducted study is based on a reasonable assumption about the possibility of improving the efficiency of resource consumption with the use of an algorithm for allocation of production resources with consideration of the marginal utility of their costs. The scientific hypothesis was verified on the example of agricultural enterprises of grain specialization in the Kurgan region of the Russian Federation. Calculations showed that the optimized cost structure for grain production at agricultural enterprises of grain specialization in the Kurgan region reduces the resource intensity of marketable grain in comparison with its existed average value by 0.086 rubles or by 8.9%, increases the profit from the sale of marketable products by 194277 thousand rubles or by 30.6%, including per 1 hectare of grain crops - by 260.4 rubles or by 30.6%, for 1 centner (100 kilograms) of grain produced - by 24.1 rubles or 36.9%. The level of profitability at the same time increases by 11.4%. Thus, the economic efficiency of grain production at agricultural enterprises of grain specialization in the Kurgan region increases at allocation of production costs with consideration of their marginal utility.

*Corresponding author (G.A.Beznosov) E-mail: beznosov-ga@mail.ru

1. INTRODUCTION

Agriculture is one of those sectors of the economy, whose results are influenced by natural and climatic conditions. Precision farming can also have a positive impact on the productivity and economy of farms, as it provides higher or the same yields at lower production costs than conventional methods [1]. In particular, the use of precision farming technologies allows reducing the effect of high temperatures on photosynthetic activity [2, 3], increasing resistance to high temperatures [4, 5], reducing the deficit of moisture in arid areas [6, 7, 8, 9], regulating the microclimate at crop production [10]. According to researchers, precision farming technologies will reduce risks and face the current challenges in agriculture.

Development of the economic mechanism of resource saving in agricultural production is based on the fact that economically feasible allocation of productive resources at an agricultural enterprise should ensure the priority of such allocation and its progression with consideration the marginal utility of each unit of resources used. And the final result of this process should be a maximum possible positive effect, like a reduction in the cost of production resources per unit of output and the increase in profits from its sale.

Allocation of productive resources should be scientifically proved in modern conditions of their shortage at agricultural enterprises. To achieve the goals of resource saving, we consider it necessary to model the number of costs of production resources on the basis of their marginal utility, expressed in an additional income of an agricultural enterprise from the use of an additional unit of a given type of production resources. This task can be implemented by means of an appropriate algorithm; its prototype was a variant of allocation (proposed by [11]) of subsidies between groups with a fixed initial income, which, on the basis of utilitarian criteria, ensures maximization of social welfare, as a sum of individual usefulness of all society members [1].

2. Material and methods

The basis of a proposed algorithm is the utility function; its mathematical notation is as follows:

$$U(x) = \sum_i u_i(x_i), \tag{1}$$

where u_i is the additional gross profit of an agricultural enterprise per unit of a used resource x_i.

We denote the desired amount of production resources (V) to be allocated as $\Delta_1, \Delta_2, ..., \Delta_n$, while the following terms must be met:

$$\sum \Delta_i = V; \tag{2}$$

$$\Delta_i \geq 0. \tag{3}$$

The algorithm for consideration of optimal allocation of available resources (V) is as follows. First of all, it is necessary to order the productive resources according to the marginal utility of each unit, which is expressed in additional profit. In this case, the first place will be taken by a resource, whose marginal utility of its use for the unit will be higher than the marginal utility of use for a unit of other resources.

$$u_1'(x_1) \geq u_2'(x_2) \geq \ \ldots \ \geq u_n'(x_n). \tag{4}$$

Then it is necessary to allocate the available amount of production resources to meet a previously mentioned condition. Then, when choosing a resource, a unit of which it would be preferable to use in production, the choice should be settled on the first by a value of its marginal utility, as the use of a unit of such a resource will result in the greatest increase in gross profit of the agricultural enterprise.

Increasing the amount of a resource, which is in the first place in the ranked series, we reduce the marginal utility of each following unit. We will increase the amount of this resource until the marginal utility of its unit becomes equal to the marginal utility of the unit of a resource at the second place.

$$u_1'(x_1 + \Delta_1) = u_2'(x_2) \geq \ldots \geq u_n'(x_n). \tag{5}$$

We will increase $\boldsymbol{x_1 + \Delta_1}$ and $\boldsymbol{x_2}$ by the sum $\boldsymbol{\Delta_2}$ until the following condition is met:

$$u_1'(x_1 + \Delta_1 + \Delta_2) = u_2'(x_2 + \Delta_2) = u_3'(x_3) \geq \ldots \geq u_n'(x_n). \tag{6}$$

We should continue until the whole available amount of resource V is allocated.

$$\begin{gathered} u_1'(x_1 + \Delta_1 + \Delta_2) = u_2'(x_2 + \Delta_2) = \ \ldots \\ = u_m'(x_m + \Delta_m) \geq u_{m+1}'(x_{m+1} + \Delta_{m+1}) \geq \ \ldots \geq u_n'(x_n). \end{gathered} \tag{7}$$

If there is no possibility to allocate the remaining amount of resources to all m groups so that their marginal utility is at the level m + 1, as the amount of available resources is almost completely used, the remainder of the available resources should be allocated in groups in such a way that their marginal utility after allocation is equaled each other. The algorithm is as follows (Figure 1):

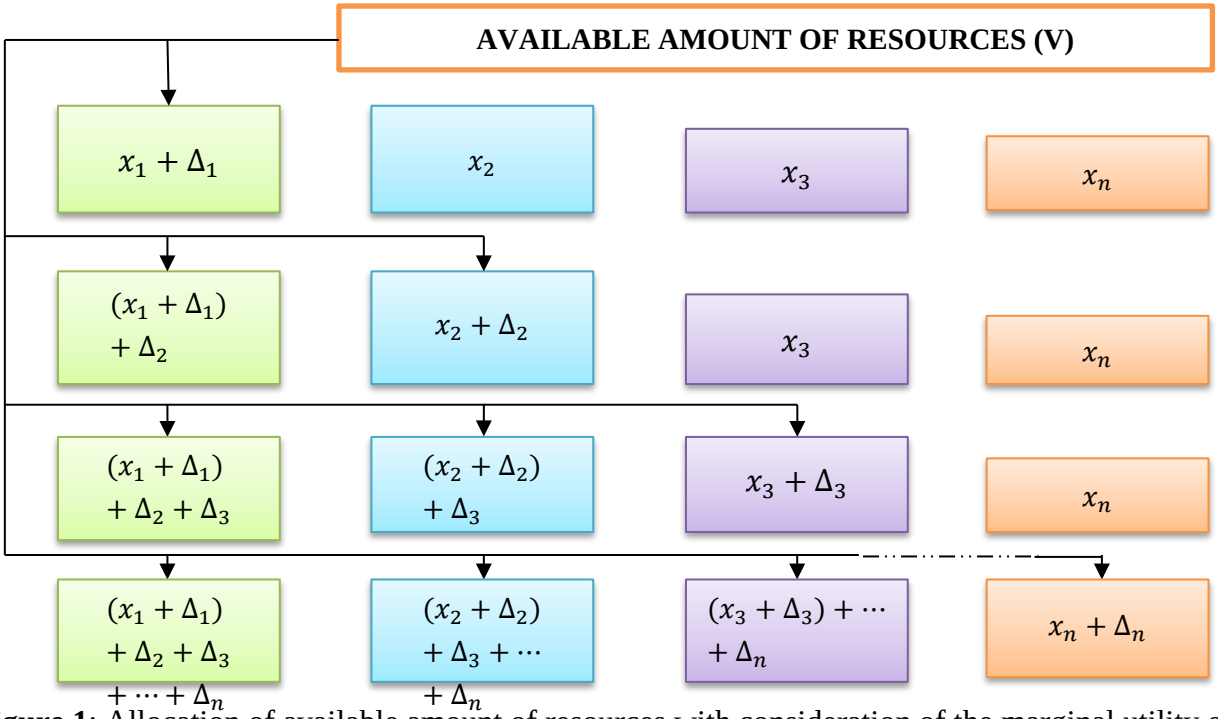

Figure 1: Allocation of available amount of resources with consideration of the marginal utility of a resource unit

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3. Results and discussion

3.1 Groupings

In order to calculate production costs, which are impractical to exceed when carrying out economic activities for the production of grain at agricultural enterprises of grain specialization of the Kurgan region, we will group them to identify patterns in the behavior of gross profit depending on production costs (Table 1).

Table 1: The impact of production costs on the efficiency of grain production at agricultural enterprises of grain specialization in the Kurgan region.

Indicator	Production costs per 100 ha of grain acreage (thous. Rub)			
	under 300	301–450	451– 600	over 600
Number of enterprises in a group, pcs.	4	19	13	14
Production costs per 100 ha of grain crops acreage, thous. rub	256.0	438.4	508.1	828.0
Grain yields, centner/ha	5.3	12.4	10.0	13.0
Cost value of 1 centner of grain, rub	1146.7	377.4	453.8	516.8
The selling price of 1 centner of grain, rub	390.0	399.6	455.4	434.4
Gross profit per 100 ha of grain acreage, rub	5.0	24.7	20.6	-35.2
Level of profitability of production, %	-12.8	27.1	6.9	-8.9

Table 2 shows that agricultural enterprises of grain specialization in the Kurgan region get the greatest profits from production and sale of grain crops when the production costs are from 301 thousand rubles up to 450 thousand rubles per 100 hectares of grain crops acreage. The level of profitability with this amount of costs is 27.1%. It is important to note that the gross profit and, consequently, the profitability of production, decreases with a decrease or increase in production costs. We consider that the production costs at agricultural enterprises of grain specialization in the Kurgan region on grain production should be on average 438.4 thousand rubles per 100 hectares of grain crops acreage.

Labour costs at agricultural enterprises of grain specialization in the Kurgan region are viable if they do not exceed 50 thousand rubles per 100 hectares of grain crops acreage. If labour costs are on average 37.6 thousand rubles per 100 hectares of grain crops acreage, the gross profit is on average 30.2 thousand rubles, the profitability is 15.2%. Exceeding a specified amount of labour costs leads to a decrease in economic indicators of the efficiency of grain production (Table 2).

Table 2: The impact of labour costs on the efficiency of grain production at agricultural enterprises of grain specialization in the Kurgan region

Indicator	Labour costs per 100 ha of grain acreage, thous. rub			
	under 50	51–100	101–150	over 150
Number of enterprises in a group, pcs.	20	20	6	4
Labour costs per 100 ha of grain acreage, thous. Rub	37.6	76.3	121.2	233.4
Grain yields, centner/ha	10.7	9.1	9.0	14.0
Cost value of 1 centner of grain, rub	393.9	658.2	366.3	412.6
The selling price of 1 centner of grain, rub.	425.1	451.3	329.1	412.6
Gross profit per 100 ha of grain acreage, thous. rub	30.2	-15.8	-35.0	-46.5
Level of profitability of production, %	15.2	-4.6	-6.6	-14.5

The share of material costs in grain production at agricultural enterprises of grain specialization in the Kurgan region is over half of the total production costs. Agricultural enterprises of grain specialization get the highest profit of about 43.8 thousand rubles per 100 hectares of grain crops acreage if the amount of material costs is on average 273.4 thousand rubles (Table 3).

Table 3: The impact of material costs on the efficiency of grain production in agricultural enterprises of grain specialization of the Kurgan region.

Indicator	Material costs per 100 ha of grain acreage, thous. rub			
	under 150	151–300	301–450	over 450
Number of enterprises in a group. pcs.	4	23	16	7
Material costs per 100 ha of grain acreage. thous. rub	101.2	273.4	323.1	640.2
Grain yields. centner/ha	6.5	11.1	9.3	12.5
Cost value of 1 centner of grain. rub	338.8	440.1	578.8	454.5
The selling price of 1 centner of grain. rub	369.8	470.3	405.7	402.6
Gross profit per 100 ha of grain acreage. thous. rub	2.7	43.8	-14.4	-15.3
Level of profitability of production, %	6.0	34.0	-3.2	-9.7

Agricultural enterprises of grain specialization in the Kurgan region which have the costs on seeds on average of 108.2 thousand rubles per 100 hectares of grain crops acreage. the profitability of production is 38.8% with a gross profit of 59.4 thousand rubles per 100 hectares of grain crops acreage. With an increase in costs on seeds. these indicators significantly reduce (Table 4).

Table 4: Impact of costs on seeds on the efficiency of grain production at agricultural enterprises of grain specialization in the Kurgan region

Indicator	Costs on seeds per 100 ha of grain acreage. thous. rub			
	under 75	76 – 150	151 – 225	over 225
Number of enterprises in a group, pcs.	11	27	9	3
Costs on seeds per 100 ha of grain acreage. thous. rub	55.2	108.2	185.0	455.8
Grain yields, centner/ha	8.8	11.0	8.9	11.0
Cost value of 1 centner of grain, rub	334.5	423.0	493.5	582.9
The selling price of 1 centner of grain, rub	407.1	437.3	403.9	411.4
Gross profit per 100 ha of grain acreage. thous. rub	19.6	59.4	-73.2	-86.1
Level of profitability of production, %	10.5	38.8	-28.4	-61.1

The gross profit averages 57.2 thousand rubles per 100 hectares of grain crops acreage with costs on fertilizers from 51 thousand rubles up to 75 thousand rubles and is on average 62.5 thousand rubles per 100 hectares of grain crops. Table 5 shows that if this factor of costs on fertilizers decreases or increases, the economic efficiency of grain production at agricultural enterprises of grain specialization in the Kurgan region decreases.

Agricultural enterprises of grain specialization in the Kurgan region get the largest gross profit per 100 hectares of grain crops and the profitability of grain production if their costs on plant protection products per 100 hectares of grain crops acreage are on average 42.3 thousand rubles. Agricultural enterprises of grain specialization in the Kurgan region, the cost of plant protection products which are higher or lower than the specified level, the indicators of efficiency of grain production are lower (Table 6).

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Table 5: The impact of the costs on fertilizers on the efficiency of grain production at agricultural enterprises of grain specialization in the Kurgan region

Indicator	Costs on fertilizers per 100 ha of grain acreage, thous. rub			
	under 25	26 – 50	51 – 75	over 75
Number of enterprises in a group, pcs.	29	6	5	10
Costs on fertilizers per 100 ha of grain acreage, thous. rub	3.8	43.0	62.5	99.4
Grain yields, centner/ha	10.6	10.1	14.9	10.7
Cost value of 1 centner of grain, rub	617.5	495.3	487.1	404.5
The selling price of 1 centner of grain, rub	462.7	412.3	533.7	444.7
Gross profit per 100 ha of grain acreage, thous. rub	-9.7	-28.4	57.2	39.0
Level of profitability of production, %	-10.4	-15.4	18.5	15.2

Table 6: The impact of costs on plant protection products on the efficiency of grain production at agricultural enterprises of grain specialization in the Kurgan region

Indicator	Costs on plant protection products per 100 ha of grain acreage, thous. rub			
	under 15	16 – 30	31 – 45	over 45
Number of enterprises in a group, pcs.	7	9	31	3
Costs on plant protection products per 100 ha of grain acreage, thous. rub	4.0	21.6	42.3	78.6
Grain yields, centner/ha	9.2	12.8	14.4	9.7
Cost value of 1 centner of grain, rub	531.9	457.5	477.7	418.3
The selling price of 1 centner of grain, rub	414.4	428.8	473.8	393.1
Gross profit per 100 ha of grain acreage, thous. rub	2.1	5.4	36.2	-8.9
Level of profitability of production, %	0.7	1.5	13.8	-1.4

A significant part of material costs at agricultural enterprises of grain specialization in the Kurgan region is the costs of petroleum products. The gross profit averages 54.6 thousand rubles per 100 hectares of grain crops acreage with the profitability of 14.7% when costs on petroleum products are about 54.2 thousand rubles per 100 hectares of grain crops. Indicators of efficiency of grain production in this group are higher than the rest ones, it may reveal inexpediency of a significant reduction or increase in the costs on petroleum products concerning the specified value (Table 7).

Table 7: The impact of costs on petroleum products on the efficiency of grain production at agricultural enterprises of grain specialization in the Kurgan region.

Indicator	Costs on petroleum products per 100 ha of grain acreage, thous. rub			
	under 50	51 – 100	101 – 150	over 150
Number of enterprises in a group, pcs.	10	26	12	2
Costs on petroleum products per 100 ha of grain acreage, thous. Rub	37.9	54.2	115.9	268.3
Grain yields, centner/ha	8.1	9.8	12.2	12.2
Cost value of 1 centner of grain, rub	773.9	418.9	468.2	321.5
The selling price of 1 centner of grain, rub	400.9	401.1	499.3	362.8
Gross profit per 100 ha of grain acreage, thous. rub	6.4	54.6	32.1	-1.2
Level of profitability of production, %	0.8	14.7	7.6	-0.7

To ensure the most efficient grain production, the costs n keeping the fixed assets per 100 hectares of grain crops should be at the level of 73.1 thousand rubles (Table 8).

Table 8: The impact of costs on keeping the fixed assets on the efficiency of grain production at agricultural enterprises of grain specialization in the Kurgan region

Indicator	Costs on keeping the fixed assets per 100 ha of grain acreage, thous. rub			
	under 150	51 – 100	101 – 150	over 150
Number of enterprises in a group, pcs.	18	12	11	9
Costs on keeping the fixed assets per 100 ha of grain acreage, thous. rub	18.9	73.1	118.2	257.3
Grain yields, centner/ha	8.8	9.2	12.4	11.2
Cost value of 1 centner of grain, rub	570.7	396.8	411.8	591.7
Selling price of 1 centner of grain, rub	404.7	412.3	431.9	463.6
Gross profit per 100 ha of grain acreage, thous. rub	9.8	36.1	29.1	-73.9
Level of profitability of production, %	2.4	19.7	7.0	-16.9

The profit from grain production averages 36.1 thousand rubles per 100 hectares of grain crops acreage when profitability equals on average 19.7% in the case with these costs after grouping the agricultural enterprises of grain specialization in the Kurgan region.

3.2 OPTIMAL COST STRUCTURE

The study of dependence of production costs on grain production per 100 hectares of grain crops acreage at agricultural enterprises of grain specialization in the Kurgan region make us think that the maximum profit is possible if we optimize the structure of production costs according to the proposed algorithm based on the marginal utility of costs with consideration the following conditions:

$$U(x) = \sum_{i=1}^{8} u_i(x_i); \quad (8),$$

$$U(x) \rightarrow \max; \quad (9),$$

$$x_1 \leq 108{,}2;\ x_2 \leq 62{,}5;\ x_3 \leq 42{,}3;\ x_4 \leq 54{,}2;\ x_5 \leq 273{,}4 - \sum_{i=1}^{4} x_i; \quad (10),$$

$$x_6 \leq 37{,}6;\ x_7 \leq 73{,}1;\ x_8 \leq 438{,}4 - \sum_{i=1}^{6} x_i, \quad (11),$$

where

x_1 - production costs on seeds at an agricultural enterprise of grain specialization in the Kurgan region per 100 hectares of grain crops acreage, thousand rubles;

x_2 - production costs on fertilizers at an agricultural enterprise of grain specialization in the Kurgan region per 100 hectares of grain crops acreage, thousand rubles;

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x_3 - production costs on plant protection products at an agricultural enterprise of grain specialization in the Kurgan region per 100 hectares of grain crops acreage, thousand rubles;

x_4 - production costs on petroleum products at an agricultural enterprise of grain specialization in the Kurgan region per 100 hectares of grain crops acreage, thousand rubles;

x_5 - other material costs at an agricultural enterprise of grain specialization in the Kurgan region per 100 hectares of grain crops acreage, thousand rubles;

x_6 - production costs on labour remuneration at an agricultural enterprise of grain specialization in the Kurgan region per 100 hectares of grain crops acreage, thousand rubles;

x_7 - production costs on keeping the fixed assets at an agricultural enterprise of grain specialization in the Kurgan region per 100 hectares of grain crops acreage, thousand rubles;

x_8 - other production costs at an agricultural enterprise of grain specialization in the Kurgan region per 100 hectares of grain crops acreage, thousand rubles.

The structure of production costs on grain production at agricultural enterprises of grain specialization in the Kurgan region is as follows (Figure 2).

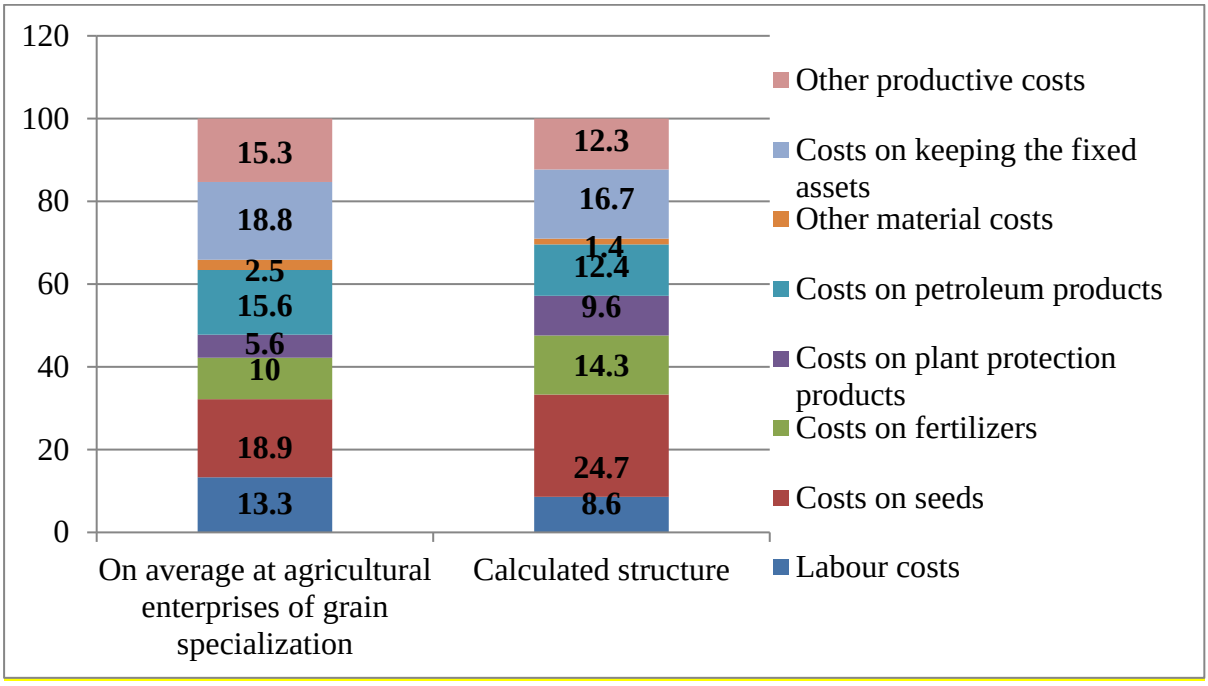

Figure 2: The optimized production cost structure for agricultural enterprises of grain specialization in the Kurgan region per 100 hectares of grain crops, %.

The structure of production costs at agricultural enterprises of grain specialization in the Kurgan region was developed on the basis of revealed patterns of behavior of productive indicators of economic activity, and it has some fluctuations from the existing structure of production costs.

The proposed cost structure on grain production at agricultural enterprises of grain specialization in the Kurgan region allows increasing profits from the sale of the produced grain, reducing the resource intensity of production, increasing the level of profitability.

4. DISCUSSION

In order to evaluate the efficiency of production costs with regard to their marginal utility, let us compare the efficiency of grain production at the existing level of production costs at the agricultural enterprises in the Kurgan region, as well as the average area of grain crops, average grain yield, marketability and a selling price of 1 centner of grain with the values of our observations and calculations (Table 9).

Table 9: Economic efficiency of grain production with consideration of the marginal utility of production costs at agricultural enterprises of grain specialization in the Kurgan region

Indicator	On average at agricultural enterprises of grain specialization	Calculated amounts	Fluctuations	
			(+;-)	%
Grain crops acreage, ha	746081	746081	–	–
Grain yield, centner/ha	13.0	12.4	-0.6	95.4
Grain produced, centner	9699053	9251404	-447649	95.4
Grain sold, centner	8544866	8150487	-394379	95.4
Marketability level, %	88.1	88.1	–	–
Costs on grain production - total, thousand rub.	4157842	3270819	-887023	78.7
including per 1 ha, rub.	5586.6	4384.0	-1202.6	78.5
per 1 centner, rub.	478.6	353.5	-125.1	73.9
Sale revenues – total, thousand rub	4298922	3711732	-587190	86.3
including per 1 ha, rub.	5762.0	4975.0	-787.0	86.3
per 1 centner, rub.	503.1	455.4	-47.7	90.5
Resource intensity, thousand rub.	0.967	0.881	-0.086	91.1
The cost value of products sold, thousand rubs.	3663059	2881592	-781467	78.7
Profit (+), negative profit (-) from sale - total, thousand rub	635863	830140	194277	130.6
including per 1 ha, rub.	852.3	1112.7	260.4	130.6
per 1 centner, rub.	65.6	89.7	24.1	136.9
Cost effectiveness of production, %	17.4	28.8	11.4	–

The number of costs on grain production, set with regard to their marginal utility, is lower by 887023 thousand rublesce or 21.3% than the value that prevails at agricultural enterprises of grain specialization in the Kurgan region. At this level of costs, the yield averages 12.4 centners per hectare, which is 4.6% less than the current yield. The selling price of 1 centner of grain is 9.5% lower than the current level.

In such conditions, the allocation of production costs with consideration of their marginal utility allows agricultural enterprises of grain specialization in the Kurgan region to reduce the resource intensity of marketable grain in comparison with its existed average value by 0.086 rubles or by 8.9%, to increase the profit from the sale of marketable products by 194277 thousand rubles or by 30.6%, including per 1 hectare of grain crops - by 260.4 rubles or by 30.6%, for 1 centner of grain produced - by 24.1 rubles or 36.9%. The level of profitability at the same time increases by 11.4%.

5. CONCLUSION

Thus, the efficiency of agricultural production is inversely related to the level of its resource intensity. The optimization of resource consumption should be carried out with gradual allocation of

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production resources with consideration of the marginal utility of their costs.

Approbation of the scientific hypothesis formulated in this study makes it possible to assume with a high degree of certainty that optimization of the structure of production costs based on the developed algorithm reduces the resource intensity of marketable products, increases profits and the level of production profitability; that indicates an increase in the economic efficiency of the agricultural enterprise during the allocation of production costs with consideration of their marginal utility.

6. CONFLICT OF INTERESTS

The authors confirm that the presented information does not contain a conflict of interest.

7. ACKNOWLEDGMENT

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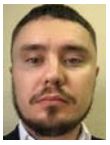

G.A. Beznosov is a Candidate of Economic Sciences, Ural State Agrarian University, Russia. His scientific interests include the development of the economic mechanism of resource conservation, economic and mathematical modeling of economic, processes and phenomena in the system of precision farming, the development of the organizational and economic mechanism of sustainable land management based on modern digital technologies, the profitability of agricultural production.

Professor Dr.N.V. Ziablitckaia is Professor at South Ural State University, Chelyabinsk, Russia. She holds the Doctor of Economics degree. Her research interests encompass Business planning, competitive advantages of an organization, lean manufacturing, development of petrochemical clusters, petrochemical industry.

L.A. Novopashin is an Associate Professor at Ural State Agrarian University, Russia. He is a Candidate of Technical Sciences. His research interests embrace Problems of Starting Transport and Technological Machines, Digitalization of Agriculture, Research on Alternative Energy Types.

L.V. Denyozhko is an Associate Professor at Ural State Agrarian University, Russia. She is a Candidate Of Technical Sciences. Her research areas involve Working Processes In Internal Combustion Engines, Application of Digital Technologies in Research of Processes in TTM, and Alternative Types of Energy.

A. A. Sadov is a Postgraduate Student, Ural State Agrarian University, Russia. His research focuses on Renewable Alternative Energy Types, Digitalization of Agriculture, Development of Robotic Complexes for the needs of Agriculture.

N.K. Pryadilina is an Associate Professor at Ural State Forest Engineering. She is a Candidate of Economic Sciences. Her scientific interests concentrate on Strategic Planning of the Forest Sector, Urban Forests, Forest Plan, Forest Management, Problems of the Forest Sector.