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Economic and Mathematical Modelling of Estimating the Use of Basic Production Resources of Agricultural Formations

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Abstract. Based on the materials of specific agricultural formations in the Almaty region, this paper presents a methodological approach to assessing the effectiveness of using a resource potential. Approved economic-mathematical model of optimizing production and industrial structure, justifying the optimal parameters of elements of the resource potential through which there are revealed reserves for increasing efficiency of using a resource potential. The research results show that the use of economic and mathematical optimization models will significantly increase the efficiency of production and the use of the resource potential of specific agricultural formations. Practical recommendations are given to substantiate the optimal parameters of the resource potential of all types of agricultural enterprises in the Almaty region based on this methodology.

INTRODUCTION

Theoretical and practical problems associated with increasing the efficiency of managing the processes of formation and use of the resource potential of agricultural units can contribute to the actualization of methodological approaches to the assessment of unstable operating environments and better understanding of the impact of climate change on the agricultural sector [1–8]. Indeed, an effective elaboration of information support for resource management determines the relevance of the issue and the choice of research direction [9–14]. The ability to correctly use the available opportunities to a decisive extent depends on the efficiency of the functioning of agricultural formations and the pace and quality of development of its business [15–28]. At the same time, agricultural development depends on economic [29–41], social and ecological conditions in the country. In this regard, the identification and qualitative assessment of the potential of agricultural formations, their implementation and nonsales parts are of great importance. These circumstances actualize the need for a practical solution to a set of problems, both

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in terms of methodology and in terms of instrumental assessment of the potential of agricultural formations and their mathematical modelling.

The purpose of this work is to determine the resource potential of agricultural formations based on the natural, climatic, and macroeconomic conditions of management. This includes specialization of production and a combination of industries that would achieve the maximum economic effect. To achieve this goal, a number of tasks were solved: an economic and mathematical problem was set to optimize the sectoral structure of production, and an optimality criterion was chosen; input information for the economic-mathematical model was prepared and substantiated; an economic and mathematical model for optimizing the sectoral structure of production was developed; the set economic and mathematical task was implemented on a computer; and an analysis of the results of the solution was carried out. The main goal of these tasks has been fulfilled and is given in [11–13]. The method of economic and mathematical modelling was used as the main research method.

METHODS OF ECONOMIC AND MATHEMATICAL MODELLING

Industry 4.0 and digitalization have provoked rapid changes in all sectors, including agriculture [42–59]. The use of information technology in economic and mathematical modelling has allowed farmers to make more informed decisions about how to best utilize their limited resources, resulting in increased efficiency and productivity in agricultural production. In addition, Industry 4.0 and digitalization require sufficient finance [60–76], knowledge [77–92], market infrastructure [93–108], etc. The use of methods of economic and mathematical modelling for the development of the optimal structure of crop and livestock production allows the most rational use of limited production resources and ensures a significant increase in the economic efficiency of agricultural production. The presented algorithm for optimizing types of production can serve as a methodological basis for constructing different scenarios for the development of the reproduction process for other agricultural organizations that have similar values of resource availability, sizes and levels of resource potential use.

Economic and mathematical models can be recommended as tools for on-farm planning at the stage of developing and implementing budgets and can also be modified for any planning horizon. Dual constraint estimates have an important economic meaning in the analysis of problem solution. Constraint estimates show how the efficiency of the optimal variant (objective function value) can change when the volume of constraints changes. With the help of these constraint estimates, it is possible to identify "bottlenecks" that hinder the growth of the efficiency of the obtained optimal variant. They are estimates that show which resources are the scarcest and which are the least, as well as how you can change the initial conditions in order to get a more efficient option for the development of the economy.

RESULTS AND DISCUSSION

To improve the efficiency of the use of resource potential, we propose a model development of a combination of the structure of types of production on the example of selected agricultural organizations in the Almaty region [3]. All farms selected by us are typical, and their performance indicators can be considered as references (models) for the Almaty region. Based on the calculated index of resource potential use efficiency, the initial population was divided into 3 groups [3,6]. It should be noted that the results of the study and optimization of the use of production resources of model agricultural organizations, KFH “Luch” (1st group, with the lowest rating) and JSC APK "Adal" (2nd group, more typical, where intensive processes of formation and development of market relations, with an average rating), were tested in international scientific conferences and published, respectively, in studies [12,14].

This paper presents the results of solving a model development on the example of an agricultural enterprise (AE) “Avangard” of the Almaty region, belonging to the 3rd group, which has the best index of efficiency in the use of resource potential. In the study and optimization of the use of production resources of the Avangard AE, we used the developed calculation technology using economic and mathematical methods, given in [11,13]. The structure of marketable products consists mainly of marketable crop and livestock products, with wheat occupying the largest share. Grain production is successfully combined with the development of dairy cattle. The average annual livestock for the last 3 years is 1453 heads of cattle, incl. 585 cows or 40.3%; 2248 heads of sheep, incl. 1500 heads of ewes or 66.7%; 884 heads of pigs, incl. 200 sows (22.6%) and 78 horses, incl. 21 mares (26.9%). On the farm, the total area of agricultural land is 16532 ha, incl. hayfields 606 ha or 3.7%, pastures 7789 ha or 47.1%, arable land 8118 ha or 49.1%, of which irrigated 2111 ha or 26.0% of the arable land. The arable land of the farm is mainly occupied by grain crops and perennial grasses. The average grain yield, including corn for grain, for 2017-2018 amounted to 16.1 centners per 1 ha. The development of crop growing industries with limited resources requires optimizing the structure of sown areas. Each specific optimization object includes those industries that determine its production direction. The commonality of the resources used between industries leads to a close relationship in the development of various industries. In this regard, the problem of determining the structure and placement of sown areas is multivariant [109–112,114]. The development of animal husbandry and the production of its products are planned to take into account the biological characteristics of the development of farm animals. Modelling the turnover of the herd of animals involves the division of the herd into sex and age groups. Optimization of the herd structure determines the most effective ratio of individual sex and age groups based on economic and zootechnical requirements. The structure of the herd of each particular farm is closely dependent on its production line and specialization of the livestock industry, the fertility of the queens, the duration of the rearing of young animals, the timing of the production use of the breeding stock and the conditions for keeping and feeding animals. This dependence of the factors that determine the efficiency of the herd structure forces us to consider many options and choose the best among them. It should be noted that the vast majority of agricultural formations in the Almaty region (approximately 70%) have a livestock production line and specialize in milk production in combination with the rearing of superrepair young animals. They are located in approximately the same natural and climatic zones and have equivalent economic management conditions.

With this in mind, we have developed an economic and mathematical model, the purpose of which is to achieve the maximum level of use of the resource potential in the economy on the basis of such a structure of production that would meet the needs of the market for the sale of a certain volume of products. At the same time, the efficient use of production resources and a significant improvement in other economic indicators would be ensured. In addition, the economic and mathematical model for optimizing the resource potential should provide the following conditions:

- obligatory fulfilment of the current sales volumes of products in terms of assortment and quantity;
- designing the size of industries, taking into account the available production resources;
- compliance of the projected structure of sown areas with the scientifically based zonal farming system;
- the impact of changes in the level of livestock feeding on animal productivity;
- the level of labour supply for certain categories of workers at the lowest labour costs and the maximum level of profitability.

The economic-mathematical model of resource potential optimization developed by us includes 33 variables and 53 constraints. The target function, along with traditional economic indicators, including maximizing profits, also includes a generalizing indicator of the efficiency of using the resource potential, which is called the cumulative efficiency index and is determined according to the methodology given in [112]. The following groups of variables were introduced into the resource potential optimization model:

1. Area of agricultural crops and lands ($x_1 \div x_{18}$), ha.
2. Straw for fodder and the rest for sale ($x_{20} \div x_{21}$), c.
3. Average annual number of livestock ($x_{22} \div x_{29}$), heads.
4. Attracting additional labour resources (x_{30}), man-hours.
5. Effective economic indicators ($x_{31} \div x_{33}$), thousand tenge.

When compiling a detailed economic and mathematical model for optimizing the resource potential, the necessary initial data were prepared. To calculate the yield of marketable products and nutrients per unit area, it is necessary to know what part of the product is lost, what part is used for seeds and what part is used for fodder. Other initial data are prepared accordingly using the following sources [114–116].

THE RESULTS OF OPTIMIZING THE RESOURCE POTENTIAL OF THE AGRICULTURAL ENTERPRISE "AVANGARD"

The problem was solved on a computer using the program "Search for a solution" in MS Excel. The unknowns received the values shown in Table 1. A machine printout of the results of solving the problem is shown in Figures 1, 2, 3 and 4. As a result of solving the problem, the size of sown areas by crops and the number of livestock by species were determined. The structure of sown areas, despite the development of dairy cattle breeding, is characterized by a high proportion of grain crops (67.2%), including winter crops (61.1%). Providing fodder rations with fodder units and digestible protein required large areas of winter fodder barley, the share of which amounted to 6.8% of the arable land. The share of fodder crops in the structure of sown areas amounted to 21.7%. Including corn for silage 1.4%, perennial grasses – 14.2% (for hay 12.4% and for haylage 1.8%) and annual grasses for green fodder 4.3%. The share of industrial crops, in particular safflower, accounts for 1.8% of arable land, and its sown area was determined only at the level of ensuring the proposed sales plan. Compared with other crops, spring cereals were not effective.

TABLE 1. Solution results (optimal value of the resource potential)

Variable	Name of unknown	Value, ha, heads, c, thousand tenge	Cultivated areas, % to the area arable land
X_1	Winter wheat (commercial and seed)	4404,88	54,25
X_4	Winter barley fodder	548,03	6,8
X_3	Winter barley (commercial and seed)	4,09	0,05
	Total winter crops	4957,0	61,1
X_2	Spring wheat (commercial and seed)	0,0	0,0
X_5	Spring barley (commercial and seed)	0,0	0,0
X_6	Spring barley fodder	0,0	0,0
	Total spring	0,0	0,0
X_7	Oat	0,0	0,0
X_8	Corn grain for fodder	497,3	6,08
X_9	Corn grain (commercial and seed)	1,32	0,02
	Total cereals	**5455,62**	**67,2**
X_{10}	Corn for silage	112,38	1,4
X_{11}	Corn for green fodder	0,0	0,0
	Total corn	611,0	3,5
X_{12}	Perennial grasses for hay and seeds	1008,76	12,4
X_{13}	Perennial grasses for haylage	142,02	1,8
X_{14}	Perennial herbs for goods	0,0	0,0
	Total perennial grasses	1150,78	14,2
X_{15}	Annual herbs for green fodder	349,22	4,3
	Total forage grasses including seeds	1500,0	18,5
X_{18}	Saflor	150,0	1,8
	Total forage (silage, haylage and grasses)	**1762,38**	**21,7**
X_{19}	Clean steam	900,0	11,1
	Total area of arable land	**8118,0**	**100,0**
X_{16}	Haymaking (total area of haymaking – 606 ha)	606,0	100,0
X_{17}	Pastures (total pasture area - 7789 ha)	7789,0	100,0
X_{20}	Grain straw for feed, c	5689,0	
X_{21}	The rest of the straw for sale, c	24751,0	
	Livestock:		
X_{22}	Cow	585	
X_{23}	Young and other livestock groups	479	
X_{24}	Sows	226	
X_{25}	Young and other groups of pigs	906	
X_{26}	Sheep	6366	
X_{27}	Young and other groups of sheep	933	
X_{28}	Mares	50	
X_{29}	Young horses and working horses	117	
X_{30}	Attraction of an additional labor resource	0,0	
X_{31}	Material and monetary costs	430818,94	
X_{32}	The amount of gross output	849422,49	
X_{33}	The amount of marketable products (revenue)	567720,73	
	Functionality (profit)	**136901,79**	

The high share of grain crops and the relatively low share of fodder crops with developed dairy cattle breeding is the result of the efficient use of fodder resources, including the maximum use of natural pasture grasses (100.0% of the total area), which provide livestock with cheap green fodder throughout the entire pasture period. Comparative indicators of the efficiency of using the production resources of the economy are shown in Table 2. It can be seen from Table 2 that sheep breeding has received predominant development in the optimal plan, which was determined at the rate of 7299 heads, which is 5299 heads more than the actual amount (2000 heads), including 6366 heads of ewes, which is 4966 heads more than the actual amount.

TABLE 2. Comparative efficiency of using the resource potential of the AE "Avangard"

Industries	In fact		According to the optimal solution	
	ha, heads	%	ha, heads	%
Total farmland	16513	100,0	16513	100,0
Of them:				
- pastures	7789	100,0	7789	100,0
- haymaking	606,0	100,0	606,0	100,0
- arable land	8118,0	100,0	8118,0	100,0
Of which: for grain	5395,0	66,5	5455,62	67,2
Including:				
a) total winter crops	3500,0	43,1	4957,0	61,1
- wheat	3500,0	43,1	4404,88	54,25
- barley	–	–	552,12	6,85
b) total spring	1740,0	21,4	0,0	0,0
- wheat	212,0	2,6	0,0	0,0
- barley	1528,0	18,8	0,0	0,0
c) oats	55,0	0,7	0,0	0,0
d) corn for:				
- grain	100,0	1,2	498,6	6,1
- silo	300,0	3,8	112,4	1,4
- green fodder	80,0	0,9	–	–
Perennial herbs for:				
- hay	1000,0	12,3	1008,8	12,4
- haylage	105,0	1,3	142,0	1,8
Annual herbs for:				
- green fodder	156,0	1,9	349,2	4,3
safflower	150,0	1,8	150,0	1,8
Clean steam	932,0	11,5	900,0	11,0
Livestock, heads				
Cow	600	100,0	585	97,5
Young and other livestock groups	794	100,0	479	60,3
Sows	200	100,0	226	113,0
Young and other groups of pigs	611	100,0	906	148,3
Mares	21	100,0	50	238,1
Young and other groups of horses	57	100,0	117	205,3
Ewes	1400	100,0	6366	454,7
Young and other groups of sheep	600	100,0	933	155,5
Profit, thousand tenge	99107,11	–	136901,79	–
Profitability, %	24,1	–	31,8	–

Such a structural change in sheep breeding occurred due to the rational use of production resources, including pasture fodder, the identification of the cultivation of inefficient grain crops and the reduction in the average annual number of young animals and other groups of cattle by 315 heads, which shows the poor efficiency of cattle breeding compared to other areas of animal husbandry. At the same time, dairy cattle breeding, which was considered the leading industry in the economy, is entering the secondary plan with the number of livestock in the amount of 1064 heads, which is 330 heads less than the actual (1394 heads), including 585 cows, which is 15 heads less than the actual one. Sectors of pig and horse breeding, mainly organized to meet on-farm needs, are characterized by different efficiencies, which shows the level of their structural change. There were no significant changes in the structure of fodder crops (Table 3), with the exception of corn for green fodder, which turned out to be ineffective.

TABLE 3. The structure of commercial products of AE "Avangard"

Industry and product type	**In fact**		**Optimal**	
	thousand tenge	**%**	**thousand tenge**	**%**
Crop production:	450364,69	88,2	493475,84	86,9
- wheat	400814,6	78,5	476211,75	83,9
- barley	0,0	0,0	251,67	0,04
- corn grain	32143,0	6,3	424,75	0,1
- others	17407,09	3,4	16587,67	2,86
Livestock:	60170,63	11,8	74244,9	13,1
- cattle breeding	49306,56	9,7	45343,35	8,0
including milk	41970,0	0,0 (8,2)	40920,75	0,0(7,2)
- pig breeding	4906,55	1,0	6850,97	1,2
- sheep breeding	5580,0	1,1	21243,91	3,7
- others	377,52	0,1	806,67	0,1
Housekeeping Total	510535,32	100,0	567720,74	100,0

Milk production should be combined with commercial grain and fodder root crops. However, the farm is not engaged in the production of fodder root crops. As a result, the share of livestock in commercial products has changed significantly (from 9.7% to 8.0%, including milk – from 8.2 to 7.2%), while this indicator in other areas of animal husbandry tends to increase, and the general trend is from 11.8% to 13.1% for the optimal design. In the structure of marketable products, the share of corn grain decreased from 6.3 to 0.1%, and vice versa, the share of marketable wheat increased from 78.5% to 83.9%. In general, there were no significant changes in crop production. Although there is a tendency to reduce the marketable crop production from 88.2 to 86.9%, this cannot be argued in terms of monetary terms of marketable crop production, which actually amounts to 450364.69 thousand tenge, and according to the optimal project, it amounts to 493475.84 thousand tenge. From here, the direction of specialization of production clearly emerges, which requires the search for a different combination of industries under given land conditions. The effectiveness of the optimal use of production resources and a combination of industries or a promising area of specialization of the economy can be judged by the level of production of the main types of products per 100 hectares of land (Table 4).

The structure of cereals has also changed. Therefore, for example, the share of winter crops amounted to 61.1% of arable land against the actual 43.1%, while spring crops, on the contrary, are not effective according to the optimal plan, but actually 21.4%. With a significant change in the structure of the average annual livestock, there was no significant difference in the monetary terms of marketable products in some livestock industries, particularly in sheep and pig breeding. This is because, in fact, the economy does not take into account some of the marketable products used for on-farm needs. In particular, payment for the work of workers in kind with livestock products is taken into account as wage costs, etc.

As shown in Table 4, the gross output in terms of money under the optimal project increased by almost 1.22 times, and the amount of net income increased by more than 1.11 times. Gross grain harvest increases almost 1.32 times, and its sale – more than 1.13 times. At the same time, the production of corn grain products is sharply reduced, and vice versa, wheat production will increase by more than 1.19 times. Milk production per 100 hectares of agricultural land is 106.28 centners, which is lower than for typical dairy farms in the zone and shows the inefficiency of expanding dairy cattle breeding due to limited fodder resources with sufficient land resources. The level of profitability rises from 24.1% to 31.8%. The increase in the level of profitability is associated with structural shifts in the sale of products and an increase in the volume of sales of more profitable products (winter wheat, sale of haylage and beef cattle breeding). The resulting solution meets all the requirements set in the problem. The arable land on the farm is fully used, a rational crop rotation is ensured due to the annual allocation of 900 hectares of rain-fed arable land for recreation in the form of pure fallow, the area of 2111 hectares of irrigated arable land is fully used, and the need for labour does not exceed the available resources. However, our calculation based on actual data shows that due to the irrational organization of the use of labour resources in the economy, 221,527 man-hours of labour resources remain unused annually. From the analysis of the use of feed resources, it can be seen that, in fact, on the farm, due to the imbalance of diets with individual nutrients and the failure to comply with the permissible limits of individual feed groups, there is an over expenditure with a low level of animal productivity.

TABLE 4. Comparative assessment of the use of production resources for the production of products per 100 hectares of land

Indicators	Unit	Actual	For the optimal solution	Optimal in% to actual
Cereals per 100 ha of arable land	c	730,0	961,4	131,7
including commodity	c	682,5	771,4	113,0
Of them:				
- wheat	c	648,0	770,5	118,9
- barley	c	0,0	0,44	0,0
- corn grain	c	34,5	0,46	1,3
Haylage per 100 ha of arable land	c	219,9	297,5	135,3
Milk per 100 ha of farmland	c	109,01	106,28	97,5
Weight gain per 100 ha of farmland	c	11,9	17,7	148,7
including livestock	c	5,83	3,51	60,2
- in pig breeding	c	3,38	4,73	139,9
- in sheep breeding	c	2,47	9,01	364,8
- in horse breeding	c	0,22	0,45	204,5
Gross output per 100 hectares of agricultural land	thousand tenge	4233,0	5144,0	121,5
Net income per 100 hectares of agricultural land	thousand tenge	3092,0	3438,0	111,2
Profitability level	%	24,1	31,8	-
Aggregate index		4,5	15,7	-

According to the optimal solution, own feed production fully satisfies the needs of animal husbandry, both in terms of quantity and content of certain types of feed in diets (Table 5).

TABLE 5. Analysis of the use of feed resources on the farm

Food groups	Types of food	Permissible limit	Actually			By project		
			demand	manufacturing	Surplus+ flaw-	demand	manufacturing	Surplus+ flaw-
1	concentrates	min max	12050,5 20756,6	14778,8	*balance*	14409,9 23759,5	23759,5	*balance*
2	juicy (silo)	min max	4782,0 9564,0	10080,0	+516,0	3775,9 7551,8	3775,9	*balance*
3	rough	min max	5453,6 12276,5	12010,5	*balance*	6152,0 14040,9	14040,9	*balance*
	including hay	min max	3997,6 10671,9	3956,16	-6715,7	3973,0 12491,4	3973,0	*balance*
	haylage	min max	1900,7 5629,6	6063,8	+434,2	3668,3 8201,7	8201,7	*balance*
	straw	min	2079,1	1728,2	-350,9	1861,5	1593,7	-267,8
4	green food	min max	10489,3 20268,5	24540,9	+4272,4	18447,9 28230,5	28230,5	*balance*
	including pastures	max	14167,3	16356,9	+2146,0	16356,9	23222,7	+6865,8
Total forages		unit	62108,5	62806,8	-698,27	69827,8	69827,8	*balance*
Overcooked protein		c	6835,71	12330,9	+5495,2	10270,7	15412,6	+5141,9

From the group of roughage, the lack of straw of grain crops and the surplus of natural pasture grasses is quite acceptable according to zoo technical requirements. As a result of the redundancy of pasture grasses, there was a surplus in the annual balance of digestible protein in the whole livestock sector. The optimal programme fully ensures the fulfilment of the proposed plan for the sale of products (Table 6), and for the most effective types of products, it is over fulfilment. Thus, sales of wheat are exceeded by more than 17.9 times. In the future, the farm will not be engaged in the production of corn grain for sale due to the unprofitability of this crop but will continue to grow it for on-farm needs. According to the project, the situation is the same for the production of barley for the commodity. For this culture, the plan was not fulfilled. The situation in the livestock sector in terms of the implementation of the production plan is related to the above-described provisions. I would like to once again draw attention to the fact that the potential of forage resources is not used efficiently in the economy and, as a result, the profitability of dairy cattle breeding is reduced.

TABLE 6. Implementation of the proposed plan for the sale of products, c

Product types	Sale plan	Selling by the best solution	Surplus +/Flaw -	Product types	Sale plan	Selling by the best solution	Surplus +/Flaw -
Wheat	3500,00	62549,32	+59049,32	Beef	1052,00	580,00	-472,00
Barley	6800,00	36,00	-6764,00	Pork	349,00	781,35	+432,35
Corn grain	0,00	37,00	+37,00	horsemeat	42,00	75,00	+33,00
haylage	1700,00	24143,45	+22443,45	Mutton	459,00	1489,00	+1030,00
Remaining straw	0,00	24750,51	+24750,51	Wool	85,00	277,36	+192,36
Milk	18566,00	17550,00	-1016,00				

Therefore, all the conditions set in the task are met. When the initial conditions change, other options for optimal solutions can be calculated. In our task, of the resources that are available on the farm, arable land and natural hayfields turned out to be scarce. They are fully used in all intended production situations with high dual ratings. Below in the text, a specific production situation and the corresponding problem statement are considered. The dual assessment of arable land that we use shows how much the objective function can be increased if an additional unit of this resource is involved. Therefore, for example, an additional hectare of arable land occupied by crops would lead to an increase in profit by 1.95 thousand tenge, and an increase in the sown area occupied by corn (for grain and seeds, for green fodder and silage) would increase profit by 61.45 thousand tenge. Therefore, it is necessary to increase the area under corn for grain, seeds, silage and green fodder. This decision was also made by the Department of Agriculture of the Almaty region. Estimating the state (redundancy or insufficiency) of resources by the value of dual estimates, we set tasks in different formulations and, accordingly, developed models under various constraints.

Thus, 10 options for solving problems have been calculated, of which, for a meaningful analysis and assessment of the resource potential, we present only five options below. The results of a computer experiment to study the system of relationships between the elements of the resource potential of the AE “Avangard” are summarized in Table 7.

Option 1. (Table 7). A distinctive feature of this option is that the use of arable land for perennial grasses for hay, haylage, commercial and seed purposes is given freedom of choice, i.e., restrictions on their volumes are not set either from below or from above. Thus, the maximum production of marketable wheat is ensured. Based on the introduced matrix, the problem was solved according to the profit maximization criterion. As a result of solving the problem, the following optimal production structure of the economy was obtained. Optimal crop area structure:

- winter wheat for sale and seeds – 5852.8 ha (70.1%);
- winter barley for seeds – 4.2 ha (0.05%);
- corn grain for fodder – 577.14 ha (7.1%);
- corn grain for goods and seeds – 330.14 ha (4.1%);
- corn for silage – 170.96 ha (2.1%);
- corn for green fodder – 136.76 ha (1.7%);
- perennial grasses for hay – 795.08 ha (9.8%);
- perennial grasses for haylage – 100.91 ha (1.2%);
- safflower – 150.0 ha (1.8%);
- pure fallow – 0.0 ha (0.0%).

The area of natural haymaking is fully used 606.0 ha (100.0%), and pasture is 7480 ha (96.0%). The annual resource of roughage includes straw of spikelet – in the amount of 7070.66 centners, and straw – in the amount of 35378.29 centners. can be put up for sale. According to the first option, the farm should contain 1014 heads of cattle

(cattle), including 585 heads of cows, 990 heads of pigs, including 198 sows, 4286 heads of sheep, including 1500 heads of ewes and 167 heads of horses, including 50 heads of mares.

TABLE 7. The results of the study of the optimal proportion of the resource potential of the SHP "Avangard" according to the options for the production situation

Indicators	Variants				
	I	II	III	IV	V
Area of arable land, ha	8118,0	8118,0	8118,0	8118,0	8118,0
including:					
Winter wheat for the commodity, seeds	5852,8	246,48	246,48	246,48	0,0
Spring wheat for goods, seeds	0,0	0,0	0,0	0,0	255,47
Winter barley: for goods and seeds	4,2	1330,58	0,0	2231,53	2506,25
for forage	0,0	2379,95	2461,0	2178,99	1450,75
Spring barley: for goods and seeds	0,0	1000,0	1236,36	0,0	0,0
for forage	0,0	0,0	0,0	300,0	744,53
Corn grain: for fodder	577,14	0,0	0,0	600,0	0,0
for goods and seeds	330,14	905,24	904,06	891,54	1635,98
Corn: for silage	170,96	170,18	169,73	171,0	126,76
for green fodder	136,76	138,87	140,09	139,71	0,0
Perennial grasses: for hay	795,08	795,08	795,08	806,51	96,65
on the haylage	100,91	101,63	102,04	102,18	97,10
Saflor	150,0	150,0	150,0	150,0	150,0
Clean steam	0,0	900,0	900,0	900,0	900,0
Natural lands					
Natural hayfields	606,0	606,0	606,0	606,0	871,0
Natural pastures	7480,0	7508,01	7524,10	7552,05	6971,26
Animal population, head:					
total cattle	1064	1064	1064	1073	1000
including cows	585	585	585	590	600
Pigs in total	990	1119	1192	1111	796
including sows	198	224	238	167	40
sheep total	4286	4286	4286	4286	4286
including ewes	1500	1500	1500	1500	1500
Horses	167	167	167	167	86
including the mares	50	50	50	50	15
Gross output, thousand tenge	1086067	760109,2	696401,6	757301,2	974819,8
Revenue, thousand tenge	823392,3	531868,1	462125,8	522324,7	776663,0
Costs, thousand tenge	482844,2	404846,8	362268,2	405367,8	423850,4
Profit, thousand tenge	340548,1	127021,3	99857,63	116956,9	352812,6
Profitability level, %	70,5	31,4	27,6	28,9	83,2

Labour resources are fully utilized, that is, the number of workers on the farm meets the requirement. The results of the calculations showed the following: profit is 340548.13 thousand tenge, material and monetary costs are 482844.21 thousand tenge, the amount of gross output is 1086067.21 thousand tenge, the cost of marketable products is 823392.34 thousand tenge and profitability is 70.5%. Despite the high values of economic indicators, this variant of calculations when solving the problem has a number of disadvantages. For example, only corn grain is used as a concentrated feed, with the possibility of growing barley for fodder. In addition, the value of the area under bare fallow was equal to zero, which contradicts the requirement of crop rotation.

Option 2. (Table 7). A distinctive feature of this option is that we set an upper limit on the plan for the production of marketable wheat, and thus, the production of barley products is a priority among all types of grain crops.

In addition, the restrictions provide for the production of barley for livestock feed and seeds.

As a result of solving this version of the problem, the following optimal production structure of the economy was obtained. Optimal crop area structure:

- winter wheat for sale and seeds – 246.48 ha (3.0%);
- winter barley for goods and seeds – 1330.58 ha (16.4%);

- winter barley for fodder – 2379.95 ha (29.3%);
- spring barley for goods and seeds – 1000 ha (12.3%);
- corn grain for goods and seeds – 905.24 ha (11.2%);
- corn for silage – 170.18 ha (2.1%);
- corn for green fodder – 138.87 ha (1.7%);
- perennial grasses for hay – 795.08 ha (9.8%);
- perennial grasses for haylage – 100.63 ha (1.2%);
- safflower – 150.0 ha (1.8%);
- pure fallow – 900.0 ha (11.1%).

The area of land of natural haymaking is fully used 606.0 ha (100.0%), and pasture is 7508.01 ha (96.4%). In the annual roughage resources, 7070.66 q of spikelet straw and 1295.82 q of straw can be put up for sale. In the optimal solution, there was no significant change in the structure of animal husbandry, with the exception of pigs. The farm should contain 1014 heads of cattle, including 585 heads of cows; 1119 heads of pigs, including 224 sows; 4286 heads of sheep, including 1500 heads of ewes; and 167 heads of horses, including 50 heads of mares. As you can see, the number of pigs increased by 129 heads, including sows by 29 heads, then in the first variant. Labour resources are fully utilized. The volume of profit is 127 021.29 thousand tenge, material and monetary costs – 404 846.84 thousand tenge, the amount of gross output – 760 109.16 thousand tenge and the cost of marketable products – 531 868.13 thousand tenge and profitability – 31.4%.

Option 3. (Table 7) similar production condition as in the second option. Only the barley production plan is limited from above, i.e., the farm cannot produce more barley than planned. After such a restriction, the production of wheat and barley becomes an equal priority. As a result, we obtain the following optimal structure of sown areas:

- winter wheat for sale and seeds – 246.48 ha (3.0%);
- winter barley for fodder – 2461 ha (30.3%);
- spring barley for goods and seeds – 1236.36 ha (15.2%);
- corn grain for goods and seeds – 904.06 ha (11.1%);
- corn for silage – 169.73 ha (2.1%);
- corn for green fodder – 140.09 ha (1.2%);
- perennial grasses for hay – 795.08 ha (9.8%);
- perennial grasses for haylage – 102.04 ha (1.3%);
- safflower – 150.0 ha (1.8%);
- pure fallow – 900.0 ha (11.1%).

The area of land of natural haymaking is fully used 606.0 hectares (100.0%), and pastures are 7524.1 hectares (96.6%). Labour resources are fully utilized. Straw enters the annual roughage resource at 7070.66 centners, and straw at 9075.17 centners can be put up for sale. In the results of the optimal solution of the problem, there was no significant change in the structure of animal husbandry, with the exception of the share of pigs. The number of pigs increased by 73 heads, including sows, by 14 heads (compared to the result of the second option). Such progress in pig breeding is explained by the factor of creating favourable ratios of feed groups and feed resources in the pig breeding farm. However, in doing so (as shown in the calculation listing), the economic performance deteriorates. The profit is 99857.63 thousand tenge, material and monetary costs – 362268.15 thousand tenge, the amount of gross output – 696401.59 thousand tenge, and the cost of marketable products – 462125.78 thousand tenge and profitability – 27.6%.

Option 4 (Table 7). A distinctive feature of this option is the maximum use of arable land for corn and barley. In addition, our model limits the production of barley for livestock feed and barley for sale. As a result of solving the problem, the following optimal production structure of the economy was obtained. Optimal crop area structure:

- winter wheat – 246.48 ha (3.0%);
- winter barley for fodder – 2178.99 ha (26.8%);
- winter barley for goods – 2231.53 ha (27.5%);
- spring barley for fodder – 300.0 ha (3.7%);
- corn grain for fodder – 600.0 ha (7.4%);
- corn grain for goods and seeds – 891.54 ha (11.0%);
- corn for silage – 171.0 ha (2.1%);
- perennial grasses for hay – 806.51 ha (9.9%);
- perennial grasses for haylage – 102.18 ha (1.3%);
- safflower – 150.0 ha (1.8%);

- pure fallow – 900.0 ha (11.1%).

The areas of natural haymaking are fully used, and pastures, on the contrary, are only 7 552.05 ha (96.9%), which shows its (haymaking) clear redundancy in the economy, as in all variants of the problem being solved. The remaining elements of the structure of crop production and livestock production remained the same as in the first variant. Nevertheless, there is a noticeable increase in the number of livestock in the structure of cattle breeding (by 9 heads) and in pig breeding (by 121 heads). The profit is 116 956.91 thousand tenge, material and monetary costs – 405 367.8 thousand tenge, the cost of marketable products – 522 324.72 thousand tenge and profitability – 28.9%.

Option 5. (Table 7) In this option, the transformation of the unused part of natural pastures into natural hayfields is envisaged, and the maximum milk production and the restriction on the cultivation of corn for grain are taken at the lower limit. In addition, the production of barley for livestock feed is provided. As a result of solving the problem on a computer, we obtained the optimal production structure of the economy, which is given in the Abangard5 application. According to the fifth option, the following structure of sown areas is proposed:

- spring wheat – 255.45 hectares (3.1%), and this area provides the production plan for the volume of marketable wheat, which is 3500 centners;
- winter barley for goods – 2506.25 ha (30.9%);
- winter barley for fodder – 1450.75 ha (17.9%);
- spring barley for fodder – 744.53 ha (9.2%);
- corn grain for goods – 1635.98 ha (20.1%);
- corn for silage – 126.76 ha (1.6%);
- perennial grasses for hay – 96.65 ha (1.2%);
- perennial grasses for haylage – 97.10 ha (1.2%);
- safflower – 150.0 ha (1.8%);
- pure fallow – 900.0 ha (11.2%);

Of the area of pastures, 265 ha (606+265=871 ha) was transformed into the area of natural hayfields, and this area was used in the amount of 871 ha (100%), respectively: 606.0 ha (100.0%), and the remaining area (7789 – 265 = 7524 ha) pastures were used in total in the amount of 6971.26 ha (92.7%). According to the fifth calculation option, the farm should contain 1,000 heads of cattle, including 600 heads of cows, which provide a milk production plan in the amount of 18,000 centners. In total, the number of pigs, according to calculations, was 796 heads, while the number of sows decreased to 40 heads. This increase proved to be unprofitable. A similar change occurred in the structure of the horse population, where the entire population decreased from 167 to 86 heads, including only 15 mares. There were no changes in the structure of sheep breeding, and the total number of sheep – 4286 heads – remained at the same level as in the previous versions. Thus, from the considered options for solving the problem of optimizing the resource potential, a promising direction of production is revealed, which is clearly distinguished by dairy cattle breeding and beef sheep breeding. In the future, AE “Avangard” is not profitable for increasing pig and horse breeding. The volumes of these industries should be gradually reduced to the level of meeting the internal needs of the economy. In this variant of solving the problem, all agro technical and zoo technical conditions are met and the maximum value of profit is reached, which is 352812.67 thousand tenge, the cost of gross output is 974819.84 thousand tenge, the cost of marketable products is 776663.07 thousand tenge, material and monetary the costs were 423,850.4 thousand tenge and the profitability of production reached its maximum value and amounted to 83.2%. From the analysis of the use of feed resources, it can be seen that in all the options we have considered, according to the optimal solution, our own feed production fully satisfies the needs of animal husbandry, both in terms of quantity and content of certain types of feed in diets [116–125].

CONCLUSION

The increasing performance of the agriculture sector positively affects the sustainable development of the country [126–135]. At the same time, scholars have confirmed that the agricultural sector could impact the energy security of the country [136–152]. In this case, the policy of agricultural development should be coherent with the policy on extending renewable energy [153–160] in the country, which consequently could bring a vast range of economic, ecological and social effects [161–170]. In addition, the spread of information technology could boost the positive effect. Considering the results of the investigation, the following conclusions were formulated:

1. On the basis of the developed model, as a result of computational experiments on the optimal development of the AE “Avangard” according to the criterion of maximum profit using the simplex method of linear programming, several options for its optimal use of resource potential were established, depending on possible production situations.

For AE “Avangard”, it is recommended to be guided in its development by the structures and options for using the resource potential shown in Table 7. To increase the profitability of production, the farm needs to increase the productivity of dairy cattle by organizing a rational sowing of fodder crops, including the preparation of a scientifically based animal feeding ration; increase the area of winter wheat by reducing the area under spring barley; increase the production of barley for livestock feed by reducing commercial barley; increase the yield of agricultural crops, including fodder crops, and carry out other activities that will significantly increase the profit of the farm; the farm to effectively specialize in the production of dairy cattle and meat sheep; it is not profitable for the economy to increase pig and horse breeding. These industries should be gradually reduced to the level of meeting domestic needs.

2. As a result of practical imitation of the actual conditions of the economy (the first option for solving the problem), the size of sown areas by crops and livestock types was determined. According to the AE “Avangard” calculated:

a) The structure of sown areas, despite the development of dairy cattle breeding, is characterized by a high proportion of grain crops (67.2%), including winter crops (61.1%). Providing fodder rations with fodder units and digestible protein required large areas of winter fodder barley, the share of which amounted to 6.8% of arable land. The share of fodder crops in the structure of sown areas amounted to 21.7%. Including corn for silage 1.4; perennial grasses – 14.2 (for hay 12.4 and for haylage 1.8) and annual grasses for green fodder 4.3%. Industrial crops, in particular safflower, account for 1.8% of arable land. Its sown area was determined only at the level of provision of the proposed sales plan. Compared with other crops, spring cereals were not effective. The high share of grain crops and the relatively low share of fodder crops with developed dairy cattle breeding is the result of the efficient use of fodder resources, including the maximum use of natural pasture grasses (100.0%), which provide livestock with cheap green fodder throughout the pasture period.

b) Sheep breeding has received predominant development in the optimal plan, which was determined in the amount of 7299 heads, which is 5299 heads more than the actual (2000 heads), including 6366 heads of ewes, which is 4966 heads more than the actual. Such a structural change in sheep breeding occurred due to the rational use of production resources, including pasture fodder, by identifying the cultivation of inefficient grain crops and reducing the average annual number of young animals and other groups of cattle by 315 heads, which indicates a poor efficiency of livestock breeding compared to other areas of animal husbandry. At the same time, dairy cattle breeding, which was considered the leading industry in the economy, is moving to a secondary level in terms of priority with the number of livestock in the amount of 1064 heads, which is 330 heads less than the actual (1394 heads), including 585 cows, which is 15 fewer heads than actual. The pig and horse breeding industries, which are mainly organized to meet on-farm needs, are characterized by different efficiencies, which shows the levels of their structural changes (Tables 2 and 3).

c) From the analysis of the use of feed resources (Table 5), it can be seen that, in fact, due to the imbalance of diets with individual nutrients and noncompliance with the permissible limits of individual feed groups, aimless overspending occurs on farms with a low level of animal productivity. The resulting optimal feed production fully satisfies the needs of animal husbandry, both in terms of quantity and content of certain types of feed in diets (Table 5).

3. Approbation of the model showed the high efficiency of its use in optimal and indicative planning and the need to recommend it as a methodological tool for practical application in the activities of the employees of the economic department of the AE “Avangard”. The use of the model allows the computer to carry out such complex creative work as optimal, indicative planning, evaluating the efficiency of using resource potential, conducting many creative computational experiments, and substantiating effective directions for the development of production. At the same time, the quality and scientific level of developments are greatly improved, the time spent on calculations is significantly reduced, and optimal solutions to problems are achieved in any production situation, which are practically impossible to obtain based on traditional methods.

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REFERENCES

1. Y. Chen, O. Lyulyov, T. Pimonenko, A. Kwilinski, Energy & Environment, **0** (2023).
2. O. Chygryn and R. Miśkiewicz, Virtual Economics **5**(2), 24–42 (2022).
3. B. Czyżewski, A. Matuszczak, and R. Miśkiewicz, Technological and Economic Development of Economy, **25**, 82–102 (2019).
4. W. Drożdż, G. Kinelski, M. Czarnecka, M. Wójcik–Jurkiewicz, A. Maroušková, and G. Zych, Energies **14**, 2640 (2021).
5. H. Dzwigol, N. Trushkina, and A. Kwilinski, Virtual Economics **4**(2), 41–75 (2021).
6. T. Pimonenko, O. Lyulyov, and Y. Us, Journal of Tourism and Services, 12(23), 169–180 (2021)
7. M. Soliman, O. Lyulyov, H. Shvindina, R. Figueiredo, and T. Pimonenko, European Journal of Tourism Research, 28, 2801 (2021)
8. O. Panchenko, M. Domashenko, O. Lyulyov, N. Dalevska, T. Pimonenko, and N. Letunovska, Management Systems in Production Engineering **29(3),** 235–241 (2021).
9. K.M. Tireuov, K.A. Akhmetov, Z.Z. Kozhamkulova, and G.O. Seidalieva, *Revista Turismo Estudos e Práticas-RTEP/UERN* **2**, 1–15 (2020).
10. K.M. Tireuov, K.A. Akhmetov, G.O. Seydaliyeva, and Zh.Zh. Kozhamkulova, International Journal of Advanced Biotechnology and Research **1**, 111–120 (2019).
11. K.M. Tireuov, and K.A. Ahmetov *Jeffektivnoe upravlenie resursnym potencialom sel'skohozjajstvennyh formirovanij s primeneniem informacionnyh tehnologij i matematicheskih metodov* («Ajtumar», Almaty, 2020).
12. K.A. Ahmetov, A.B. Bekbosynova, and A.A. Tazhibaeva, East European Scientific Journal Wschodnioeuropejskie Czasopismo Naukowe **52**, 40-46 (2019).
13. K.A. Ahmetov, and A.B. Bekbosynova, "Tehnologija rascheta proizvodstvennogo potenciala sel'skohozjajstvennoj organizacii Almatinskoj oblasti na komp'jutere," in *Proceedings Problemy jekonomiki, organizacii i upravlenija v Rossii i mire* (World Press s. r.o., Cheshskaja Respublika, 2019), p. 117
14. K.A. Ahmetov, and G.R. Madiev, Problemy Agrorynka» **3**, 1–15 (2019).
15. L. Banasik, R. Miśkiewicz, A. Cholewa–Domanagić, K. Janik, and S. Kozłowski, "Development of Tin Metallurgy in Rwanda," in *31st International Conference on Metallurgy and Materials*, Proceedings 31st International Conference on Metallurgy and Materials, METAL 2022 (TANGER Ltd., Ostrava–Zabreh, 2022), pp. 662–668.
16. V. Boiko, A. Kwilinski, M. Misiuk, and L. Boiko, Economic Annals–XXI **175**, 68–72 (2019).
17. Y. Chen, A. Kwilinski, O. Chygryn, O. Lyulyov, and T. Pimonenko, Sustainability 13(24), 13679 (2021).
18. O. Chygryn, Y. Bilan, and A. Kwilinski, Marketing and Management of Innovations **3**, 358–370 (2020).
19. V.V. Dementyev and A. Kwilinski, Journal of Institutional Studies **12**, 100–116 (2020).
20. H. Dzwigol, M. Dzwigol–Barosz, and A. Kwilinski, International Journal of Entrepreneurship **24**, 1–5 (2020).
21. S. Furmaniak, P. A. Gauden, M. Leżańska, R. Miśkiewicz, A. Błajet–Kosicka, and P. Kowalczyk, Molecules **26**, 1509 (2021).
22. S. Furmaniak, P.A. Gauden, A. Patrykiejew, R. Miśkiewicz, and P. Kowalczyk, Journal of Physics Condensed Matter **31**, 135001, 1–12 (2019).
23. A. Kuzior, A. Kwilinski, and I. Hroznyi, Energies 14, 2572 (2021).
24. A. Kwilinski, Y. Zaloznova, N. Trushkina, and N. Rynkevych, Organizational and Methodological Support for Ukrainian Coal Enterprises Marketing Activity Improvement, E3S Web of Conferences **168**, 00031 (2020).
25. A. Kwilinski, I. Slatvitskaya, T. Dugar, L. Khodakivska, and B. Derevyanko, International Journal of Entrepreneurship **24**, 1–8 (2020).
26. M. Nawawi, H. Samsudin, J. Saputra, K. Szczepańska–Woszczyna, and S. Kot, Production Engineering Archives **28**, 193–200 (2022).
27. V. Tkachenko, A. Kwilinski, M. Klymchuk, and I. Tkachenko, Management Systems in Production Engineering **27**, 119–123 (2019).
28. A. Zielińska–Chmielewska, J. Kaźmierczyk, and I. Jaźwiński, Agronomy **12**, 92 (2021).
29. R. Abazov, "Independent Tajikistan: Ten years lost," in *Oil, Transition and Security in Central Asia*, edited by S. Cummings (Routledge, London, 2010), pp. 59–71.
30. S. Cyfert, A. Chwiłkowska–Kubala, W. Szumowski, and R. Miśkiewicz, PLoS ONE **16**, e0249724 (2021).
31. V. Dementyev, N. Dalevska, and A. Kwilinski, "Institutional Determinants of Structuring the World Political and Economic Space," in *37th International Business Information Management Association Conference*

(IBIMA), Proceedings of the 37th International Business Information Management Association (IBIMA), edited by K. S. Soliman (IBIMA Publishing LLC, King of Prussia, PA, 2021), pp. 2187–2199.
32. H. I. Hussain, M. Haseeb, F. Kamarudin, Z. Dacko–Pikiewicz, and K. Szczepańska–Woszczyna, Processes **9**, 1103 (2021).
33. Y. Kharazishvili, A. Kwilinski, H. Dzwigol, and M. Dzwigol–Barosz, "Modelling Innovation Contribution to Economic Growth of Industrial Regions," in *VIII International Scientific Conference Determinants of Regional Development*, Conference Proceedings – VIII International Scientific Conference Determinants of Regional Development. Volume II, edited by J. Polcyn (Pila, Stanislaw Staszic University of Applied Sciences in Piła, 2021), pp. 558–578.
34. Y. Kharazishvili, A. Kwilinski, H. Dzwigol, and V. Liashenko, Virtual Economics **4**, 7–40 (2021).
35. A. Kwilinski, M. Dielini, O. Mazuryk, V. Filippov, and V. Kitseliuk, Journal of Security and Sustainability Issues **10**, 345–358 (2020).
36. A. Kwilinski, N. Dalevska, and V. V. Dementyev, Journal of Risk and Financial Management, **15**, 124 (2022).
37. A. Kwilinski, O. Lyulyov, and T. Pimonenko, Energies **16**, 2511 (2023).
38. O. Lyulyov, T. Pimonenko, A. Kwilinski, and Y. Us, The Heterogeneous Effect of Democracy, Economic and Political Globalization on Renewable Energy, E3S Web of Conferences **250**, 03006 (2021).
39. O. Lyulyov, T. Pimonenko, A. Kwilinski, H. Dzwigol, M. Dzwigol–Barosz, V. Pavlyk, and P. Barosz, Energies **14**, 373 (2021).
40. O. Melnychenko, V. Matskul, and T. Osadcha, Virtual Economics **5**, 7–23 (2022).
41. K. Szczepańska–Woszczyna, D. Gedvilaitė, J. Nazarko, A. Stasiukynas, and A. Rubina, Technological and Economic Development of Economy **28**, 1572–1588 (2022).
42. S. Bogachov, A. Kwilinski, B. Miethlich, V. Bartosova, and A. Gurnak, Entrepreneurship and Sustainability Issues **8**, 487–499 (2020).
43. V. Dementyev, N. Dalevska, and A. Kwilinski, Virtual Economics **4**(1), 54–76 (2021).
44. Y. Kharazishvili and A. Kwilinski, Virtual Economics **5**(4), 7–26 (2022).
45. A. Kuzior and A. Kwilinski, Management Systems in Production Engineering 30, 109–115 (2022).
46. A. Kwilinski, L. Hnatyshyn, O. Prokopyshyn, and N. Trushkina, Virtual Economics **5**, 43–70 (2022).
47. A. Kwilinski, Academy of Accounting and Financial Studies Journal **23**, 1–6 (2019).
48. A. Kwilinski, Marketing and Management of Innovations **4**, 116–128 (2018).
49. A. Kwilinski and A. Kuzior, Management Systems in Production Engineering **28**, 133–138 (2020).
50. A. Kwilinski, V. Litvin, E. Kamchatova, J. Polusmiak, and D. Mironova, International Journal of Entrepreneurship **25**, 1–8 (2021).
51. A. Kwiliński, J. Polcyn, K. Pająk, and S. Stępień, "Implementation of Cognitive Technologies in the Process of Joint Project Activities: Methodological Aspect," in *VIII International Scientific Conference Determinants of Regional Development*, Conference Proceedings – VIII International Scientific Conference Determinants of Regional Development. Volume II, edited by J. Polcyn (Pila, Stanislaw Staszic University of Applied Sciences in Piła, 2021), pp. 96–126.
52. R. Miśkiewicz, Virtual Economics **2**(2), 37–47 (2019).
53. R. Miśkiewicz, A. Rzepka, R. Borowiecki, and Z. Olesińki, Energies, **14**, 6776 (2021).
54. R. Miśkiewicz, K. Matan, and J. Karnowski, Energies **15**, 3805 (2022).
55. N. Sharma, S. Rawat, and A. Kaur, Virtual Economics **5**(2), 95–113 (2022).
56. V. Tkachenko, A. Kwilinski, O. Korystin, N. Svyrydiuk, and I. Tkachenko, Journal of Security and Sustainability Issues **8**, 375–385 (2019).
57. V. Tkachenko, A. Kuzior, and A. Kwilinski, Journal of Entrepreneurship Education **22**, 1–10 (2019).
58. A. Zhanibek, R. Abazov, and A. Khazbulatov, Virtual Economics **5**, 71–94 (2022).
59. Q. Wang, Y. Chen, H. Guan, O. Lyulyov, and T. Pimonenko, Sustainability (Switzerland), 14(14) (2022)]
60. R. Abazov, Communist Economies and Economic Transformation **9**, 431–448 (1997).
61. O. Dubina, Y. Us, T. Pimonenko, and O. Lyulyov, Virtual Economics **3**, 53–66 (2020).
62. A. Kwilinski, I. Ruzhytskyi, V. Patlachuk, O. Patlachuk, and B. Kaminska, Journal of Legal, Ethical and Regulatory Issues **22**, 1–6 (2019).
63. A. Kwilinski, O. Lyulyov, and T. Pimonenko, Energies **16**, 2372 (2023).
64. V. Lakhno, V. Malyukov, T. Bochulia, Z. Hipters, A. Kwilinski, and O. Tomashevska, International Journal of Civil Engineering and Technology **9**, 1802–1812 (2018).
65. O. Lyulyov, and B. Moskalenko, Virtual Economics **3**, 131–146 (2020).
66. O. Melnychenko, Journal of Risk and Financial Management **13**, 191 (2020).

67. O. Melnychenko, Energies **14**, 8213 (2021).
68. B. Moskalenko, O. Lyulyov, T. Pimonenko, A. Kwilinski, and H. Dzwigol, International Journal of Environment and Pollution **69**, 80–98 (2022).
69. B. Moskalenko, O. Lyulyov, T. Pimonenko, and I. Kobushko, Virtual Economics **5**, 50–64 (2022).
70. J. Oláh, Y. A. Hidayat, Z. Dacko–Pikiewicz, M. Hasan, and J. Popp, Sustainability **13**, 9947 (2021).
71. O. Prokopenko and R. Miśkiewicz, Entrepreneurship and Sustainability Issues **8**(2), 269–284 (2020).
72. O. Lyulyov, M. Paliienko, L. Prasol, T. Vasylieva, O. Kubatko, and V. Kubatko, International Journal of Global Energy Issues, 43(2–3), 166–182 (2021).
73. B. Moskalenko, O. Lyulyov, and T. Pimonenko, Forum Scientiae Oeconomia, **10**(2), 153–172 (2022).
74. O. Chigrin, and T. Pimonenko, International Journal of Ecology & Development **3**, 1–13 (2014).
75. A. Sokolovska, T. Zatonatska, A. Stavytskyy, O. Lyulyov, and V. Giedraitis, Research in World Economy **11**(4), 1–15 (2020).
76. T. Pimonenko, and J. Cebula, International Journal of Ecology & Development **2**, 20–30 (2015).
77. R. Abazov, Engaging in the internationalization of education and SDGs: Case study on the global hub of UNAI on sustainability, E3S Web of Conferences **307**, 06001 (2021).
78. H. Dzwigol, Academy of Strategic Management Journal **19**, 1–8 (2020).
79. H. Dźwigoł, Virtual Economics **2**, 31–48 (2019).
80. H. Dzwigol, Virtual Economics **5**(1), 78–93 (2022).
81. H. Dzwigol, Virtual Economics **5**(4), 27–49 (2022).
82. H. Dzwigol, Methodological Approach in Management and Quality Sciences, E3S Web of Conferences **307**, 01002 (2021).
83. H. Dzwigol, M. Dzwigol–Barosz, R. Miskiewicz, and A. Kwilinski, Entrepreneurship and Sustainability Issues **7**, 2630–2644 (2020).
84. H. Dzwigol and M. Trzeciak, Forum Scientiae Oeconomia **11**, 67–90 (2023).
85. J. Kaźmierczyk, Entrepreneurship and Sustainability Issues **6**, 1938–1954 (2019).
86. R. Miśkiewicz, Polityka Energetyczna **21**, 49–62 (2018).
87. R. Miśkiewicz, "Knowledge and innovation 4.0 in today's electromobility," in *Sustainability, Technology and Innovation 4.0*, edited by Z. Makieła, M.M. Stuss, and R. Borowiecki (Routledge, London, UK, 2021), pp. 256–275.
88. Z. Shafait, M. A. Khan, U.F. Sahibzada, Z. Dacko–Pikiewicz, and J. Popp, PLoS ONE **16**, e0255428 (2021).
89. M. M. Stuss, K. Szczepańska–Woszczyna, and Z. J. Makieła, Sustainability **11**, 4988 (2021).
90. K. Szczepańska–Woszczyna and S. Gatnar, Forum Scientiae Oeconomia **10**(3), 107–130 (2022).
91. M. Trzeciak, T. P. Kopec, and A. Kwilinski, Journal of Open Innovation: Technology, Market, and Complexity **8**, 58 (2022).
92. R. Veckalne, and T. Tambovceva, Virtual Economics **5**(4), 65–86 (2022).
93. Z. Dacko-Pikiewicz, Forum Scientiae Oeconomia **7**, 37–51 (2019).
94. M. Dzwigol–Barosz and H. Dzwigol, Managing Family Businesses in Light of Methodological Assumptions for Higher Education, E3S Web of Conferences **307**, 06003 (2021).
95. H. Dzwigol, O. Aleinikova, Y. Umanska, N. Shmygol, Y. Pushak, Journal of Entrepreneurship Education **22**, 1–7 (2019).
96. H. Dzwigol, S. Shcherbak, M. Semikina, O. Vinichenko, and V. Vasiuta, Academy of Strategic Management Journal **18**, 1–8 (2019).
97. O. Kulakov, O. Popova, S. Popova, and E. Tomashevskaya, IOP Conference Series: Earth and Environmental Science **1126**, 012011 (2023).
98. A. Kwilinski, N. Dalevska, S. Kravchenko, I. Hroznyi, and O. Kovalenko, Journal of Entrepreneurship Education **22**, 1–7 (2019).
99. A. Kwilinski, R. Volynets, I. Berdnik, M. Holovko, and P. Berzin, Journal of Legal, Ethical and Regulatory Issues **22**, 1–6 (2019).
100. A. Kwilinski, H. Dzwigol, and V. Dementyev, International Journal of Entrepreneurship **24**, 1–5 (2020).
101. R. Miskiewicz, Marketing and Management of Innovations **3**, 371–381 (2020).
102. Y. Us, T. Pimonenko, O. Lyulyov, Y. Chen, and T. Tambovceva, Virtual Economics **5**, 24–42 (2022).
103. Ł. Wróblewski and Z. Dacko–Pikiewicz, Sustainability **10**, 3856 (2018).
104. R. Vaníčková and K. Szczepańska–Woszczyna, Polish Journal of Management Studies **21**, 425–445 (2020).
105. C. Yang, A. Kwilinski, O. Chygryn, O. Lyulyov, and T. Pimonenko, Sustainability **13**, 13679 (2021).

106. O. Petroye, O. Lyulyov, I. Lytvynchuk, Y. Paida, and V. Pakhomov, International Journal of Safety and Security Engineering **10**(4), 459–466 (2020).
107. N. Letunovska, O. Lyuolyov, T. Pimonenko, and V. Aleksandrov, Environmental management and social marketing: A bibliometric analysis, E3S Web of Conferences **234**, 00008 (2021).
108. Y. Us, T. Pimonenko, and O. Lyulyov, Polityka Energetyczna **24**(4), 5–18 (2021).
109. S.N. Volkov, and V.V. Bugaevskaja, Optimizacija **40**(57), 46-63 (1981).
110. O.K. Platov, M.A. Majorova, and M.I. Markin, Nauchnyj zhurnal «Vestnik APK Verhnevolzh'ja» **22**(2) 1-15 (2013).
111. P.V. Leshilovskij, and T.V. Kijan, APK Belorusskij jekonomicheskij zhurnal **4**, 36-45 (2008).
112. E. V. Stovba, AgroJekoInfo **2**, 1−12 (2011).
113. A.P. Kalashnikova, V.I. Fisinina, V.V. Shheglova, and N.I. Klejmenova, *Normy i raciony kormlenija sel'skohozjajstvennyh zhivotnyh* (Moskva, 2003).
114. Normativy zatrat na edinicu osnovnyh vidov sel'skohozjajstvennoj produkcii rastenievodstva. Rassmotren i odobreno na zasedanii nauchno-tehnicheskoj komissii AO «KazAgroInnovacija», 2 avgusta 2010 goda. – Astana, 2010. – 275 s.
115. Prjamye proizvodstvennye zatraty na 1 golovu, 1 c moloka v molochnom skotovodstve pri intensivnyh tehnologijah po regionam Kazahstana (Kazahskogo NII jekonomiki APK i razvitija sel'skih territorij, Almaty, 2017).
116. Srednie ceny proizvoditelej sel'skohozjajstvennoj produkcii v Almatinskoj oblasti v 2017 godu v tenge za 1 tonnu. Almatinskaja oblast' v 2017 godu (Departament Statistiki Almatinskoj oblasti, Komitet po statistike MNJe RK, Almaty, 2018).
117. Z.Z. Ainakulov, N.G. Makarenko, and T.T. Paltashev, Sovremennye Problemy Distantsionnogo Zondirovaniya Zemli Iz Kosmosa **15**(7), 43–50 (2018).
118. M. Paulus, S.A. Pfaff, A. Knierim, and P. Schüle, "Comparison of agricultural digitization of main and secondary occupation – results of a standardized survey in baden-württemberg," in *Proceedings Series Lecture Notes in Informatics of the Gesellschaft Fur Informatik* (Gesellschaft fur Informatik, Germany, 2022), p. 213-218
119. T. Keribayeva, Z. Ainakulov, R. Yergaliyev, G. Kurmankulova, I. Fedorov, and R. Anayatova, Journal of Theoretical and Applied Information Technology, 100(7), 1827–1835 (2022).
120. A. Thomas, A. Knierim, and H. Schüle, "Factors of human learning as basis for knowledge transfer in digitization: Player-based design of knowledge transfer in the DiWenkLa project – digital value chains for a sustainable small-scale agriculture,", in *Proceedings Series Lecture Notes in Informatics of the Gesellschaft Fur Informatik* (Gesellschaft fur Informatik, Germany, 2022), p. 347-350.
121. M. G. Razakova, Z.Z. Ainakulov, A.G. Kuzmin, I.O. Fedorov, R.K. Yergaliev, Remote Sensing and Spatial Information Sciences **43**(B2), 1253-1258 (2020).
122. S. A. Pfaff, M. Paulus, A. Knierim, H. Schüle, and A. Thomas, "What specific requirements does small-scale agriculture imply for digitization? – views of different stakeholders," in *Proceedings Series Lecture Notes in Informatics of the Gesellschaft Fur Informatik* (Gesellschaft fur Informatik, Germany, 2022), p. 219-224.
123. M. Razakova, A. Kuzmin, I. Fedorov, R. Yergaliev, and Z. Ainakulov, *"Methods of calculating landslide volume using remote sensing data,"* E3S Web of Conferences **149,** 02009 (2020).
124. A. Niyazbayev, F.G. Pegna, K. Khazimov, E. Umbetov, K. Akhmetov, Z. Sagyndykova, and M. Khazimov, Journal of Agricultural Engineering **53**(3), 1382 (2022).
125. A. B. Bekbosynova, G.R. Madiev, K.A. Akhmetov, and U. K. Kerimova, Espacios **39**(27), 11 (2018).
126. N. Dalevska, V. Khobta, A. Kwilinski, and S. Kravchenko, Entrepreneurship and Sustainability Issues **6**, 1839–1860 (2019).
127. H. Dzwigol, and M. Dzwigol–Barosz, Academy of Strategic Management Journal **19**, 1–7 (2020).
128. Y. Kharazishvili, A. Kwilinski, D. Bugayko, M. Hryhorak, V. Butorina, and I. Yashchyshyna, Virtual Economics **5**, 7–30 (2022).
129. A. Kuzior, O. Lyulyov, T. Pimonenko, A. Kwilinski, and D. Krawczyk, Sustainability **13**, 8145 (2021).
130. A. Kwilinski, O. Lyulyov, and T. Pimonenko, Land **12**, 511 (2023).
131. R. Miśkiewicz, Energies **15**, 9571 (2022).
132. D. Pudryk, A. Kwilinski, O. Lyulyov, and T. Pimonenko, Forum Scientiae Oeconomia **11**(1), 113–131 (2023).
133. O. Lyulyov, T. Pimonenko, N. Stoyanets, and N. Letunovska, Research in World Economy **10**(4), 97–105 (2019).
134. Y. Bilan, T. Pimonenko, and L. Starchenko, Sustainable business models for innovation and success: Bibliometric analysis, E3S Web of Conferences **159**, 04037 (2020).

135. T. Pimonenko, O. Lyulyov, Y. Chortok, and O. Borovik, International Journal of Ecology & Development **3**, 1–10 (2015).
136. H. H. Coban, W. Lewicki, E. Sendek–Matysiak, Z. Łosiewicz, W. Drożdż, and R. Miśkiewicz, Energies **15**, 8218 (2022).
137. H. Dźwigol, M. Dźwigoł–Barosz, Z. Zhyvko, R. Miśkiewicz, and H. Pushak, Journal of Security and Sustainability Issues **8**, 307–317 (2019).
138. S. Furmaniak, P. A. Gauden, A. Patrykiejew, G. Szymański, R. Miśkiewicz, and P. Kowalczyk, Chemical Engineering Communications **208**(2), 171–182 (2019).
139. S. Furmaniak, P. A. Gauden, A. Patrykiejew, R. Miśkiewicz, and P. Kowalczyk, Scientific Reports **8**(1), 15407 (2018).
140. L. M. Karpenko, M. Serbov, A. Kwilinski, V. Makedon, S. Drobyazko, Academy of Strategic Management Journal **17**, 1–7 (2018).
141. Y. Kharazishvili, A. Kwilinski, O. Sukhodolia, H. Dzwigol, D. Bobro, and J. Kotowicz, Energies **14**, 2126 (2021).
142. R. Kostyrko, T. Kosova, L. Kostyrko, L. Zaitseva, and O. Melnychenko, Energies **14**, 5080 (2021).
143. J. Kotowicz, D. Węcel, A. Kwilinski, and M. Brzęczek, Applied Energy **314**, 118933 (2022).
144. A. Kwilinski, O. Lyulyov, H. Dzwigol, I. Vakulenko, and T. Pimonenko, Energies, **15**, 545 (2022).
145. O. Lyulyov, I. Vakulenko, T. Pimonenko, A. Kwilinski, H. Dzwigol, and M. Dzwigol–Barosz, Energies **14**, 3497 (2021).
146. R. Miśkiewicz, Energies **13**, 6106 (2020).
147. R. Miśkiewicz, Journal of Risk and Financial Management **14**, 59 (2021).
148. P. W. Saługa, K. Szczepańska–Woszczyna, R. Miśkiewicz, and M. Chład, Energies **13**, 4833 (2020).
149. Y. Ziabina, A. Kwilinski, O. Lyulyov, T. Pimonenko, Y. Us, Energies **16**, 998 (2023).
150. Y. Us, T. Pimonenko, and O. Lyulyov, Polityka Energetyczna **23**(4), 49–66 (2021).
151. Y. Ziabina, T. Pimonenko, O. Lyulyov, Y. Us, and D. Proshkin, "Evolutionary development of energy efficiency in the context of the national carbon–free economic development," *E3S Web of Conferences* **307**, 09002 (2021).
152. T. Pimonenko, Y. Us, L. Lyulyova, and N. Kotenko, "The impact of the macroeconomic stability on the energy–efficiency of the European countries: A bibliometric analysis," *E3S Web of Conferences* **234**, 00013 (2021).
153. H. H. Coban, W. Lewicki, R. Miśkiewicz, and W. Drożdż, Energies **16**, 178 (2022).
154. H. Dzwigol, A. Kwilinski, O. Lyulyov, and T. Pimonenko, Energies **16**, 1117 (2023).
155. H. Dzwigol, A. Kwilinski, O. Lyulyov, and T. Pimonenko, **16**, 3090 (2023).
156. N. Gavkalova, Y. Lola, S. Prokopovych, O. Akimov, V. Smalskys, and L. Akimova, Virtual Economics **5**(1), 65–77 (2022).
157. J. Polcyn, Y. Us, O. Lyulyov, T. Pimonenko, and A. Kwilinski, Energies **15**, 108 (2022).
158. P. W. Saługa, K. Zamasz, Z. Dacko–Pikiewicz, K. Szczepańska-Woszczyna, and M. Malec, Energies **14**, 6840 (2021).
159. Y. Ziabina, and T. Pimonenko, Virtual Economics **3**(4), 147–168 (2020).
160. T. Pimonenko, O. Prokopenko, J. Cebula, and S. Chayen, International Journal of Ecology and Development **32(1)**, 98–107 (2017).
161. O. Arefieva, O. Polous, S. Arefiev, V. Tytykalo, and A. Kwilinski, "Managing sustainable development by human capital reproduction in the system of company`s organizational behavior," *IOP Conference Series: Earth and Environmental Science* **628**, 012039 (2021).
162. Y. Kharazishvili, O. Grishnova, and B. Kamińska, Virtual Economics **2**(2), 7–36 (2019).
163. Y. Kharazishvili, A. Kwilinski, O. Grishnova, and H. Dzwigol, Sustainability **12**, 8953 (2020).
164. A. Kuzior, W. Grebski, A. Kwilinski, D. Krawczyk, and M. E. Grebski, Sustainability **14**, 11011 (2022).
165. A. Kwilinski, V. Tkachenko, and V. Kuzior, Journal of Security and Sustainability Issues 9, 561–570 (2019).
166. A. Kwilinski, O. Lyulyov, T. Pimonenko, H. Dzwigol, R. Abazov, and D. Pudryk, Sustainability **14**, 6413 (2022).
167. N. Letunovska, R. Abazov, and Y. Chen, Virtual Economics **5**(1), 87–99 (2022).
168. I. Rajiani, R. Bačík, R. Fedorko, M. Rigelský, and K. Szczepańska–Woszczyna, Polish Journal of Management Studies **17**, 194–208 (2018).
169. V. A. Smiianov, O. V. Lyulyov, T. V. Pimonenko, T. A. Andrushchenko, S. Sova, and N. V. Grechkovskaya, Wiadomosci Lekarskie (Warsaw, Poland : 1960), 73(11), 2332–2338 (2020)
170. T. Pimonenko, M. S. M. Abaas, O. Chygryn, and O. Kubatko, Problems and Perspectives in Management **16(4)**, 155–168 (2018).