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Economic and Mathematical Modeling of Regional Industrial Processes

O.Y. Voronkova[1], A.M. Zadimidcenko[2],
L.V. Goloshchapova[3], A.G. Polyakova[4], S.G. Kamolov[5], E.M. Akhmetshin[6]

Abstract:

The paper presents a method for the parallel optimization of the structure of sown areas for calculating economic and mathematical models for the traditional and organic-oriented land use systems characterized by the introduction of an additional set of environmental criteria constraints.

Based on the proposed methodology, an economic-mathematical model has been calculated and the effectiveness of the functioning of the Altai Foothills zonal agroecocluster has been proved.

Considering the full involvement in the agricultural production turnover of land suitable to produce organic products, the level of profitability was 39.7% against 17.3% in case of optimizing the structure of the sown areas in the traditional system of agricultural production.

Keywords: *Economic and mathematical modeling, sectoral economics, organic products, optimization of production processes, production efficiency.*

JEL Classification*: C29, C61, O13, R10, Q24.*

[1]*Altai State University, Barnaul, Russia, olka2004@yandex.ru*
[2]*Surgut State Pedagogical University, Surgut, Russia, 610969@mail.ru*
[3]*Plekhanov Russian University of Economics, Moscow, Russia, cool.lvg2012@yandex.ru*
[4]*Industrial University of Tyumen, Tyumen, Russia, Financial University under the Government of the Russian Federation, Moscow, Russia, agpolyakova@mail.ru*
[5]*Moscow State Institute of International Relations (MGIMO), Moscow, Russia, skamolov@yahoo.com*
[6]*Kazan Federal University, Elabuga Institute of KFU, Elabuga, Russia, elvir@mail.ru*

1. Introduction

The main criterion for effective land use is the output of products and the receipt of profit per unit area. At the same time, from the consumers' point of view, the energy value of agricultural products made in an area and its environmental safety are of the greatest interest (Pavlov *et al.,* 2016; Zakharchenko *et al.,* 2018). As a result, the task of environmental-economic assessment of agricultural production becomes urgent, for a comprehensive solution to which the authors propose to use an economic-mathematical model to optimize the structure of sown areas with the introduction of an additional set of organic (environmental) criteria constraints.

2. Methods

The theoretical and methodological basis of the study consisted of the works of domestic and foreign scholars on the problems of the production of organic products; land development issues; economic and mathematical modeling. The methodological basis was a systematic approach, which made it possible to ensure the comprehensiveness and purposefulness of the research. The work also used analytical, design-calculated, economic-statistical, economic-mathematical, and monographic research methods.

3. Results

During the study, an attempt was made to create an optimized land-use model of the Altai Foothills zonal agroecocluster using economic and mathematical modeling based on the parallel functioning of both the traditionally established industrial system of agricultural production and the organically oriented system (Korableva *et al.,* 2017a, Pavlyshyn *et al.,* 2018; Saifullova *et al.,* 2018). The authors consider it reasonable that the transition to an organically oriented system of agricultural production should be phased, with the gradual introduction of fallow and unused land into agricultural circulation (Voronkova, 2014; Baryshnikov, 2016; Burkaltseva *et al.,* 2017; Sibirskava *et al.,* 2016).

Formulation of the problem. In the projected Altai Foothills agroecocluster, such a structure should be formed that would ensure maximum agricultural production from each hectare of land subject to simultaneous parallel industrial and organic land use, taking into account soil fertility, conditions of the territory, requirements of agricultural engineering, crop rotation, economic efficiency of production of certain types of crops, contractual obligations and sales plans of organic products (Takhumova *et al.,* 2018; Shaykhelislamova *et al.,* 2013; Shaykhelislamova *et al.,* 2014). According to the model building conditions, it is required, based on the available production resources, to identify the most optimal structure of sown areas, both for industrial and organic land use, which would ensure the fulfillment of plans for food sales, would cover the internal needs of the business entity with the maximum economic effect (Perova *et al.*, 2017). The optimality criterion in a problem can be: the maximum of gross or marketable output in monetary terms, the maximum production of a certain type of product in physical terms, the maximum of net profit (Wolter *et al.*, 2018; Glukhov, 2005; Mauch and Tarman, 2016; Korableva and Kalimullina, 2016; Usenko *et al.*, 2018; Osadchy *et al.*, 2018).

The estimated sales price of organic agricultural products is higher than that of similar products produced by traditional agricultural technology by at least 20-40%. It is also necessary to provide an additional 10-15% of the cost for changing the agricultural technology of cultivation of crops, certification, advertising, promotion of organic products. Economic and mathematical models for optimizing the structure of sown areas are presented in the works by Russian scientists; in the mathematical formulation, they have the following form (Dik, 2005; Shikin, 2004). Identifying the maximum function (maximum net income) in equation 1:

$$Z_{\max} = \sum_{j \in A} c_j x_j - k, \tag{1}$$

where:
c_j – gross output in terms of money received from 1 ha of crops of the *j*-th crop;
x_j – crop area of the *j*-th crop;
k – production costs for the cultivation of a variety of crops *A*.

1) Limited land resources:

$$\sum_{j \in A} a_{ij} x_j \le b_i \, (i \in M) \tag{2}$$

where: a_{ij} – cost of the land resource of the *i*-th type;
b_i – volume of the land resource of the *i*-th type;
M – multitude of types of the land resource.

2) Identification of production costs:

$$\sum_{j \in D} d_{ij} x_j = K \tag{3}$$

where: D – multitude of types of production costs;
d_{ij} – production costs per 1 ha of the *j*-th cultivated crop.

3) Fulfillment of agrotechnical requirements for the cultivation of crops and certain organizational and economic conditions:

$$\sum_{j \in A} x_j >< Q_j \tag{4}$$

where: Q – crop rotation saturation limits for individual crops or groups of crops;
or

$$\sum_{j \in A} a_{ij} x_j \leq a_{ij}^{\Theta} x_j \tag{5}$$

where:
a_{ij}, a_{ij}^{Θ} – coefficients of the ratio between forecrops and individual crops.

Ensuring the needs of animal husbandry with own fodder products:

$$\sum_{j \in A} v_{ij} x_j \geq V_i \tag{6}$$

where: v_{ij} – output of the *i*-th type of fodder from 1 ha of sown crops;
V_i – need for fodder of the *i*-th type.

To develop an economic-mathematical model of a zonal agroecocluster, an economic assessment of cultivated crops, applied crop rotations and agricultural technologies should be carried out and the necessary information should be prepared: the size of arable land, the list of crops cultivated in this area, information on their yield, gross output in monetary terms or net income per 1 hectare of acreage; the availability of production resources and the norms of their costs per 1 hectare of cultivated crops; agrotechnical requirements; introduction of organic and mineral fertilizers, etc (Sycheva *et al.*, 2017; Shaikhelislamova *et al.*, 2012).

The authors developed and applied a method for the parallel optimization of the structure of sown areas in economic and mathematical modeling to assess the economic efficiency of parallel agricultural production using organic and traditional agricultural systems, where an additional set of organic criterion constraints – the area of land suitable for organic production products, gross organic output, production costs in organic products – is introduced into the value of the objective function.. The objective function takes the following form:

$$Z_{\max} = \sum_{j \in A} c_j x_j - k + \sum_{j \in A} c_{jo}{}^{*} x_{jo}{}^{*} - k_o{}^{*}, \tag{7}$$

where:
c_j – gross output in terms of money received from 1 ha of the *j*-th crop sown;
x_j – crop area of the *j*-th crop;
k – production costs for the cultivation of a variety of crops A.
$c_{jo}{}^{*}$ – gross output in monetary terms obtained from 1 ha of crops from a reserve of land suitable for the production of organic products of the *j*-th crop with an organic system of agricultural production;
$x_{jo}{}^{*}$ – the sown area of the reserve of land suitable to produce organic products of the *j*-th crop in the organic system of agricultural production;

k_{jo}^{*} – production costs for the cultivation of a variety of crops *A* with the organic system of agricultural production on the area of the reserve land suitable to produce organic products.

1) Limited land resources:

$$\sum_{j \in A} a_{ij} x_j \le b_i (i \in M), \tag{8}$$

where: a_{ij} – cost of the land resource of the *i*-th type;
b_i – volume of the land resource of the *i*-th type;
M – variety of types of the land resource.

2) Identification of production costs:

$$\sum_{j \in D} d_{ij} x_j = K, \tag{9}$$

where: *D* – variety of types of production costs;
d_{ij} – production costs per 1 ha of the *j*-th cultivated crop.

3) Fulfillment of agrotechnical requirements for the cultivation of crops and some organizational and economic conditions:

$$\sum_{j \in A} x_j >< Q_j, \tag{10}$$

where: *Q* – crop rotation saturation limits for individual crops or groups of crops;

or

$$\sum_{j \in A} a_{ij} x_j \le a_{ij}^{\Theta} x_j, \tag{11}$$

where: a_{ij}, a_{ij}^{Θ} – coefficients of the ratio between forecrops and individual crops.

4) Ensuring the needs of animal husbandry with own fodder products:

$$\sum_{j \in A} v_{ij} x_j \ge V_i, \tag{12}$$

where: v_{ij} – output of the *i*-th type of fodder from 1 ha of sown crops;
V_i – need for fodder of the *i*-th type.

Designation of variables:
x_1 – area planned for winter rye;
x_2 – area planned for wheat;
x_3 – area planned for barley;

x_4 – area planned for oats;
x_5 – area planned for buckwheat;
x_6 – area planned for peas;
x_7 – area planned for sowing other cereals and leguminous crops;
x_8 – area planned for soybeans;
x_9 – area planned for rapeseed;
x_{10} – area planned for sunflower;
x_{11} – area planned for potato;
x_{12} – area planned for vegetables;
x_{13} – area planned for annual grasses for hay;
x_{14} – area planned for annual grasses for green fodder;
x_{15} – area planned for perennial grasses for hay;
x_{16} – area planned for perennial grasses for green fodder;
x_{17} – area planned for corn for silage and green fodder;
x_{18} – area planned for silage crops;
x_{19} – area planned for disuse (fallow);
x_{20} – total area of arable land;
x_{21} – hay area;
x_{22} – grassland area;
x_{23} – fallow land area;
x_{24} – area under perennial plantings;
x_{25} – total agricultural land;
x_{26} – total value of commercial agricultural products, thousand rubles;
x_{27} – amount of cost of agricultural production, thousand rubles;
x_{28} – reserve of lands suitable for the production of organic products, ha;
x_{29} – area of winter rye (from a reserve of land suitable for organic products);
x_{30} – area of wheat (from a reserve of land suitable for organic products);
x_{31} – area of barley (from a reserve of land suitable for organic products);
x_{32} – area of oats (from a reserve of land suitable for organic products);
x_{33} – area of buckwheat (from a reserve of land suitable for organic products);
x_{34} – area of peas (from a reserve of land suitable for organic products);
x_{35} – area of cereals and leguminous crops (from a reserve of land suitable for organic products);
x_{36} – area of sunflower (from a reserve of land suitable for organic products);
x_{37} – area of potato (from a reserve of land suitable for organic products);
x_{38} – area of vegetables (from a reserve of land suitable for organic products);
x_{39} – total value of commercial products (produced on the area from a reserve of land suitable for organic products), thousand rubles;
x_{40} – amount of production costs (on the area of a reserve land suitable to produce organic products), thousand rubles.
$x_1, x_2 \ldots x_{40} \geq 0$

It seems expedient to compile three variants of economic and mathematical models for the agroecocluster "Foothills of Altai". The first option provides for the optimization of the existing structure of arable lands of agricultural producers of the foothill zone, while fully maintaining the traditional farming system. The second option is to introduce into the structure of sown areas suitable to produce organic products (from the area of fallow land and unused arable land), or arable land suitable for organic products (ALSOP), in the amount of 50,000 hectares. The third option is the involvement in agricultural circulation of all not used cropland and fallow land of the Foothill Altai Region zone (ALSOP) in an amount of 181,333 hectares. The second and third variants provide for obtaining organic products from the area of organically applicable fallow land (OAFL), as well as the application of organic fertilizers in ALSOP.

The total area of the foothill zone is 1,899 thousand hectares of land, including 1,722 thousand hectares of agricultural land, 728 thousand hectares – arable land, 266 thousand hectares – natural hayfields, 680 thousand hectares – pastures. In accordance with the agrotechnical requirements of crop rotation, the following minimum and maximum possible limits for the cultivation of individual crops or groups of crops are defined in percent of the total arable land. Because of solving the economic and mathematical problem in Microsoft Excel software, the first option optimized the existing structure of the acreage. The optimized area of agricultural land amounted to 1,722.5 thousand hectares, arable land – 728 thousand hectares, hayfields – 265.9 thousand hectares, pastureland – 680 thousand hectares, fallow land – 46.3 hectares, perennial plantations – 2.2 thousand hectares.

Table 1. *Optimized structure of sown areas in the farms of the foothill zone according to the first option (traditional farming system)*

Parameters	Existing area, ha	% to total	Optimal solution	% to total	Deviations (+;-) ha
Grain crops total	393,424	54.0	393,990	54.1	566
Industrial crops	45,640	6.3	45,671	6.3	31
Potato	7,212	1.0	7,214	1.0	2
Vegetables	1,261	0.2	1,261	0.2	0
Feed crops	121,468	16.7	111,752	15.4	–9,716
Disused (out of crop)	23,974	3.3	33,093	4.5	9,119
Unused land	135,000	18.5	135,000	18.5	0
Arable land	727,979	100.0	727,979	100.0	0

By the optimal solution, the arable land area is fully used and amounts to 728 thousand hectares. Grain crops account for the largest share in the optimal structure of arable land and make up 54.1% (394 thousand hectares), which is higher than the actual value by 566 hectares. By the optimal solution, the area of spring wheat increased by 2,172 hectares, barley – by 141 hectares, buckwheat – by 710 hectares. The area of sunflower increased by 96 hectares; in general, the area under industrial crops increased by 31 hectares. The area of feed crops decreased by 9.7 thousand hectares, while at the same time the area disused (out of crops) according to the optimal solution was 4.5% (33.1 thousand hectares), having increased by 9.1

thousand hectares. The optimized structure of the acreage than the existing one meets the requirements of crop rotation for this zone.

The second variant of the economic-mathematical model for optimizing the structure of sown areas provides for the introduction into agricultural use of 50 thousand hectares of ALSOP to produce ecological food in this area. To this end, the authors will introduce an additional criterial set of environmental variables and restrictions, including the introduction of organic fertilizers, additional material and labor costs for maintaining an organic farming system, as well as yields, costs and prices for organic food that are different from the traditional farming system.

Table 2. *Optimized structure of sown areas in the farms of the foothill zone according to the second option (parallel farming using traditional and organically oriented systems)*

Parameters	**Area, ha**	**% to total**	**Optimal solution**	**% to total**	**Deviations (+;-) ha**
Grain crops total	393,424	54.0	402,121	51.7	8,697
Industrial crops	45,640	6.3	47,925	6.2	2,285
Potato	7,212	1.0	7,764	1.0	552
Vegetables	1,261	0.2	1,463	0.2	202
Feed crops	121,468	16.7	125,135	16.1	3,667
Disused (out of crop)	23,974	3.3	62,238	8.0	38,264
Unused land	135,000	18.5	131,333	16.9	–3,667
Arable land	727,979	100.0	777,979	100	50,000

In this version of the economic-mathematical model, there is no unused arable land left. Grain crops account for the largest share in the optimal structure of arable land and make up 51.7% (402.1 thousand hectares), which is higher than the actual value by 8.7 thousand hectares. The optimal structure of the acreage under this option almost fully meets the requirements of crop rotation for this zone.

The third variant of the economic-mathematical model for optimizing the structure of the sown areas of agricultural producers in the foothill zone provides for the involvement of the entire area of fallow land and unused arable land (ALSOP) for the purposes of maintaining organically oriented land use. As well as in the second optimization model, in parallel, the authors introduce an additional set of variables and restrictions on the making of ecological products.

Table 3. *Optimization of the structure of sown areas in the farms of the foothill zone according to the third option (parallel farming according to traditional and organically oriented systems)*

Parameters	**Area, ha**	**% to total**	**Optimal solution**	**% to total**	**Deviations (+;-) ha**
Grain crops total	393,424	54.0	464,587	60.0	71,163
Industrial crops	45,640	6.3	61,945	8.0	16,305

Potato	7,212	1.0	9,834	1.3	2,622
Vegetables	1,261	0.2	1,781	0.2	520
Feed crops	121,468	16.7	158,734	20.5	37,266
Disused (out of crop)	23,974	3.3	77,431	10.0	53,457
Unused land	135,000	18.5	0	0	–135,000
Arable land	727,979	100.0	774,312	100	46,333

The optimal structure of the crop acreage according to the third option fully complies with the crop rotation requirements for this zone. For systematic transition of part of agricultural enterprises to the principles of organically oriented land use and the production of high-quality and environmentally friendly domestic food, successful experience in the operation of environmentally oriented companies is required, as well as innovative developments in the field of agriculture, which can be implemented at the regional level through a system of zonal agroecoclusters (Akhmetshin *et al.*, 2018; Nagimov *et al.*, 2018).

Table 4. *The distribution of the introduced ALSOP by crop groups*

Parameters	Introduction of 50,000 ha of ALSOP (second option)		Introduction of 181,333 ha of OAFL (third option)	
	ha	%	ha	%
Grain crops	8,697	17.4	71,163	39.2
Industrial crops	2,285	4.6	16,305	9.0
Potato and vegetables	754	1.5	3,142	1.7
Feed crops	0	0	37,266	20.6
Disused (out of crop)	38,264	76.5	53,457	29.5
Total	50,000	100.0	181,333	100

According to the second option, the largest share in the structure of the organically applicable fallow land involved in agricultural production will be disused area, as it is a good background for cereals, industrial crops, potatoes and vegetables. In the current land use structure of this zone, the disused area does not meet the requirements of crop rotations.

Table 5. *Financial results obtained as a result of optimization of the structure of sown areas*

Parameters	Actual	Option 1	Option 2	Option 3
Revenue, thousand rubles	1,413.8	1,549.7	1,728.6	2,914.5
Costs, thousand rubles	1,230.0	1,314.7	1,406.7	2,086.4
Profit, thousand rubles	183.8	227.3	321.9	828.1
Profitability, thousand rubles	14.9	17.3	22.9	39.7

4. Discussion

The calculation of three variants of economic and mathematical models showed the economic efficiency of a gradual transition to organically oriented land use. When calculating economic and mathematical models of land use optimization (Kurbanova *et al.*, 2018; Korableva *et al.*, 2018; Saraev *et al.*, 2017), the authors have developed and applied a method for the parallel optimization of the structure of sown areas under the traditional land use system and the farming system which takes greening into account (Magsumov and Nizamova, 2015; Korableva *et al.*, 2017b; Magsumov, 2016). The calculation of the proposed options for optimizing the structure of the acreage, including partial and full involvement of an organically applicable fallow land in agricultural circulation, suggests the viability of the proposed project of the Altai Foothills agroecocluster (Kolesnikov *et al.*, 2018).

The formation of an organically oriented farming system does not mean a rejection of industrial agricultural production. In the authors' opinion, both organic and industrial farming systems can function effectively in parallel with each other, gradually transforming into such an agrarian technology that can meet the current and expected public needs for high-quality and environmentally safe food (Akmarov, 2012; Miloserdov, 2012; Avarsky *et al.*, 2014).

5. Conclusion

For a systematic transition of part of agricultural enterprises to the principles and production of high-quality and environmentally friendly domestic food, successful experience in the operation of environmentally-oriented companies is required, as well as innovative developments in the agro-industrial sector, which can be implemented at the regional level through a system of zonal agroecoclusters. The implementation of the proposed recommendations is possible if there is an effective organizational and economic mechanism of governmental support and stimulation of ecologically oriented agricultural entrepreneurship, which, in turn, should be considered as an important component of the global organic market structure, which is currently in a dynamic development stage.

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