



**OPTIMIZATION OF ECONOMIC AND ECOLOGICAL COMPONENTS
OF USING AGRICULTURAL LANDS FOR BALANCED LAND USE
AND RURAL AREAS DEVELOPMENT**

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ABSTRACT

The study is devoted to solving a topical problem related to the deterioration of land quality in Ukraine and in many countries around the world. This article proposes the use of economic and mathematical modelling to optimize the structure of sown areas of crops on the example of the whole of Ukraine in the direction of ensuring the balance of humus in the soil depending on the influence of a number of environmental and economic factors. The formation of the economic and mathematical model was the basis of the research methodology in this work. Based on the use of a systematic approach to assessing the effectiveness of the agricultural land use system, a number of environmental and economic indicators were selected and three groups of restrictions in the field of intensification of agricultural land use were formed. The applied approach made it



possible to develop a task to optimize the sown area of crops in order to preserve the quality of land. The results of solving the formed problem showed the need to limit the sown area under crops, the cultivation of which leads to the loss of humus in the soil; in particular, it is proposed to limit the sown area under sunflower. The results of the study allowed us to draw the following conclusions: a positive effect on the quality of soils from the cultivation of annual and perennial grasses was established, which requires an increase in sown areas under these crops; promising indicators for achieving a deficit-free balance of humus in soils during the cultivation of crops have been identified; an algorithm for choosing solutions to ensure balanced use of agricultural land in the agricultural sector has been developed that the presented procedure for choosing solutions will increase the environmental and economic efficiency of agricultural land use; it is established that for the realization of certain goals in the system of land use, the decisive importance should be given to the consideration and coordination of environmental, economic and social interests.

Keywords: humus balance, model, optimization, ecological and economic factors, perspective indicators, structure of sown areas, decision selection algorithm, rural areas, balanced land use

1. INTRODUCTION

Resource use in the agricultural sector should take into account the ability of natural systems to neutralize the negative impact of the results of the use of agricultural land in the production process and to renew their quality components. Therefore, the process of optimizing the use of agricultural land is important, which should be aimed at ensuring the effective implementation of agro-landscapes of the relevant functions, while maintaining their properties as integrated agro-ecosystems. Agro-ecological impact of crops on the qualitative characteristics of the soil environment is an indicator of anthropogenic pressure on agricultural land and the formation of the structure of sown areas set aside for growing these crops.

In view of this, optimizing the structure of sown areas of crops in the direction of balancing humus in the soil when growing them, taking into account the impact of a number of environmental and economic factors will ensure the most efficient use of material and natural resources to obtain maximum output per unit area indicators of land. This process is crucial for further planning of measures to improve the quality of agricultural land that requires more in-depth research. Therefore, we decided to investigate the impact of a number of environmental and economic factors on the quality of agricultural land, when they are used for growing crops within the territory of Ukraine.



2. LITERATURE REVIEW

The issues of theoretical and methodological support of the process of preserving the quality of agricultural lands, determining the optimal parameters of their use, substantiation of promising indicators of land use have been reflected in the scientific works of many scientists.

In particular, a number of scientists focus on the problem of balancing different types of land use (Moilanen et al., 2011), pointing to the importance of land use balancing processes for biodiversity conservation. Other scientists (Williams et al., 2017) studied the impact of land use on biodiversity, balancing food production depending on the impact of production processes on land, social consequences of applying different land use strategies.

The ways of optimization of land use with cartographic visualization at the municipal level proposed by the team of authors (Zaburaeva, Zaurbekov and Taimaskhanov, 2018) deserve attention. These ways are based on the concept of balanced land use and aimed at ensuring ecological land use.

One of the options for achieving efficient land use is also to intensify the processes of landscape-ecological optimization, aimed at solving a set of environmental and economic problems in the field of land use (Kirillov, Ryabinina and Grechishkin, 2019).

A number of scientists have found that the productivity of agricultural lands is influenced by the following factors: agro-landscape infrastructure, optimal structure of sown areas, crop rotations, a sufficient share of perennial grasses, the functioning of agro-ecosystems, etc. (Trofimov, Trofimova and Yakovleva, 2017).

However, the analysed works cover, as a rule, the theoretical principles of optimizing the use of land in the direction of preserving their quality characteristics.

Therefore, an important component for further improving the efficiency of land use is to assess the intensity of environmental and economic factors on the state of individual territories and opportunities to optimize the structure of land use based on the study of balance of different land uses (Kapitalchuk, 2018).

Determinants from the point of view of preservation of fertility of agricultural lands are research of balance of nutrients in soil and influence on it of a complex of social and economic factors (Karna and Bauer, 2020).

Some authors propose to apply the method of parallel optimization of the structure of sown areas for the calculation of economic and mathematical models in the traditional and



production-oriented system of land use, which is characterized by the introduction of additional block of environmental criteria (Voronkova and Sycheva, 2017), which is very important for maintaining soil fertility.

Also valuable are studies of optimizing the structure of sown areas and improving the territorial distribution of fields taking into account environmental conditions (Vazhov, Odintsev and Kozil, 2014) and economic efficiency of production of individual crops (Hrytsiuk, Babych and Mandziuk, 2019).

One of the methods of assessing the impact of environmental and ecological factors on the state of natural economic systems is the use of economic and mathematical modelling (Ivashchuk, 2008).

Nevertheless, these works do not take into account the complex impact of a number of environmental and economic factors on one of the main parameters that characterize the quality of agricultural land and the possibility of using it for growing agricultural products, namely humus content in soils.

The purpose of the article was to substantiate the example of Ukraine the optimal parameters of the structure of sown areas of crops, taking into account the impact of a number of environmental and economic factors and to propose the necessary measures to balance the humus content in soils.

3. METHODOLOGY

When conducting research on the impact of environmental and economic factors on the quality of agricultural land, it is crucial to minimize the negative effects of their effects on the quality characteristics of land resources. The research methodology included consideration of the factor of optimization of sown areas of agricultural crops as an integral element of ensuring the improvement of the quality of land, where the process of balancing the content of humus in the soil plays a decisive role.

In the process of research in revealing the essence of optimization processes and their features in the direction of balancing the humus content in soils, as well as for the formation of a set of indicators and their limitations used dialectical and systematic methodological approaches. Optimization of sown areas of agricultural crops in the direction of balancing humus in soils was carried out using the method of economic and mathematical modeling. Methods such as induction and deduction, as well as methods of abstraction and formalization



have been used to substantiate the use of agricultural land in order to ensure the balance of humus in the soil, theoretical generalization and formulation of conclusions.

We have proposed to form the optimal structure of sown areas of agricultural crops based on the frequency of placement of agricultural crops in crop rotations. To determine the maximum share of crops in the structure of sown areas, we propose to use the concentration factor, which is recommended to be calculated by the following formula:

$$K_{\text{conc}}=1/T_{\text{max}}, \quad (1)$$

where K_{conc} – the coefficient of concentration of sown areas of agricultural crops;

T_{max} – the maximum duration of the period of possible return of the crop to crop rotation, years

Accordingly, the maximum share of agricultural crops in the structure of sown areas is proposed to be determined by the following formula:

$$\omega = K_{\text{conc}} \times 100\% \quad (2)$$

We have developed a mathematical model that can balance the humus in the soil when growing crops, adjusting the ratio of crops in crop rotations and the area under cultivation, taking into account the influence of factors such as crop yields and amounts of organic fertilizers for individual crops. To achieve a balance of humus in agriculture in Ukraine, we will take into account the following parameters:

the area of cultivated crops;

2) actual and maximum crop yields;

3) maximum and minimum areas of crops in crop rotations (calculated according to formulas 1-2);

4) actual and optimal application of organic fertilizers;

5) loss of humus during the cultivation of crops;

6) the yield of plant remains in the cultivation of the crop;

7) humification coefficients of plant remains and organic fertilizers.

To formalize the model, we use the following notation:

Z – humus balance in the soil; g_i – coefficient of humification of plant remains of i culture; w_{1i} – yield of root crop residues for i culture (t/ha); w_{2i} – yield of surface plant remains for i

culture (t/ha); h – humification coefficient of organic fertilizers; y_i – the amount of applied organic fertilizers (t/ha) under i culture; v_i – humus consumption during cultivation i culture (t/ha); z_i – the area of grown i culture (thousand hectares); x_i – crop capacity of i agricultural culture (t/ha); y_i – mass of applied organic fertilizers (t/ha) under i culture; a_i and b_i – minimum and maximum permissible norms of productivity of i culture, accordingly (t/ha); c_i – rates of application of organic fertilizers (t/ha); s_i , S_i – minimum and maximum standards for cultivated area of i culture, accordingly (thousand hectares); S – the total area of crops in Ukraine (thousand hectares).

The development of the model involves three groups of constraints.

The first group of restrictions on the maximum allowable yields of crops:

$$a_i \leq x_i \leq b_i, \quad i = \overline{1, n}. \quad (3)$$

The second group of restrictions on the amount of applied organic fertilizers:

$$0 \leq y_i \leq c_i, \quad i = \overline{1, n}. \quad (4)$$

The third group of restrictions on the size of sown areas:

$$s_i \leq z_i \leq S_i, \quad i = \overline{1, n},$$

$$\sum_{i=1}^n z_i = S. \quad (5)$$

The criterion of optimality in this model is to ensure a deficit-free balance of humus in agriculture of Ukraine, i.e. the total mass of humus losses for each crop on the respective area of its cultivation should be equal to its growth with optimal distribution of sown areas, organic fertilizers and crop yields. Accordingly, the economic and mathematical model with restrictions (3-5) will look like this:

$$Z = \sum_{i=1}^n g_i (w_{1i} + w_{2i}) + h y_i - v_i \times z_i \rightarrow 0 \quad (6)$$

4. RESULTS AND DISCUSSIONS

4.1. The content of the method of optimization of sown areas of crops taking into account the complex of ecological and economic factors of influence

Optimization of agricultural land use should be considered through the prism of the degree of balance of production processes in the agricultural sector. Mutual transformation of economic and environmental effects indefinitely necessitates the expansion of the range of measurements and estimates. Thus, the balance of land use by ecological component should be characterized by indicators of the structure of land use and their quality (Sokhnych and Tibilova, 2006).

The optimal use of agricultural land should be aimed at ensuring the effective performance of agricultural landscapes of the relevant functions, while maintaining their properties as integral agro-ecosystems (Hensiruk, 1992).

The main task in developing a system of measures to optimize agricultural land use is a detailed analysis of the current state of land use, identifying the most pressing environmental problems and identifying measures to address them.

The working hypothesis of the study assumes the existence of economic and environmental factors on the humus content in soils in the optimization of sown areas of crops, which determines the quality of land and their suitability for agricultural use.

To ensure efficient, environmentally safe use of land resources, it is necessary to optimize the structure of sown areas of crops, taking into account new production, innovation and agro-landscape approaches to the organization of rural areas and natural and economic conditions (Kostyshyn, 2017).

After all, it is the structure of sown areas that determines not only the level of economic efficiency of crop production, but also the level of technological and technical burden on agricultural land.

Using the above methodology, calculations were performed based on the data shown in Table 1.

Table 1: Estimated data for optimizing the structure of sown areas of crops in the direction of ensuring the balance of humus in the soil

Agricultural cultures	Area of cultivated crop or group, thousand hectares	Maximum allowable crop yields, c / ha		Application of organic fertilizers, t / ha	Amount of humification of org. fertilizers	Amount of humification of plant residues	Lost humus, t / ha	The rate of application of organic fertilizers, t / ha	Norms of sown areas, thousand hectares	
		Minimum (actually)	Max.						Min.	Max.
Winter wheat	6645.3	41.6	100	0.3	0.058	0.20	1.35	20	5405.2	8918.0
Spring barley	1552.4	32.4	90	0.3	0.058	0.22	1.23	20	1600.6	5405.2
Corn for grain	4986.9	55.1	150	0.7	0.058	0.20	1.56	20	1351.3	6756.5
Soy	1612.8	19.7	50	0.2	0.058	0.23	1.50	30	1351.3	6756.5
Sunflower	5958.9	20.2	55	0.2	0.058	0.14	1.39	30	1351.3	2999.9
Sugar beets	221.3	461.1	930	3.7	0.058	0.10	1.61	30	270.0	5806.8
Rape (winter, spring)	1279.2	25.6	65	0.5	0.058	0.15	1.39	30	270.0	2702.6
Potato	1308.8	154.8	350	1.6	0.058	0.13	1.61	30	405.4	1351.3
Vegetables	452.4	205.9	350	0.4	0.058	0.13	1.61	30	297.3	1351.3
Corn for silage and green fodder	246.6	160.0	400	6.1	0.058	0.17	1.47	20	270.2	2162.1
Sown grasses (total)	1955.1	39.2	160	0.8	0.058	0.25	0.60	20	1351.3	8107.8

Source: Formed on the basis of statistical information and Boiko, Kovalenko (2015), Hospodarenko (2018).

The result of solving the mathematical model is shown in Table 2.

Table 2: Prospective indicators of optimization of the structure of sown areas of crops in the direction of ensuring the balance of humus in the soil

Agricultural cultures	Area of cultivated crop or group, thousand hectares	Crop yields, c/ha	Application of organic fertilizers, t/ha	Formed humus from: (t/ha)			Lost humus, t/ha	The balance of humus	
				org. fertilizers	plant residues	total		t/ha	thousand tons
Winter wheat	6341.1	44.00	11.13	0.65	1.29	1.94	1.35	0.59	3741.25
Spring barley	2193.6	33.90	2.87	0.17	0.97	1.14	1.23	-0.09	-197.42
Corn for grain	4590.8	57.34	7.27	0.42	1.36	1.78	1.56	0.22	1009.98
Soy	2197.9	20.00	3.07	0.18	0.32	0.50	1.50	-1.00	-2197.90
Sunflower	2999.9	21.77	4.83	0.28	0.60	0.88	1.39	-0.51	-1529.95
Sugar beets	629.6	475.00	3.85	0.22	0.40	0.62	1.61	-0.99	-623.30
Rape (winter, spring)	787.9	27.86	1.19	0.07	2.01	2.08	1.39	0.69	543.65
Potato	1351.3	167.00	3.93	0.23	0.42	0.65	1.61	-0.96	-1297.25
Vegetables	785.6	207.00	1.29	0.07	0.16	0.23	1.61	-1.38	-1084.13
Corn for silage and green fodder	622.7	227.00	7.44	0.43	0.74	1.17	1.47	-0.30	-186.81
Sown grasses (total)	2397.2	40.85	3.88	0.22	1.14	1.36	0.60	0.76	1821.89
Total in Ukraine	24897.6	-	-	-	-	-	-	-	0

Source: Calculated by the authors

Comparative characteristics of the actual and optimized structure of sown areas of the most common crops, occupying about 80.0% of the arable land area are presented in the table (Table 3).

Evaluating the simulation results, it should be noted that to balance the loss of humus in the soil it is necessary to increase sown areas and yields for all major crops except sunflower, the sown area under which must be reduced by more than 2 times. An important component for balancing humus is also an increase in the application of organic fertilizers per 1 hectare of sown area of all crops.

Table 3: Optimized actual structure of sown areas of crops in the direction of ensuring the balance of humus in the soil

Agricultural cultures	Optimized area of cultivated agricultural crop, thousand hectares	The actual area of cultivated agricultural crops, thousand hectares	Optimized structure, %	Actual structure, %
Winter wheat	6341.1	6645.3	19.4	20.3
Spring barley	2193.6	1552.4	6.7	4.7
Corn for grain	4590.8	4986.9	14.0	15.2
Soy	2197.9	1612.8	6.7	4.9
Sunflower	2999.9	5958.9	9.2	18.2
Sugar beets	629.6	221.3	1.9	0.7
Rape (winter, spring)	787.9	1279.2	2.4	3.9
Potato	1351.3	1308.8	4.1	4.0
Vegetables	785.6	452.4	2.4	1.4
Corn for silage and green fodder	622.7	246.6	1.9	0.8
Sown grasses (total)	2397.2	1955.1	7.3	6.0

Source: Calculated by the authors

To optimize the structure of sown areas of agricultural crops and ensure balanced use of agricultural land at the level of agricultural formations, we proposed to use the following algorithm (Figure 1).

According to the algorithm for the balanced use of land in agricultural production and the choice of further land use (application of intensive technologies or greening of production processes) we propose to take into account the dynamics of humus content in the soil, which will be determined according to agrochemical surveys and agricultural land structure of sown areas of agricultural crops. In case of deterioration of these indicators, the land use system should be greened, and when their improvement is observed, it is a precondition for further intensification of agricultural activity.

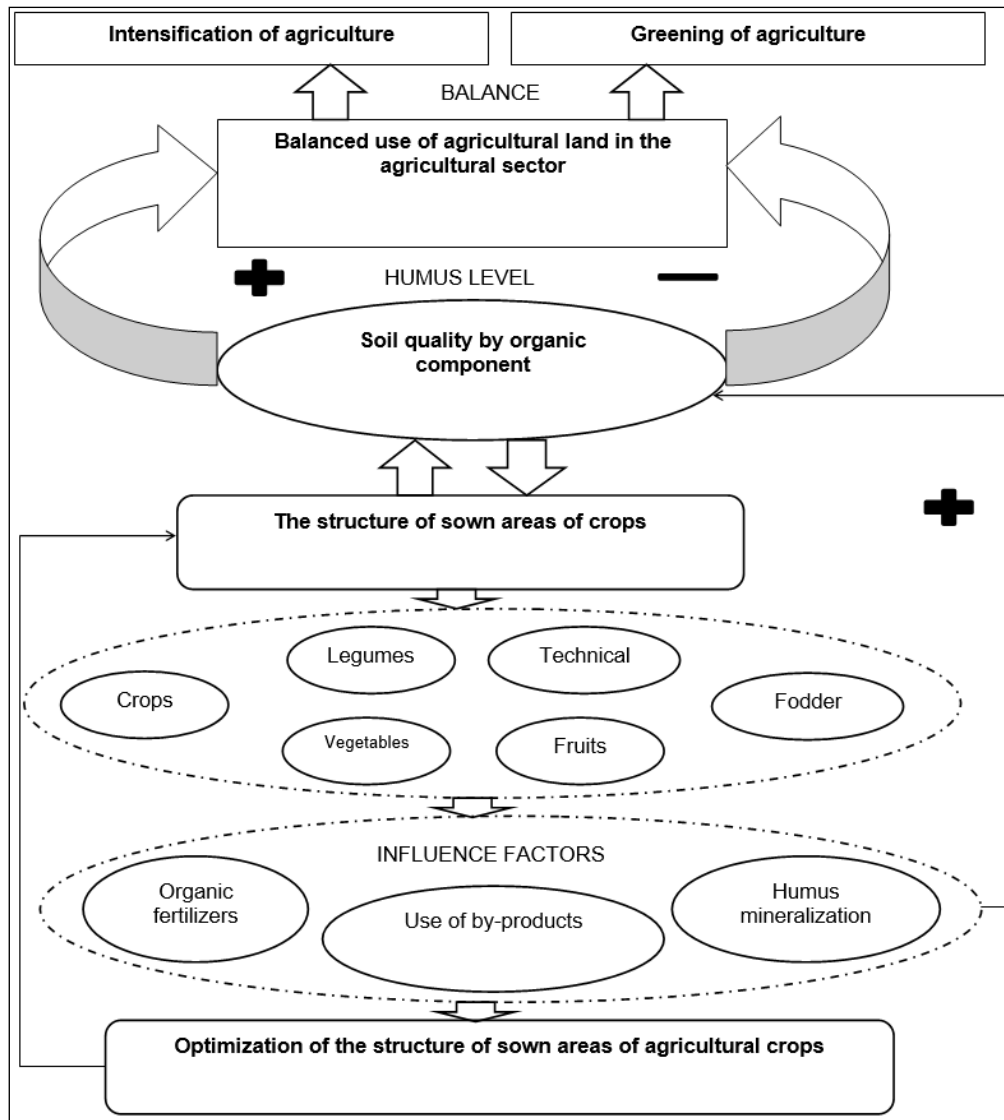


Figure 1: Algorithm for choosing solutions to ensure balanced use of agricultural land in the agricultural sector
 Source: developed by the authors

This algorithm of actions is aimed at choosing the directions of land use, primarily at the local level (intensification or greening of the management system), based on the dynamics of humus content in soils. The decisions taken should be aimed at optimizing the structure of sown areas of crops depending on the impact of the technology of their cultivation on the quality of land.

4.2. Practical aspects of application of economic and mathematical model

As a result of optimizing the structure of sown areas of crops to ensure the balance of humus in the soil, it is possible to choose areas for further use of by-products of these crops, in particular to increase the level of humus in the soil by plowing the residues of agricultural products or the use of by-products for bioenergy production.

Therefore, the optimization of the structure of agricultural lands should be carried out based on the data of agri-environmental monitoring of lands. The consolidated ecological and agrochemical assessment of land plots, which is based on the main agro-physical and agrochemical indicators, is of great importance for sound regulation of land relations, determination of ecologically appropriate crop rotation system in order to optimize land use by agricultural formations.

The availability of up-to-date and reliable information on the state of agricultural land resources will increase the environmental and economic efficiency of land use in the agricultural sector and create preconditions for the application of legal liability and incentives for landowners and land users as a result of their compliance with norms and rules in the field of land use.

Optimization of land use through the implementation of effective optimization measures will lead to inexhaustible and balanced use of land resources, as well as the formation of regional environmental systems, which will contribute to the stable and full restoration and functioning of natural and economic territorial complexes.

Taking into account the environmental factor in optimizing the use of land in the agricultural sector requires comprehensive interdisciplinary research, taking into account the priorities of balanced economic growth of the agricultural sector.

Research of qualitative characteristics of agricultural lands, in particular indicators of humus content in soils, and influence of a complex of ecological and economic factors on them will create opportunities for formation of system of balanced agricultural land use by development and implementation of appropriate organizational and economic, normative and legal mechanisms for preservation and improvement of land lands.

In this case, organizational and economic mechanisms are aimed at creating a favourable environment in order to implement a system of balanced agricultural land use to preserve the quality of land. Normative and legal measures will promote the implementation of legal conditions for the protection of agricultural land from excessive anthropogenic impact and the deterioration of their quality characteristics by improving existing regulations or creating new provisions within international law.

To implement the declared measures it is necessary to ensure the coordination of environmental, economic and social interests at different levels of government, in particular: to prioritize maintaining the quality of land in the process of their use for agricultural



production, to ensure the effectiveness of financial and administrative levers of influence in the direction of forming a system of balanced land use, to assess the effectiveness of agricultural land use by taking into account the impact of environmental and economic factors on the development trends of agricultural systems, etc.

5. CONCLUSIONS AND RECOMMENDATIONS

The obtained results show that it is important to take into account the influence of ecological and economic factors in the process of optimizing the structure of sown areas of agricultural crops in order to preserve the quality of land. Accordingly, it is advisable to use the results of modelling the structure of sown areas of major crops grown in Ukraine, to further balance the humus content in the soil.

Optimization of land use through the implementation of effective optimization measures at the level of individual land users will lead to inexhaustible and balanced use of land, as well as the formation of regional environmental systems, which will contribute to stable and full restoration and functioning of natural and economic complexes.

The author's position takes into account a set of limiting factors that affect the humus content in soils during the cultivation of crops, to further preserve its level and improve the environmental and economic efficiency of land use in crop production. In our case, the set of influencing factors includes a number of parameters that in practice are interdependent and determine the level of anthropogenic pressure on the state of land.

This necessitates the formation of an economic and mathematical model based on the study of interactions. From an economic point of view, the level of anthropogenic pressure should be reviewed in the context of taking into account the three main interest groups: economic, environmental and social in the direction of balancing them. Based on this, specific components will be proposed for the formation of an ecological and economic mechanism of balanced land use to address pressing issues related to the deterioration of the quality parameters of land.

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